Santos

Dorado Development Offshore Project Proposal

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Acronyms and Abbreviations

Acronym	Definition
3-D	three-dimensional
AFZ	Australian Fishing Zone
ALARP	as low as reasonably practicable
AMP	Australian marine park
AMSA	Australian Maritime Safety Authority
AMSL	above mean sea level
API	American Petroleum Institute
Basel Convention	Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1972
AWS	Australian Whale Sanctuary
BIA	biologically important area
BMSL	below mean sea level
Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals
bpd	barrel per day
BSL	below sea level
BTEX	benzene, toluene, ethylbenzene and xylene
CAES	Catch and Effort System
CAMBA	Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment
CAPEX	capital expenditure
CH_4	methane
CMP	Conservation Management Plan
CO	carbon monoxide
CO_2	carbon dioxide
CO_{2-e}	carbon dioxide equivalent
cP	centipoise, a unit of dynamic viscosity, equal to one hundredth of a poise
CPP	central processing platform
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment
DEWHA	Department of Environment, Water, Heritage and the Arts (now Department of the Environment and Energy)
DISER	Department of Industry, Science , Energy and Resources
DMIRS	Department of Mines, Industry Regulation and Safety

Acronym	Definition
DPIRD	Department of Primary Industries and Regional Development
DRS	Delayed Recovery Scenario
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (now Department of Agriculture Water and the Environment)
DTM	disconnectable turret mooring
EMBA	environment that may be affected
ENSO	El Niño-Southern Oscillation
EP	Environment Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPO	environmental performance outcome
ESD	ecologically sustainable development
FEED	front-end engineering and design
FID	final investment decision
FPSO	floating production, storage and offloading (facility)
FSO	floating storage and offloading (facility)
GBSS	gravity-based support structure
GHG	greenhouse gas
H&S	health and safety
HFC	hydrofluorocarbon
HFO	heavy fuel oil
IFO	intermediate fuel oil
IMF	Interim Managed Facility
IMMR	inspection, monitoring, maintenance and repair
IMO	International Maritime Organization
IMS	invasive marine species
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
JAMBA	Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment
KEF	key ecological feature
KSTB	thousand standard barrels
London Convention	Prevention of Marine Pollution by Dumping of Wastes and Other Matter
LNG	liquefied natural gas
LPG	liquefied petroleum gas

Acronym	Definition
µg	millionth of a gram
µm	millionth of a metre, or thousandth of a millimetre
m^3	cubic metre
MARPOL 73/78, MARPOL Convention	International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978
MDO	marine diesel oil
MGO	marine gas oil
MMbbl	million barrels
MMscf	million standard cubic feet
MMscfd	million standard cubic feet per day
MNES	matter of national environmental significance
MODU	mobile offshore drilling unit
MSL	mean sea level
$MtCO_{2-e}$	million tonnes of carbon dioxide equivalent
NA	not applicable
NAF	non-aqueous fluid
NDC	Nationally Determined Contribution
NGER	National Greenhouse and Energy Reporting
NGER Act	*National Greenhouse and Energy Reporting Act 2007*
nm	nautical mile, a unit of length used in air, marine, and space navigation and for the definition of territorial waters; equal to 1,852 m
N_2O	nitrous oxide
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NOx	nitrogen oxides
NWS	North West Shelf
NZE	Net zero emissions by 2050
OIW	oil in water
OOC	Oil on cuttings
OPEP	Oil Pollution Emergency Plan
OPEX	operating expense
OPGGS (E) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009

Acronym	Definition
OPGGS (RMA) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Resource Management Administration) Regulations 2011
OPGGS (S) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009
OPGGS Act	*Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPP	Offshore Project Proposal
PAH	polycyclic aromatic hydrocarbon
PEC	perfluorocarbon
PK	peak sound pressure level
$PM_{2.5}$	particulate matter less than or equal to 2.5 microns in diameter
PM_{10}	particulate matter less than or equal to 10 microns in diameter
PMST	Protected Matters Search Tool
ppb	part per billion
ppt	part per thousand
PTS	permanent threshold shift
PW	produced water
RAAF	Royal Australian Air Force
Ramsar, Ramsar Convention	Convention on Wetlands of International Importance
RO	reverse osmosis
ROKAMBA	Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds
ROV	remotely operated vehicle
SBM	synthetic based mud
SDS	Sustainable Development Scenario
SEL	sound exposure level
SEL_{24h}	cumulative 24-hour sound exposure level - a cumulative metric that reflects the measured dose impact of noise levels over 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position
SPL	sound pressure level
STEPS	Stated Policies Scenario
TEC	threatened ecological community
TTS	temporary threshold shift
VOC	volatile organic compound
WAFIC	Western Australian Fishing Industry Council
WBM	water-based mud

Acronym	Definition
WHA	World Heritage Area
WHP	wellhead platform

Executive Summary

ES-1. Introduction

Project Overview and Location

Santos WA Northwest Pty Ltd (Santos) proposes to develop petroleum resources in the Bedout Sub-basin, located in Commonwealth waters approximately 140 km offshore from Port Hedland, Western Australia (Figure 0-1).

The Dorado Development will develop the oil resources of the Dorado field and potential future tiebacks and will require gas reinjection to enhance oil recovery. There is potential for a second phase of development to recover and export the gas.

Phase 1 of the Dorado Development (Dorado Phase 1) will produce oil from the Dorado field and potentially from future tiebacks. In this phase, the recovered gas will be reinjected to the Dorado reservoir to enhance liquids recovery. Dorado Phase 1 will be designed for liquid handling rates of 100 thousand standard barrels per day (KSTB/d) and gas reinjection capacity of 235 million standard cubic feet per day (MMscf/d). With the inclusion of future tiebacks, Dorado Phase 1 will export a volume of up to 350 million barrels (MMbbl) of liquids over 20 years.

Dorado Phase 1 will contribute to meeting the world's future needs for oil resources, and will also bolster energy security for Australia in the wake of global energy supply shocks following the global pandemic and the Russia-Ukraine conflict.

Based on global energy studies and forecasts, oil plays a major role in the energy mix for a sustainable energy future and currently is forecast to provide the main source of energy for the transport sector into the future. Even under the most aggressive accelerated energy transition scenarios, including the IEA Net Zero by 2050 scenario, there remains a requirement for investment in oil and gas production to maintain sufficient supply through the transition.

Future gas production is subject to future exploration and investment decisions and would be executed as Phase 2 of the Dorado Development. The exploration and appraisal activities in the Bedout Basin are undertaken via separate environment plans and approvals. Should Phase 2 of the Dorado Development progress it would require separate assessment under environment regulatory approval processes if considered commercially and technically viable. The recovered gas will be exported for onshore processing to supply either domestic and/or international markets.

This offshore project proposal (OPP) has been submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) for assessment under Part 1A of the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (OPGGS (E) Regulations). This OPP outlines Santos' commitment to undertaking Dorado Phase 1 in a manner that ensures environmental impacts and risks are acceptable.

The oil resources that will be developed lie within petroleum titles WA-437-P and WA-438-P. The Dorado Phase 1 development will consist of:

+ a wellhead platform (WHP) with up to sixteen wells (production and gas injection);
+ a floating production, storage and offloading (FPSO) facility;
+ subsea flowlines and umbilicals between the WHP and the FPSO facility; and
+ potential future tiebacks.

This OPP for Dorado Phase 1 includes potential for future tiebacks (noting that prospects have not yet been appraised) within the Project Area to augment Dorado field oil production. These tiebacks will connect to the Dorado WHP or FPSO.

All planned petroleum activities, including the future tiebacks, will take place within the Project Area defined for the Dorado Development (**Figure 0-1**) and will include:

+ site surveys;
+ drilling;
+ vertical seismic profiling (drilling and 3-D);
+ construction and installation;
+ commissioning;
+ operations and facilities maintenance; and
+ decommissioning of infrastructure and plug and abandonment of wells.

The proposed locations of the Dorado FPSO and WHP are approximately 143 km and 145 km north of the town of Port Hedland respectively. Future tiebacks, if developed, will be located within the Project Area. Water depths in the Project Area range between approximately 70 and 120 m.

Dorado Phase 1 is intended to operate for a life of 20 years (inclusive of potential future tiebacks), commencing operations as early as 2027. The Dorado Phase 1 infrastructure will be decommissioned at the end of the commercial life of the project in accordance with legislative requirements.

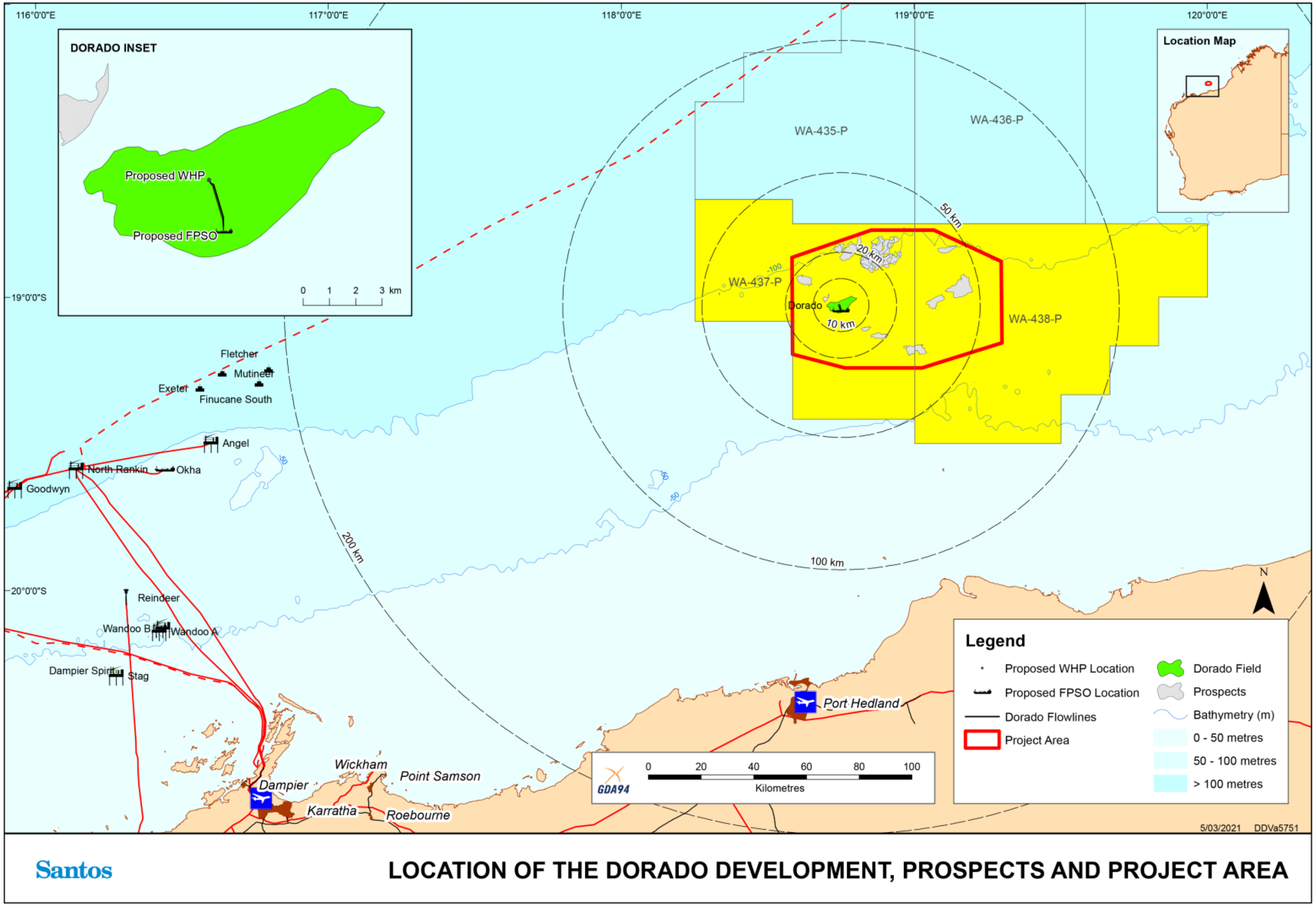

Figure 0-1: Location of the Dorado Development, Prospects and Project Area

Purpose of the Dorado Development Offshore Project Proposal

The purpose of the Dorado Development OPP is to:

+ provide a whole-of-project assessment of the environmental impacts and risks of Dorado Phase 1;
+ define and demonstrate the acceptable levels of environmental impacts and risks for Dorado Phase 1;
+ provide relevant information to the public and an opportunity for the public to comment on Dorado Phase 1; and
+ meet the regulatory requirements of the OPGGS (E) Regulations.

Information about the Proponent

Santos WA Northwest Pty Ltd (Santos), as operator of the Dorado Joint Venture, is the proponent for the Dorado Development OPP. An Australian company founded in 1954, Santos is one of the leading independent oil and gas producers in the Asia-Pacific region, supplying the energy needs of homes, businesses and major industries across Australia and Asia.

Santos originated in the Cooper Basin; has extensive exploration and production acreage in Australia, as well as extensive infrastructure; and is committed to supplying domestic markets, unlocking resources, and driving value and performance. Santos is dedicated to being the safest oil and gas operator in Australia and preventing harm to people and the environment.

ES-2. Relevant Requirements

Dorado Phase 1 lies entirely within Commonwealth waters and hence lies within the jurisdiction of the Australian Government. The two key pieces of Commonwealth legislation that apply to the environmental approval of Dorado Phase 1 are the:

+ *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and subsidiary regulations; and
+ *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Other relevant requirements that apply to the environmental approval of Dorado Phase 1 include:

+ additional Commonwealth legislation;
+ international agreements and conventions; and
+ policy, advice and guidelines.

Santos has applied the above relevant requirements to the environmental impact assessment and management of Dorado Phase 1.

Offshore Petroleum and Greenhouse Gas Storage Act 2006

The OPGGS Act provides the regulatory framework for petroleum exploration and recovery and the injection and storage of greenhouse gas (GHG) substances in Commonwealth waters. The OPP is required under subsidiary OPGGS (E) Regulations.

The OPGGS (E) Regulations are the principal regulations for the environmental management of petroleum activities in Commonwealth waters. In addition to the OPP, the OPGGS (E) Regulations also require Santos to have in place accepted Environment Plans (EPs) and Oil Pollution Emergency Plans (OPEPs) for the petroleum activities within the scope of Dorado Phase 1.

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act and supporting regulations provide for the protection of the environment and conservation of biodiversity in Australia (including Commonwealth waters) specific to matters of national environment significance (MNES). Amendments to the OPGGS Act and OPGGS (E) Regulations in February 2014 require matters protected under Part 3 of the EPBC Act to be considered in the Dorado Development OPP.

ES-3. Description of the Environment

The OPP describes the physical, biological and socio-economic environment that may be affected (EMBA) from planned and unplanned events associated with the Dorado Phase 1 activities, including MNES protected under the EPBC Act. This description informs the assessment of environmental impacts and risks.

The outer boundary of the EMBA is the worst-case and largest spatial extent where unplanned hydrocarbon releases from Dorado Phase 1 activities could have an environmental consequence. The EMBA is based on the cumulative extent of 300 stochastic model simulations for all exposure probabilities, using the 'low' exposure values for each modelled oil component, that is 1 gram per square metre (g/m^2) floating oil, 10 parts per billion (ppb) dissolved and entrained oil and 10 g/m^2 for oil on shoreline. All planned activities will occur within the Project Area (**Figure 0-1**).

Environmental Studies

Santos commissioned a range of environmental studies to better understand the existing environment within and surrounding the Project Area. These studies are described in subsequent sections and include:

- benthic habitat surveys;
- benthic habitat modelling;
- sediment quality surveys; and
- water quality surveys.

Results of these studies supported the assessment of environmental impacts and risks.

Physical Environment

The seabed within the Project Area is generally flat and featureless, which is consistent with much of the mid-continental shelf in the North West Shelf (NWS) region. There are no known bathymetric features, such as reefs, shoals or banks, within the Project Area.

Water movement in the Project Area is dominated by strong tidal regimes, as such the water movement is regular and predictable, in a northwest and southeast direction. There is relatively little variation in this pattern throughout the year, with little apparent influence of the mesoscale currents, such as the Holloway Current, which typically occur on the outer continental shelf in water depths more than 100 m. Tides in the Project Area are semidiurnal (two high and two low tides per day), with slight diurnal inequality. The tidal range in the region is large, with the maximum tidal range at the port of Port Hedland in excess of 7 m. This large tidal range accounts for the strength of tidal currents observed in the Project Area. In the EMBA beyond the Project Area, mesoscale currents, such as the Holloway and Leeuwin currents, play an important role in water movements. Smaller-scale water movements, such as tidal and wind-driven currents, are superimposed over these mesoscale currents.

Water and sediment quality within the Project Area is high, with little evidence of contamination. Turbidity levels in surface waters are low, with increased levels of turbidity near the seabed likely due to sediment resuspension by currents at the seabed. Concentrations of metals and hydrocarbons in water and sediments were below the recommended guideline values for slightly to moderately disturbed marine systems, with many of the concentrations below the laboratory limits of reporting. Sediments in the Project Area were characterised as varying grades of sand – ranging from slightly gravelly muddy sand to gravelly sand.

The climate of the Project Area is arid and tropical, experiencing high summer temperatures and periodic tropical cyclones in summer. Rainfall in the region is low, although intense rainfall may occur during the passage of summer tropical cyclones and thunderstorms. The summer and winter seasons fall into the periods September to March and May to July, respectively. Winters are characterised by clear skies, fine weather, predominantly strong east to southeast winds and infrequent rain. Summer winds are more variable, with strong southwesterlies dominating. Transitional wind periods, during which either pattern may predominate, can be experienced in April, May and September of each year.

The Project Area is remote from potential sources of atmospheric pollutants, and air quality in the Project Area is high.

Biological Environment

Benthic habitat within the Project Area consists of bare sediments and hard substrate areas that typically have a low or no cover of epibenthic biota. These habitats were homogenous throughout the surveyed area and are well represented outside the Project Area.

Habitats within the Project Area can be described as the following:

+ Areas of flat, silty sand and silty mud that are sparsely populated with epibiota and support a low to medium density of tube worms, scattered sea pens, crinoids and anemones; bioturbation by small fish and invertebrates also occurs;
+ Areas of low, probably mobile, sand waves supporting very little epibiota other than occasional sea pens and worm tubes; and
+ Exposed hard substrates supporting a low to medium density of filter-feeding assemblages generally dominated by small gorgonians, sea whips, soft corals and sponges.

No key ecological features (KEF) occur within the Project Area. A range of other communities and habitats occur within the EMBA beyond the Project Area, including:

+ benthic habitats, such as:
  - bare substrate;
  - reefs, shoals and banks;
  - seagrasses; and
  - macroalgae.
+ coastal habitats, such as:
  - mangroves;
  - intertidal sand and mudflats;
  - intertidal platforms;
  - sandy beaches; and
  - rocky shorelines.

A number of threatened or migratory species listed under the EPBC Act were listed within the Project Area and EMBA, including:

- 13 fishes (including sharks) (10 within the Project Area and another three within the EMBA beyond the Project Area);
- 16 marine mammals (seven within the Project Area and another nine within the EMBA beyond the Project Area);
- nine reptiles (five within the Project Area and another four within the EMBA beyond the Project Area); and
- 76 birds (10 within the Project Area and another three within the EMBA beyond the Project Area).

Socio-economic Environment

No protected areas overlap the Project Area, although a number occur within the EMBA beyond the Project Area, including:

- 18 Commonwealth Australian marine marks (AMPs);
- 14 Western Australian marine protected areas;
- 14 Western Australian terrestrial protected areas; and
- six wetlands of international importance (Ramsar wetlands).

Nine Western Australian–managed fisheries overlap the Project Area, with the Pilbara Interim Trawl Fishery the most active within the Project Area. Three Commonwealth-managed fisheries overlap the Project Area, none of which have notable historic fishing effort within the Project Area. Numerous Western Australian and Commonwealth-managed fisheries overlap the EMBA beyond the Project Area. No aquaculture activities occur within the Project Area, but aquaculture occurs within the EMBA beyond the Project Area.

No World, Commonwealth or national heritage properties occur within the Project Area. Several heritage properties occur within the EMBA beyond the Project Area, including:

- two World Heritage Places (Ningaloo Coast and Shark Bay);
- eight Commonwealth heritage places; and
- nine national heritage places.

No Aboriginal heritage sites occur within the Project Area. Numerous Aboriginal heritage places registered under the Western Australian *Aboriginal Heritage Act 1972* occur along the coastline within the EMBA beyond the Project Area, predominantly along the Dampier Peninsula.

No tourism activities occur within the Project Area, but they do occur throughout the EMBA beyond the Project Area.

The maritime industry within the Project Area consists primarily of commercial shipping, with a shipping fairway for commercial vessels transiting to and from Port Hedland overlapping the Project Area. Maritime industry within the EMBA includes shipping, ports, and petroleum exploration and production.

There are no designated Department of Defence exercise areas overlapping the Project Area.

ES-4. Acceptable Levels of Impacts and Risks

The OPGGS (E) Regulations require that Santos demonstrate the environmental impacts and risks associated with Dorado Phase 1 are of an acceptable level. Santos has defined acceptable levels of impacts and risks for the environmental receptors that may credibly be impacted by Dorado Phase 1 to address this requirement. The predicted environmental impacts and risks from all aspects of Dorado Phase 1 were then compared to the predefined acceptable levels to evaluate whether the impacts and risks were below the acceptable level.

The following criteria were considered by Santos when developing receptor-specific acceptable levels of impacts and risks:

+ the environmental value of the receptor;
+ the principles of ecologically sustainable development;
+ relevant requirements;
+ internal context; and
+ external context.

ES-5. Analysis of Alternatives

The petroleum resources within the Project Area could be developed using numerous field development concepts, each concept could be implemented using different types of production facilities, and each alternative has relative advantages and disadvantages.

In progressing the Dorado Development, Santos has considered a range of alternatives to inform development concepts and to understand the feasibility of alternative field development concepts. The assessment process used by Santos involved a multidisciplinary evaluation of concept and design alternatives across five criteria: technical feasibility, health and safety (H&S), environment, economic, and societal. After identifying that technically and commercially viable alternatives existed, Santos started identifying the preferred Dorado Development concept. The development concept to develop the oil resource ('liquids only') was selected as it enables the use of LPG-rich gas reinjection, which is required to enhance the volume of recoverable liquids from the Dorado field. It will be implemented via a wellhead platform and FPSO to achieve the early development of the resource and maximise the recovery of the liquids resource. This is Dorado Phase 1. Adopting the gas reinjection concept also preserves the potential for a future gas export development (Dorado Phase 2), subject to separate approvals, including an OPP, once the oil resource has been recovered and the recoverable gas resources are well understood.

After selection of the preferred field development concept, Santos considered and assessed a wide range of facilities, installation and construction methods, field gas management, produced water management and mooring design alternatives. These are detailed in the OPP.

The alternatives analysis process used and described in the OPP will be continued through the detailed design and engineering stages of the project.

ES-6. Description of the Project

The Dorado Development will develop the oil resources identified in the Bedout Sub-basin, with initial production being the light oil from the Caley reservoir, the main target reservoir, and condensate from the Baxter, Crespin and Milne reservoirs (which underlie the Caley). Collectively, these resources make up the Dorado reservoir and are termed the Dorado field, will produce Dorado oil, and are the foundation for Dorado Phase 1. The key characteristics of the proposed Dorado Phase 1 development are summarised in **Table 0-1.** The current development concept shown in **Figure 0-2** comprises:

+ A not normally manned wellhead platform (Dorado WHP) with provision for 16 wells (oil/gas production and gas reinjection) drilled from a single drill centre on the WHP. Gas will be reinjected via the wells (located on the WHP) into the reservoir to enhance oil recovery. The WHP will be remotely powered and operated from the FPSO;

- Infield flowlines approximately 2.2-km in length to transport the hydrocarbons and associated production fluids and an umbilical to provide chemicals, power and communications between the Dorado WHP and the FPSO;
- An FPSO connected to the seabed via a disconnectable turret mooring (DTM). The FPSO will include accommodation and processing facilities and will allow for the storage and offloading of the hydrocarbons via an offtake tanker; and
- The future development of prospects identified in the Project Area (targeting the Archer Formation) as tiebacks to either the Dorado WHP or the FPSO to augment oil production for the project life. The characteristics of these future tieback reservoirs are expected to be similar to that of the Dorado field (i.e. from the Archer Formation, yielding similar products).

The Dorado field and future tiebacks are expected to produce hydrocarbons over the operating life of the facilities (20 years). At the end of the commercial lifetime, Dorado Phase 1 infrastructure will be decommissioned in accordance with standard industry practices and relevant legislation at the time of decommissioning.

Table 0-1: Key characteristics of the Dorado Phase 1 development

Project Element	Number, Extent, or Range
Project Area	The Dorado Development Project Area is spatially defined in **Figure 6-4.**
Wells	A maximum total of 38 wells, being a combination of oil and gas development wells and gas reinjection wells, located within the Project Area, will be comprised of: + Up to 16 wells with dry trees on the Dorado WHP, being: - 6 x oil production; - 2 x gas production; - 2 x gas reinjection; and - Up to 6 additional wells that are a combination of production and gas reinjection wells. + Up to 22 wells will be future tie-backs located within the project area, with the breakdown of production and gas reinjection wells to be determined by the tieback reservoir characteristics.
WHPs	A maximum of three (3) not normally manned WHPs, comprising: + One gravity based not normally manned WHP located in the Dorado field, in the vicinity of the site described in Table 6-2, with 16 slots for production and gas reinjection wells. + Up to an additional two (2) not normally manned WHP's located in the project area.
FPSO facility	One (1) FPSO located at the Dorado field, in the vicinity of the site described in **Table 6-2**, moored by a DTM system used for processing and treatment of the recovered liquids for export, reservoir gas for power generation, pilot flare, and gas reinjection. FPSO connected to the WHP via flowlines (initially two hydrocarbon production and one gas reinjection), an umbilical and risers.

Project Element	Number, Extent, or Range
Future tie-backs - pipelines and subsea systems	Comprising flowlines, umbilical's and potentially manifolds depending on the tie-back concept, providing for two future tie-backs.
Dorado Phase 1 hydrocarbons	Light oil and condensate as described in **Section 6.4,** with a total volume of 350 MMbbls over 20 years.
Project life	Project life is presented in **Table 0-2**, including operation of the FPSO for a 20-year period.

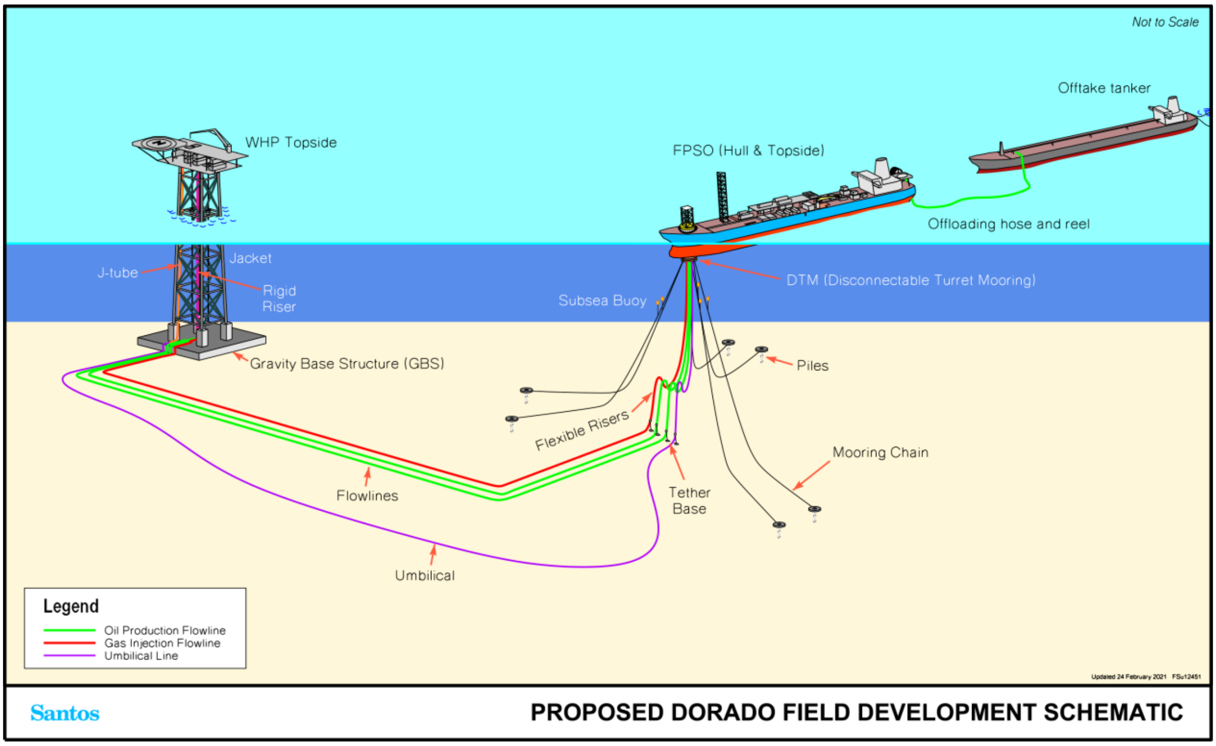

Figure 0-2: Proposed Dorado Phase 1 Field Development Concept

Vessels transiting to and from the Project Area are not considered a petroleum activity: they fall under other maritime legislation, including the Commonwealth Navigation Act 2012, and therefore are excluded from the scope of this OPP. In addition, helicopter activities outside a petroleum safety zone are also not defined as petroleum activities.

Development Schedule

The indicative timeframes and development schedule of key activities are presented in **Table 0-2.**

Table 0-2: Indicative Dorado Phase 1 schedule

Activity	Approximate Timing	Approximate Duration
Dorado WHP installation and FPSO mooring installation (including piling)	Approximately 18 to 24 months post FID	3 to 6 months

Activity	Approximate Timing	Approximate Duration
Dorado reservoir wells drilling (up to16)	Approximately 18 to 24 months post FID following Dorado WHP installation	24 months
FPSO arrival and commissioning (ready for start-up)	Approximately 4 years post-FID	3 months prior to the ready for start-up date
Production Operations commence	2027 (pending FID timing)	20 years
Future tieback well drilling (up to 22)	Within the 20-year operating life of Dorado Phase 1	
Decommissioning	At the end of the commercial lifetime of Dorado Phase 1 (expected to be approximately 2047 at the earliest).	

Project Stages

The key activities within these project stages are summarised in **Table 0-3**. Future tiebacks are expected to involve components of the same key stages and activities as those of the Dorado WHP and FPSO development. The Dorado WHP and FPSO locations will remain unchanged for Dorado Phase 1.

Table 0-3: Project stages and key activities

Project Stage	Key Activities
Installation of the Dorado WHP and FPSO mooring piles	+ Transport and installation of Dorado WHP substructure + Transport and installation of Dorado WHP topsides + Transport, piling and installation and of FPSO mooring piles
Development drilling	+ Drilling of oil/gas production and gas reinjection wells + Well testing
Installation of subsea equipment and connections between infrastructure	+ Installation of subsea system, including flowlines, MWA, risers, manifolds and umbilicals + Transport, installation and mooring of the DTM + Transport, piling and installation of FPSO mooring piles (optional if not completed at time of WHP installation activities)
Hook-up of FPSO	+ Sail away and connection of the FPSO to the DTM and FPSO hook-up
Commissioning	+ Commissioning, testing and monitoring of systems and equipment on the Dorado WHP and FPSO topsides + Commissioning of the flowlines and umbilicals (e.g. hydrotesting and dewatering)
Operations and maintenance	+ Dorado WHP and FPSO operations + Planned maintenance and shutdown campaigns + Periodic product offtake by offloading tankers temporarily connected to the FPSO for transport to market + Well interventions activities

Project Stage	Key Activities
	+ Drilling of infill wells at the Dorado WHP + Vertical seismic profiling (drilling and 3-D)
Future tiebacks	+ Development of reservoirs (currently identified as prospects) within the Dorado Development Project Area. Key activities associated with these future developments may include: - Site surveys - Drilling of additional wells (with the potential installation of subsea trees) - Installation and commissioning of subsea flowlines or pipelines, WHPs or manifolds (if subsea development) and umbilicals from the additional wells to the Dorado WHP or FPSO
Decommissioning	+ Flush flowlines and WHP from FPSO + Disconnection of the FPSO and sail away for offsite decommissioning or reuse + Plugging and abandonment of the production and gas reinjection wells + Disconnection and decommissioning of the Dorado WHP + Decommissioning of the subsea system

ES-7. Evaluation of Environmental Impacts and Risks

Santos has undertaken environmental impact and risk assessments for Dorado Phase 1 in accordance with the Santos' Risk Management General Procedure and risk management processes specific to Santos' offshore operations.

Santos operates under an overarching Risk Management Policy, which is underpinned by Santos' health, safety and environment management processes. The key steps of Santos' process for assessing environmental impacts and risks for this OPP are shown in **Figure 0-3**.

The impact or risk for each activity and associated hazards was assessed following the application of controls. For planned events, only the consequence of the impact was assessed. Likelihood was not assessed, as the occurrence of planned events is effectively certain. The consequence for planned events was based on all controls functioning effectively. For unplanned events, the environmental residual risk of the event was determined based on the likelihood and consequence of the events. The likelihood of an unplanned event occurring was based on all controls functioning effectively. The consequence was based on a worst-case event occurring with all controls having failed. This provides a conservative approach to assessing consequence, as the likelihood of a worst-case event with the failure of all controls is remote.

The resulting consequence (planned events) or residual risk (unplanned events) was then compared to Santos' acceptable levels of impact and risk, including receptor-specific acceptable levels of impact. If the impact or residual risk was determined to not be acceptable, additional controls were applied and the impact or risk was assessed again. This process was repeated until each impact or residual risk was reduced to an acceptable level. The impacts and risks resulting from planned events along with key controls are provided in **Table 0-4.** The impacts and risks resulting from unplanned events are provided in **Table 0-5**, along with the key controls.

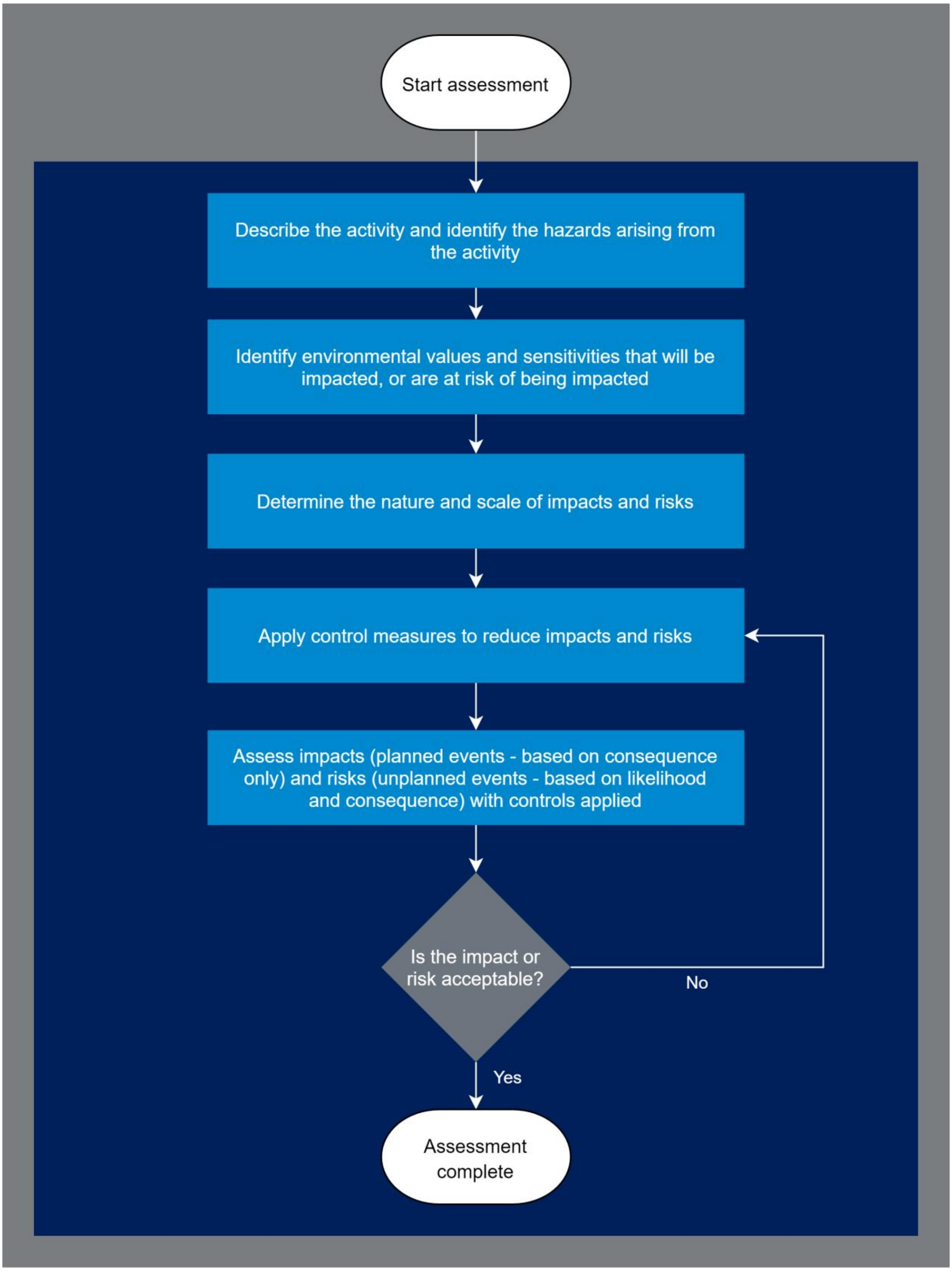

Figure 0-3: Environmental impact and risk assessment process

Cumulative Impact Assessment

In addition to assessing each aspect and its associated hazards independently, Santos has also undertaken a cumulative impact assessment. This cumulative impact assessment considered potential synergistic impacts on environmental values and sensitivities from all aspects of Dorado Phase 1 and third-party activities. The cumulative impact assessment was only undertaken for planned events. No consideration of cumulative impacts from unplanned events was made, as these events are not expected to occur during Dorado Phase 1.

All cumulative impacts were assessed against the acceptable levels of impact defined for Dorado Phase 1 and found to be acceptable.

ES-8. Environmental Performance Framework

Santos will ensure that environmental impacts and risks will be maintained within acceptable levels and that environmental performance outcomes (EPOs) will be achieved by implementing an environmental performance framework. The OPGGS (E) Regulations require that Santos develop and implement EPs for all petroleum activities within the scope of this OPP. Each EP must be assessed and accepted by NOPSEMA prior to Santos commencing the petroleum activities. EPs for activities within the scope of this OPP may not be submitted until this OPP has been accepted by NOPSEMA. The effective application of EPOs will be demonstrated through the implementation of subsequent EPs.

EPs will contain EPOs (these are the EPOs that will be accepted as part of this OPP), environmental performance standards, measurement criteria and a detailed implementation strategy. The EPOs in the EPs will maintain an equivalent level of environmental performance than that stated in this OPP.

Santos will have an Emergency Response Plan in place to address all credible operational risks and scenarios. The plan will provide procedural guidance specific to the activity to control, coordinate and respond to an emergency or incident, including hydrocarbon spills.

The OPGGS (E) Regulations require the implementation strategy in an EP to contain an OPEP. The OPEP must include adequate arrangements for responding to oil pollution that may arise from the petroleum activities considered in the EP, as well as testing arrangements to ensure ongoing capability. The arrangements must be tested at least every 12 months, as well as when they are introduced or modified.

Table 0-4: Summary of the assessment of planned environmental impacts and risks from Dorado Phase 1

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
Discharges-Drilling Fluids and Cuttings Discharges (**Section 7.2.1**)	Water Quality	Localised decrease in water quality during drilling operations.	**EPO1A**: Impacts to sediment quality and water quality as a result of Dorado Phase 1 drilling fluids and cuttings discharges restricted to a 1 km radius from Dorado facilities. **EPO2A**: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area. **EPO3A**: No mortality or significant[1] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of drilling fluids and cuttings.	**CM1**: All wells to be drilled using water-based mud (WBM), with non-aqueous fluid (NAF)/ synthetic based mud (SBM) only to be used where technical requirements preclude the use of WBM. **CM2**: Santos chemical selection process will be implemented to select drilling chemicals, muds and fluids with low environmental risk, while meeting technical requirements. **CM3**: Drilling fluids inventory will be developed and tracked to reduce discharge of excess powders, brines, and drilling fluids. **CM4**: Drill cuttings will be processed on the mobile offshore drilling rig (MODU) to recover drilling fluids and reduce residual fluids content prior to overboard discharge. **CM5**: An assessment of drill cuttings and fluids discharges will be undertaken prior to drilling future tieback wells to ensure impacts to environmental values and sensitivities are within acceptable levels. **CM6**: Benthic habitat surveys will be undertaken prior to drilling at future tieback locations to identify and avoid sensitive benthic habitat.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect
	Sediment Quality	Deposition of drill cuttings during drilling operations.			
	Benthic Habitats	Localised smothering and loss of habitat.			
	Marine Fauna (benthic infauna)	Oxygen degradation and bioaccumulation of contaminants in benthic infauna.			
Discharges-Produced Water Discharge (**Section 7.2.2**)	Water Quality	Localised decrease in water quality during the operational stage of the Dorado Development.	**EPO3B**: No mortality or significant[2] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of produced water (PW). **EPO4A**: Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring a 99 % species protection level (based on ANZG 2018) for water quality is achieved outside of the PW mixing zone boundary[2]. **EPO5A** Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring ANZG 2018 sediment quality guideline values are not exceeded outside the PW mixing zone[2]. **EPO6A:** Dorado Phase 1 is managed so that seafood caught within the project area remains safe for human consumption**.**	**CM7**: PW treatment system to meet OIW discharge standards: + Less than 30 mg/L OIW during steady state operations averaged over 24 h + between 30 mg/L and 100 mg/L OIW averaged over 24 h during the initial start-up period and for commissioning of future tieback (up to 6 months after first oil) **CM8**: Adaptive PW management plan including: + PW modelling, + in-field environmental monitoring to verify predicted mixing zone modelling, + in-field environmental monitoring to assess potential impacts against ANZG 2018 water quality and sediment quality guidelines, + PW chemical characterisation, + PW ecotoxicity testing, + tiered management system in response to off-specification water (e.g. storage onboard and retreatment prior to discharge), + studies to verify whether bioaccumulation of toxicants in biota attributable to the discharge of PW, + adaptive management triggers and mitigative measures in response to results of bioaccumulation studies, + adopt changes in relevant legislative requirements and updates to ANZG to PW discharges.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect
	Sediment Quality	Deposition of very small quantities of precipitated solids during the operational stage of Dorado Phase 1.			
	Marine Fauna	Bioaccumulation of contaminants in marine fauna.			

[1] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

[2] Produced water mixing zone determined to be 1000 m from the FPSO during a <30 mg/L PW discharge.

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
				CM9: Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements.	

Discharges-Wastewater Discharges
(Section 7.2.3)
	Water Quality	Localised decrease in water quality around wastewater discharge locations.	**EPO3C**: No mortality or significant[3] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of wastewater.
			EPO7A: Dorado Phase 1 routine planned wastewater discharges compliant with relevant established industry standard environmental discharge limits
				CM9: Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements.
				CM10: All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification):
				+ Marine Order 91 (Marine Pollution Prevention – Oil), which implements Annex I of MARPOL 73/78, including (as required by vessel class):
				  + Machinery space bilge/oily water shall have International Maritime Organization (IMO)-approved oil filtering equipment (oil/water separator) with an on-line monitoring device to measure OIW content to be less than 15 ppm prior to discharge.
				  + A deck drainage system capable of controlling the content of discharges for areas of high risk of fuel/oil/grease or hazardous chemical contamination.
				  + Valid International Oil Pollution Prevention Certificate.
				+ Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including:
				  + Garbage management plan in place.
				  + Garbage record book maintained onboard.
				+ Marine Order 96 (Marine Pollution Prevention – Sewage), which implements Annex IV of MARPOL 73/78, including (as required by vessel class):
				  + a valid International Sewage Pollution Prevention Certificate,
				  + an IMO-approved sewage treatment plant, or
				  + a sewage comminuting and disinfecting system, or
				  + a sewage holding tank sized appropriately to contain all generated waste (black and grey water), and
				  + discharge of sewage will occur at a moderate rate while vessel is proceeding (at more than 4 knots).
					Minor – II
					Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect

	Sediment Quality	Minor increase in concentrations of contaminants, nutrients and organic carbon in sediments, along with a small increase in biochemical oxygen nutrients around wastewater discharge locations.			
	Marine Fauna	Potential behavioural disturbance in close proximity to the discharge and bioaccumulation of contaminants in marine fauna.			
Emissions – Artificial Light **(Section 7.2.4)**	Plankton Fish Marine Mammals Reptiles Birds	Potential changes in behaviour, such as attraction, avoidance and disorientation, of marine fauna.	**EPO3D**: No mortality or significant[4] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 artificial light emissions. **EPO8A**: Artificial light emissions do not result in the displacement of marine turtles from habitat critical to their survival.	**CM11**: Align lighting design on Dorado Development facilities (e.g. WHP, FPSO) with light design described in National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2020), including: + Using minimum number and intensity of lighting to meet operational requirements (e.g. safety, navigation etc.), + Adapting lighting for colour, intensity and timing where practicable, and + Using non-reflective, dark-coloured surfaces where practicable (i.e. where safety is not compromised). **CM12:** Manage lighting on vessels to reduce light spill to the environment where practicable. **CM13**: Implement adaptive management (e.g. shielding, retrofitting with lower intensity lights etc.) of artificial light emissions if there is a moderate environment incident resulting from light emissions.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect

[3] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
				CM14: Flaring limited to operation of the flare pilot during steady state operations.	
Emissions- Acoustic Emissions (**Section 7.2.5**)	Marine Mammals	Potential permanent threshold shift (PTS), temporary threshold shift (TTS), behavioural impacts and masking.	**EPO3E**: No mortality or significant[4] impacts to EPBC Act listed, threatened, migratory or cetacean species as a result of Dorado Phase 1 acoustic emissions. **EPO9A** Undertake Dorado phase 1 in such a manner that noise in biologically important areas will be managed to prevent any displacement of threatened species as per EPBC Act species conservation requirements. **EPO10A** No impacts from Dorado Phase 1 acoustic emissions to pre-existing commercial fish stocks that occur within the project area that could be subject to existing or future fishing effort. **EPO11A:** No injury to pygmy blue whales in a pygmy blue whale BIA. **EPO12A:** noise generating activities of Dorado Phase 1 are managed in such a manner to prevent PTS and reduce the risk of TTS and biologically important behavioural disturbance to all whales in the Commonwealth marine area.	**CM15:** Vessels movements and helicopter flights comply with Part 8 of EPBC Regulations for interacting with cetaceans. **CM16**: Implement Santos' Protected Marine Fauna Interaction and Sighting Procedure. **CM17**: Undertake acoustic emissions modelling for piling, 3D VSP and drilling VSP activities for potential future tiebacks. **CM18**: Implement mitigation measures for drilling VSP and 3-D VSP activities aligned with EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a), including: + development of low-power and shutdown zones, + marine fauna observers, + pre-start visual observations, + soft-start procedures, + stop work procedures, and + night-time and low visibility procedures. **CM19**: Implement mitigation measures for piling activities, including: + marine fauna observers, + pre-start visual observations, + soft-start procedures, + stop work procedures, and + night-time and low visibility procedures **CM20:** Where future activity specific acoustic emissions modelling results indicate PTS, TTS envelopes overlap with a pygmy blue whale BIA, related impulsive noise generating activities will not occur during corresponding peak migration periods.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect
	Fishes	Potential mortal injury, recoverable injury, TTS and behavioural disturbance.			
	Reptiles	Potential PTS, TTS and behavioural disturbance.			
Emissions- Greenhouse Gas (**Section 7.2.6**)	Australian Environment	Potential impacts as a result of climate change have been modelled by Commonwealth Scientific and Industrial Research Organisation (CSIRO). The modelling indicates that temperatures will increase across Australia; rainfall patterns will change significantly; and extreme events, such as droughts, floods and wildfires, will become more common. These changes are likely to impact on individual species, ecosystems and ecosystem services, such as food and	**EPO13A**: Dorado Phase 1 Scope 1 GHG emissions managed in accordance with the Safeguard Mechanism benchmark baseline set by the Clean Energy Regulator, in support of meeting the Australian Government's Paris Agreement Nationally Determined Contribution of net zero emissions by 2050. **EPO14A**: As the Paris Agreement is the most comprehensive global agreement to seek to limit global temperature rise as specified in Article 2 of the Agreement and no significant[5] impacts to the environment globally, including in Australia, Dorado	**CM14:** Flaring limited to operation of the flare pilot during steady state operations. **CM21:** Optimise facility design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable. **CM22:** The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare, and direct them to be reinjected with the produced gas. **CM23:** Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities. **CM24**: During routine operations, reinject produced gas (other than safety flare and fuel gas) to recover liquids. **CM25:** Embed fugitive emissions surveillance and management into facilities operations and maintenance. **CM26:** Undertake fuel and flare analysis, baselining and forecasting throughout Dorado Development operational life.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect

[4] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013)

[5] As defined by the significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
		water availability. Within decades, environments across Australia may be substantially different (CSIRO and Bureau of Meteorology 2015).	Phase 1 oil is only sold to customers from countries that have: + a net-zero emissions by 2050 (NZE) commitment; and/or + are signatories to the Paris Agreement and have Nationally Determined Contributions (NDC) in place to reduce or offset GHG emissions.	**CM27:** Establish annual setting of energy efficiency improvements and targets throughout the life of Dorado Phase 1 facilities. **CM28:** Throughout the life of Dorado Phase 1 facilities undertake optimisation of energy efficiency through periodic opportunity identification workshops or studies, evaluation and implementation. **CM29**: Dorado Phase 1 will report on Scope 1 GHG emissions as required per the National Greenhouse and Energy Reporting (NGER) Scheme. **CM30**: Dorado Phase 1 will comply with the requirements of the Safeguard Mechanism, including purchase and/or surrender of Australian carbon credit units for any emissions above the baseline for the year, to support achievement of Australia's NDC emissions targets. **CM31**: Dorado Phase 1 will implement a GHG management plan that incorporates an adaptive management approach that facilitates a continuous cycle of monitoring, evaluating, and implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations including: + Evaluation of emissions monitoring data and ensuring the implemented controls deliver predicted emission reductions; + Seeking new and relevant data/information from external sources relevant to GHG emission management including Commonwealth legislation or policy; + Ensuring effectiveness of internal processes and procedures to reduce and manage GHG emissions; + Responding to changes from detailed engineering outcomes; and + Implementing corrective actions identified from the above. **CM32**: Dorado Phase 1 will limit sales to customers from countries that have a NZE commitment or are signatories to the Paris Agreement, and will cease to supply customers in countries that withdraw from the Paris Agreement or NZE commitments. **CM33:** Regular monitoring of Dorado Phase 1 customer country compliance with NZE or NDC emissions targets (Article 4) through the Paris Agreement monitoring and assurance mechanisms: + the enhanced transparency framework 5-yearly reporting (Article 13) + the 5-yearly Global Stocktake (Article 14); and + implementation and compliance committee annual reporting (Article 15). **CM34:** If results of CM33 identify gaps in customer country compliance against NZE or NDC emissions targets, Dorado will cease to supply those customers or take mitigation actions to offset their Dorado Phase 1 product emissions.	
Emissions-Atmospheric Emissions (**Section 7.2.7**)	Air Quality	Change in air quality.	**EPO15A**: No significant[6] impacts to air quality throughout the life of Dorado Phase 1.	**CM14**: Flaring limited to operation of the flare pilot during steady state operations. **CM21:** Optimise facility design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable. **CM22:** The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare, and direct them to be reinjected with the produced gas.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect

[6] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
				CM23: Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities. **CM25:** Embed fugitive emissions surveillance and management into facilities operations and maintenance. **CM35**: The MODU, vessels, and FPSO will comply with MARPOL Annex VI (Prevention of Air Pollution from Ships), the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and subsequent Marine Orders, which require vessels to have a valid International Air Pollution Prevention Certificate (for vessels more than 400 tonnage) and to use low-sulphur fuel. **CM36:** Ozone-depleting substances onboard vessels and the facilities will comply with relevant MARPOL 73/78 (Annex VI - air pollution), Navigation Act 2012, Protection of the Sea (Prevention of Pollution) Act 1983 *a*nd subsequent Marine Order requirements (as appropriate for vessel classification). **CM37**: Measure, monitor or estimate facility fuel and flare emissions (in accordance with the National Pollutant Inventory) to inform and optimise management practices and minimise environmental impact of emissions. **CM38**: National Pollutant Inventory reporting records (or contemporary requirements at the time of the activities) will be complied with during the project.	

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
Physical Presence- Interactions with Other Users (**Section 7.2.8**)	Commercial Fisheries Maritime industry	Displacement of other users from exclusion zones within the Project Area during installation/drilling operations Exclusion of other users from the gazetted PSZ during production operations	**EPO16A**: No adverse interactions[7] between Santos' activities and other maritime users within the Project Area. **EPO17A**: The installation and drilling operations, production operations and decommissioning activities of the project will be managed in a manner that does not interfere with other marine users within the Project Area to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties of Santos under the Dorado petroleum titles. **EPO18A** Decommissioning of Dorado facilities in compliance with Section 572 (3) of the OPGGS Act 2009.	**CM39**: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the *Navigation Act 2012* and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM40**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM41**: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM42**: Should potential future tiebacks overlap within Australian Maritime Safety Authority (AMSA) fairways, Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way. **CM43**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM44**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM45**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development facilities. **CM46**: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3) of the OPGGS Act. **CM47:** exclusion zones/petroleum safety zones will be limited to the minimum area necessary to exercise rights and perform duties under project specific petroleum titles. **CM48:** residual impacts to other marine users of the environment are managed to not interfere with their rights.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect
Physical Presence – Seabed Disturbance (**Section 7.2.9**)	Water Quality Sediment Quality	Temporary, localised decrease in water quality during installation and removal of components on the seabed. Localised, minor modification of sediment characteristics, such as geological origin and particle size distribution.	**EPO2B**: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area. **EPO18B** Decommissioning of Dorado facilities in compliance with Section 572 (3) of the OPGGS Act 2009	**CM49**: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3) of the OPGGS Act. **CM50**: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints. **CM51**: Undertake benthic habitat surveys for future tieback locations and proposed subsea infrastructure corridors prior to development to identify and avoid sensitive benthic habitat where practicable within technical and safety constraints.	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect

[7] Whether an interaction constitutes an adverse interaction will be determined on a case by case basis. Examples of adverse interactions may include substantiated complaints by other marine users to Santos or NOPSEMA, vessel collisions, or damage to unsupervised fishing equipment (e.g. traps). Interactions where other users have not taken reasonable measures to avoid the interaction (e.g. third-party vessel not adhering to standard maritime requirements or ignoring advice provided during consultation) are not considered to be adverse.

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Consequence
	Benthic Habitats	Localised, minor modification of benthic habitats from the introduction of artificial hard substrates.	**EPO3F**: No mortality or significant[8] impacts to EPBC act listed threatened and migratory species as a result of Dorado Phase 1 seabed disturbance. **EPO19A**: Impacts to sediment quality and water quality as a result of seabed disturbance from Dorado Phase 1 restricted to a 1 km radius from Dorado facilities		
	Fishes	Increased fish diversity and abundance due to modification of benthic habitats.			
	Fisheries	Potential enhanced recruitment of targeted species and increased catches.			

[8] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Table 0-5: **Summary of the assessment of unplanned environmental impacts and risks from Dorado Phase 1**

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Likelihood	Consequence	Residual Risk
Accidental Release – Hydrocarbon and Chemical Spills (**Section 7.3.1**)	Water Quality	Potential widespread decrease in water quality from hydrocarbon pollution.	**EPO20A** Undertake Dorado Phase 1 in a manner that will prevent unplanned discharge of chemicals or hydrocarbons to the marine environment. **EPO21A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of reservoir fluids to the marine environment due to a LOWC, or failure of a flowline or FPSO cargo tank. **EPO22A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of MDO/MGO or HFO to the marine environment due to vessel collision, failure of a storage tank or release during refuelling. **EPO23A** In an event of an unplanned release of chemicals or hydrocarbons, spill response control measures will be implemented in accordance with an accepted EP/OPEP.	**CM9** Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements. **CM52**: Accepted well operations management plans in place for all wells detailing: + blowout preventer installation and testing, + competency of the drillers engaged, + monitoring of wellbore progress and drilling fluid balance, and + well designs that consider reservoir characteristics. **CM53**: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the *Navigation Act 2012* and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM54**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM55**: All project vessels subject to Santos' marine assurance procedures. **CM56**: All offtake tankers subject to Santos' tanker vetting procedures. **CM57**: Bunkering procedures to manage the transfers of fuel that include: + weather limits on bunkering operations, + bunkering equipment specifications and inspections, + visual observations during transfers, and + emergency shutdowns. **CM58**: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM59**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM60**: Should potential future tiebacks overlap within AMSA fairways Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way. **CM61**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM62**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development.	Unlikely – B	Major -IV + Large-scale impact to Environmental Value(s) of conservation significance + Moderate scale surface water impact	Low
	Sediment Quality	Potential localised decrease in water quality from hydrocarbon pollution.					
	Communities and Habitats	Potential widespread impacts to benthic and coastal communities and habitats from hydrocarbon pollution.					
	Fishes	Potential acute and chronic toxic effects.					
	Marine Mammals						
	Reptiles						
	Birds						
	Protected Areas	Potential impacts to the natural and socio-economic values of marine and coastal protection areas.					
	Fisheries	Potential temporary closure of fisheries due to hydrocarbon pollution.					
	Heritage	Potential loss of cultural values of heritage sites.					
	Tourism	Potential impacts to tourism through loss of nature-based tourism resources due to hydrocarbon pollution.					

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Likelihood	Consequence	Residual Risk
				CM63: FPSO will be designed, constructed and operated to Santos' specified requirements, including: + double-hulled construction, + cyclone and adverse weather avoidance procedures, and + structural integrity inspection regime. **CM64:** Oil-spill modelling and environmental risk assessments for the Dorado Phase 1 Eps and OPEPs will consider the full range of worst-case scenario LOWC consequences based on the best available oil-spill modelling. **CM65:** During Development Well drilling and drilling of tieback wells, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. **CM66:** Accepted EP/OPEPs in place for all Dorado Development activities. **CM67**: All vessels involved in the project will have a valid Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan (as appropriate for vessel classification). **CM68**: Source control emergency response plans in place for all drilling activities. **CM69:** Emergency response capability (including equipment, personnel contracts, MOUs) will be maintained in accordance with approved SOPEPS accepted EPs and OPEPs.			

Accidental Release – Loss of Solid Material
(**Section 7.3.2**)
	Benthic Habitat	Modification of benthic habitats from accidental loss of solid material.	**EPO3G**: No mortality or significant[9] impacts to EPBC act listed threatened migratory or cetacean species as a result of Dorado Phase 1 loss of solid material.
			EPO24A: No significant impacts[8] to benthic habitats and communities.
			EPO25A Undertake the Dorado Phase 1 in a manner that will prevent an unplanned discharge of solid waste to the marine environment.
			EPO26A Undertake the Dorado Phase 1 in a manner that will prevent unplanned seabed disturbance.
				CM10: All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification):
				+ Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including:
				  + garbage management plan in place.
				  + garbage record book maintained onboard.
				CM70: Crane and lifting operations will comply with the following:
				+ lifting equipment will be inspected and certified,
				+ preventative maintenance will be carried out, and
				+ lifting operators will be competent and qualified.
				CM71: Objects dropped overboard will be recovered where practicable to mitigate the environmental consequences from objects remaining in the marine environment, unless the environmental consequences are minor or safety risks are disproportionate to the environmental consequences.
				CM72: Waste management procedures will include:
					Occasional – D	Minor – II
						Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect
							Low

	Marine Fauna	Injury or mortality of marine fauna due to ingestion of or entanglement with lost solid material.					

[9] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Likelihood	Consequence	Residual Risk
				+ classification of wastes, including segregation of wastes into recyclable and non-recyclable materials, + appropriate storage of wastes, and + transportation and disposal of wastes by a licenced waste contractor at licenced waste management facilities in accordance with waste classifications. **CM73:** After completion of the drilling and installation stages a site clean-up activity will be undertaken to identify and remove, if safe, any dropped objects or solid materials that may have been lost.			
Physical Presence – Introduction of Invasive Marine Species (IMS) **(Section 7.3.3)**	Benthic Habitats	Change in ecosystem dynamics.	**EPO27A:** Undertake Dorado Phase 1 in a manner that will prevent the introduction, establishment and spread of IMS in the natural environment attributable to the development. **EPO28A:** No significant[10] impacts to benthic habitats and communities, KEF and exploited fisheries resource stocks within the Project Area.	**CM74**: Ballast water exchange operations will comply with the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (as appropriate to vessel class), Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020), Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 and Biosecurity Act 2015, including: + all ballast water exchanges conducted more than 12 nautical miles (nm) from land, and + Vessel Ballast Water Management Plan stipulating that ballast water exchange records will be maintained. **CM75**: Implementation of Dorado FPSO Biofouling Management Plan when the FPSO sails to the Project Area from international waters (such as when it first hooks up or comes back from dry dock) and as per the anti-fouling and in-water cleaning guidelines (Department of the Environment and New Zealand Ministry for Primary Industries 2015). **CM76**: Compliance with Santos IMS Management Plan. **CM77:** Biofouling management for vessels will be in accordance with the IMO Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Marine Environment Protection Committee 2011). **CM78:** Compliance with the International Convention on the Control of Harmful Anti-fouling Systems on Ships 2001, including vessels (of appropriate class) having a valid International Anti-fouling Systems Certificate. **CM79:** Fisheries will be provided with information on the timing, nature and scale of aspects of Dorado Phase 1 through Santos' consultation activities.	Unlikely (b)	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect	Very Low
	KEF	Changes to the functions, interests or activities of other users.					
	Fisheries	Reduction in fishery resource stocks.					
Physical Presence –Interactions with marine Fauna **(Section 7.3.4)**	Marine Mammals	Injury, disturbance/mortality to marine fauna.	**EPO29A**: No vessel or helicopter interactions within the Dorado Phase 1 Project operational area with EPBC Act listed threatened, migratory or cetacean species.	**CM16**: Implement Santos' Protected Marine Fauna Interaction and Sighting Procedure. **CM80:** Vessels within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans (except in emergency conditions or when manoeuvring is not possible), which include: + implement a caution zone of 150 m for dolphins and 300 m for whales, + vessels will not knowingly approach closer than 50 m to a dolphin and 100 m to a whale (i.e. no approach zone),	Unlikely – B	Minor – II Detectable but insignificant change to local population, industry or ecosystem factors.	Very Low
	Fishes						
	Reptiles						

[10] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)	Likelihood	Consequence	Residual Risk
				+ make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale, + vessels will not knowingly travel more than 6 knots within the caution zone of a dolphin or whale, and + there will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone). **CM81:** Helicopters within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans (except in emergency conditions or when manoeuvring is not possible), which includes: + not operating the helicopter at a height lower than 1 650 feet or within a horizontal radius of 500 metres of a cetacean + not allowing the aircraft to approach a cetacean from head on **CM82**: If a Part 13 Permit for the disturbance of listed migratory birds is required under the EPBC Act a Santos Bird Management Plan will be developed and implemented.		Localised effect	

ES-9. Stakeholder Consultation

To complement the NOPSEMA assessment process for OPPs and provide stakeholders with sufficient time to consider Dorado Phase 1, Santos will adopt a phased consultation approach for this OPP:

+ Phase 1 Consultation – prior to publication of the OPP by NOPSEMA (NOPSEMA Stage 1 Assessment);
+ Phase 2 Consultation – during formal public comment period on the OPP;
+ Phase 3 Consultation – after the public comment period and prior to resubmission of the OPP to NOPSEMA (NOPSEMA Stage 2 Assessment); and
+ Phase 4 Consultation – ongoing consultation post OPP acceptance to support preparation of EPs and operations.

Santos will consider all feedback provided by stakeholders and, where relevant, incorporate information provided by stakeholders into the environmental management of the Dorado Development.

1 Introduction

This document is the offshore project proposal (OPP) for the development of oil resources in the Bedout Sub-basin, located in Commonwealth waters approximately 140 km offshore from Port Hedland, Western Australia (**Figure 1-1**). Development of these resources is referred to within this OPP as the Dorado Development.

The Dorado Development will be developed through several phases: a first phase of oil production, including future tiebacks to augment oil production and export, and potentially a second phase for gas production:

- Dorado Phase 1 – oil production from the Dorado field and future tiebacks to augment oil production. In this phase recovered gas will be reinjected to the Dorado reservoir to enhance oil recovery. Dorado Phase 1 will be designed for liquid handling rates of 100 thousand standard barrels per day (KSTB/d) and gas reinjection capacity of 235 million standard cubic feet per day (MMscf/d). Dorado Phase 1 includes provision for future tiebacks with a total export volume of 350 million barrels (MMbbl) over 20 years.
- Dorado Phase 2 – future gas production. Recovered gas will be exported to either domestic gas and/or liquefied natural gas (LNG) facilities and will be optimised based on discovered resources in the Bedout Sub-basin at that time. Phase 2 will be subject to future exploration and investment decisions and separately assessed under environment regulatory approval processes.

This OPP seeks approval for Dorado Phase 1 only and has been prepared by Santos WA Northwest Pty Ltd, which is the proponent for the development. Santos WA Northwest Pty Ltd is a 100%-owned subsidiary of Santos Energy Limited (Santos). This OPP has been submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) for assessment under Part 1A of the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (OPGGS (E) Regulations), specifically its suitability for publication under Regulation 5C. This OPP outlines Santos' commitment to undertaking Dorado Phase 1 in a manner that ensures environmental impacts and risks are acceptable.

Dorado Phase 1 will contribute to meeting the world's future needs for oil resources, and will also bolster energy security for Australia in the wake of global energy supply shocks following the global pandemic and the Russia-Ukraine conflict.

Based on global energy studies and forecasts, oil plays a major role in the energy mix for a sustainable energy future and currently is forecast to provide the main source of energy for the transport sector into the future (**Section 7.2.6.5**). Even under the most aggressive accelerated energy transition scenarios, including the IEA Net Zero by 2050 scenario, there remains a requirement for investment in oil and gas production to maintain sufficient supply through the transition (refer to **Figure 1-1** and **Section 7.2.6.5**).

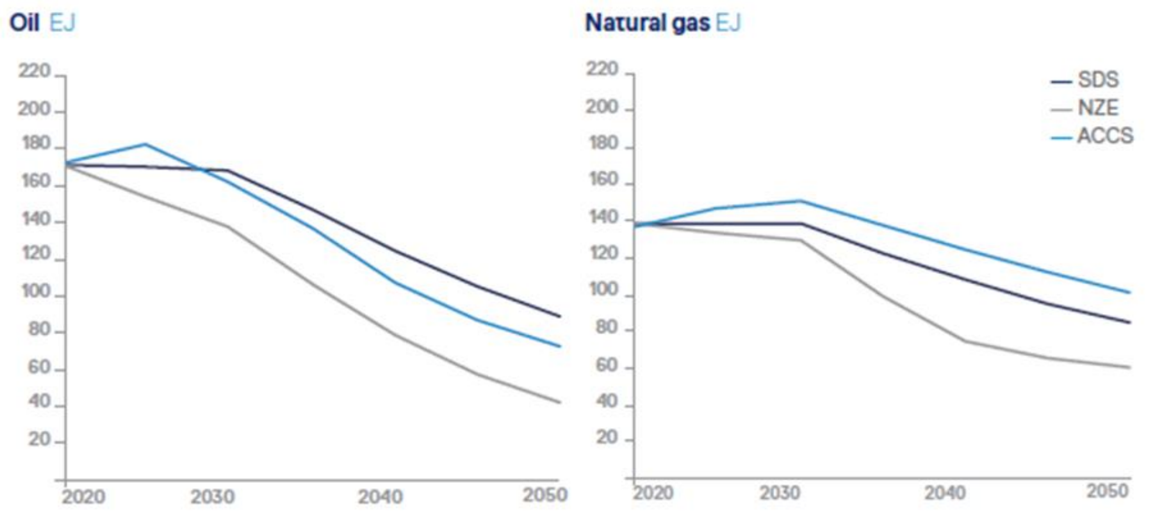

Figure 1-1: Total Energy Supply under Accelerated Energy Transition Scenarios; SDS – IEA Sustainable Development Scenario; NZE – IEA Net Zero Emissions by 2050 Scenario; ACCS – IHS Markit Accelerated CCS Scenario (Source: Santos 2022 Climate Change Report)

1.1 Project Overview and Location

The oil resources that will be developed lie within petroleum titles WA-437-P and WA-438-P. The foundation development of Dorado Phase 1 will consist of:

+ a wellhead platform (WHP) with up to 16 wells (production and gas injection);
+ a floating production, storage and offloading (FPSO) facility; and
+ subsea flowlines and umbilicals between the WHP and the FPSO.

This OPP for Dorado Phase 1 includes potential for future tiebacks to augment oil production. These tiebacks will connect to the Dorado WHP and FPSO. Each tieback may consist of a well or series of wells connected to the Dorado Phase 1 infrastructure by subsea risers, flowlines and umbilicals. Tieback wells may be subsea or connected to additional WHPs or subsea facilities, such as a subsea gathering system.

Exploration activities and appraisal drilling within the Bedout Sub-basin are excluded activities from the scope of this OPP. The NOPSEMA accepted Bedout Basin Multi-Well Drilling Environment Plan (Bedout Multi-Well Drilling Environment Plan - SO-00-BI-20003) includes for drilling of up to 8 wells (exploration and/or appraisal) in permit areas WA-437-P, WA-438-P , specifically within 2 operational areas located within the Dorado Phase 1 Project Area. Exploration drilling of the prospects identified within the Project Area as future tiebacks within this OPP (refer **Figure 1-2**) will be drilled using this accepted Environment Plan.

All planned petroleum activities, including the future tiebacks, will take place within the Dorado Development Project Area (**Figure 1-1**) and include:

+ drilling;
+ construction and installation;
+ commissioning;
+ operations; and
+ decommissioning.

The proposed locations of the FPSO and WHP are approximately 143 km and 145 km north of the town of Port Hedland respectively. Water depths for the Dorado Development range between approximately 70 and 120 m (**Figure 1-2**).

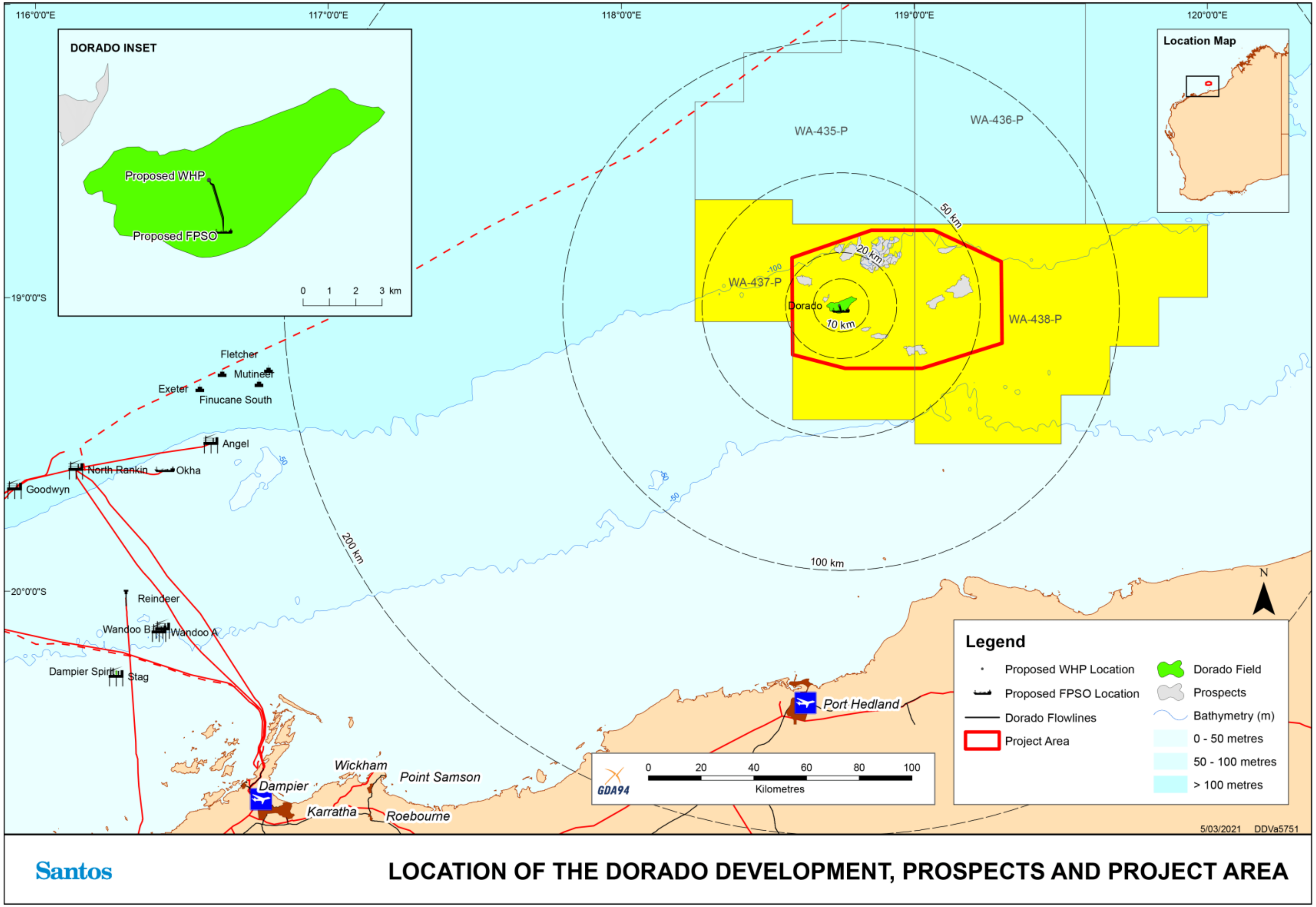

Figure 1-2: Location of the Dorado Development, Prospects and Project Area

Oil will be produced and gas will be reinjected into the reservoirs to enhance oil recovery. Produced water (PW) will be discharged overboard after being treated onboard the FPSO. Construction of Dorado Phase 1 facilities in construction yards is scheduled to commence 12 months post FID. Dorado Phase 1 is intended to operate for a life of 20 years commencing operations in 2027. Dorado Phase 1 infrastructure will be decommissioned at the end of the commercial life of the project in accordance with Section 572 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and Australia's international obligations to remove disused installations and structures.

Potential prospects that could be future tie-backs, if exploration is successful and the reservoir commercially viable are shown on **Figure 1-2**. The hydrocarbons produced from future tie-backs are yet to be confirmed. As the potentially targeted prospects (within the Project Area) were generated by the same petroleum system within the Bedout Sub-basin, the hydrocarbon reservoir properties, geochemistry and pressures of the future tie-backs will be comparable to the Dorado reservoir hydrocarbons sourced from the Caley, Baxter, Crespin and Milne formations, as presented in the Bedout Basin Multi-Well Drilling Environment Plan (the plan under which exploration wells in future prospects will be drilled) which has been accepted by NOPSEMA. The hydrocarbons from any future tie-back wells will be processed on the FPSO located at Dorado, and gas not required for safety flare and energy supply will be re-injected. The timing of future tie-backs is currently unknown, but if tie-backs are to occur it will be within the proposed 20 year life of Phase 1 of the development.

A detailed description of the activities and timing of Dorado Phase 1 is provided in **Section 6**.

1.2 Purpose of the Dorado Development Offshore Project Proposal

The Dorado Development is a new petroleum activity in Commonwealth waters that will recover petroleum, as defined by the OPGGS (E) Regulations. The regulations require that an OPP be assessed and accepted by NOPSEMA prior to Santos undertaking any of the petroleum activities within the scope of the Dorado Development OPP. All petroleum activities within the scope of Dorado Phase 1 also require that an Environment Plan (EP) accepted by NOPSEMA be in place prior to commencing the activities.

The purpose of the Dorado Development OPP is to:

+ provide a whole-of-project assessment of the environmental impacts and risks of Dorado Phase 1;
+ define and demonstrate the acceptable levels of environmental impacts and risks for Dorado Phase 1;
+ provide relevant information to the public and an opportunity for the public to comment on Dorado Phase 1; and
+ meet the regulatory requirements of the OPGGS (E) Regulations.

NOPSEMA's assessment process for the OPP considers the potential environmental impacts and risks of petroleum activities conducted over the entire duration of Dorado Phase 1. The staged assessment process shown in **Figure 1-3** includes a public comment period prior to NOPSEMA's acceptance. Santos is required to demonstrate in the OPP that all environmental impacts and risks from Dorado Phase 1 are at an acceptable level. A detailed description of the OPP assessment process is provided in **Section 2.2**.

NOPSEMA became the sole Commonwealth regulator for environmental management of offshore petroleum activities in 2014 after streamlining of regulatory processes under the OPGGS Act and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The effect of the streamlining is that offshore petroleum activities in Commonwealth waters only require approval by NOPSEMA under the OPGGS Act and no longer require separate approval by the Minister for the Environment under the EPBC Act. The amendments require matters of national environmental significance (MNES) to be addressed in NOPSEMA's assessments of offshore petroleum development approvals as part of the Commonwealth streamlined environmental approvals process. Therefore, the OPP process under the OPGGS (E) Regulations supersedes the Commonwealth referral process under the EPBC Act and replaces the requirement to prepare environmental approvals for submission to the Department of Agriculture, Water and the Environment (DAWE) for petroleum development activities in Commonwealth waters. This OPP addresses the EPBC Act requirements for Dorado Phase 1, including those outlined in the EPBC Act management plans, recovery plans and conservation advice.

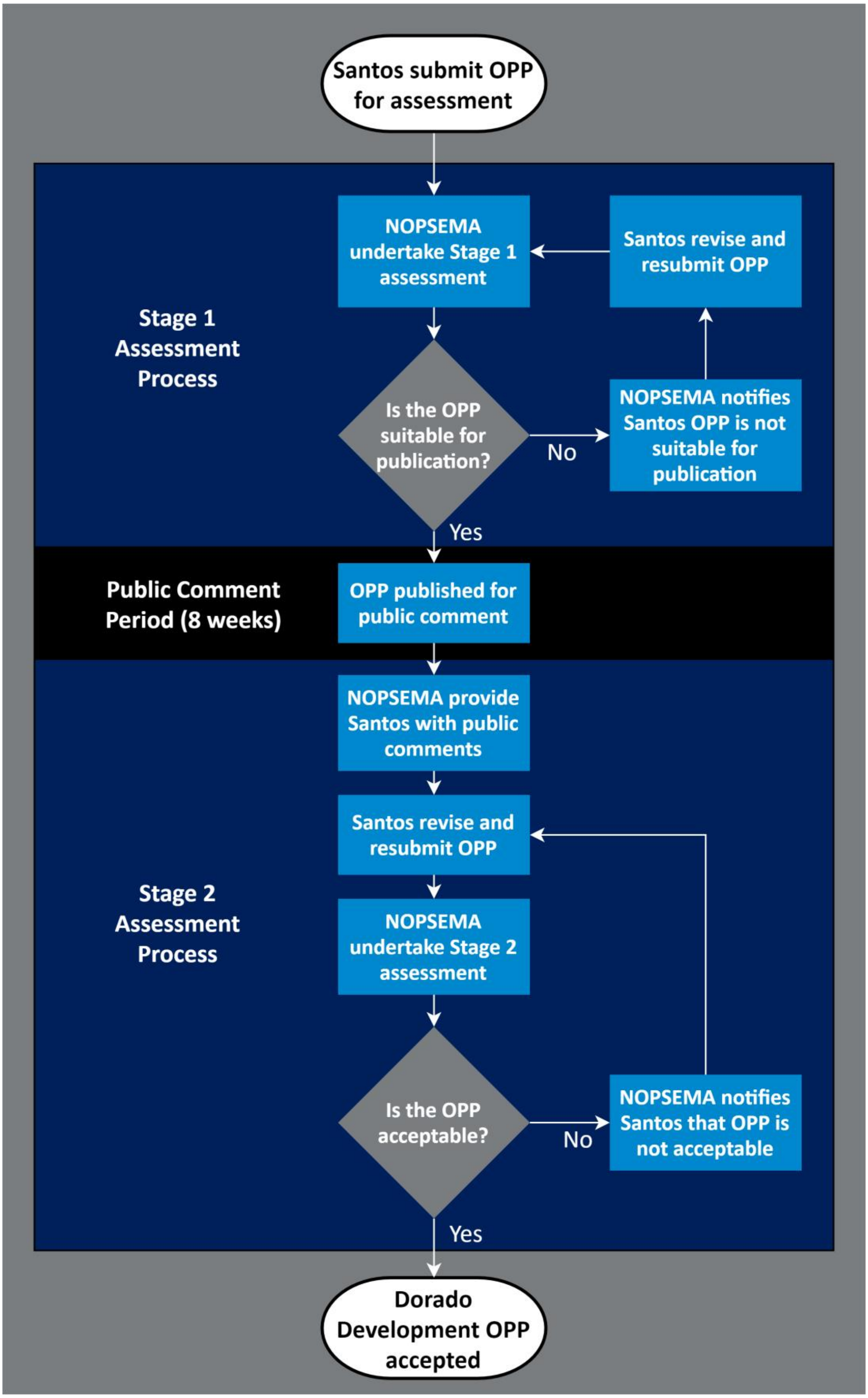

Figure 1-3: Assessment process flow chart for the Dorado Development OPP

1.3 Structure of the Dorado Development Offshore Project Proposal

The OPP has been prepared to align with NOPSEMA's current OPP content requirements (N-04790-GN-1663, Rev 4) (NOPSEMA March 2019a). The structure of the Dorado Development OPP for Phase 1 is outlined in **Table 1-1**. This structure is aligned to the processes that Santos uses to assess environmental risks and impacts, the requirements of the OPGGS (E) Regulations and NOPSEMA's content requirements for OPPs (NOPSEMA 2019a). Mapping of the OPP content to the requirements of the OPGGS (E) Regulations is provided in **Section 2**.

Table 1-1: Descriptions of Dorado Development OPP sections

Section Title	Description of Section Content
Executive Summary	A summary of the content in the Dorado Development OPP. It allows readers to become familiar with the key information contained in the OPP.
1 – Introduction	An introduction to the Dorado Development (Phase 1 and potential future Phase 2), and the OPP assessment process. It also provides information on Santos as the project's proponent.
2 – Relevant Requirements	A summary of legislation and other requirements that Santos must comply with during Phase 1 of the Dorado Development. Many of these requirements are references in the environmental management measures that Santos has committed to implementing during Phase 1.
3 – Description of the Environment	A description of the environmental values and sensitivities that will be affected or are at risk of being affected by Dorado Phase 1. These values and sensitivities are considered in the evaluation of environmental impacts and risks.
4 – Acceptable Levels of Impacts and Risks	A description of the acceptable levels of environmental impacts and risks specific to environmental values and sensitivities. Santos must demonstrate that the impacts and risks from Dorado Phase 1 are consistent with these acceptable levels of environmental impacts and risks.
5 – Analysis of Alternatives	Comparative assessments of the feasible alternatives to Santos' development concept for the Dorado Development. The comparative assessments considered environmental, technical, economic, safety and social criteria for each feasible alternative.
6 – Description of the Project	A description of Dorado Phase 1. The description summarises all of the petroleum activities and facilities within the scope of the Dorado Development OPP. The proposed timing and location of all activities is provided in this section.
7 – Evaluation of Environmental Impacts and Risks	Environmental impact and risk assessments for all of the aspects of Dorado Phase 1. This section includes demonstrations that all environmental impacts and risks will be managed to an acceptable level. The section also contains controls that will be implemented to manage environmental impacts and risks.
8 – Environmental Performance Framework	A description of the systems and processes that Santos will apply during Dorado Phase 1 to meet the levels of environmental performance outlined in the Dorado Development OPP.

Section Title	Description of Section Content
9 – Consultation	A description of the consultation Santos has undertaken in relation to the OPP and other activities within the Bedout Sub-basin. Guidance on making public comment on the OPP is provided in this section.
10 – References	A bibliography of the literature cited within the Dorado Development OPP.

1.4 Information about the Proponent

Santos WA Northwest Pty Ltd (Santos), as operator of the Dorado Joint Venture, is the proponent for the Dorado Development OPP. An Australian company founded in 1954, Santos is one of the leading independent oil and gas producers in the Asia-Pacific region, supplying the energy needs of homes, businesses and major industries across Australia and Asia.

Santos began in the Cooper Basin; has extensive exploration and production acreage in Australia, as well as extensive infrastructure; and is committed to supplying domestic markets, unlocking resources and driving value and performance. Santos is committed to being the safest oil and gas company wherever we have a presence and preventing harm to people and the environment.

The Dorado Development is a joint venture between Santos and Australian oil and gas exploration company Carnarvon Energy Pty Ltd.

As required by Regulation 5A (5)(a), Santos' name and contact details are provided in **Table 1-2**.

Table 1-2: Proponent's name and contact details

Name	Santos WA Northwest Pty Ltd, which is a 100%-owned subsidiary of Santos Energy Limited
Address	Level 7, 100 St Georges Terrace, Perth, Western Australia 6000
Website	https://www.santos.com/
Email	Offshore.environment.admin@santos.com
Telephone	+61 8 6218 7100
Facsimile	+61 8 6218 7200

2 Relevant Requirements

Identifying and complying with relevant requirements, such as legislation, standards and guidelines, is an integral part of the Santos management system. The system obliges Santos to ensure that relevant environmental management requirements are identified and met when undertaking Dorado Phase 1.

The OPGGS (E) Regulations require Santos to describe the requirements that apply to Dorado Phase 1, along with how they will be met in this OPP. These requirements have been considered by Santos in developing the environmental management measures that will be applied to Dorado Phase 1. This section provides an overview of the relevant legislation, standards and guidelines that are applicable to the environmental management of Dorado Phase 1. These include:

+ Commonwealth policy – **Section 2.1**;
+ Commonwealth legislation – **Section 2.2**;
+ international agreements and conventions – **Section 2.3**; and

+ guidelines – **Section 2.4**.

The following sections describe the items in each of the categories above. Each item is briefly described, along with its relevance to Dorado Phase 1.

Why isn't the Dorado Development being assessed under the EPBC Act?

NOPSEMA became the sole Commonwealth regulator for environmental management of offshore petroleum activities in 2014 after streamlining of regulatory processes under the OPGGS Act and the EPBC Act.

Prior to the streamlining arrangements, Phase 1 of the Dorado Development would have been referred for assessment, and assessed, under the EPBC Act by DAWE. It would also require EPs accepted by NOPSEMA in accordance with the OPGGS (E) Regulations for all of the petroleum activities within the scope of the Dorado Development. The Australian Government recognised there was duplication of regulatory effort under the two Acts, resulting in an administrative burden on proponents. This was the rationale for the streamlining of offshore petroleum industry environmental approvals.

The effect of streamlining is that offshore petroleum activities in Commonwealth waters only require approval by NOPSEMA under the OPGGS Act and no longer require separate approval by the Minister for the Environment under the EPBC Act. As such, the Dorado Development is subject to the OPP assessment process under the OPGGS (E) Regulations and is not assessed under the referral and assessment process under the EPBC Act.

The Program by which the streamlining arrangements are implemented has been endorsed by the Minister for the Environment. The Program outlines the commitments and undertaking of NOPSEMA to ensure adequate protection of matters protected under Part 3 of the EPBC Act. NOPSEMA consider the policy framework established by DAWE, along with the range of publications made under the EPBC Act in relation to matters protected under Part 3 of the Act (e.g. recovery plans and conservation advice).

2.1 Commonwealth Policy

2.1.1 Australian Offshore Petroleum Development Policy

The Australian Government has a long-standing policy of encouraging investment in, and development of, petroleum resources in Commonwealth waters. The policy is implemented through:

+ the identification and release of prospective petroleum acreage;
+ applications to explore petroleum acreage;
+ granting of petroleum titles;
+ regulation of petroleum activities; and
+ surrender of petroleum titles.

Dorado Phase 1 and associated activities are shown within this policy framework in **Figure 2-1**.

The exploration titles within the Project Area (WA-437-P and WA-438-P) were granted in 2009. These titles oblige the titleholder to explore for and develop petroleum resources. Exploration activities (e.g. seismic data acquisition and processing, exploration wells etc.) have been undertaken since the initial grant of these titles and have subsequently discovered the hydrocarbon resources that will be developed.

Implementation of Commonwealth policy on developing offshore petroleum resources includes an independent regulator (NOPSEMA) and a petroleum titles administrator (the National Offshore Petroleum Titles Administrator (NOPTA))

NOPSEMA perform a range of functions under the OPGGS Act and subsidiary regulations, including:

+ providing advice;
+ assessment;
+ inspection,
+ investigation; and
+ enforcement.

NOPTA provides advice and recommendations to the Joint Authorities and responsible Commonwealth minister, administers petroleum titles and manages data.

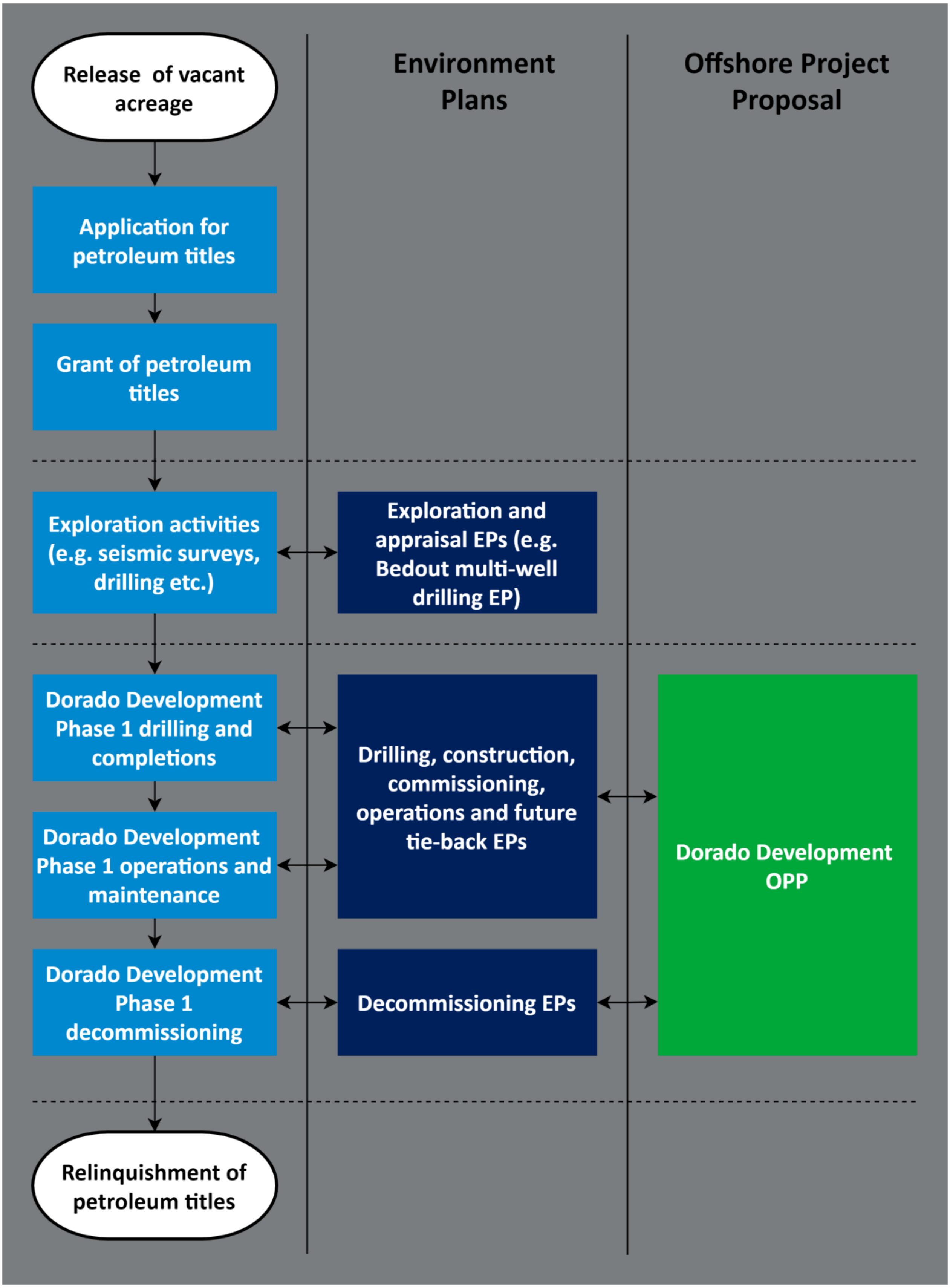

Figure 2-1: Application of Commonwealth petroleum policy in relation to the oil resources in the Dorado Development Project Area

2.1.2 Australia's Oceans Policy

Australia's Oceans Policy was introduced in 1998. The policy has a number of aims, including:

- exercising and protecting Australia's rights over its marine jurisdictions;
- meeting its obligations under the United Nations Conventions on the Law of the Sea 1982, which was ratified in 1994;
- understanding and protecting the marine environment; and
- promoting ecologically sustainable economic development and establishing integrated planning and management.

Under the Oceans Policy, a nationally representative system of Australian marine parks (AMPs) has been established. These are based on the principles of multiple-use and ecologically sustainable development (ESD). This policy has been implemented through the EPBC Act, as outlined in the Strategic Plan of Action for the National Representative System of Marine Protected Areas (Task Force on Marine Protected Areas 1998).

2.1.3 Climate Change Policy

As a party to the Paris Agreement, Australia sets commitments in the form of Nationally Determined Contributions (NDC) to reduce greenhouse gas (GHG) emissions, most recently updated in 2022:

- Reduce 43% below 2005 levels by 2030 and reach net zero emissions by 2050.

Australian Government climate change policy and its relevance to management of Dorado GHG emissions is discussed further in **Section 7.2.6.**

2.2 Commonwealth Legislation

Dorado Phase 1 is located wholly within Commonwealth waters and is therefore subject to Commonwealth legislation. Two key Commonwealth Acts (and subsidiary legislation) are relevant to the environmental management of Dorado Phase 1:

- the OPGGS Act; and
- the EPBC Act.

The relevance of these Acts and subsidiary legislation to Dorado Phase 1 is considered in **Section 2.2.1** and **Section 2.2.2**. Additional Commonwealth legislation that is applicable to Dorado Phase 1 is considered in **Section 2.2.3**.

2.2.1 Offshore Petroleum and Greenhouse Gas Storage Act 2006

The OPGGS Act provides the regulatory framework for petroleum exploration and recovery and the injection and storage of GHG substances in Commonwealth waters. The Act provides for the granting of petroleum and GHG titles and licences and the establishment of an independent safety and environmental regulator (NOPSEMA) and titles administrator (NOPTA). The Act also provides for the "polluter pays" principle in the event of an oil spill. The Act requires titleholders to maintain adequate financial assurance arrangements (e.g. insurance) for liabilities that may arise from an oil spill.

Several subsidiary regulations made under the OPGGS Act are relevant to the environmental management of Dorado Phase 1:

- OPGGS (E) Regulations;

- *Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011* (OPGGS (RMA) Regulations); and
- *Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009* (OPGGS (S) Regulations).

Section 572 of the OPGGS Act places duties on titleholders in relation to the maintenance and removal of structures, equipment and property brought onto title. Decommissioning of the Dorado facilities to meet the requirements of Section 572 of the OPGGS Act is addressed in **Section 6.7.7**.

2.2.1.1 Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009

The OPGGS (E) Regulations are the principle legislative instrument for the environmental management of petroleum activities in Commonwealth waters. The object of the OPGGS (E) Regulations is to ensure that petroleum activities in Commonwealth waters are carried out in a manner:

- consistent with the principles of ESD set out in section 3A of the EPBC Act;
- by which the environmental impacts and risks of the activity will be reduced to as low as reasonably practicable (ALARP); and
- by which the environmental impacts and risks of the activity will be at an acceptable level.

The OPGGS (E) Regulations include requirements for Santos to consider MNES defined in Part 3 of the EPBC Act; refer to **Section 2.2.2** for a description of Matters of National Environmental Significance.

2.2.1.1.1 Offshore Project Proposal

The OPGGS (E) Regulations require that Santos submit an OPP to NOPSEMA for assessment of Dorado Phase 1. The Dorado Development OPP must undergo a two-stage assessment process and public comment period before it can be accepted. The OPP must be accepted prior to Santos submitting any EPs (and Oil Pollution Emergency Plans (OPEPs)) for activities within the scope of Dorado Phase 1. The OPP must demonstrate that all environmental impacts and risks are of an acceptable level. (Unlike EPs, the OPP is not required to demonstrate that all environmental impacts and risks are managed to ALARP.)

The OPGGS (E) Regulations specify the content requirements for the Dorado Development OPP. This includes consideration of all relevant environmental values and sensitivities that may credibly be affected by Dorado Phase 1. This includes MNES protected under Part 3 of the EPBC Act.

Regulation 5A of the OPGGS (E) Regulations states the requirements for an OPP. **Table 2-1** outlines and maps these requirements to the sections of the Dorado Development OPP that fulfil each requirement.

Table 2-1: OPGGS (E) Regulations regarding OPP requirements and the corresponding sections of the Dorado Development OPP

OPGGS (E) Regulations Reference	Regulation Text	Relevant Sections of the OPP
5A (5)(a)	The proposal must: + Include the proponent's name and contact details.	**Section 1.4**

OPGGS (E) Regulations Reference	Regulation Text	Relevant Sections of the OPP
5A (5)(b)	Include a summary of the project, including the following: + a description of each activity that is part of the project; + the location or locations of each activity, + a proposed timetable for carrying out the project, + a description of the facilities that are proposed to be used to undertake each activity, and + a description of the actions proposed to be taken, following completion of the project, in relation to the facilities.	**Section 6**
5A (5)(c) and 5 (5)(d)	Describe the existing environment that may be affected by the project. Include details of the particular relevant values and sensitivities (if any) of that environment.	**Section 3**
5A (5)(e)	Set out the environmental performance outcomes for the project.	**Section 8**
5A (5)(f)	Describe any feasible alternative to the project, or an activity that is part of the project, including: + a comparison of the environmental impacts and risks arising from the project or activity and the alternative; and + an explanation, in adequate detail, of why the alternative was not preferred.	**Section 5**
5A (6)	Without limiting paragraph (5)(d), particular relevant values and sensitivities may include any of the following: + the world heritage values of a declared World Heritage property within the meaning of the EPBC Act, + the national heritage values of a National Heritage place within the meaning of that Act, + the ecological character of a declared Ramsar wetland within the meaning of that Act, + the presence of a listed threatened species or listed threatened ecological community within the meaning of that Act, + the presence of a listed migratory species within the meaning of that Act, and + any values and sensitivities that exist in, or in relation to, part or all of: i. a Commonwealth marine area within the meaning of that Act, or ii. Commonwealth land within the meaning of that Act.	**Section 3**
5A (7)	The proposal must: + describe the requirements, including legislative requirements, that apply to the project and are relevant to the environmental management of the project, and + describe how these requirements will be met.	**Section 2**
5A (8)	The proposal must include: + details of the environmental impacts and risks for the project, and	**Section 7**

OPGGS (E) Regulations Reference	Regulation Text	Relevant Sections of the OPP
	+ an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk.	

2.2.1.1.2 Environment Plans

The OPGGS (E) Regulations require Santos to submit an EP (or EPs) to NOPSEMA for assessment of all petroleum activities within the scope of the Dorado Development OPP. An EP for a petroleum activity within the scope of the OPP may not be submitted prior to NOPSEMA accepting the OPP. EPs for petroleum activities must be accepted by NOPSEMA prior to commencing the activity.

EPs are required to demonstrate that environmental impacts and risks from petroleum activities are managed to a level that is acceptable. EPs are also required to demonstrate that environmental impacts and risks are managed to a level that is ALARP. All environmental sensitivities that may credibly be affected by the petroleum activities must be considered in the EP, including MNES protected under Part 3 of the EPBC Act.

EPs for activities within the scope of the accepted Dorado Development OPP must ensure that the level of performance of the environmental management of the activity is as good as or better than the levels stated in the accepted OPP.

The OPGGS (E) Regulations require Santos to consult with all relevant persons when preparing an EP for activities within the scope of the Dorado Development OPP. This requirement is in addition to the public comment period of the OPP. Refer to **Section 9** for further information on Santos' consultation practices.

2.2.1.1.3 Oil Pollution Emergency Plans

Environment Plans are required to include an Oil Pollution Emergency Plan (OPEP). The OPEP is required to include adequate arrangements for responding to an oil spill. This includes testing of the response arrangements and environmental monitoring of impacts to the environment from spilled oil. Based on the nature and scale of the credible spill scenarios outlined in the EP and OPEP, response strategies are assessed as potentially applicable for combatting a spill through a Net Environment Benefit Assessment. Potential spill response strategies assessed may include:

- Source Control;
- In-situ Burning;
- Monitor and Evaluate;
- Chemical Dispersion;
- Offshore Containment and Recovery;
- Mechanical Dispersion;
- Protection and Deflection;
- Shoreline Clean-up;
- Oiled Wildlife Response; and
- Scientific Monitoring.

2.2.1.2 Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011

The OPGGS (RMA) Regulations are intended to ensure that petroleum activities in Commonwealth waters:

- are carried out in accordance with good oilfield practice;
- optimise the long-term recovery of petroleum; and
- reduce risks to well integrity to ALARP.

The OPGGS (RMA) Regulations also ensure that information on petroleum exploration activities, discoveries, production and operations are provided in a timely manner to the administrators of the OPGGS Act.

The OPGGS (RMA) Regulations require Santos to have in place an accepted Field Development Plan for Dorado Phase 1 and an accepted Well Operations Management Plan in place for Dorado Development wells.

2.2.1.3 Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009

The OPGGS (S) Regulations are intended to ensure that offshore facilities undertaking petroleum activities protect the health and safety of people undertaking these activities. The OPGGS (S) Regulations require:

- validation of the design, construction, operation and decommissioning of facilities undertaking petroleum activities;
- safety cases that provide for management of safety risks, including major accident events, for petroleum facilities; and
- diving safety management systems.

While intended to protect the health and safety of personnel, many management measures considered in validation of facilities and safety cases also protect the environment by preventing uncontrolled releases of hydrocarbons.

2.2.2 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act and supporting regulations provide for the protection of the environment and conservation of biodiversity in Australia (including Commonwealth waters). Amendments to the OPGGS Act and OPGGS (E) Regulations made in February 2014 require matters protected under Part 3 of the EPBC Act to be considered in the Dorado Development OPP. NOPSEMA became the sole environmental regulator in Commonwealth waters following these streamlining arrangements. Matters of National Environmental Significance (MNES) protected under Part 3 of the EPBC Act include:

- the world heritage values of a declared World Heritage property within the meaning of the EPBC Act;
- the national heritage values of a National Heritage place within the meaning of that Act;
- the ecological character of a declared Ramsar wetland within the meaning of that Act;
- the presence of a listed threatened species or listed threatened ecological community within the meaning of that Act;
- the presence of a listed migratory species within the meaning of that Act; and
- any values and sensitivities that exist in, or in relation to, part or all of:
  - a Commonwealth marine area within the meaning of that Act; or

- Commonwealth land within the meaning of that Act.

The EPBC Act also gives effect to several international conventions for the protection of migratory species to which Australia is a signatory, including:

- the Convention on the Conservation of Migratory Species of Wild Animals (commonly referred to as the Bonn Convention);
- the Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (commonly referred to as JAMBA);
- the Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (commonly referred to as CAMBA);
- the Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds (commonly referred to as ROKAMBA);
- the Convention on Wetlands of International Importance (commonly referred to as the Ramsar Convention); and
- the Agreement on the Conservation of Albatrosses and Petrels.

Environmental values and sensitivities, including matters protected under Part 3 of the EPBC Act, are described in **Section 3**. These descriptions inform the assessment of environmental impacts and risks in **Section 7**.

Why isn't the Dorado Development being assessed under the EPBC Act?

NOPSEMA became the sole Commonwealth regulator for environmental management of offshore petroleum activities in 2014 after streamlining of regulatory processes under the OPGGS Act and the EPBC Act.

Prior to the streamlining arrangements, Phase 1 of the Dorado Development would have been referred for assessment, and assessed, under the EPBC Act by DAWE. It would also require EPs accepted by NOPSEMA in accordance with the OPGGS (E) Regulations for all of the petroleum activities within the scope of the Dorado Development. The Australian Government recognised there was duplication of regulatory effort under the two Acts, resulting in an administrative burden on proponents. This was the rationale for the streamlining of offshore petroleum industry environmental approvals.

The effect of streamlining is that offshore petroleum activities in Commonwealth waters only require approval by NOPSEMA under the OPGGS Act and no longer require separate approval by the Minister for the Environment under the EPBC Act. As such, the Dorado Development is subject to the OPP assessment process under the OPGGS (E) Regulations and is not assessed under the referral and assessment process under the EPBC Act.

The Program by which the streamlining arrangements are implemented has been endorsed by the Minister for the Environment. The Program outlines the commitments and undertaking of NOPSEMA to ensure adequate protection of matters protected under Part 3 of the EPBC Act. NOPSEMA consider the policy framework established by DAWE, along with the range of publications made under the EPBC Act in relation to matters protected under Part 3 of the Act (e.g. recovery plans and conservation advice).

Does an OPP provide the same level of environmental assessment and protection as the EPBC Act?

There are a range of features of the environmental approvals process for offshore petroleum activities that ensure the level of environmental assessment and protection is equivalent to, or better than, that provided for under the EPBC Act.

The commitments under the streamlining arrangements require NOPSEMA to ensure adequate protection of matters listed under Part 3 of the EPBC Act. NOPSEMA must consider publications made under the EPBC Act in relation to matters protected under Part 3 of the Act. This includes material published by the Commonwealth intended to protect threatened and migratory species, such as conservation advice and recovery plans. This requirement is aligned to the decision-making process for assessments under the EPBC Act.

The OPP assessment process reflects the level of transparency and opportunity for public comment that is provided for through Environmental Impact Statement/Public Environmental Review assessments under the EPBC Act. Santos must respond to all comments made during the public comment period – this is the same standard applied to the EPBC Act process.

The OPGGS (E) Regulations require EPs also be accepted by NOPSEMA for all petroleum activities within the scope of the Dorado Development OPP. The levels of environmental performance in the EPs must be as good as, or better than, the levels committed to in this OPP. This in an important link between environmental management of specific activities and the overarching environmental assessment in the OPP.

NOPSEMA are the environmental regulator for offshore petroleum activities. NOPSEMA has a range of powers relating to assessment, inspection and enforcement. NOPSEMA frequently inspects the environmental performance of petroleum titleholders to verify compliance with environmental commitments. NOPSEMA can undertake enforcement actions, such as issuing directions, and can require a titleholder to cease an activity.

As described above, there is a clear intention for the OPP assessment process to provide the same, or better, level of environmental assessment and protection. The OPGGS (E) Regulations provide for an independent regulator with strong powers to assess, inspect and enforce environmental performance. This provides the Australian public with the confidence that the OPP assessment process delivers the same, or better, protection than the EPBC Act assessment process.

2.2.2.1 Principles of Ecologically Sustainable Development

NOPSEMA considers the principles of ESD defined in the EPBC Act when assessing the environmental performance outcomes (EPOs) in an OPP. These principles are:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;

- the principle of intergenerational equity-- that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and
- improved valuation, pricing and incentive mechanisms should be promoted.

Santos has considered these principles when developing acceptable levels of environmental impacts and risks. Refer to **Section 4** for further information.

2.2.2.2 Environment Protection and Biodiversity Conservation Act Policy Statements

A number of policy statements have been made that give practical advice to the application of the EPBC Act. Relevant policies include:

- 'indirect consequences' of an action: Section 527E of the EPBC Act; and
- EPBC Policy Statement 2.1 Interaction between offshore seismic exploration and whales: Industry guidelines.

2.2.2.3 Marine Bioregional Plans

A series of marine bioregional plans have been developed for each of the marine regions within Commonwealth waters. The plans describe the conservation values within each region, identify pressures affecting conservation values and outline regional priorities, strategies and actions. The objectives of these plans are to:

- conserve biodiversity and maintain ecosystem health;
- ensure the recovery and protection of threatened species; and
- improve the understanding of the region's biodiversity and ecosystems and the pressures they face.

The Project Area and the spatial extent of all planned impacts from Dorado Phase 1 lie entirely within the North-west Marine Region. The Marine bioregional plan for the North-west Marine Region (Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) 2012a) has been considered when describing the existing environment and the assessment of environmental impacts and risks from Dorado Phase 1.

Modelling studies indicate some worst-case credible unplanned hydrocarbon spills may impact upon environmental sensitivities in the South-west Marine Region. The Marine bioregional plan for the South-west Marine Region (DSEWPaC 2012b) has been considered when describing the existing environment and the assessment of environmental risks of some worst-case unplanned hydrocarbon spill scenarios.

2.2.2.4 Australian Marine Park Management Plans

The EPBC Act provides for the declaration of AMPs based on the International Union for the Conservation of Nature (IUCN) principles and guidelines for categorising protected areas. Australia has established a network of AMPs throughout Commonwealth waters, and these are managed under a series of region-based management plans. These plans detail the management objectives of the AMPs, the environmental values within each of the AMPs and the activities that area permissible within the zones of the AMPs. AMPs are part of the Commonwealth marine environment, which is an MNES.

Australian IUCN Reserve Management Principles (Environment Australia 2002) for each category are set out in the EPBC Regulations. The planned petroleum activities considered within this OPP will not credibly impact any AMPs. Some worst-case credible unplanned hydrocarbon spill scenarios may impact upon several AMPs within the North-west and South-west marine bioregions. Both the North-west Marine Parks Network Management Plan 2018 (Director of National Parks 2018a) and the South-west Marine Parks Network Management Plan 2018 (Director of National Parks 2018b) identify oil pollution as a pressure on the values of these AMPs. Santos has considered these plans when developing acceptable levels of environmental impacts and risks and controls to prevent hydrocarbon spills in the Dorado Development OPP.

2.2.2.4.1 Australian Whale Sanctuary

The EPBC Act established the Australian Whale Sanctuary (AWS) (from 3 nm extending 200 nm from the coast) in 1999 giving high levels of protection to all Cetaceans (45 species of whales, dolphins and a porpoise) in Commonwealth waters. This protection extends to all anthropogenic threats to cetaceans and is not limited to potential impacts from any one sector.

Under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) all cetaceans (whales, dolphins and porpoises) are protected in Australian waters:

- the AWS includes all Commonwealth waters from the three nautical mile state waters limit out to the boundary of the Exclusive Economic Zone (i.e. out to 200 nautical miles and further in some places);
- within the AWS it is an offence to kill, injure or interfere with a cetacean. Severe penalties apply to anyone convicted of such offences; and
- all states and territories also protect whales and dolphins within their waters.

The AWS comprises the Commonwealth marine area, beyond the coastal waters of each state and the Northern Territory. It includes all of Australia's Exclusive Economic Zone (EEZ).

Table 2-2: EPBC Management plans for threatened species that may be affected by Dorado Phase 1

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
All Vertebrate Fauna	Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018)	N/A	There are four main objectives: + Contribute to the long-term prevention of the incidence of harmful marine debris + Remove existing harmful marine debris from the marine environment + Mitigate the impacts of harmful marine debris on marine species and ecological communities + Monitor the quantities, origins and impacts of marine debris and assess the effectiveness of management arrangements over time for the strategic reduction of debris.	Marine debris	No explicit management actions for non-fisheries related industries (note that management actions in the plan relate largely to management of fishing waste (for example 'ghost' gear), and State and Commonwealth management through regulation.
Sawfish and River Sharks	Sawfish and river shark multispecies recovery plan (CoA 2015)	N/A	The primary objective of this recovery plan is to assist the recovery of sawfish and river sharks in Australian waters with a view to: + Improving the population status leading t the removal of the sawfish and river shark species from the threatened species list of the EPBC Act	Habitat degradation / modification	Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			+ Ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future. The specific objectives of the recovery plan (relevant to industry) are: + Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species. + Objective 6: Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life.		
Great White Shark (*Carcharodon carcharias*)	Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPC, 2013)	Vulnerable	The overarching objective of this recovery plan is to assist the recovery of the white shark in the wild throughout its range in Australian waters with a view to: + Improving the population status leading to future removal of the	Habitat degradation / modification	No explicit relevant management actions; habitat modification identified as a threat.
				Climate change	No explicit relevant management actions; climate change identified as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			white shark from the threatened species list of the EPBC Act + Ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future. The specific objectives of the recovery plan (relevant to industry) are: + Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas.		
Grey Nurse Shark (*Carcharias taurus* – west coast population)	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DOE 2014)	Vulnerable	The overarching objective of this recovery plan is to assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: + Improving the population status + Ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark	Pollution and disease	Review and assess the potential threat of introduced species, pathogens and pollutants.
				Habitat degradation / modification	Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
					Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.
				Climate change	No explicit relevant management actions; climate change identified as a threat.
Northern River Shark (*Glyphis garricki*)	Approved Conservation Advice for *Glyphis garricki* (northern river shark) (DoE 2014)	Endangered	No explicit relevant objectives	Habitat degradation / modification	Implement measures to reduce adverse impacts of habitat degradation and/or Modification.
				Marine Debris	No explicit relevant management actions; marine debris identified as a threat.
Dwarf Sawfish (*Pristis clavata*)	Approved Conservation Advice for *Pristis clavate* (Dwarf Sawfish) (DEWHA 2009)	Vulnerable	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
Freshwater Sawfish (*Pristis pristis*)	Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014).	Vulnerable	No explicit relevant objectives	Habitat degradation / modification	Implement measures to reduce adverse impacts of habitat degradation and/or modification.
Green Sawfish (*Pristis zijsron*)	Approved conservation advice for Green Sawfish (DEWHA 2008)	Vulnerable	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
Whale Shark (*Rhinocodon typus*)	Conservation advice *Rhincodon typus* (Whale Shark) (DoE 2015) [Note the Recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015]	Vulnerable	To maintain existing levels of protection for the whale shark in Australia while working to increase the level of protection afforded to the whale shark within the Indian Ocean and Southeast Asian region to enable population growth so that the species can be removed from the threatened species list of the EPBC Act.	Habitat degradation / modification	Implement measures to reduce adverse impacts of habitat degradation and/or modification.
				Vessel disturbance	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath (as set out in the Conservation Values Atlas, DoE, 2014).
				Marine debris	No explicit relevant management actions; marine debris identified as a threat.

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Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
				Climate change	No explicit relevant management actions; climate change identified as threat.
Seabirds	Draft Wildlife Conservation Plan for Seabirds (CoA 2019)	N/A	Seabirds and their habitats are protected and managed in Australia.	Habitat degradation / modification	No explicit relevant management actions; identified as a threat.
				Anthropogenic disturbance	Ensure all areas of important habitat for seabirds are considered in the development assessment process. Manage the effects of anthropogenic disturbance to seabird breeding and roosting areas.
				Climate Change	No explicit relevant management actions; identified as a threat.
				Invasive species	Ensure seabirds are protected from the adverse effects of invasive species.
				Pollution (marine debris, light, water)	Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.
Migratory Shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)	N/A	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	Habitat degradation / modification	No explicit relevant management actions; identified as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
				Anthropogenic disturbance	Investigate the significance of cumulative impacts on migratory shorebird habitat and populations in Australia. Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes (specifically for coastal developments).
				Climate change	Investigate the impacts of climate change on migratory shorebird habitat and populations in Australia.
Albatrosses and Giant Petrels	National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)	N/A	Overall objective: + To ensure the long-term survival and recovery of albatross and giant petrel populations breeding and foraging in Australian jurisdiction by reducing or eliminating human related threats at sea and on land. Specific objectives: + Land-based threats to the survival and breeding success of albatrosses and giant petrels	Pollution	No explicit management actions; marine pollution recognised as a threat.
				Climate change	Where climate change is identified as having the potential for significant negative impacts on Australian populations of seabirds: + Appropriate monitoring strategies are implemented to fill information gaps + Mitigation actions are identified and adopted where feasible and appropriate.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			breeding within areas under Australian jurisdiction are quantified and reduced. + Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.		
Australian Lesser Noddy (*Anous tenuirostris melanops*)	Conservation Advice *Anous tenuirostris melanops* Australian lesser noddy (DoE 2015)	Vulnerable	No explicit relevant objectives	Habitat degradation / Modification (oil spills)	No explicit relevant management actions; oil pollution recognised as a threat.
Red Knot (*Calidris canutus*)	Conservation Advice Red Knot (*Calidris canutus*) (DOE 2016)	Endangered	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; oil pollution recognised as a threat.
				Climate change	No explicit relevant management actions; climate change recognised as a threat.
Curlew Sandpiper (*Calidris ferruginea*)	Conservation Advice Curlew Sandpiper (*Calidris ferruginea*) (DOE 2015)	Critically Endangered	Australian Objective: + Reduce disturbance at key roosting and feeding sites	Habitat degradation/ modification (oil pollution)	No explicit relevant management actions; oil pollution recognised as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
Great Knot (*Calidris tenuirostris*)	Conservation Advice Great Knot (*Calidris tenuirostris*) (DOE 2016)	Critically Endangered	No explicit relevant objectives	Habitat degradation/ modification (oil pollution)	Identifies research priorities and the need for actions to prevent destruction of key breeding and migratory staging sites.
Cape Barren Goose (*Cereopsis novaehollandiae grisea*)	Approved Conservation Advice for *Cereopsis novaehollandiae grisea* (Cape Barren Goose (south-western)) (DEWHA 2008)	Vulnerable	No explicit relevant objectives	Habitat degradation/ modification	No explicit relevant management actions; habitat loss, disturbance and modification recognised as a threat.
				Disease	No explicit management actions; disease, fungi and parasites recognised as a threat.
Greater Sand Plover (*Charadrius leschenaultia*)	Conservation Advice Greater Sand Plover (*Charadrius leschenaultii*) (DOE 2016)	Vulnerable	No explicit relevant objectives	Habitat degradation/ modification (oil pollution)	Identifies research priorities and the need for actions to prevent destruction of key breeding and migratory staging sites
Lesser Sand Plover (*Charadrius mongolus*)	Conservation Advice Lesser Sand Plover (*Charadrius mongolus*) (DOE 2016)	Endangered	No explicit relevant objectives	Habitat degradation/ modification (oil pollution)	Outlines research and survey priorities and recommends habitat restoration/ maintenance.
Christmas Island Frigatebird (*Fregata andrewsi*)	Conservation Advice for the Christmas Island Frigatebird – *Fregata andrewsi* (DAWE 2020)	Endangered	Long-term Objective: + To reduce anthropogenic threats to allow the conservation status of Fregata andrewsi (the Christmas Island Frigatebird) to improve so that it can be removed from the threatened species list of the Environment	Disease	Undertake a risk assessment to determine the most likely source of a new avian disease so that any changes to procedure are targeted.
				Habitat degradation/ modification	Preventing activities in habitat critical to the survival that will remove nesting and roosting habitat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			Protection and Biodiversity Conservation Act 1999 (EPBC Act). Short-term Objectives: + The extent and quality of habitat critical to the survival of the Christmas Island Frigatebird is maintained or improved. + Anthropogenic threats to Christmas Island Frigatebird are demonstrably reduced.		Preventing activities in buffer areas identified in Map 1 that may disturb nesting and roosting birds
				Pollution	No explicit management actions; marine pollution recognised as a threat.
				Marine debris	No explicit relevant management actions; marine debris recognised as a threat.
Blue Petrel (*Halobaena caerulea*)	Conservation Advice *Halobaena caerulea* blue petrel (DoE 2015)	Vulnerable	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; habitat loss, disturbance and modification recognised as a threat.
Bar-tailed Godwit (baueri) (*Limosa lapponica baueri*)	Conservation Advice *Limosa lapponica baueri* (Bar-tailed Godwit (Western Alaskan)) (DoE 2016)	Vulnerable	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; oil pollutions recognised as a threat.
Northern Siberian Bar-tailed Godwit (*Limosa lapponica menzbieri*)	Conservation Advice *Limosa lapponica menzbieri* Bar-tailed godwit (northern Siberian) (DoE 2016)	Critically Endangered	No explicit relevant objectives	Habitat degradation / modification	No explicit relevant management actions; oil pollutions recognised as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
Eastern Curlew (*Numenius madagascariensis*)	Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015)	Critically Endangered	Australian objectives: + Achieve a stable or increasing population. + Maintain and enhance important habitat. + Reduce disturbance at key roosting and feeding sites.	Habitat degradation / modification	No explicit relevant management actions; habitat loss and degradation recognised as a threat.
Fairy Prion (*Pachyptila turtur subantarctica*)	Conservation Advice Fairy Prion (*Pachyptila turtur subantarctica*) (DOE 2015)	Vulnerable	No explicit relevant objectives	Habitat degradation / Modification	No explicit management actions; habitat loss, disturbance and modification recognised as a threat.
Abbott's Booby (*Papasula abbotti*)	Conservation Advice for the Abbott's Booby - *Papasula abbotti* (DAWE 2020)	Endangered	Long-term Objective: + To reduce anthropogenic threats to allow the conservation status of Papasula abbotti (Abbott's Booby) to improve so that it can be removed from the threatened species list of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Short-term Objectives: + The extent and quality of habitat critical to the survival of Abbott's Booby is maintained or improved.	Climate change	Develop and implement a response plan to enhance the adaptation of Abbott's Booby to climate change.
				Disease	No explicit management actions; disease recognised as a threat.
				Marine debris	No explicit management actions; marine debris recognised as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			+ Anthropogenic threats to Abbott's Booby are demonstrably reduced.		
Christmas Island White-tailed Tropicbird (*Phaethon lepturus fulvus*)	Conservation Advice *Phaethon lepturus fulvus* white-tailed tropicbird (Christmas Island) (DOE 2014)	Endangered	No explicit relevant objectives	Oil Spills	No explicit management actions; oil spills recognised as a threat.
Soft-plumaged Petrel (*Pterodroma mollis*)	Conservation Advice *Pterodroma Mollis* soft-plumaged petrel (DoE 2015)	Vulnerable	No explicit relevant objectives	Habitat degradation / Modification (wetlands)	No explicit management actions; habitat loss, disturbance and modification recognised as a threat.
Australian Painted Snipe (*Rostratula australis*)	Approved Conservation Advice Australian Painted Snipe (*Rostratula australis*) (DSEWPC 2013)	Endangered	No explicit relevant objectives	Habitat degradation / Modification (wetlands)	Habitat recovery actions are a priority.
Australian Fairy Tern (*Sternula nereis nereis*)	Conservation Advice for *Sterna nereis nereis* (Fairy Tern) (DSEWPaC 2011)	Vulnerable	No explicit relevant objectives	Habitat degradation / modification (oil pollution)	Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.
Shy Albatross (*Thalassarche cauta*)	Conservation Advice *Thalassarche cauta* Shy Albatross (DAWE 2020)	Endangered	Conservation Advice refers to the objectives set out in the National Recovery Plan for Threatened	Climate change	No explicit management actions; climate change recognised as a threat.
				Disease	No explicit management actions; disease recognised as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
			Albatrosses and Giant Petrels 2011-2016 (DSEWPaC 2011).	Marine debris	No explicit management actions; marine debris recognised as a threat.
Marine Turtles	Recovery plan for Marine Turtles in Australia (DoEE 2017)	N/A	Long-term recovery objective: + Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: + Anthropogenic threats are demonstrably minimised.	Habitat degradation / modification	Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. Manage anthropogenic activities in Biologically Important Areas to ensure that biologically important behaviour can continue.
				Vessel disturbance	Vessel interactions identified as a threat; no specific management actions in relation to vessels prescribed in the plan.
				Light pollution	Minimise light pollution: + Artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats. + Develop and implement best practice light management guidelines for existing and future developments adjacent to marine turtle nesting beaches.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
					+ Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.
				Pollution (persistent toxic pollutants)	Minimise chemical and terrestrial discharge.
				Climate change	Adaptively manage turtle stocks to reduce risk and build resilience to climate change and variability: + Continue to meet Australia's international commitments to address the causes of climate change. + Identify, test and implement climate-based adaptation measures.
				Marine debris	Reduce the impacts from marine debris: + Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on vertebrate marine life.
				Noise interference	Assess and address anthropogenic noise:

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
					+ Understand the impacts of anthropogenic noise on marine turtle behaviour and biology.
				Disease and pathogens	No explicit management actions; disease and pathogens recognised as a threat.
Short-nosed Seasnake (*Aipysurus apraefrontalis*)	Approved Conservation Advice for *Aipysurus apraefrontalis* (Shortnosed Seasnake) (DSEWPaC 2011)	Critically Endangered	No explicit relevant objectives	Habitat degradation / modification	Monitor known populations to identify key threats. Ensure there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species.
Leaf-scaled Seasnake (*Aipysurus foliosquama*)	Approved Conservation Advice for *Aipysurus foliosquama* (leaf-scaled sea snake) (DSEWPaC 2011)	Critically Endangered	No explicit relevant objectives	Habitat degradation / modification	Ensure there is no disturbance in areas where the Leaf-scaled Sea Snake occurs, excluding necessary actions to manage the conservation of the species.
Leatherback Turtle (*Dermochelys coriacea*)	Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (DEWHA 2008)	Endangered	No explicit relevant objectives	Vessel disturbance	No explicit relevant management actions; vessel strikes identified as a threat.
				Marine debris	No explicit relevant management actions; marine debris identified as a threat.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
				Climate change	No explicit relevant management actions; climate change identified as a threat.
Sei Whale (*Balaenoptera borealis*)	Conservation Advice *Balaenoptera borealis* sei whale (DoE 2015)	Vulnerable	There is insufficient data on sei whales in Australian waters to determine abundance estimates, or an increase or decline in the population, and the full extent of their distribution in Australian waters is uncertain. To implement a range of Conservation Management Actions research needs to be undertaken as a priority to define the spatial and temporal distribution of sei whales and further define biologically important areas so that adaptive management and additional mitigation measures can be implemented if necessary (ie: within defined foraging or breeding areas).	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined, assess the impacts of increasing anthropogenic noise (including seismic surveys, port expansion, and coastal development).
				Climate change impacts	Understanding impacts of climate variability and change: + Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
				Vessel disturbance	Minimising vessel collisions: + Develop a national vessel strike strategy that investigates the risk of vessel strikes on Sei Whales and also identifies potential mitigation measures. + Ensure all vessel strike incidents are reported in the National Vessel Strike Database.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
				Pollution (persistent toxic pollutants)	No explicit relevant management actions; pollution identified as a threat.
Blue (*Balaenoptera musculus*) and Pygmy Blue Whale (*Balaenoptera musculus brevicauda*)	Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (DOE 2015)	Endangered	The long-term recovery objective is to minimise anthropogenic threats to allow the conservation status of the Blue Whale to improve so that it can be removed from the threatened species list under the EPBC Act.	Noise interference and anthropogenic noise	Assess and address anthropogenic noise: shipping, industrial and seismic noise. Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area. Ensure EPBC Act Policy Statement 2.1— Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a) is applied to all seismic surveys

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
	Guidance on key terms within the Blue Whale Conservation management plan (DAWE, 2021)			Vessel disturbance	Minimise vessel collisions: + Develop a national vessel strike strategy that investigates the risk of vessel strike on blue whales and also identifies potential mitigation measures. + Ensure all vessel strike incidents are reported in the National Ship Strike Database. + Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, appropriate mitigation measures are implemented.
				Climate change impacts	Understanding impacts of climate variability and change: + Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
Fin Whale (*Balaenoptera physalus*)	Conservation Advice *Balaenoptera physalus* fin whale (DoE 2015)	Vulnerable	No explicit relevant objectives	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined, assess the impacts of increasing anthropogenic noise

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
					(including seismic surveys, port expansion, and coastal development).
				Vessel disturbance	Develop a national vessel strike strategy that investigates the risk of vessel strikes on Fin Whales and identifies potential mitigation measures. Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
				Climate change impacts	Understanding impacts of climate variability and change: + Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
Southern Right Whale (*Eubalaena australis*)	Conservation Management Plan for the Southern Right Whale. A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999	Endangered	Long term recovery objective: + To minimise anthropogenic threats to allow the conservation status of the southern right whale to improve so that it can be removed from	Noise interference	Assess and address anthropogenic noise: shipping, industrial and seismic noise.
				Vessel disturbance	Address vessel collisions: + Develop a national ship strike strategy that quantifies vessel movements within the

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
	2011-2021 (DSEWPC 2012)		the threatened species list under the EPBC Act Interim Recovery Objective 5: + Anthropogenic threats are demonstrably minimised		distribution ranges of southern right whales and outlines appropriate mitigation measures that reduce impacts from vessel collisions.
				Climate change	Assess impacts of climate variability and change. Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
				Marine debris	No explicit relevant management actions; entanglement in marine debris identified as a threat.
Australian Sea Lion (*Neophoca cinerea*)	Conservation Advice *Neophoca cinerea* Australian Sea Lion (DAWE 2020)	Endangered	Primary conservation actions: + Mitigate the impacts of marine debris on Australian Sea Lions + Improve understanding of the threats posed to Australian Sea Lion populations, including cumulative impacts.	Habitat degradation / pollution	Require all vessels to have oil spill mitigation measures in place, and implement jurisdictional oil spill response strategies as required. Protect all sea lion habitat from habitat degradation due to onshore and offshore developments.

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
				Noise pollution	Monitor and mitigate impacts (including cumulative impacts) of human interactions on Australian Sea Lion colonies. Control access to breeding colonies to minimise the impacts of disturbance on Australian Sea Lions.
				Marine debris	Assess the impacts of marine debris on Australian Sea Lion populations and identify the sources of marine debris which have an impact. Develop and implement measures to mitigate the impacts of marine debris on the species (including reducing the amount of these marine debris entering the oceans), noting linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life.
				Climate change	Review and adjust management measures to address the threats from disease/parasites and prey depletion, if

Species / Sensitivity	Plan	EPBC Act Protection	Relevant Objectives	Relevant Key Threats Identified	Relevant Conservation Actions
					it is demonstrated that increased temperatures compound these threats.
				Disease and parasites	Improve human wastewater management to minimise dispersal of bacteria, parasites and pollutants into the marine environment.

2.2.2.5 Recovery Plans

The EPBC Act provides for the development of recovery plans for species listed as threatened under the EPBC Act. Recovery plans are intended to ensure the recovery of threatened species by setting recovery objectives. These objectives are informed by:

+ descriptions of the state of the threatened species in Australia and globally;
+ identification of threats to the species; and
+ identification of actions by which these threats may be mitigated and the recovery objectives achieved.

A number of threatened species have been identified as potentially occurring within the environment that may be affected (EMBA) by the planned and unplanned activities of Dorado Phase 1. Santos has considered the recovery plans (**Table 2-2**) in place for these species when describing the existing environment and assessing the environmental impacts and risks from Dorado Phase 1.

2.2.2.6 Conservation Advice

Conservation advice for threatened species and communities may be published under the EPBC Act. This advice is developed in consultation with the Threatened Species Scientific Committee. Conservation advice:

+ describes the threatened species, including its distribution, habitat and conservation status;
+ describes threats to the recovery of the species; and
+ outlines research priorities and conservation actions to prevent further decline of the threatened species.

A number of threatened species have been identified as potentially occurring within the EMBA and that may be affected by the planned and unplanned activities of Dorado Phase 1. Conservation advice in relation to these species is summarised in **Table 2-2**. Santos has considered the conservation advice in place for these species when describing the existing environment and assessing the environmental impacts and risks from Dorado Phase 1.

2.2.2.7 Wildlife Conservation Plans

Wildlife conservation plans may be made under the EPBC Act for the protection, conservation and management of species protected under the Act.

Wildlife conservation plans relevant to the Dorado Development OPP are:

+ Wildlife conservation plan for migratory shorebirds (Commonwealth of Australia 2015c); and
+ Wildlife Conservation Plan for Seabirds (DCCEEW 2022).

These plans apply to a number of seabirds and migratory shorebirds (listed as migratory under the EPBC Act). The objectives of these plans is to protect important habitat, address knowledge gaps and reduce anthropogenic risks to seabirds and migratory shorebirds.

2.2.2.8 Threat Abatement Plans

Threat abatement plans may be made under the EPBC Act for threatening processes on native species and ecological communities. These plans describe objectives for the mitigation of threatening processes and the actions intended to achieve these objectives.

One threat abatement plan is relevant to the Dorado Development OPP – the Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia 2018). Relevant objective and actions from this plan are described in **Section** 3.3.3.3 **.** The assessment of environmental impacts and risks from Dorado Phase 1 presented in **Section 7** includes controls to prevent the release of debris to the marine environment.

2.2.3 Additional Relevant Commonwealth Legislation

In addition to the OPGGS Act and the EPBC Act, a range of other legislation is relevant to the environmental management of Dorado Phase 1. These are listed in **Table 2-3** along with a description of their relevance to Dorado Phase 1.

Table 2-3: Commonwealth legislation relevant to the environmental management of Dorado Development Phase 1 (in addition to the OPGGS Act, EPBC Act and subsidiary legislation)

Legislation	Description	Relevance to Dorado Phase 1
Air Navigation Act 1920	This Act is responsible for managing navigation within the avian environment.	Helicopter and other aircraft activities occurring throughout all phases of the project are required to abide to the requirements under this Act.
Australian Heritage Council Act 2003	This Act identifies and protects areas of heritage value, including those listed on the World Heritage List, National Heritage List and the Commonwealth Heritage List (all of which are MNES under the EPBC Act).	Heritage values protected under the Act may be impacted by Dorado Phase 1 (**Section 3.4.4**). These values are considered in the assessment of environmental impacts and risks (**Section 7**). No impacts to heritage values will occur as a result of the planned activities within the scope of Dorado Phase 1.
Australian Jobs Act 2013	This Act ensure Australian entities have full, fair and reasonable opportunity to supply key goods or services to the Dorado Development. The Act requires proponents to create Australian Industry Participation Plans for projects where the capital expenditure (CAPEX) is $500 million dollars or more. The plans are assessed by the Department of Industry, Science, Energy and Resources (DISER). Proponents must report to DISER on the implementation of an accepted plan.	Santos has an approved Australian Industry Participation Plan for the Dorado Development and for the Operations Phase of the Dorado Development. The summaries are published here: https://www.industry.gov.au/sites/default/files/aip/aip-dorado-project_summary-7feb20.pdf https://www.industry.gov.au/sites/default/files/aip/aip-dorado-operations_summary-7feb20.pdf
Australian Maritime Safety Authority Act 1990	The Act aims to: + promote maritime safety; + protect the marine environment from: - pollution from ships and - other environmental damage caused by shipping; and + provide for a national search and rescue service. The authority responsible for applying the Act is AMSA.	The Act applies to offshore petroleum activities that have the potential to affect maritime safety and/or result in environmental damage, including pollution associated with the operation of vessels. This is also relevant to oil spills from vessels during petroleum activities.

Legislation	Description	Relevance to Dorado Phase 1
Australian Radiation Protection and Nuclear Safety Act 1998	This Act aims at protecting the health and safety of people and the environment from radiation effects.	The use of radioactive material during formation evaluation must comply with the Act.
Biosecurity Act 2015	This Act and its supporting legislation are intended to manage the risk of pests and diseases entering Australian territory. The Act creates requirements intended to reduce the risk of the introduction of invasive marine species (IMS). The Act gives effect to the International Convention for the Control and Management of Ships' Ballast Water and Sediment 2004.	Controls to reduce the risk of the introduction of IMS as a result of Dorado Phase 1 are provided in **Section 7.3.3**. These controls are consistent with the requirements of the Act.
Environment Protection (Sea Dumping) Act 1981	This Act prevents pollution of the sea by prohibiting the discharge of controlled materials to the sea. The Act gives effect to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (commonly referred to as the London Convention) under Commonwealth law.	The assessment of environmental impacts and risks from Dorado Phase 1 presented in **Section 7.3.1** includes controls to prevent the release of controlled materials to the marine environment. Any planned dumping of controlled materials arising from Dorado Phase 1 (e.g. decommissioning in situ) will be done in accordance with a sea dumping permit granted under the Act.
Environment Protection and Biodiversity Conservation Regulations 2000: 8.1	Provides regulations for operating aircraft and vessels in the vicinity of cetaceans.	All aircraft and vessels to operate at required distances from cetaceans. The requirements are detailed in the Australian National Guidelines for Whale and Dolphin Watching (DoE 2017)
Hazardous Waste (Regulation of Exports and Imports) Act 1989	This Act regulates the export, import and transport of hazardous waste to ensure that hazardous waste is managed appropriately so that human health and the environment are protected from the harmful effects of the waste. The Act gives effect to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1972 (commonly referred to as the Basel Convention) under Commonwealth law.	Dorado Phase 1 will comply with the requirements of the Act for the export, import and transport of hazardous waste. These requirements will be included in the waste management arrangements applied during Dorado Phase 1.

Legislation	Description	Relevance to Dorado Phase 1
National Environment Protection (National Pollutant Inventory) Measure 1998 (established under the *National Environment Protection Council Act 1994*)	This measure provides the framework for the development and establishment of the National Pollutant Inventory, which provides publicly available information on the types and amounts of numerous toxic substances being emitted into the Australian environment. These substances have been identified as important due to their possible effect on human health and the environment.	Dorado Phase 1 will comply with the National Pollutant Inventory National Environment Protection Measure through the reporting of relevant National Pollutant Inventory substances.
National Greenhouse and Energy Reporting Act 2007 National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015	The Act provides a single, national framework for the reporting and distribution of information related to GHG emissions, GHG projects, energy production and energy consumption. Reporting obligations are imposed upon corporations that meet emissions or energy thresholds. The Act includes National Greenhouse and Energy Reporting (NGER) requirements and the Safeguard Mechanism requirements.	Santos will report GHG emissions associated with Dorado Phase 1 in accordance with the NGER requirements.
Navigation Act 2012, Marine Order 21 (Safety and emergency arrangements) 2016, Marine Order 27 (Safety of navigation and radio equipment) 2016 Marine order 28 (Operations standards and procedures), Marine Order 30 (Prevention of Collisions) 2009,	This Act and subsidiary Marine Orders give effect to several international conventions relating to maritime safety to which Australia is a signatory, including: + International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, and + International Regulations for Preventing Collisions at Sea 1972. The Act regulates vessel crew, vessel survey and certification, occupational health and safety, passengers,	All vessels and facilities undertaking activities within the scope of Dorado Phase 1 will comply with the requirements of the Act. These requirements reduce the risk of accidents and unplanned interactions with other users of the marine environment in the Project Area.

Legislation	Description	Relevance to Dorado Phase 1
Marine Order 47 (Offshore Industry Units), Marine Order 60 (Floating offshore facilities), Marine Order 71 (Masters and Deck Officers) 2014.	personnel qualifications and welfare, vessel construction standards, handling of cargoes, marine pollution prevention, and monitoring and enforcement activities.	
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	The Act and subsidiary regulations protect the environment by regulating emissions of ozone-depleting substances and synthetic greenhouse gases. Manufacturing, importing and exporting of ozone-depleting substances and synthetic greenhouse gases and products containing these gases are controlled under the Act and subsidiary regulations. The Act gives effect to several international conventions to which Australia is a signatory: + the Vienna Convention for the Protection of the Ozone Layer, + the Montreal Protocol on Substances that Deplete the Ozone Layer, and + United Nations Framework Convention on Climate Change and its Kyoto Protocol.	Dorado Phase 1 will adhere to restrictions on import and use of ozone-depleting substances and synthetic greenhouse gases.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 Marine Order 98 (Marine pollution – anti-fouling systems)	The Act and subsidiary Marine Order prohibit the use of organotin compounds in anti-fouling coatings on ships. These compounds have been shown to result in deformations and sex changes in molluscs. The Act and subsidiary Marine Order give effect to the Convention on the Control of Harmful Anti-fouling Systems on Ships.	All vessels undertaking activities within the scope of Dorado Phase 1 are required comply with the requirements of the Act and subsidiary Marine Order.

Legislation	Description	Relevance to Dorado Phase 1
Protection of the Sea (Prevention of Pollution from Ships) Act 1983, Marine Order 91 (Marine pollution prevention — oil) 2014, Marine Order 93 (Marine pollution prevention — noxious liquid substances) 2014, Marine Order 94 (Marine pollution prevention — packaged harmful substances) 2014, Marine Order 95 (Marine pollution prevention — garbage) 2018, Marine Order 96 (Marine pollution prevention — sewage) 2018, and Marine Order 97 (Marine pollution prevention — air pollution) 2013	The Act controls discharges from ships to protect the sea from pollution. This includes regulation of discharges of oil or oily mixtures, noxious liquid substances, packaged harmful substances, sewage and garbage to the sea. The Act imposes a duty to report certain incidents involving prohibited discharges and to maintain record books and management plans. The Act and subsidiary Marine Orders enact the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (commonly referred to as the MARPOL 73/78 Convention).	All vessels undertaking activities within the scope of Dorado Phase 1 are required comply with the requirements of the Act.
Underwater Cultural Heritage Act 2019	This Act protects shipwrecks and associated relics in Commonwealth waters that are more than 75 years old. The Act aims to ensure that historic shipwrecks are protected for their heritage values and maintained for recreational, scientific and educational purposes.	Santos will ensure that Dorado Phase 1 does not impact upon cultural heritage properties protected under the Act. No underwater cultural heritage properties have been identified within the Project Area.

2.3 International Agreements and Conventions

Australia is signatory to several international conventions and agreements that are relevant to the environmental management of Dorado Phase 1. These are typically implemented by Commonwealth legislation detailed in **Section 2.2.3**. International agreements and conventions relevant to Dorado Phase 1 are provided in **Table 2-4**. Refer to **Table 2-3** for the legislation giving effect to the agreements and conventions in **Table 2-4** and their relevance to Dorado Phase 1.

Table 2-4: Summary of relevant international agreements and conventions

International Agreement / Convention	Description
Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974 (commonly referred to as JAMBA)	JAMBA provides for cooperation between Japan and Australia to minimise harm to major areas used by birds that migrate between the two countries. The EPBC Act gives effect to JAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act. Migratory species are MNES.
Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment, 1986 (commonly referred to as CAMBA)	CAMBA provides for cooperation between China and Australia to minimise harm to major areas used by birds that migrate between the two countries. The EPBC Act gives effect to CAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act. Migratory species are MNES.
Agreement between the Government of Australia and the Government of the Republic of Korea for the Protection of Migratory Birds and their Environment, 2002 (commonly referred to as ROKAMBA)	ROKAMBA provides for cooperation between the Republic of Korea and Australia to minimise harm to major areas used by birds that migrate between the two countries. The EPBC Act gives effect to ROKAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act. Migratory species are MNES.
Convention on the Conservation of Migratory Species of Wild Animals, 1979 (Bonn Convention)	The Bonn Convention aims to conserve migratory species within their migratory ranges. The Bonn Convention provides specific protection for migratory species threatened with extinction or requiring international cooperation to conserve effectively. The EPBC Act gives effect to the Bonn Convention through listing species as migratory under Part 3 of the Act. Migratory species are MNES.
Convention on Wetlands of International Importance (Ramsar Convention)	The Ramsar Convention provides for the conservation and sustainable use of wetlands. The EPBC Act gives effect to the Ramsar Convention by providing specific protection for wetlands recognised by the Convention under Part 3 of the EPBC Act. These wetlands are termed "wetlands of international importance" and are MNES.
International Convention for the Control and Management of Ships' Ballast Water and Sediment, 2004	The Convention aims to prevent the spread of harmful aquatic organisms from one region to another via ballast water and sediment. The *Biosecurity Act 2015* gives effect to the Convention.
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention)	The London Convention is an agreement to control pollution of the sea by dumping. The *Environment Protection (Sea Dumping) Act 1981* gives effect to the London Convention.

International Agreement / Convention	Description
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1972 (Basel Convention)	The Basel Convention reduces the movement of hazardous wastes (excluding radioactive wastes) between nations, particularly from developed to less developed countries. The *Hazardous Waste (Regulation of Exports and Imports) Act 1989* gives effect to the convention.
International Convention for the Safety of Life at Sea 1974	The International Convention for the Safety of Life at Sea 1974 sets minimum safety standards for construction, equipment and operation of merchant ships. The convention requires signatory flag states to ensure that ships flagged by them comply with these standards as a minimum. The *Navigation Act 2012* and subsidiary Marine Orders give effect to the convention.
International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 sets out minimum standards for masters, officers and watch personnel on merchant vessels. The *Navigation Act 2012* and subsidiary Marine Orders give effect to the convention.
International Regulations for Preventing Collisions at Sea 1972	The International Regulations for Preventing Collisions at Sea 1972 outline internationally recognised navigation rules to be used by vessels at sea to avoid collisions. The regulations are published by the International Maritime Organization (IMO). The *Navigation Act 2012* and subsidiary Marine Orders give effect to the regulations.
United Nations Framework Convention on Climate Change 1992	The United Nations Framework Convention on Climate Change is an international environmental treaty addressing climate change. The convention seeks the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the earth's climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.
Kyoto Protocol	The Kyoto Protocol is an international treaty that extends the 1992 United Nations Framework Convention on Climate Change, which commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that global warming is occurring and that human-made CO_2 emissions are driving it.
Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001	The convention prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and subsidiary Marine Order give effect to the Convention.

International Agreement / Convention	Description
Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001	The convention prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and subsidiary Marine Order gives effect to the Convention.
International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL 73/78)	MARPOL 73/78s aim to minimise pollution of the sea from ships. All ships flagged under countries that are signatories to MARPOL 73/78 are subject to its requirements, regardless of where they sail. Member nations are responsible for vessels registered on their national ship registry. Several Annexes apply directly to offshore petroleum activities: MARPOL 73/78 Annex I (Prevention of pollution by oil), MARPOL 73/78 Annex II (Control of pollution by noxious liquid substances in bulk), MARPOL 73/78 Annex III (Prevention of pollution by harmful substances carried by sea in packaged form), MARPOL 73/78 Annex IV (Pollution by sewage from ships), MARPOL 73/78 Annex V (Pollution by garbage from ships), and MARPOL 73/78 Annex VI (Prevention of air pollution from ships). The *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsidiary Marine Orders give effect to MARPOL 73/78.
The Paris Agreement	Article 2 of the Paris Agreement aims to limit global temperature increase to well below 2 C while pursuing efforts to limit the temperature increase to 1.5 C. As a party to the Paris Agreement, the Australian Government has developed local policy, legislation, regulation and a suite of initiatives and programs in support of meeting its commitments under the Paris Agreement. Santos will be required to comply with all applicable Commonwealth legislation.
The Minamata Convention on Mercury	The Minamata Convention on Mercury requires parties to address adverse effects of mercury to protect human health and the environment. Australia is a signatory and ratified the Minamata Convention on Mercury on 7th December 2021. Mercury releases associated with the Oil and Gas industry are proposed to be tabled at Conference of Parties 5 in 2023. The Minamata Convention on Mercury is applicable to all stages of the Dorado Development lifecycle and Santos will be required to comply.

2.4 Guidelines

Applicable guidelines for Dorado Phase 1 are summarised in **Table 2-5**. While guidelines do not typically have force under legislation, they are often considered to be consistent with good practice. Santos has considered the guidelines in **Table 2-5** in the environmental management of Dorado Phase 1.

Table 2-5: Guidelines, standards and codes of practice

Guidelines, Standards and Codes	Description	Relevance to Dorado Phase 1
Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018)	The guidelines provide a comprehensive set of tools for the assessment and management of ambient water and sediment quality in a range of water resource types.	Several aspects of Dorado Phase 1 may result in changes to water quality within the Project Area. Santos will use the methods and guideline concentrations for potential toxicants in the guideline when assessing environmental impacts and risks from Dorado Phase 1.
Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020)	The requirements state the obligations on vessel operators to manage ballast water and ballast sediment when operating in Australian waters.	Vessels undertaking Dorado Phase 1 will carry ballast water. All vessels undertaking Dorado Phase 1 will be required to comply with the requirements.
Code of Environmental Practice 2008 (Australian Petroleum Production and Exploration Association 2008)	The code outlines example environmental objectives for petroleum activities in Australia. This is intended to be align with objective-based, rather than proscriptive, environmental management.	Santos recognises the environmental objectives and will align the environmental management of Dorado Phase 1 with the code.
EPBC Act Policy Statement 2.1 – Interactions between offshore seismic activities and whales (Department of the Environment, Water, Heritage and the Arts 2008a)	This policy statement provides advice on reducing the risk of acoustic disturbance from seismic sources to whales. The policy statement also provides advice to operators conducting seismic surveys on their legal responsibilities under the EPBC Act.	Exploration seismic surveys are beyond the scope of the activities considered in the Dorado Development OPP. Vertical seismic profiling of wells may be undertaken, which will require a seismic source. Santos will align the environmental management of vertical seismic profiling with the policy statement, where relevant.
National biofouling management guidelines for the petroleum production and exploration industry (Marine Pest Sectoral Committee 2018)	The guidelines provide voluntary biofouling management advice to the offshore petroleum industry. The guidelines are intended to reduce the risk of translocation of IMS.	Vessels undertaking Dorado Phase 1 may have low levels of biofouling. Santos will align management of biofouling on vessels, facilities and equipment with the guidelines.

Guidelines, Standards and Codes	Description	Relevance to Dorado Phase 1
National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020)	The guidelines outline a process for managing potential impacts of artificial lighting on fauna that may be sensitive to light pollution.	Dorado Phase 1 will emit artificial light into the environment. Santos will consider the advice provided by the guidelines when designing and operating Dorado Phase 1.
NOPSEMA Offshore Project Proposal Content Requirements Guidance Note (NOPSEMA 2020a)	The guidance note assists proponents in preparing an OPP in accordance with the OPGGS (E) Regulations by providing an overview of the content requirements of an OPP	Santos has developed the Dorado Development OPP in accordance with the guidance note.
Offshore Installations – Biosecurity Guide (Department of Agriculture and Water Resources 2020)	This document provides the offshore petroleum industry with guidance on Australian biosecurity requirements.	The vessels and petroleum facilities within the scope of Dorado Phase 1 will be subject to the requirements of this biosecurity guideline.
NOPSEMA Bulletins - Oil Spill Modelling (NOPSEMA 2019b)	The guidance note primarily gives advice relating to the application of stochastic modelling to support risk evaluations, but also has application to the use of deterministic modelling in response planning.	Santos has undertaken the oil spill modelling in accordance with the guidance note.
NOPSEMA Policy – Section 572 Maintenance and removal of property (NOPSEMA 2020b)	This policy outlines NOPSEMA expectation of what is to be included in an OPP submitted to NOPSEMA for acceptance.	Santos has included the required information in the OPP.
NOPSEMA Information paper - Reducing marine pest biosecurity risks through good practice biofouling management (NOPSEMA 2021)	This information paper clarifies the biosecurity requirements relevant to offshore activities, provides coordinated good practice advice that is consistent with the expectations of all jurisdictions responsible for regulating biofouling management within the Australian marine environment to the boundary of the Economic Exclusion Zone and/or over the continental shelf of Australia (Australian waters) and supports the industry's contribution to marine pest risk management consistent with objective 1 of Australia's National Strategic Plan for Marine Pest Biosecurity (2018-	Santos has complied with the relevant biosecurity requirements including adopting requirements that may apply to the movement of vessels into and between commonwealth and state jurisdiction.

Guidelines, Standards and Codes	Description	Relevance to Dorado Phase 1
	2023) – 'Minimise the risk of marine pest introduction, establishment and spread'.	

Santos

3 Description of the Environment

3.1 Introduction

This section describes the physical, biological and socio-economic characteristics of the EMBA by planned and unplanned Dorado Phase 1 activities. It describes the environmental values and sensitivities, including MNES protected under the EPBC Act. The section informs the evaluation of credible environmental impacts and risks from Dorado Phase 1 presented in **Section 7**.

3.1.1 Environment that May Be Affected

The EMBA is determined by the combined spatial extent of impacts and risks of the planned and unplanned Dorado Phase 1 activities. All planned activities will occur within the Project Area. Santos has used several methods for determining the spatial extent of the EMBA from Dorado Phase 1, including:

- the location and design of the facilities that will be constructed;
- the predicted characteristics and volumes of emissions and discharges; and
- modelling studies of planned and unplanned emissions and discharges, including:
  - drill cuttings and fluid discharges (**Attachment 6**);
  - PW discharges (**Attachment 7**);
  - credible worst-case hydrocarbon spills (**Attachment 8**);
  - artificial light emissions (**Attachment 9**);
  - underwater acoustic emissions (**Attachment 10, Attachment 14**); and
  - GHG emissions (**Attachment 12**).

Further information on the items listed above is available in **Section 6** and **Section 7**.

While the EMBA represents the largest possible spatial extent that could be contacted by any of the worst-case spill events modelled, an actual spill event is more accurately represented by only one of the simulations from the stochastic modelling, resulting in a much smaller spatial footprint in the event of an actual spill. The description of the EMBA also considers the nature and scale of the environmental impacts and risks of Dorado Phase 1. Additional detail has been provided in describing environmental values and sensitivities that are predicted to be impacted by planned activities. Impacts to these values and sensitivities are almost certain to occur as a result of Dorado Phase 1 and can be predicted with a relatively high degree of certainty.

Impacts to environmental values and sensitivities from unplanned activities are unlikely to occur. Santos invests significant effort to prevent unplanned activities, such as hydrocarbon spills, from occurring. Environmental values and sensitivities that have a relatively low probability of being impacted by unplanned activities are described in sufficient detail to inform the assessment of the impacts and risks from the unplanned activity. Examples of such environmental values and sensitivities include far-field receptors within the EMBA predicted by worst-case credible hydrocarbon spill modelling. Such values and sensitivities are described in sufficient detail to inform the assessment of environmental risks from unplanned activities. However, the level of detail of the description may be less than that provided for environmental values and sensitivities that will be impacted by planned activities.

The outer boundary of the description of the EMBA was derived from the results of stochastic modelling of the worst-case credible hydrocarbon spill scenarios that may occur from all activities during the Dorado Development. Santos has identified a Loss of well control as the worst-case type of credible oil release scenario that could potentially occur during the activity. A loss of well control incident may discharge directly to the sea surface or at the seabed, depending on the type of failure that occurs. Each stage of the development may have other spill scenarios (refer to **Table 7-69** and **Table 7-70**) that result in smaller spills than the worst-case credible spills used to inform the EMBA. Santos has used a combination of Loss of well control spill scenarios defined as the worst case credible for the Dorado Activity, whereby all other spill scenarios fit within this. These spill scenarios drive the EMBA and associated environmental impacts and risks described in **Section 7.**

The worst-case spill scenarios include:

- A loss of well control from the Dorado Development (refer to **Table 7-69**); and
- A loss of well control from Future Tieback Reservoirs (**Table 7-70**).

The low exposure values are used as a predictive tool to set the outer boundaries of EMBAs and may not necessarily result in ecologically significant impacts. To inform the evaluation of potential environmental consequences of a hydrocarbon release (impact assessment), modelling is undertaken using higher exposure values (the concentrations at which environmental consequences may result). This boundary was based on the concentrations of hydrocarbons that may result in impacts and risks to biological receptors derived from the oil spill modelling bulletin published by NOPSEMA (2019b). Two worst-case credible spill scenarios, the subsea and topsides loss of well containment scenarios (from the Dorado Reservoir), account for the outer boundary of the EMBA (**Section 7.3.1**). The largest EMBA is determined by the extent of the entrained hydrocarbon as a result of a loss of well control event. Modelling results indicate the spatial extents of potential impacts from other worst-case credible spill scenarios are considerably smaller than the two worst-case loss of well containment scenarios. Hydrocarbon spill modelling studies are provided in **Attachment 8** and considered in **Section 7.3.1**. The EMBA for both the low threshold and moderate threshold is shown in **Figure 3-1**. A low exposure threshold, which approximates a range of socio-economic effects, is considered to provide a conservative extent of potential impacts. Biological impacts are expected to occur within the moderate and high exposure values which represent a subset of the EMBAs.

Exploration drilling of the prospects identified within the Project Area as future tiebacks within this OPP (refer **Figure 1-2**) are proposed to be drilled under separate environment plans for exploration and appraisal drilling activities including the NOPSEMA accepted Bedout Basin Multi-Well Drilling Environment Plan (Bedout Multi-Well Drilling Environment Plan). The EMBA associated with the subsea and topsides loss of well containment scenario at the Bedout Apus-1 well location was compared with the Dorado Development EMBA. The EMBA defined in the Bedout Basin Multi-Well Drilling Environment Plan, has a smaller spatial extent when compared to the Dorado Development EMBA, excepting for the southern extent, which extends further south and east around the southern coast of Western Australia.

3.1.2 Dorado Development Environmental Studies

Santos commissioned a range of studies to better understand the EMBA within the Project Area. These are described in subsequent sections and include:

- benthic habitat surveys (**Attachment 2**);
- benthic habitat modelling (**Attachment 3**);
- sediment quality survey (**Attachment 4**); and
- water quality survey (**Attachment 5**).

Dorado Phase 1 environmental studies' boundaries and sampling locations are shown in **Figure 3-2.**

Santos has also undertaken, and continues to undertake, studies within the Project Area to inform the design of Dorado Phase 1, such as meteorological, oceanographic, geotechnical and geophysical studies. Results from these studies have informed the engineering design, and they have also been considered where their results inform the assessment of environmental impacts and risks from Dorado Phase 1.

3.1.2.1 Benthic Habitat Survey

Santos commissioned RPS to conduct a benthic habitat survey within and around the Project Area in December 2019. This sampling was conducted in conjunction with sediment and water quality sampling. The benthic habitat survey was designed by CSIRO, RPS and Santos to representatively sample the range of ecotypes (habitat types), with targeted sampling around the Dorado WHP and FPSO locations. The survey design focused on representation of the ecotypes identified by CSIRO in preliminary modelling and which lie within the Project Area. The survey report is provided as **Attachment 2**.

The benthic habitat survey included the following sampling methods:

+ benthic video transects completed by a remotely operated vehicle (ROV). A total of 39 sites were surveyed at water depth between 75 and 138 m below sea level (BSL). Benthic habitats and biota were described by an experienced marine biologist during each transect; and
+ infaunal samples were collected using a 0.25-m^2 van Veen grab from five sites across the Dorado Phase 1 baseline survey area.

Habitat characterisation was completed using CSIRO's Tappity software, which records data on benthic substrates, habitats and biota using predetermined descriptors. These descriptors were used by CSIRO to complete the ecotype modelling of the benthic habitat within the Dorado Phase 1 baseline survey area (**Attachment 3**). In addition to the Tappity descriptors, handwritten field notes were collected to provide benthic habitat and community descriptions prior to analyses completed by CSIRO.

3.1.2.2 Habitat Modelling

Santos commissioned CSIRO to undertake habitat modelling to predict the types and distributions of benthic habitats and biological assemblages within and around the Project Area. CSIRO used historical data sets (primarily fish trawl catch and benthic imagery), public databases of fish and marine invertebrate biodiversity, recent environmental surveys and bio geophysical environmental data to inform the modelling.

The habitat model produced by CSIRO (**Attachment 3**) provided predictions of the spatial patterns and composition of biological assemblages (ecotypes) in and around the proposed Project Area. Substrate types, topography and benthic habitats were also described based on historical and recent observations of the seabed. In addition, the report provided a description of the fish and invertebrate biodiversity of the Project Area and its surrounds in the context of the North West Shelf (NWS) region.

3.1.2.3 Sediment Quality

Santos commissioned RPS to undertake sediment quality sampling within and around the Project Area (**Attachment 4**). Sediment quality sampling was conducted in conjunction with the benthic habitat survey and water quality sampling. Sediment samples were collected using a van Veen grab at 14 locations, and the sediments were analysed for:

- metals;
- hydrocarbons;
- tributyltin;
- naturally occurring radioactive material;
- nutrients; and
- particle size distribution.

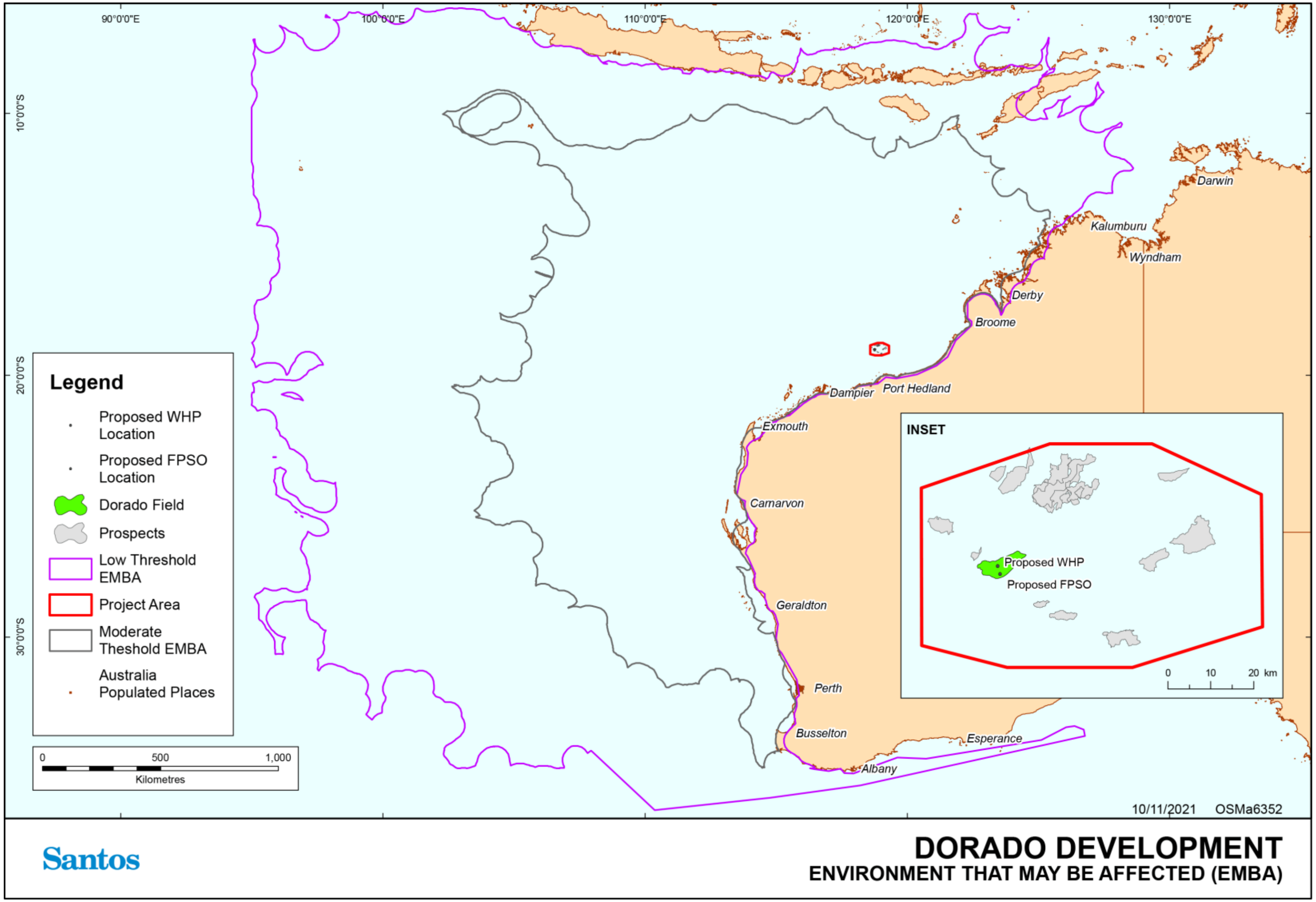

Figure 3-1: EMBA for planned and unplanned Dorado Phase 1 activities

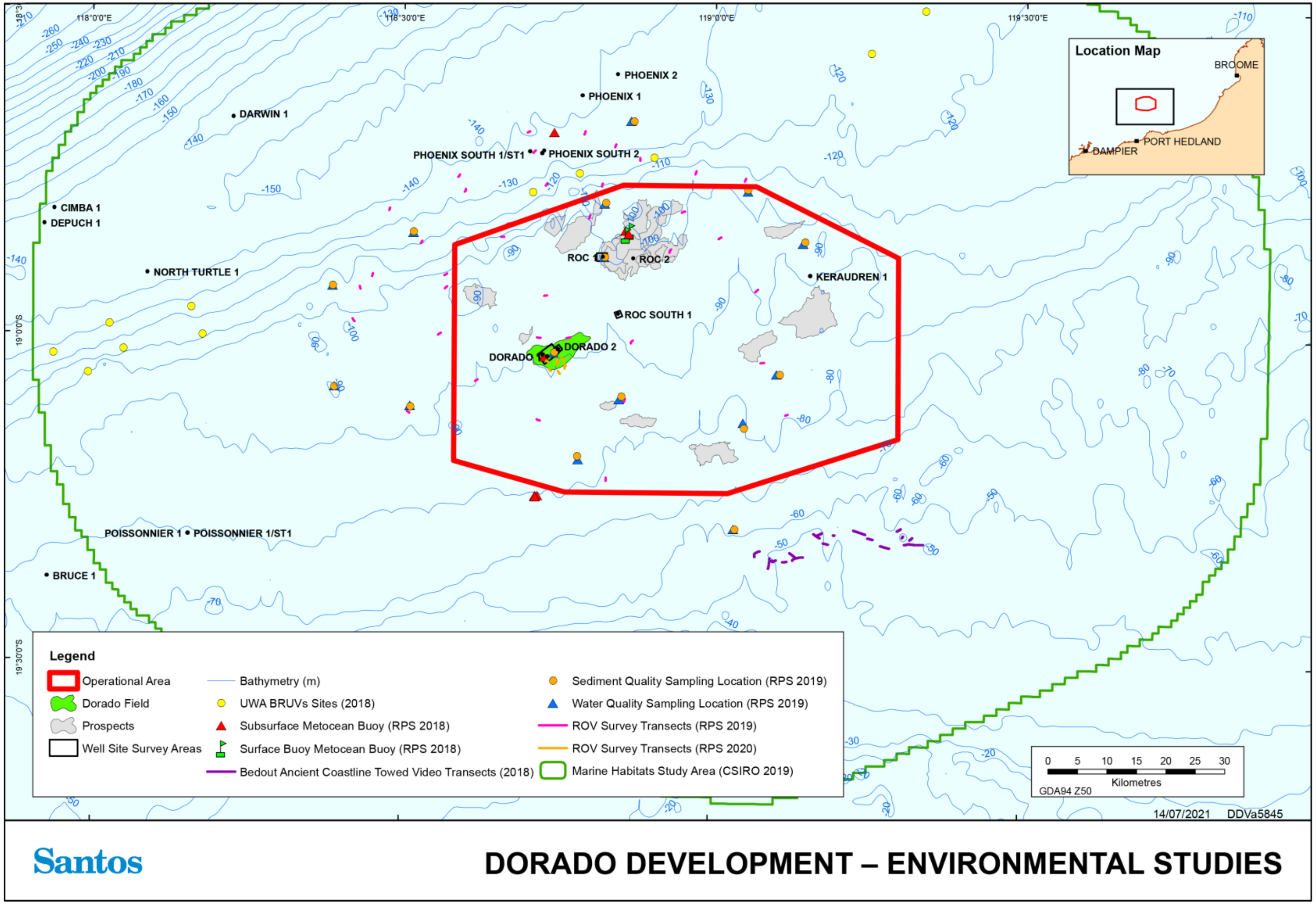

Figure 3-2: Dorado Development Environmental Studies

3.1.2.4 Water Quality

Santos commissioned RPS to undertake water quality sampling within, and around, the Project Area (**Attachment 5**). Water quality sampling was conducted in conjunction with the benthic habitat survey and sediment quality sampling. Water quality sampling was undertaken at 15 sites, with the following parameters sampled:

+ depth (pressure);
+ salinity (conductivity);
+ water temperature;
+ pH;
+ dissolved oxygen;
+ turbidity;
+ photosynthetically-active radiation;
+ chlorophyll a;
+ total suspended solids;
+ metals and metalloids;
+ naturally occurring radioactive material; and
+ hydrocarbons.

3.2 Physical Environment

3.2.1 Bathymetry

The seabed within the Project Area is generally flat and featureless (**Figure 3-3**), which is consistent with much of the mid-continental shelf in the NWS region. The northern part of the Project Area features relatively complex bathymetry, which corresponds to the relic shoreline from changes in sea level during the last 100,000 years. This relic shoreline was identified as a key ecological feature (KEF) – the Ancient Coastline at 125 m – in the Marine bioregional plan for the North-west Marine Region (DSEWPaC 2012a).

There are no known bathymetric features, such as reefs, shoals or banks, within the Project Area.

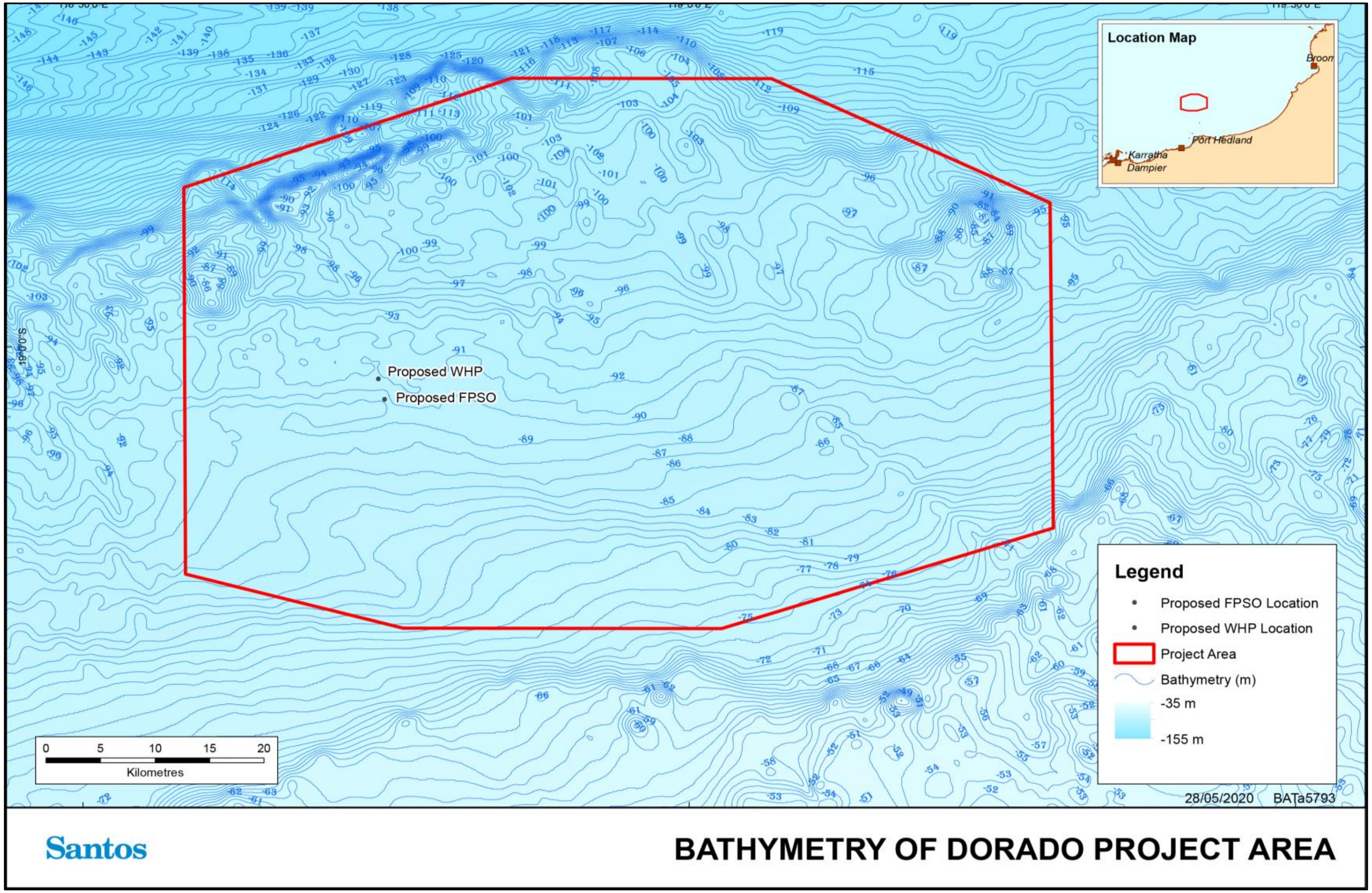

Figure 3-3: Bathymetry of the Project Area

3.2.2 Climate

The climate of the Project Area is arid and tropical, experiencing high summer temperatures and periodic tropical cyclones in summer (**Figure 3-4**). Long-term average daily maximum air temperatures range from 33.7°C in March to 25.1 C in July; long-term average daily minimum temperatures range from 27.7°C in March to 19.6°C in July (**Figure 3-4**). Rainfall in the region is low, although intense rainfall may occur during the passage of summer tropical cyclones and thunderstorms.

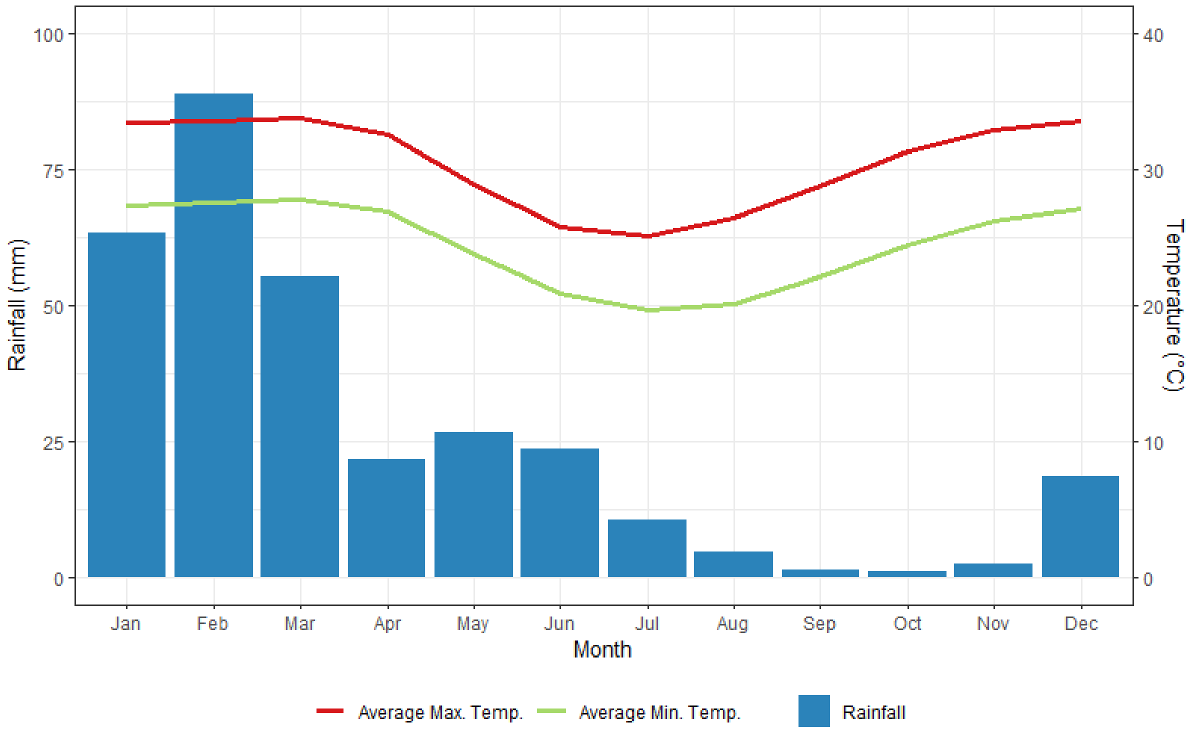

Figure 3-4: Average daily maximum and minimum temperatures and average monthly rainfall in the Dorado Project Area

The summer and winter seasons fall into the periods September to March and May to July, respectively. Winters are characterised by clear skies, fine weather, predominantly strong east to southeast winds and infrequent rain. Summer winds are more variable, with strong southwesterlies dominating. Transitional wind periods, during which either pattern may predominate, can be experienced in April, May and September of each year (**Figure 3-5**).

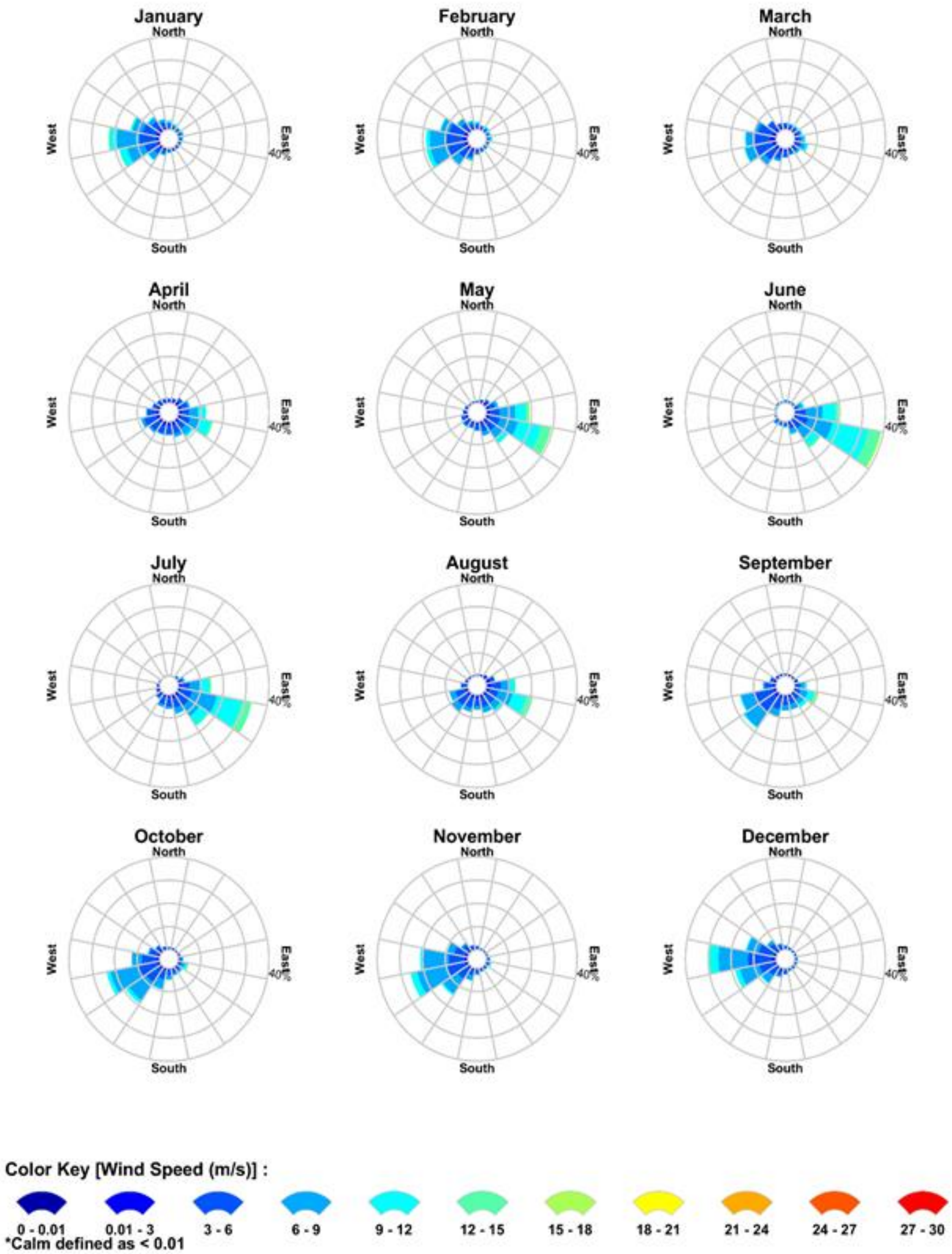

Figure 3-5: Monthly wind distribution (2009 to 2018, inclusive) derived from the Climate Forecast System Reanalysis closest data point modelled hydrocarbon release locations. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record (RPS 2020a)

Tropical cyclones generate the most significant storm conditions in the area. These clockwise-spiralling storms have generated wind speeds of 50 to 120 knots. Tropical cyclones passing over the NWS region typically develop in the eastern Indian Ocean, Timor Sea and Arafura Sea during the summer months. Three to four cyclones per year are typical, with the official cyclone season being November through to April (Bureau of Meteorology n.d.).

3.2.3 Oceanography

Water movement in the Project Area is dominated by strong tidal regimes, which result in very regular, predictable water movement along a northwest and southeast axis (**Figure 3-7**). There is relatively little variation in this pattern throughout the year, with little apparent influence of mesoscale currents (such as the Holloway Current), which typically occur on the outer continental shelf in water depths greater than 100 m. Tides in the Project Area are semidiurnal (two high and two low tides per day), with slight diurnal inequality. The tidal range in the region is large, with the maximum tidal range at the Port of Port Hedland in excess of 7 m (Pilbara Ports Authority n.d.). This large tidal range accounts for the strength of tidal currents observed in the Project Area.

Waves in the Project Area include locally generated wind waves and oceanic swell. Locally generated wind waves vary in wave height and period, based on the winds that generated the waves and the available fetch. Non-cyclonic significant wave heights in the Project Area may reach up to 6 m; cyclonic wave heights may reach up to 10 m (RPS 2019). Oceanic swell in the region is generated by distant storms, primarily in the southern Indian Ocean, although other sources, such as monsoonal- and cyclone-generated swell, may also contribute to swell in the Project Area (RPS 2019).

Figure 3-6 presents the water temperature profiles measured in December 2019 (RPS 2020b). Waters within the Project Area are stratified during summer months, with a relatively warm, well-mixed surface layer extending between the sea surface and approximately 25 m water depth. A thermocline extends between approximately 25 m and 50 to 70 m, within which temperature decreases approximately 4.5 C (RPS 2020b). Water temperatures between the base of the thermocline and the seabed decrease at a lower rate. Thermal stratification is expected to reduce in winter months due to the reduction in heating of surface waters, with the strong tidal currents resulting in mixing of the water column.

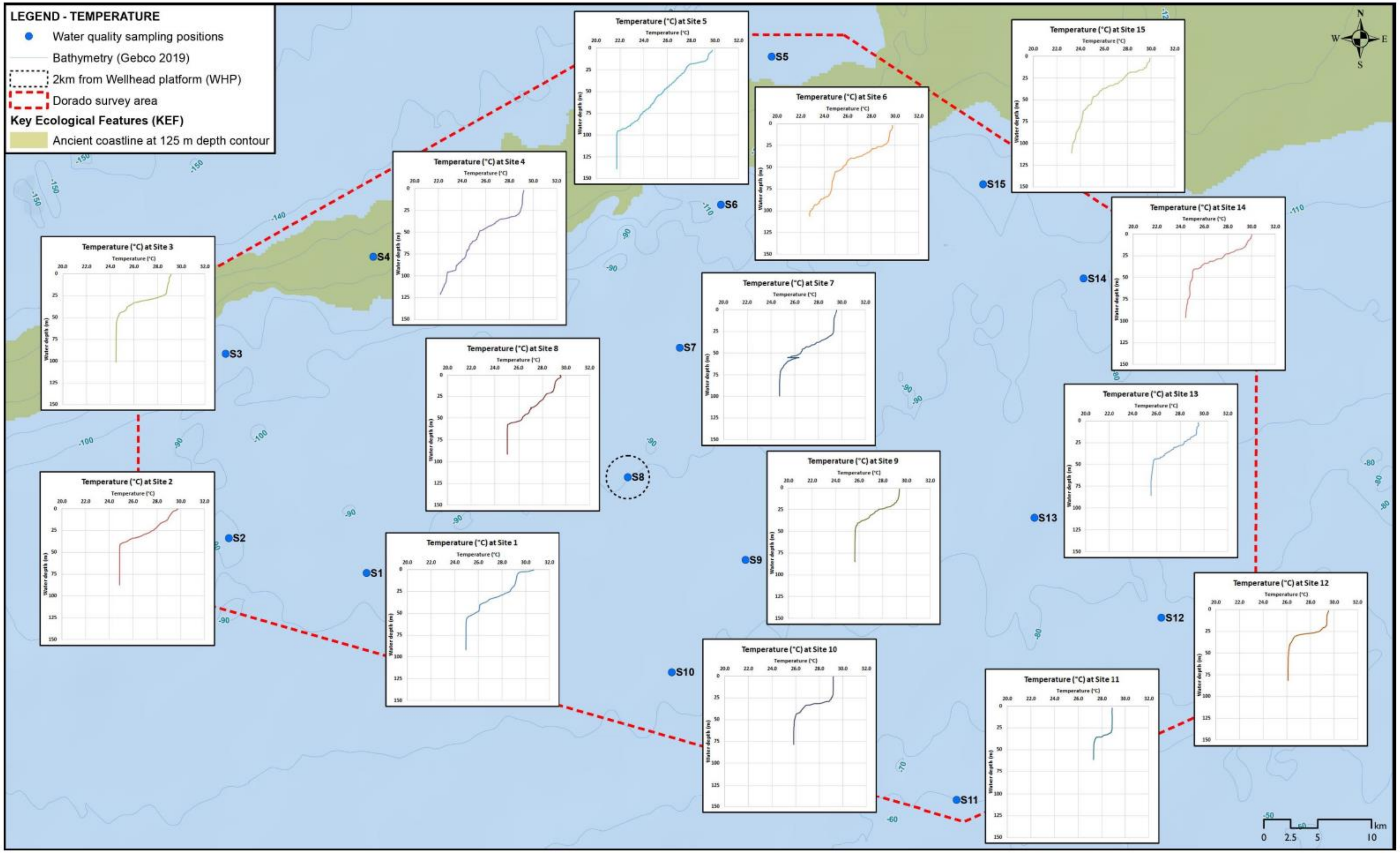

Figure 3-6: Water temperature profiles from water quality sampling locations within the Project Area (RPS 2020b)

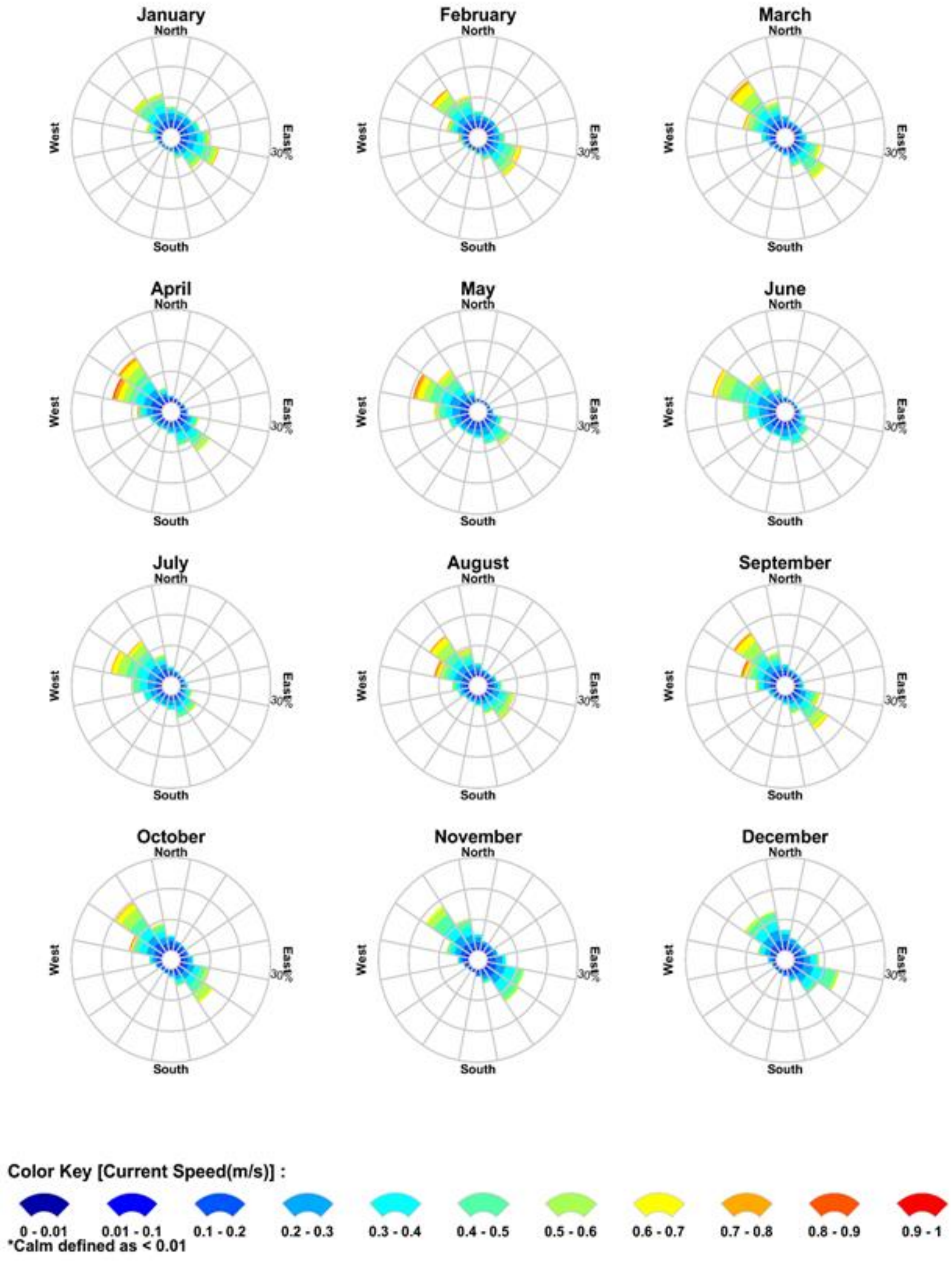

Figure 3-7: Monthly current distribution (2009 to 2018, inclusive) derived from the Hybrid Coordinate Ocean Model database near the Project Area. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record (RPS 2020a).

In the EMBA beyond the Project Area, mesoscale currents, such as the Holloway and Leeuwin currents, play an important role in water movements (**Figure 3-8**). These mesoscale currents influence a range of biological processes, such as larval transport, which in turn can influence marine ecosystems and fisheries within the EMBA. Smaller-scale water movements, such as tidal and wind-driven currents, are superimposed over these mesoscale currents.

The Holloway Current transports relatively warm, low salinity water from tropical regions along the NWS (**Figure 3-8**). The current flows to the southwest, along the outer continental shelf, with much of the water mass transported by the current in water depths between 100 and 200 m (Bahmanpour et al. 2016). Tropical water sources for the Holloway Current include tropical Pacific Ocean water emanating from South East Asian seas (the Indonesian Throughflow) and Indian Ocean water via the South Java Current (D'Adamo et al. 2007). The strength of the Holloway Current varies seasonally, with maximum flow during autumn and winter (April to July); monsoon cycles are suggested to drive this seasonal variability (Bahmanpour et al. 2016). The Holloway Current is a source of water for the Leeuwin Current.

The Leeuwin Current commences around the North West Cape, where the continental shelf narrows and its source waters consolidate (**Figure 3-8**). It flows southward along the edge of the continental shelf and may extend across southern Australia waters, with its influence being observed as far as waters off Tasmania. The Leeuwin Current is primarily a surface flow (up to 150 m deep). The Leeuwin Current is strongest during winter and slackens during summer months (Cresswell 1991). Interannual variation in the strength of the Leeuwin Current is influenced by the occurrence of El Niño and La Niña phases of the El Niño-Southern Oscillation (ENSO) (Pearce and Phillips 1988). The formation of meanders and eddies are also a feature of the Leeuwin Current (Waite et al. 2007). These may advect large masses of water away from the Western Australian coastline into the Indian Ocean. Northward-flowing wind-driven currents, such as the Ningaloo and Capes currents, may develop during summer months (Pattiaratchi and Woo 2009). These counter currents flow between the Leeuwin Current and the shore.

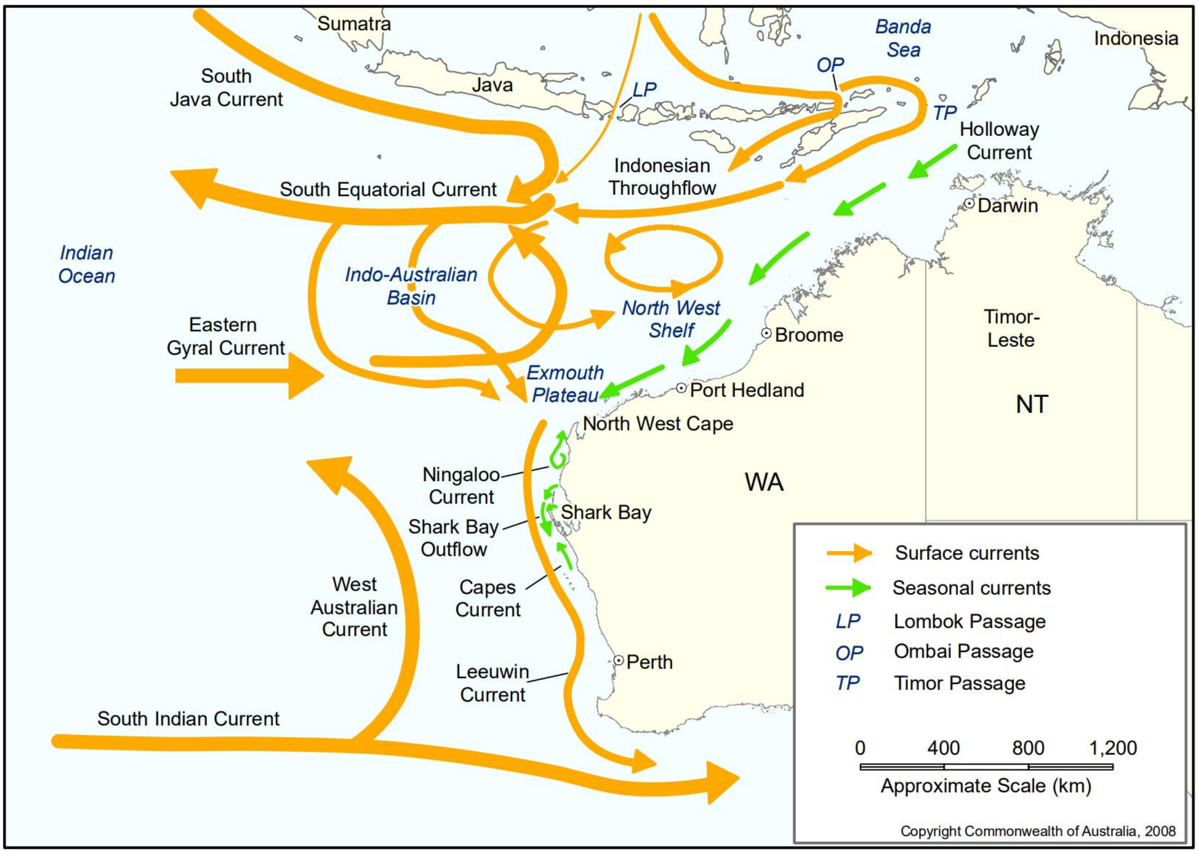

Figure 3-8: Surface currents off Western Australia (Department of the Environment, Water, Heritage and the Arts 2008b)

3.2.4 Water Quality

Results of water quality sampling in the Project Area showed that turbidity in surface waters was low, with increased levels of turbidity near the seabed suggested to be the result of sediment resuspension by currents near the seabed (RPS 2020b).

Concentrations of nutrients and photosynthetic pigments were relatively low compared to coastal waters, with no evidence of eutrophication. Highest concentrations of chlorophyll *a* were recorded midwater between 30 and 65 m BSL with low concentrations at surface or near seabed depths (RPS 2020b). Concentration of chlorophyll *a* in surface waters throughout the Project Area was below the default guideline of 9 µg/L for chlorophyll *a* in slightly disturbed tropical Australian marine offshore ecosystems (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000a).

Dissolved oxygen levels were high (approximately 100% saturated) in well-mixed surface waters, gradually declining through the thermocline to between approximately 60% (deeper sites) and 80% (shallower sites) near the seabed within the Project Area (RPS 2020b).

Concentrations of metals and hydrocarbons in water were below the recommended trigger values (where available) for slightly to moderately disturbed marine systems, with many analytes below the laboratory limits of reporting (RPS 2020b). These results are consistent with naturally low levels of contamination in mid-continental shelf waters (Wenziker et al. 2006), indicating low natural levels of potential contaminants.

Naturally occurring radioactive material concentration in the water was found to be low, with most samples recording concentration below the limit of reporting (**Attachment 5**) and all samples found to be one to two orders of magnitude lower than the trigger values presented in the guidelines for drinking water (National Health and Medical Research Council and National Resource Management Ministerial Council 2011). There are no trigger values for naturally occurring radioactive material in the *Australian and New Zealand guidelines for fresh and marine water quality* (Commonwealth of Australia and New Zealand Government 2018), and comparing the results to drinking water guidelines is deemed acceptable as they are expected to be more stringent as they relate to human health (**Attachment 5**).

3.2.5 Sediment Quality

Like water quality, results of environmental surveys by RPS (2020d) indicate sediment quality in the Project Area is high, with little evidence of contamination. Concentrations of potential contaminants, such as heavy metals, nutrients and hydrocarbons, were generally below the default guideline values (where available) for toxicants in sediments provided in the *Australian and New Zealand guidelines for fresh and marine water quality* (Commonwealth of Australia and New Zealand Government 2018).

Elevated concentrations of barium, which is a component of drilling muds, were recorded at one sediment sampling site within the Project Area. This is likely to be due to historical drilling activity (RPS 2020c). Barium is not considered to pose a high risk of inducing toxic effects; the *Australian and New Zealand guidelines for fresh and marine water quality* (Commonwealth of Australia and New Zealand Government 2018) does not specify a guideline value for barium in sediments.

Nutrient concentrations within the Project Area did not exhibit any clear spatial patterns, although a trend for slightly increased concentrations of total Kjeldahl nitrogen and total organic carbon at sites in the northern and western parts of the Project Area (RPS 2020c).

Sediments in the Project Area were characterised as varying grades of sand – ranging from slightly gravelly muddy sand to gravelly sand (RPS 2020c). Sediments were relatively coarse in the southern and south-eastern parts of the Project Area, becoming progressively finer to the north. This increase of relatively fine sediment fractions correlates with increasing water depth (RPS 2020c). Sediment particle sizes are likely to be a function of the water movement, with winnowing of relatively fine sediments by water movement near the seabed likely to account for the pattern in sediment particle sizes within the Project Area.

3.2.6 Air Quality

The Project Area is remote from potential sources of atmospheric pollutants, and air quality in the Project Area is high. The mainland coast is more than 100 km from the proposed WHP and the nearest town (Port Hedland) is approximately 145 km from the WHP.

Vessel traffic is the only known source of atmospheric pollutants in and around the Project Area. There is a relatively high density of commercial shipping traffic through and around the Project Area (**Figure 3-28)**; primarily bulk iron ore carriers transiting to and from Port Hedland. Reductions in air quality from shipping in the Project Area is localised and temporary.

3.2.7 Underwater Acoustic Environment

Ambient underwater acoustic environments, or soundscapes, consist of cumulative contributions from abiotic (geophonic e.g. sea state, wind speed, breaking waves, rainfall, earthquakes, sea ice movements), biotic (biophonic e.g. vocalisations by marine mammals, fish and invertebrates, consequences of behaviour) and man-made (anthrophonic e.g. vessel traffic, construction, oil and gas activity) sound sources (Krause 2008).

Underwater sound was recorded near the proposed Dorado WHP and FPSO with an Autonomous Multichannel Acoustic Recorder which was fitted with an M36 omnidirectional hydrophone (Lucke et al. 2022) with the goal being to document baseline underwater sound conditions at the Dorado Project Area. Recording took place between 16 December 2019 and 30 March 2020, a total of 105 days recording.

The dominant background geophonic contributor was tidal flow at low frequencies (10 – 100 Hz), however, this is considered pseudo-noise that results from eddies and vortices forming as water flows past the acoustic receiver. The most dominant biophonic contributor was fish choruses (100 – 1000 Hz) either showing a strong diurnal pattern, occurring for average of two hours at night or occurring almost continuously with fluctuations following a lunar or seasonal rhythm. Reliably detecting other sound sources is challenging if these sounds are fainter or completely overlap temporally and in frequency band with tidal or fish noise. Acoustic signals of Omura's whales, killer whales, and dolphins were also detected. Vessels were detected throughout the entire recording period, with a varying frequency from 0 to 4 vessel movements per day.

3.3 Biological Environment

The biological environment within the EMBA includes values and sensitivities, such as communities and habitats, plankton, mammals, fishes, reptiles and birds. Each of these values and sensitivities is described within this section.

Many of the species of fauna that may occur within the EMBA are listed as threatened or migratory (or both). These species are protected under Part 3 of the EPBC Act and are MNES. Threatened species typically have conservation advice published, which outlines threats to the species. Threatened species may also have recovery plans, made under the EPBC Act, which outline actions intended to assist in the recovery of threatened species. These advices and plans are considered within this section where appropriate.

3.3.1 Communities and Habitats

3.3.1.1 Benthic Habitats

The Project Area is located within the North-West Marine Region approximately 120 km from Port Hedland. Benthic habitat modelling completed by CSIRO, (**Attachment 3**) mapped three ecotypes within the Project Area and four additional ecotypes outside the Project Area (**Figure 3-9**). The ecotypes in the Project Area are characterised as soft bottom substrate of fine sediments (typically more than 90% cover) with discrete areas of filter-feeder communities. The seabed is relatively flat in topography throughout the Project Area, but hard reef substrate and complexity increase near the ancient coastline feature (outside the Project Area).

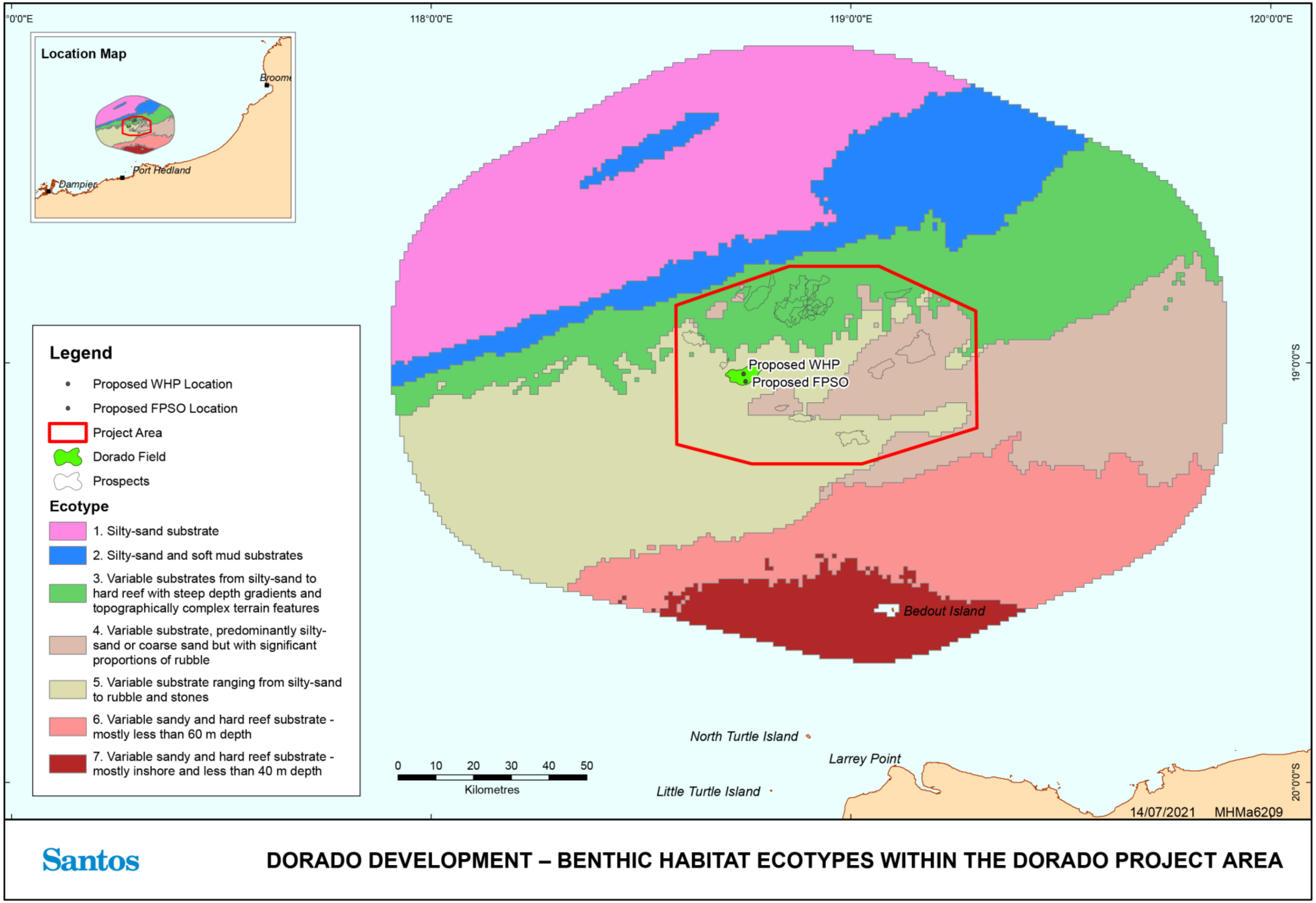

Figure 3-9: Benthic habitat ecotypes within the Project Area

3.3.1.1.1 Bare Substrate

Bare substrate habitats include sediments and hard substrate habitats that typically have a low or no cover of epibenthic biota. This benthic habitat type comprises almost all of the benthic habitat within the Project Area, with habitats composed largely of fine sediments (typically more than 90% cover) with some areas of hard pavement reef, which may host filter-feeder communities, especially whip corals, gorgonians and sponges (Keesing et al. 2020; RPS 2020d).

The benthic habitat survey identified both soft sediment (silt/sand sediment) and hard substrate (low-relief hard substrate) habitats within the Project Area (RPS 2020d). These habitats were homogenous throughout the baseline survey area and are well represented outside the baseline survey area (Keesing et al. 2020; RPS 2020d).

Habitats within the Project Area can be described as the following:

+ areas of flat, silty sand and silty mud that are sparsely populated with epibiota and support a low to medium density of tube worms. In addition, scattered sea pens, crinoids and anemones, bioturbation by small fish and invertebrates were occasionally observed;
+ areas of low, probably mobile sand waves supporting very little epibiota other than occasional sea pens and worm tubes; and
+ exposed hard substrates supported low- to medium-density filter-feeding assemblages that were generally dominated by small gorgonians, sea whips, soft corals and sponges.

Transects completed over the WHP site indicated a relatively flat and featureless soft sediment area (**Figure 3-10**), with no high conservation features or fish habitat identified within the site. The habitat mapping has indicated that the area surrounding the WHP is of a similar habitat type and is likely to continue well beyond the survey transects (RPS 2020d).

The proposed FPSO site can be inferred to be a combination of soft sediment and hard substrate habitats and communities. Both of these habitat types and the associated assemblages are well represented in the survey area; and while they have higher local environmental value, they are not significant in the broader area and there are equivalent or better examples at other sites surveyed, for example Site 21, which had extensive low- to medium-density filter-feeder communities (RPS 2020d).

Geophysical surveys have identified that the benthic habitats within the Project Area are dynamic (e.g. seasonal storms) with the changing seabed periodically covering and uncovering new habitat and communities (RPS 2020d). Communities within the Project Area did not appear to be well established, and individuals appear to be small. Therefore, the benthic communities within the Project Area are likely to have some resilience to disturbance from sediment movement and persistence for recolonisation of hard substrate when available (RPS 2020d).

No high conservation significant ecological values, habitats, communities or species were identified in the Project Area, and the habitats and communities are well represented in the local area and region (RPS 2020d).

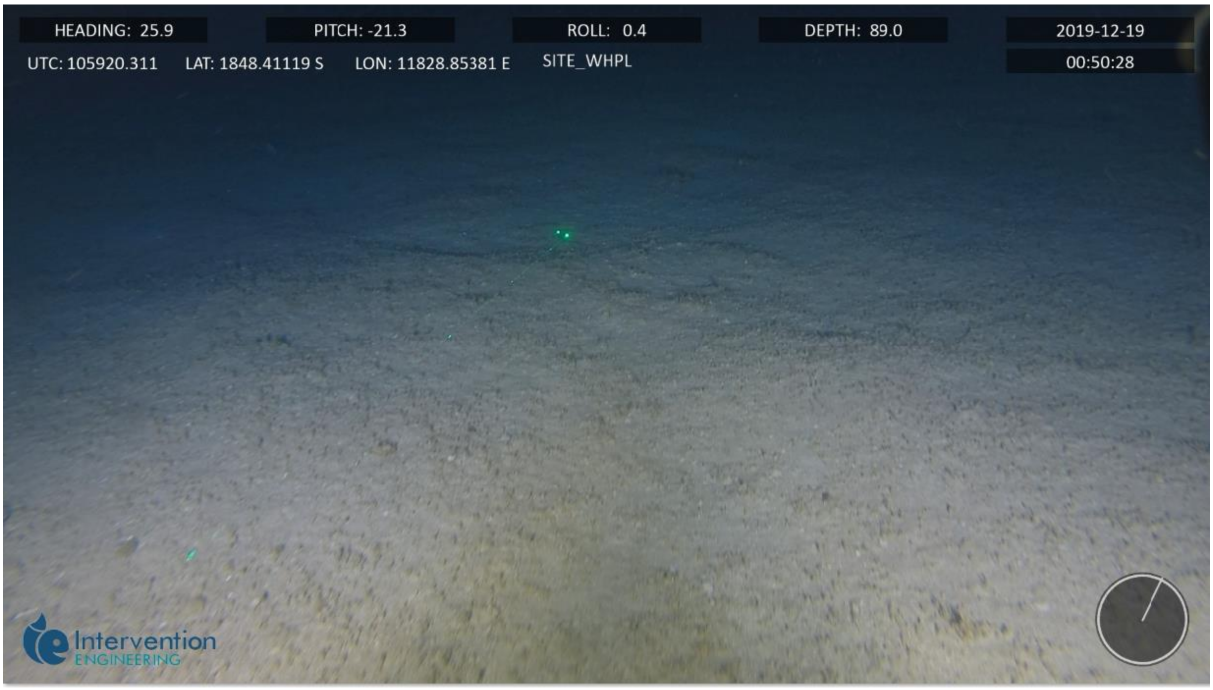

Figure 3-10: Typical benthic habitat at the WHP site

3.3.1.1.2 Reefs, Shoals and Banks

Reefs, shoals and banks typically have a higher diversity and abundance of marine organisms than the bare sediments. Reef habitats typically include reef-building corals, which may form highly productive and structurally complex habitats. These in turn host diverse fauna assemblages, such as fish and invertebrates.

There are no recognised reefs, shoals or banks within the Project Area. The seabed within the Project Area typically receives insufficient light to support zooxanthellate reef-building corals and has limited areas of hard substrate suitable for reef-building coral recruitment.

Several areas host extensive fringing coral reefs within the EMBA beyond the Project Area, including:

+ the Rowley Shoals;
+ the Dampier Archipelago;
+ Barrow, Lowendal and Montebello Islands; and
+ Ningaloo Reef.

Many of the reefs within the EMBA beyond the Project Area are within Commonwealth or state marine protected areas (**Section 3.4.2**), with Ningaloo Reef also lying within a World Heritage Area (WHA) (**Section 3.4.4.1**).

The Rowley Shoals are three distinct reef systems (Mermaid, Clerke and Imperieuse Reefs) approximately 30 to 40 km apart that rise vertically to the surface from depths of between 500 and 700 m. The nearest shoal, Imperieuse Reef, is approximately 147 km from the WHP (and 131 km from the Project Area). The marine fauna of the Rowley Shoals is considered to be exceptionally rich and diverse, including species typical of the oceanic coral reef communities of the Indo-West Pacific (Bryce 2009; Department of the Environment, Water, Heritage and the Arts 2008b). As many of these species are not found in the inshore tropical waters of northern Australia, such populations are of regional significance (DSEWPaC 2012b).

The Dampier Archipelago (approximately 230 km from the WHP) supports coral reefs in shallow waters near islands and submerged pinnacles. The most significant coral reefs have formed along the seaward slopes of Delambre Island, Hamersley Shoal, Sailfish Reef, Kendrew Island and northwest Enderby Island (Department of Conservation and Land Management 2005). Surveys of the Dampier Port and inner Mermaid Sound recorded approximately 120 coral species from 43 genera with coral reefs dominated by acroporids and pocilloporids (Blakeway and Radford 2004).

The Montebello, Lowendal and Barrow Islands (approximately 360 km from the WHP) include 315 islands associated with extensive coral reefs, the most significant of which occur in the sheltered waters on the eastern side of the islands. Examples of these significant reefs include Dugong Reef, Batman Reef and reefs along the Lowendal Shelf (Department of Environment and Conservation 2007). Subtidal coral reef communities around the islands are highly diverse, with at least 150 species of hard corals recorded from fringing and patch coral reef areas (Department of Environment and Conservation 2007).

Ningaloo Reef (approximately 560 km from the WHP) is unique in that it is the largest fringing reef in Australia and is the only large reef found on the western side of a continent in the southern hemisphere. Ningaloo Reef is comprised of a 300-km section of the coast that encompasses Red Bluff to North West Cape and extends to Bundegi in Exmouth Gulf. Ningaloo Reef supports lagoonal, intertidal and subtidal coral communities along its length. The reef is characterised by a high diversity of hard corals with at least 217 species representing 54 genera of hermatypic (reef-building) corals recorded to date (Veron and Marsh 1988). The most diverse coral communities are found in the shallow, relatively clear-water, high-energy environment of the fringing barrier reef and low-energy lagoonal areas to the west of North West Cape (Marine Parks and Reserves Authority and Department of Conservation and Land Management 2005).

3.3.1.1.3 Islands

No islands or emergent reef systems are located within the Project Area. Several islands and emergent reefs located within the EMBA in close proximity to the Project Area provide intertidal and shoreline habitats for a variety of marine fauna and ecological communities. These islands and reefs are summarised below.

Bedout Island is located 38 km south of the Project Area and is an A-class nature reserve. The island is a low and undulating, 0.3-km² sandy cay on limestone bedrock, heavily vegetated with *Spinifex longifolius*. Bedout Island supports breeding birds, such as masked booby, white-bellied sea eagle, silver gull, crested tern and lesser crested tern (BirdLife International 2018). Burbidge et al. (1987) report numbers of occupied nests of brown booby (approximately 10,000, one of the largest colonies in Western Australia), masked booby (approximately 178) and lesser frigatebird (2,290) surveyed in 1984 on Bedout Island. Bedout Island is fringed by coral reef and provides seabird and turtle foraging habitat.

North Turtle Island is located 71 km southwest of the Project Area and is an A-class nature reserve. The island is fringed by coral reef and provides turtle and seabird nesting and foraging habitat (BHP, 2011; Davidson and Thomas-Dans, Landscope article, n.d).

Bedwell Island on Clerke Reef and Cunningham Island on Imperieuse Reef are located 163 km and 131 km respectively from the Project Area and consist of unvegetated sand cays about 2 m and 3.7 m high respectively. Bedwell Island is home to one of only two colonies of red-tailed tropicbirds in Western Australia (the other being located at Ashmore Reef and Cartier Island over 300 km northwest of the WA coast), along with several other bird species. Bedwell Island also provides occasional nesting habitat for a small number of hawksbill and green turtles. Both Bedwell Island and Cunningham Island are known resting sites for migratory birds (Department of Environment and Conservation 2007).

Rowley Shoals is located 117 km from the Project Area and comprises three distinct reef systems, Imperieuse Reef, Clerke Reef and Mermaid Reef, each located approximately 30 to 40 km apart. Mermaid Reef includes low-lying sandy cays that are completely submerged at high tide and therefore fall under Australian Government jurisdiction (Commonwealth waters). The other two reefs, Clerke Reef and Imperieuse Reef, are emergent reefs with sandy islets above the high-water mark and are managed as the WA Rowley Shoals Marine Park. The marine reef fauna of the Rowley Shoals is considered to be exceptionally rich and diverse, including species typical of the oceanic coral reef communities of the Indo-West Pacific. As many of these species are not found in the inshore tropical waters of northern Australia, such populations are of regional significance (DSEWPaC 2012a).

3.3.1.1.4 Seagrass

Seagrasses are flowering plants (angiosperms) that grow on the seabed in shallow marine environments. Seagrasses require sufficient photosynthetically active radiation for growth, which restricts the distribution of seagrasses to relatively shallow waters due to the absorption of light within the water column. Seagrasses provide a range of valuable ecological functions, including primary production, habitat for biota, and sediment stabilisation. Seagrasses provide food for marine fauna, such as green turtles and dugongs. Seagrasses also provide important nursery habitat, with many animal species spending part of their lifecycle within seagrass meadows.

No seagrasses occur within the Project Area due to the water depth, although seagrasses are widespread in the EMBA beyond the Project Area. Seagrasses in the Pilbara and Kimberley coastal regions of the EMBA are typically small, ephemeral species, such as *Halophila* spp., *Cymodocea* spp. and *Syringodium* spp. (McMahon et al. 2017). Many of these species have broad Indo-Pacific tropical distributions in coastal waters, with the distributions of several species also extending along the Western Australian coastline into subtropical and temperate waters. These species tend to be adapted to disturbances, such as cyclones and grazing, and are considered to be pioneer or colonising species that typically grow from seeds (Kilminster et al. 2015).

Seagrass species assemblages in temperate waters within the EMBA also include larger, more persistent meadow-forming genera, such as *Posidonia* and *Amphibolis*. These genera tend to grow more slowly than tropical species, are persistent in the environment and can form extensive meadows (Kilminster et al. 2015). A notable example is the extensive seagrass meadows in Shark Bay (850 km from the WHP), which are characterised by extensive seagrass assemblages dominated by *Amphibolis antarctica* (Walker et al. 1988). These seagrass meadows support one of the largest populations of dugongs in the world (Preen et al. 1997).

3.3.1.1.5 Macroalgae

Macroalgae are important contributors to primary production and nutrient cycling in the marine environment, providing food and habitat for fauna, such as green turtles and dugongs (Arthur et al. 2008). Like seagrasses, macroalgae require sufficient photosynthetically active radiation for growth; hence, the distribution of macroalgae is restricted by available light at the seabed. Some macroalgae, such as red algae, can tolerate lower levels of photosynthetically active radiation compared to seagrasses and may occur over a wider range of water depths.

No macroalgae communities were observed within the Project Area. The water depths within the Project Area do not allow sufficient light to reach the seabed to support macroalgal growth. Macroalgae are widespread in coastal areas and reefs in the EMBA beyond the Project Area and are very commonly found on reefs and intertidal platforms.

3.3.1.2 Coastal Habitats

No coastal habitats occur within the Project Area. All coastal habitats described within this section occur within the EMBA for unplanned events.

3.3.1.2.1 Mangroves

Mangrove habitats are widely distributed in coastal environments throughout tropical and subtropical EMBAs beyond the Project Area. Mangroves are important primary producers and have a number of ecological and economic values, such as:

+ stabilisation of coastal sediments;
+ filtration of terrestrial run-off; and
+ breeding and nursery areas for juvenile fish and crustaceans, including commercially important species.

Mangroves play an important role in connecting the terrestrial and marine environments (Alongi 2009). Numerous studies (e.g. Nagelkerken *et al.* 2000; Alongi 2002; Alongi 2009; Kathiresan and Bingham 2001) have shown mangroves to be highly productive and an important breeding and nursery areas for juvenile fish and crustaceans, including commercially important species (Kenyon et al. 2004). They also provide habitat for many juvenile reef fish species. Mangroves also play an important ecosystem role in nutrient cycling and carbon fixing (NOAA2010). The trees absorb carbon dioxide from the atmosphere, and the organic matter – such as fallen leaves – forms nutrient-rich sediments creating a peat layer that stores organic carbon (Alongi 2009; Ayukai 1998). The muddy sediments that occur in mangrove forests are home to a variety of epibenthic, infaunal and meiofaunal invertebrates (Kathiresan and Bingham 2001). Crustaceans known to inhabit the mud in mangrove systems include fiddler crabs, mud crabs, shrimps and barnacles. Within the water channels of estuaries, various finfish are found, from the smaller fish (such as gobies and mudskippers, which are restricted to life in the mangroves) through to larger fish (such as barramundi (*Lates calcarifer*) and the mangrove jack (*Lutjanus argentimaculatus*)). Mangroves and their associated invertebrate-rich mudflats are also an important habitat for migratory shorebirds from the northern hemisphere, as well as some avifauna that are restricted to mangroves as their sole habitat (Garnet and Crowley 2000).

Substantial mangroves on the Western Australian coast range from Shark Bay to the Northern Territory border. Shark Bay supports the southernmost area of substantial mangrove habitat in Western Australia (Rule et al. 2012). The mangroves of Shark Bay comprise only one species, the white mangrove (*Avicennia marina*); and these trees occur around the coastline in widely dispersed and often isolated stands of varying size.

Mangroves occur along the mainland Pilbara coast and nearshore islands, particularly along estuaries and river deltas, such as the Ashburton and Robe rivers. Relatively small stands of mangrove are also found along the coastlines of some offshore islands within the EMBA, such as the Montebello Islands and Barrow Island. These arid-zone mangroves are unique and differ from tropical mangrove systems by tending to be smaller and less productive as a result of high water and salinity stress (Environmental Protection Authority 2001). The regional mangroves from Exmouth to Broome (within the Central Western Shelf Transition and southern part of the Northwest Shelf Province) represent Australia's only 'tropical-arid' mangroves. The most significant stand of mangroves in the Central Western Shelf Transition is Mangrove Bay on the western side of the Cape Range Peninsula in the Ningaloo Marine Park. This small area of mangrove (37 ha) represents the largest area of mangrove habitat within the Ningaloo Marine Park and is considered extremely important from a biodiversity conservation perspective (Department of Conservation and Land Management 2005).

Extensive mangrove stands occur along the Kimberley coastline and progressively become more typical of tropical mangrove systems with decreasing latitude.

3.3.1.2.2 Intertidal Sand and Mudflats

The Pilbara and Kimberley coastline experience a large tidal range and, as a result, host extensive intertidal sand and mudflats. These habitats occur to some extent along much of the sandy beach and mangrove shorelines in the region. Intertidal mudflats typically host a high abundance of invertebrates, which provide food for fish during high tide. During low tide, these intertidal areas provide foraging areas for shorebirds.

Significant areas of intertidal mudflats within the EMBA include Eighty Mile Beach and Roebuck Bay. These wetlands are important for many species of migratory shorebirds as feeding and resting areas. Both are recognised as Ramsar wetlands and listed under the EPBC Act as wetlands of international importance (**Section 3.4.2.4**).

3.3.1.2.3 Intertidal Platforms

Intertidal platforms are areas of hard bedrock and/or limestone with or without a sediment veneer of varying thickness. These platforms can vary from low to high relief and provide a habitat for a diverse range of intertidal organisms. They are common features along shorelines throughout the EMBA beyond the Project Area, both on the mainland coast and coastal islands. The large tidal range and diurnal nature of the tidal regime in the Pilbara and Kimberley regions result in relatively large intertidal platform habitat compared to areas with a smaller tidal range.

Notable areas of intertidal platform habitat within the EMBA include the Dampier Archipelago, Barrow Island, the Montebello Islands, Lowendal Islands, the Ningaloo Coast and the Dampier Peninsula. Much of the intertidal platform habitat within the EMBA lies within marine protected areas (**Section 3.4.2**).

3.3.1.2.4 Sandy Beaches

Sandy beaches are areas within the intertidal zone where unconsolidated sediment has been deposited (and eroded) by wave and tidal action. Sandy beaches can vary from low- to high-energy zones; the energy experienced influences the beach profile due to varying rates of erosion and accretion.

Sandy beaches are found throughout the EMBA and vary in length, width, gradient, sediment type, composition, and grain size. Sandy beaches provide habitat to a variety of burrowing invertebrates and subsequently provide foraging grounds for shorebirds (**Section 3.3.6**). Sandy beaches can also provide an important habitat for turtle nesting and breeding. Nature-based tourism and recreation are also important socio-economic uses of sandy beaches (**Section 3.4.5**).

3.3.1.2.5 Rocky Shorelines

Rocky shores can include pebbles or cobbles, boulders, and rocky limestone cliffs (often at the landward edge of reef platforms). Rocky outcrops typically consist of hard bedrock, but some of the coastline has characteristic karsted limestone cliffs with an undercut notch.

Rocky shorelines are found across the EMBA and are often indicative of high-energy areas (wave action) where sand deposition is limited or restricted. They are formed from limestone pavement extending out from the beach into subtidal zones, for example along the Ningaloo Coast and North West Cape; higher relief platforms (more than 0.5 m above the high water mark) are also present at a number of headlands along the North West Cape.

3.3.1.3 Key Ecological Features

KEFs are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity. KEFs meet one or more of the following criteria (DSEWPaC 2012a):

+ a species, group of species or a community with a regionally important ecological role;
+ a species, group of species or a community that is nationally or regionally important for biodiversity; and
+ an area or habitat that is nationally or regionally important for:
  - enhanced or high biological productivity;
  - aggregations of marine life; or
  - biodiversity and endemism.
+ a unique seafloor feature with ecological properties of regional significance.

There are no KEFs within the Project Area; 19 KEFs occur in the EMBA beyond the Project Area. These are shown in **Figure 3-11** and **Figure 3-12** and are described in **Table 3-1**.

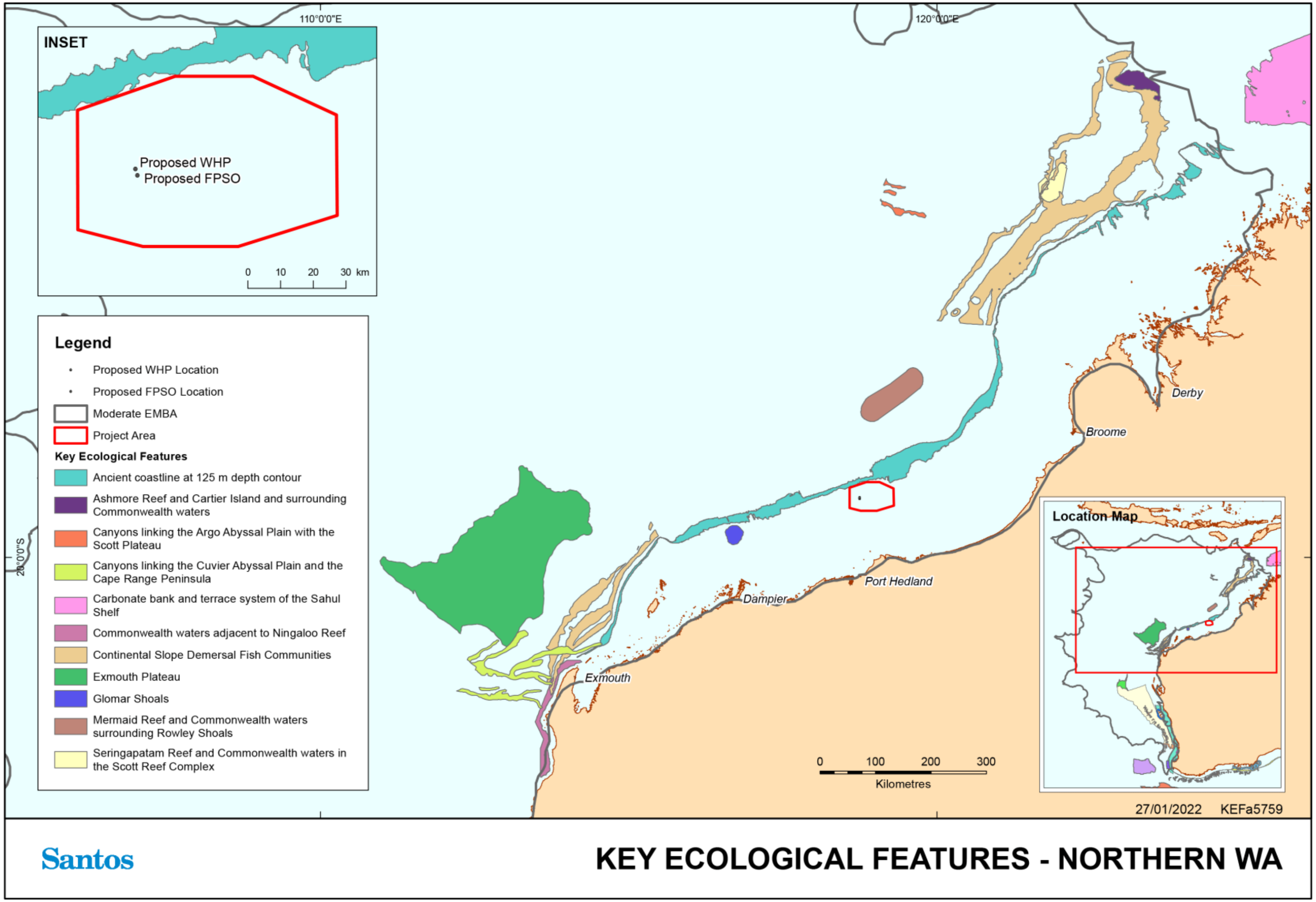

Figure 3-11: KEFs – Northern Western Australia

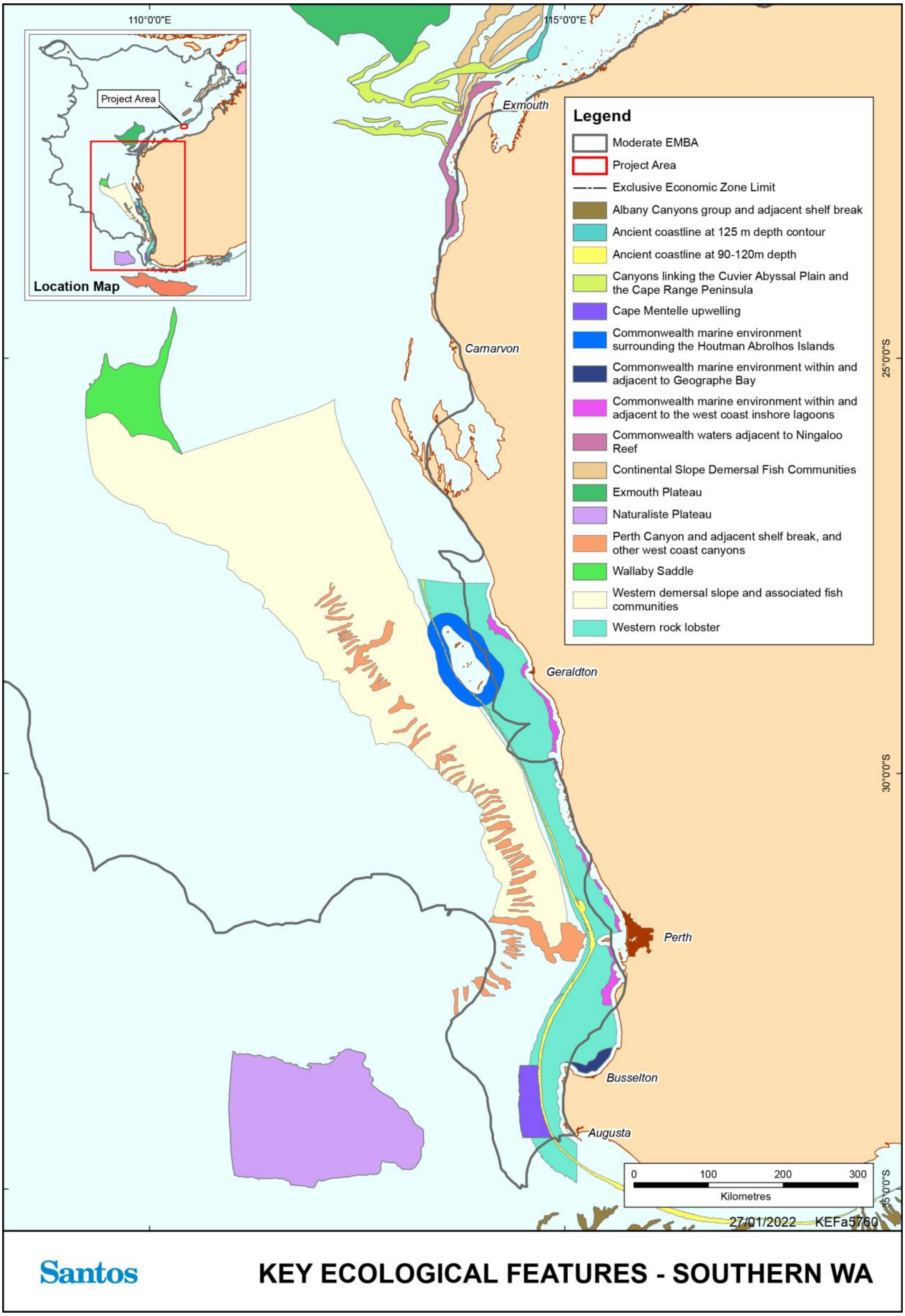

Figure 3-12: KEFs – Southern Western Australia

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Table 3-1: Summary of KEFs within the EMBA (DSEWPaC 2012b; DSEWPaC 2012a)

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
Ancient coastline at 125 m depth contour	23	0.17	*Unique seafloor feature with ecological properties of regional significance* Parts of the ancient coastline, particularly where it exists as a rocky escarpment, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column, providing relatively nutrient-rich local environments. 115 to 135 m water depth
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	138	108	*High productivity and aggregations of marine life* The Rowley Shoals consist of three atoll reefs – Clerke, Imperieuse and Mermaid Reef – that support 214 coral species and around 530 species of fish. The steep changes in slope around the reef also attract a range of migratory pelagic species, such as dolphins, tuna, billfish and sharks. The coral communities of Mermaid Reef are an important feature (300 to 480 m water depth). The enhanced productivity at the shoals is thought to be facilitated by the breaking of internal waves in the waters surrounding the reefs, causing mixing and resuspension of nutrients from water depths of 500 to 700 m into the photic zone.
Glomar Shoals	207	186	*High productivity and aggregations of marine life* The Glomar Shoals are a submerged littoral feature located approximately 150 km north of Dampier on the Rowley Shelf at depths of 33 to 77 m. While biological data is limited, the fish of Glomar Shoals are believed to be a subset of reef-dependent species. The shoals are known to be an important area for a number of commercial and recreational fish species, such as Rankin cod, brown-striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish.
Continental Slope Demersal Fish Communities	346	306	*Communities with high species biodiversity and endemism* There is a high diversity of demersal fish assemblages on the Australian continental slope from the North West Cape to the edge of the North Marine Region.

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
			Specifically, the continental slope between the North West Cape and the Montebello Trough has more than 500 fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in the whole of Australia. 180 to 1,000 m water depth.
Exmouth Plateau	459	441	*Unique seafloor feature with ecological properties of regional significance* Due to its large size, the plateau is thought to modify deep-water flow and be associated with the generation of internal tides in the Exmouth region. These oceanic processes may contribute to the upwelling of nutrients, which result in areas of increased productivity. The plateau ranges in depth between 800and 4,000 m and features valleys and channels that support a range of benthic environments. These features are also thought to provide conduits for the transport of sediment and other materials from the plateau surface to deeper areas. While the Exmouth Plateau has low habitat heterogeneity, it is likely to be an important area of biodiversity as it provides an extended area for communities adapted to depths of around 1,000 m.
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	509	485	*Unique seafloor features with ecological properties of regional significance* The nutrient-rich and highly productive waters of this KEF are associated with aggregations of whale sharks, manta sharks and rays, humpback whales, sea snakes, sharks, large predatory fish, and seabirds. The canyons are thought to connect to the Commonwealth waters adjacent to Ningaloo Reef, as well as to the Exmouth Plateau. The KEF also supports unique seafloor features of a regional significance with regards to both benthic and pelagic ecological habitats. 130 to 4,900 m water depth.

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
Canyons linking the Argo Abyssal Plain with the Scott Plateau	512	480	*High productivity and aggregations of marine life* The Bowers and Oats canyons are major canyons on the slope between the Argo Abyssal Plain and the Scott Plateau and deeply cut into the Scott Plateau at depths of approximately 2,000 to 3,000 m. The ocean area above the canyons is thought to be an area of moderately enhanced productivity, attracting aggregations of fish, sharks, toothed whales and dolphins. Water depths 3,300 to 5,100 m.
Commonwealth waters adjacent to Ningaloo Reef	555	531	*High productivity and aggregations of marine life* Ningaloo Reef is of global significance as it is the only coral reef in the world that fringes the west coast of a continent and is a seasonal aggregation site for the whale shark. The high degree of interconnectivity with regional canyons and plateaus contributes to the high levels of productivity and species richness of the Ningaloo Reef. The reef supports aggregations and migration pathways of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds. The deep water biodiversity includes unique assemblages of sponge and filter-feeder communities (compared with the Dampier Archipelago and Abrolhos Islands) which are indicative of areas of potentially high and unique sponge biodiversity. 30 to 700 m water depth.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	619	576	*High productivity and aggregations of marine life* The coral communities at Seringapatam and Scott Reefs play a key role in maintaining species richness and aggregations of marine life. The reefs and the waters surrounding them attract aggregations of marine life, including humpback whales on their northerly migration, Bryde's whales, pygmy blue whales, Antarctic minke whales, dwarf minke whales, minke whales, dwarf sperm whales, spinner dolphins and whale sharks. Green and hawksbill turtles nest during the summer months on Sandy Islet on South Scott Reef. These species also internest and forage in the surrounding waters.

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
			Scott Reef is a particularly biologically diverse system and includes more than 300 species of reef-building corals, approximately 400 mollusc species, 118 crustacean species, 117 echinoderm species, around 720 fish species and several species of sea snakes. 400 to 1,600 m water depth.
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	873	830	*High productivity and aggregations of marine life* Ashmore Reef (100 to 400 m water depth) is the largest of only three emergent oceanic reefs present within the north-eastern Indian Ocean and is the only oceanic reef in the region with vegetated islands. The emergent reefs are known to provide areas of enhanced primary productivity in otherwise oligotrophic environments (environments that offer little to sustain life). Ashmore Reef and Cartier Islands and the surrounding Commonwealth waters are regionally important for feeding and breeding aggregations of seabirds and shorebirds and for other marine life. Ashmore Reef regularly supports more than 40,000 waterbirds (those ecologically dependent on wetlands) and is estimated to support as many as 100,000 seabirds in a 12-month period. The marine habitats supported by the reefs are nationally and internationally significant, providing habitat for diverse and abundant marine reptile populations (including feeding, nesting and internesting areas for green, hawksbill and loggerhead turtles) and marine mammal populations (including dugongs). Species at Ashmore Reef and Cartier Island include more than 225 reef-building corals, 433 molluscs, 286 crustaceans, 192 echinoderms, and 709 species of fish. Thirteen species of sea snakes occur in high numbers at Ashmore reef and Cartier Island but are in decline.
Wallaby Saddle	1,057	1,031	*High productivity and aggregations of marine life* The Wallaby Saddle is an abyssal geomorphic feature located on the upper continental slope at a depth of 4,000 to 4,700 m. The feature connects the northwest margin of the Wallaby Plateau with the margin of the Carnarvon

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
			Terrace. The Wallaby Saddle is situated within the Indian Ocean water mass and is thus differentiated from systems to the north that are dominated by transitional fronts or the Indonesian Throughflow. Little is known about the Wallaby Saddle; however, the area is considered one of enhanced productivity and low habitat diversity.
Western rock lobster	1,086	1,048	*Presumed ecological role on the West Coast Continental Shelf* This species is the dominant large benthic invertebrate in the region. The lobster plays an important trophic role in many of the inshore ecosystems of the South-west Marine Region. Western rock lobsters are an important part of the food web on the inner shelf, particularly as juveniles as they are preyed upon by octopus, cuttlefish, baldchin groper, dhufish, pink snapper, wirrah cod and breaksea cod. The high biomass of western rock lobsters and their vulnerability to predation suggest that they are an important trophic pathway for a range of inshore species that prey upon juvenile lobsters. 0 to 230m water depth.
Ancient coastline between 90 and 120 m depth	1,107	1,082	*High productivity and aggregations of marine life, biodiversity and endemism* This feature contains several terraces and steps reflecting a gradual increase in sea level across the shelf that occurred during the Holocene. Some of these features create escarpments of distinct elevation, creating topographic complexity through the exposure of rocky substrates. The most prominent of these occurs close to the middle of the continental shelf off the Great Australian Bight at a depth of 90 to 120 m, which provides a complex habitat for a number of species. The area has important conservation value due to its potential for high productivity, biodiversity and aggregations of marine life. Benthic biodiversity and productivity occur where the ancient coastline forms a prominent escarpment of exposed hard substrates, where it is dominated by sponge communities of significant biodiversity and structural complexity.

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	1,128	1,104	*High levels of biodiversity and endemism in benthic and pelagic habitats* The Commonwealth marine environment surrounding the Houtman Abrolhos Islands (and adjacent shelf break) exhibits high levels of biodiversity and endemism in benthic and pelagic habitats (0 to 20 m water depth). The Houtman Abrolhos Islands and surrounding reefs support a unique mix of temperate and tropical species, resulting from the southward transport of species by the Leeuwin Current over thousands of years. The reefs are composed of 184 known species of corals that support about 400 known species of demersal fish, 492 known species of molluscs, 110 known species of sponges, 172 known species of echinoderms, and 234 known species of benthic algae. The Houtman Abrolhos Islands are the largest seabird breeding station in the eastern Indian Ocean. They support more than one million pairs of breeding seabirds. The Houtman Abrolhos Islands and surround waters are also important areas for Australian sea lions for foraging and breeding.
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	1,261	1,083	*High productivity and aggregations of marine life* This KEF is composed of a chain of inshore lagoons of limestone reef (as deep as 30 m) extending along the Western Australian coast from south of Mandurah to Kalbarri. The mix of sheltered and exposed seabeds form a complex mosaic of habitats. The lagoons are dominated by seagrass and epiphytic algae. Although macroalgae (principally *Ecklonia* spp.) and seagrass appear to be the primary sources of production, groundwater enrichment may supplement the supply of nutrients to the lagoons. The lagoons are associated with high biodiversity and endemism, containing a mix of tropical, subtropical and temperate flora and fauna.
Commonwealth marine environment within and adjacent to Geographe Bay	1,641	1,591	*High productivity and aggregations of marine life* Geographe Bay is known for its extensive beds of tropical and temperate seagrass that account for about 80% of benthic primary production in the area. This habitat supports a diversity of species, many of them not found anywhere else. The bay (15 to 45 m water depth) provides important nursery habitat for many species,

KEF	Approx. Distance from WHP (km)	Approximate Distance from Closest Project Area Boundary (km)	Summary of Environmental Values
			including juvenile dusky whaler sharks. It is also an important resting area for migrating humpback whales.
Cape Mentelle upwelling	1,654	1,633	*High productivity and aggregation soft marine life* The Cape Mentelle upwelling (100 to 450 m water depth) draws relatively nutrient-rich water from the base of the Leeuwin Current, up the continental slope and onto the inner continental shelf, where it results in phytoplankton blooms at the surface. The phytoplankton blooms provide the basis for an extended food chain characterised by feeding aggregations of small pelagic fish, larger predatory fish, seabirds, dolphins and sharks. The Cape Mentelle upwelling has a disproportionate influence on the overall nutrient-poor nature of the region's water.

3.3.1.4 Threatened Ecological Communities

Threatened ecological communities (TECs) are ecological communities that have been identified as being threatened with extinction, typically by human activities. TECs are protected under the EPBC.

No TECs have been identified within the Project Area. One coastal TEC, Subtropical and Temperate Coastal Saltmarsh, was identified within the EMBA beyond the Project Area. This TEC occurs within the subtropical and temperate climatic zones and is present in coastal areas under regular or intermittent tidal influences. This TEC occurs in Western Australia from the south coast up to the southern part of Shark Bay. The community is made up of mainly salt-tolerant vegetation that includes halophytes and a number of non-vascular plant species. The community is listed as vulnerable under the EPBC Act.

3.3.2 Plankton

Plankton abundance and distribution is patchy, dynamic and strongly linked to localised and seasonal productivity (Evans et al. 2017). Fluctuations in abundance and distribution occur both vertically and horizontally in response to tidal cycles, seasonal variation (light, water temperature and chemistry, currents and nutrients) and cyclonic events. As a key indicator for ecosystem health and change, plankton distribution and abundance has been measured for over a century in Australia (Richardson et al. 2015). The compilation of this data has been made publicly available through the Australian Ocean Data Network (Australian Ocean Data Network 2017) and has been used in the Australia State of the Environment 2016 report (Jackson et al. 2017) to nationally assess marine ecosystem health. According to their findings, warming ocean temperatures have extended the distribution of tropical phytoplankton species (which have a lower productivity) further south, resulting in a decline in primary productivity in oceanic waters north of 35°S, especially the North West Shelf (Evans et al. 2017). Trends of primary productivity across Australia are, however, variable with southwestern Australia experiencing an increase in productivity and northern Australia experiencing no change between 2002 and 2016 (Evans et al. 2017).

Within the EMBA, peak primary productivity varies on a local and regional scale. For example, peak phytoplankton biomass in waters surrounding Broome has been observed in May with a high variability recorded in August, whereas recorded phytoplankton biomass in waters surrounding Geographe Bay has been found to peak during winter and is localised close to the coast (Bloundeau-Patissier et al. 2011). In general, these peaks are linked to mass coral spawning events, peaks in zooplankton and fish larvae abundance and periodic upwelling. Regional upwelling is most common close to the coast and where surface waters diverge. Despite the suppression of major upwelling along the WA coast by the Leeuwin Current, known key upwelling regions include the Ningaloo region (Hanson and McKinnon 2009)and Cape Mentelle (Pattiaratchi 2007). It is also expected that a high abundance of plankton will occur within areas of localised upwelling in the EMBA where the seabed disrupts the current flow.

In waters surrounding Indonesia, seasonal peaks in phytoplankton biomass are linked to monsoon-related changes in wind. When the winds reverse direction (offshore vs. onshore), nutrient concentrations decrease or increase because of the suppression or enhancement of upwelling (National Aeronautics and Space Administration 2010). Annual variability of phytoplankton productivity in waters surrounding Indonesia is heavily influenced by the El Niño-Southern Oscillation climate pattern (National Aeronautics and Space Administration 2017). For example, phytoplankton productivity around Indonesia increases during El Niño events.

3.3.3 Marine Mammals

The Project Area is not recognised as a critical area for marine mammals; however, a number of marine mammals were identified as potentially occurring within the Project Area. Most of these are baleen whales, along with killer whales and bottlenose dolphins. While there are no recognised critical habitats overlapping the WHP site, the closest biologically important areas (BIAs to the WHP and Project Area are (refer **Figure 3-13**):

+ the humpback whale migration BIA, which lies approximately 26 km south and east of the WHP at the closest point and slightly overlaps the Project Area;
+ pygmy blue whale migration BIA, which lies approximately 110 km northwest of the WHP at the closest point and 86 km northwest of the Project Area; and
+ Pygmy blue whale distribution range, which overlaps the project area.

The humpback whale was de-listed as a threatened species (vulnerable) under the EPBC Act as of 26 Feb 2022 (DOE, 2022) and associated conservation advice and recovery plans are no longer in place. As a result there are no specific requirements for the humpback whale migration BIA associated with conservation advice or a conservation management plan.

The distribution range of pygmy blue whales is described as cosmopolitan in the conservation management plan (CMP) for blue whales and has been designated as extending from the shorelines of Western Australia to beyond the Continental Slope, shown as a layer in the National Conservation Values Atlas. On this basis, the Project Area overlaps with the designated distribution range for pygmy blue whales (**Figure 3-13)** but does not overlap the migratory or foraging BIAs. There are no specific requirements associated with the distribution range described in the CMP, with the precautionary approach applied to activities in or adjacent to foraging areas, and the adoption of best practice adaptive management in the event pygmy blue whales are encountered to prevent unacceptable impacts. The historical catch area (Figure 1, in the CMP) and satellite tagging and passive acoustic data referred to in the CMP indicates that pygmy blue whales occupy the continental slope rather than the continental shelf of the North West region. A recent publication by Thums et al. (2022) on pygmy blue whale movement, distribution and important areas provides a synthesis of 46 passive acoustic instruments between 2006 and 2019 and satellite tag deployments between 2009 and 2021 and indicates extensive use of the continental slope during migration rather than the shelf. The migration BIA for pygmy blue whales encompassed 79% of satellite tagging data, with the majority of the remaining 21% due to presence to the west of the migratory BIA (Exmouth plateau) and Indonesia. Only 7% of tagged pygmy blue whales occurred in shelf waters and these were mostly to the south of Ningaloo. Analysis of the passive acoustic data also indicated minimal shelf use. **Figure 3-15** (adapted from Thums et al, 2022), shows the overlap of the Project Area and tracking data.

Pygmy blue whales migrate as solitary animals or in small groups along the continental slope, typically at depths between 500 m and 1000 m on the way to the Banda and Molucca seas near Indonesia, where calving is understood to occur (Double et al., 2014). The northern migration (Augusta to Derby) tends to pass along the shelf edge at depths of 500 m to 1000 m; moving closer to the coast in the Exmouth - Montebello Islands area on southern migration. Northern migration occurs April through July, peaking in May - June, whilst southern migration occurs October through January, peaking in November – December.

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Many baleen whales that may occur within the EMBA have extensive ranges and undertake predictable seasonal migrations between feeding areas in high latitudes and calving and breeding areas in lower latitudes.

Some marine mammals identified within the EMBA, such as coastal dolphins and dugongs, have strong habitat preferences. The ranges of these species are typically large; however, their habitat preferences may result in locally high densities within their ranges interspersed with relatively low densities of these species.

Temperate species of marine mammals, such as Australian sea lions and southern right whales, may only be expected to occur within the southern part of the EMBA beyond the Project Area.

3.3.3.1 Threatened and Migratory Marine Mammals

A number of species of marine mammals listed as threatened or migratory under the EPBC Act were identified as potentially occurring within the Project Area and the EMBA beyond the Project Area based on Protected Matters Search Tool (PMST) data in **Attachment 1**. The full list of marine mammals including the species that are classified as threatened or migratory are presented in **Table 3-2** below**.** Omura's whale (*Balaenoptera omurai*) is not currently listed under the EPBC Act but is known to occur on the North West Shelf of WA.

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Table 3-2: Marine mammal species that may occur within the Project Area and EMBA

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Balaenoptera acutorostrta	Minke Whale	The minke whale is a relatively small baleen whale that is distributed worldwide. Feeding grounds for minke whales in the southern hemisphere are around Antarctica, with migration to lower latitudes during winter months thought to occur, although to a lesser extent than other baleen whales. The most northerly record in Australian waters is approximately 21° S, approximately the same latitude as the North West Cape (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Balaenoptera bonaerensis	Antarctic Minke Whale, Dark-shoulder Minke Whale	The Antarctic minke whale is distributed worldwide and has been recorded off all Australian states, feeding in cold waters and migrating to warmer waters to breed. It is thought that the Antarctic minke whale migrates up the Western Australian coast to approximately 20° S to feed and possibly breed (Bannister et al. 1996).	-	Migratory	Cetacean	-	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Balaenoptera borealis	Sei Whale	Sei whales have a worldwide oceanic distribution and is expected to migrate seasonally between low-latitude wintering areas and high-latitude summer feeding grounds (Bannister et al. 1996; Prieto et al. 2012). Sei whales have been infrequently recorded in Australian waters (Bannister et al. 1996), which could be due to the similarity in appearance of sei whales and Bryde's whales leading to incorrect recordings.	Vulnerable	Migratory	Cetacean	Species or species habitat likely to occur	Foraging, feeding or related behaviour likely to occur
Balaenoptera edeni	Bryde's Whale	The Bryde's whale occurs in tropical and temperate waters (Bannister et al. 1996). Bryde's whales occur in both oceanic and inshore waters with the only key localities recognised in Western Australia being in the Abrolhos Islands and north of Shark Bay (Bannister et al. 1996). Two forms are recognised: inshore and offshore Bryde's whales. It appears that the offshore form may migrate seasonally, heading	-	Migratory	Cetacean	Species or species habitat may occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		towards warmer tropical waters during the winter; however, behaviour of the offshore form in the Indian Ocean is not well documented. This species has been detected within the Northwest Province from mid-December to mid-June, peaking in late February to mid-April (RPS Environment and Planning 2012).					
Balaenoptera musculus *Balaenoptera musculus brevicauda*	Blue and Pygmy Blue Whale	There are two recognised subspecies of blue whale in the Southern Hemisphere, both of which are recorded in Australian waters. These are the southern (or ”true”) blue whale (*Balaenoptera musculus*) and the “pygmy” blue whale (*Balaenoptera musculus brevicauda*) (Commonwealth of Australia 2015a). In general, southern blue whales occur in waters south of 60° S, and pygmy blue whales occur in waters north of 55°S (i.e. not in the Antarctic). On this basis, nearly all blue whales likely to occur in the Project Area	Endangered	Migratory	Cetacean	Species or species habitat likely to occur	Foraging, feeding or related behaviour known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		and known to occur in the EMBA are pygmy blue whales. Pygmy blue whales undertake seasonal migration between temperate or sub-Antarctic and tropical waters (Double et al. 2014). In the Northern marine region, pygmy blue whales migrate along the 500 to 1,000-m depth contour on the edge of the slope. Sea noise loggers and satellite tracking at various locations along the Western Australian coast have detected an annual northbound migration past Exmouth and the Montebello Islands between April and August and a southbound migration from October to the end of January, peaking in late November to early December (Double et al. 2014; McCauley and Duncan 2011; McCauley and Jenner 2010). More recently, a synthesis of existing and new data on the distribution and movement of pygmy blue whales by Thums et al. (2022) concurred with					

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		these timings and migratory paths in deeper waters of the continental slope, to the west of the Project Area.					
Balaenoptera physalus	Fin Whale	Like other baleen whales, fin whales migrate annually between high-latitude summer feeding grounds and lower-latitude over-wintering areas (Bannister et al. 1996). Fin whales are thought to follow oceanic migration paths and are not commonly encountered in coastal or continental shelf waters. Antarctic waters are important feeding grounds for fin whales, but there are no known mating or calving areas in Australian waters (Morrice et al. 2004).	Vulnerable	Migratory	Cetacean	Species or species habitat likely to occur	Foraging, feeding or related behaviour likely to occur
Berardius arnuxii	Arnoux's Beaked Whale	Arnoux's beaked whale (family Ziphiidae) with a circum-Antarctic distribution. It occurs in temperate, sub-Antarctic and Antarctic oceanic waters. In Australia, it occurs south of around 34° S (approximately Cape Leeuwin), with no known key	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		localities in Australian waters (Bannister et al. 1996).					
Caperea marginata	Pygmy Right Whale	The pygmy right whale is considered the most elusive baleen whale; and as a result, very little is known about the whale's distribution in Australian waters. Records of the pygmy right whale in Australian waters are distributed between 32° S and 47° S (Kemper 2002), far south of the Project Area.	-	Migratory	Cetacean	-	Foraging, feeding or related behaviour likely to occur
Delphinus delphis	Common Dolphin, Short-beaked Common Dolphin	The common dolphin has a cosmopolitan distribution and is found in all ocean basins in warm-temperate and tropical waters. The species is gregarious and is known to congregate in large numbers (thousands of individuals). The species in not known to occur in sub-Antarctic or Antarctic waters (Bannister et al. 1996).	-	-	Cetacean	Species or species habitat may occur	Species or species habitat may occur
Dugong dugon	Dugong	Dugongs are distributed throughout tropical coastal waters in the Indo-Pacific region. They occur along the Western Australian coast	-	Migratory	-	-	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		throughout the Gascoyne, Pilbara and Kimberley, with notable populations in the following (Marsh et al. 2002; Preen et al. 1997): + Ningaloo Marine Park (state waters), + Exmouth Gulf, and + Shark Bay. Dugong distribution is correlated with seagrass habitats in which dugong feed, although water temperature has also been correlated with dugong movements and distribution (Preen 2004; Preen et al. 1997).					
Eubalaena australis	Southern Right Whale	The southern right whale occurs primarily in waters between approximately 20 and 60° S and moves from high-latitude feeding grounds in summer to warmer, low-latitude coastal locations in winter (Bannister et al. 1996). Southern right whales aggregate in calving areas along the south coast of Western Australia, such as Doubtful	Endangered	Migratory	Cetacean	-	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Island Bay, east of Israelite Bay and to a lesser extent Twilight Cove (DSEWPaC 2012b). During the calving season, between May and November, female southern right whales that are either pregnant or with calf can be present in shallow protected waters along the entire southern Western Australian coast up to approximately Two Rocks, north of Perth. Sightings in more northern waters are relatively rare; however, they have been recorded as far north as Exmouth (Bannister et al. 1996).					
Feresa attenuata	Pygmy Killer Whale	The pygmy killer whale is a species of oceanic dolphin. It is the smallest cetacean species that includes “whale” in the common name, derived from some resemblance to the orca, or killer whale. The species has a wide distribution in tropical and subtropical waters worldwide (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Globicephala macrorhynchus	Short-finned Pilot Whale	The species is a large oceanic dolphin that has been recorded in all ocean basins in oceanic and continental shelf waters. Short-finned pilot whales form socially cohesive groups and have been recorded in mass strandings at several locations around the world, including most Australian states and the Northern Territory (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Globicephala melas	Long-finned Pilot Whale	Like the only other species in the genus *Globicephala*, the short-finned pilot whale, this species is a large oceanic dolphin that has been recorded in all ocean basins in oceanic and continental shelf waters. The species is widely recorded in waters off southern Australia and has been recorded stranding in all Australian states, but not the Northern Territory (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Grampus griseus	Risso's Dolphin, Grampus	Risso's dolphin is found worldwide in tropical and temperate waters. Preferred habitat appears to be just off the continental shelf where the continental slope is steep. Records in Australian waters occur from southwestern Australia along the south coast to Queensland (Bannister et al. 1996).	-	-	Cetacean	Species or species habitat may occur	Species or species habitat may occur
Hyperoodon planifrons	Southern Bottlenose Whale	The southern bottlenose whale is a species of beaked whale (family Ziphiidae) with a circumpolar distribution in the Southern Ocean, accounting for most sightings of beaked whales in Antarctic waters. Sightings occur primarily south of 29° S (approximately south of Geraldton) (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Indopacetus pacificus	Longman's Beaked Whale	The Longman's beaked whale is a species of beaked whale (family Ziphiidae) that occurs in temperate, sub-Antarctic and Antarctic oceanic waters (Bannister et al. 1996). The species may be primarily oceanic, like other beaked whale species.	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Kogia breviceps	Pygmy Sperm Whale	The pygmy sperm whale has a cosmopolitan distribution in tropical and temperate waters worldwide. Relatively little is known about this species compared to sperm whales, due to its small size, inconspicuous behaviour, and paucity of historical whaling records. The species feeds predominantly on pelagic squid in open ocean and is less frequent on continental shelf waters (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Kogia sima	Dwarf Sperm Whale	Like the pygmy sperm whale, the dwarf sperm whale has a cosmopolitan distribution in tropical and temperate waters worldwide. It is more likely to be frequenting continental shelf and continental slope waters than the pygmy sperm whale. Squid are the main prey item (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Lagenodelphis hosei	Fraser's Dolphin, Sarawak Dolphin	Fraser's dolphin is a pelagic, oceanic dolphin species found in all ocean basins. The species is most commonly observed in oceanic and	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		continental slope waters (more than 1,000 m deep), and is relatively rarely observed in continental shelf waters. Fraser's dolphin is typically found in tropical and subtropical waters and is relatively rare in temperate waters (Bannister et al. 1996).					
Lagenorhynchus obscurus	Dusky Dolphin	The dusky dolphin's distribution is strongly linked to colder waters. In Australia, the dusky dolphin has been sighted in southern Australia from Western Australia to Tasmania. It is presumed to be primarily an inshore species but has been known to move further offshore, possibly due to its desire for colder waters (Gill et al. 2000). Dusky dolphins are expected to be limited in their distribution along the Western Australian coastline due to the presence of the southward-flowing warm water of the Leeuwin Current.	-	Migratory	Cetacean	-	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Lissodelphis peronii	Southern Right Whale Dolphin	The southern right whale dolphin is an oceanic dolphin species distributed throughout the Southern Ocean. It is the only dolphin species in the southern hemisphere that lacks a dorsal fin (similar to the southern right whale, which is the basis for the species' common name). The species is usually found well offshore in ocean basins or outer continental shelfs between 30° S and 65° S (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Megaptera novaeangliae	Humpback Whale	The species undertakes regular seasonal migrations between feeding grounds in the Southern Ocean and breeding and calving grounds off northern Western Australia, particularly Camden Sound (Jenner et al. 2001). From the North West Cape, northbound humpback whales travel along the edge of the continental shelf passing to the west of the Muiron, Barrow and Montebello Islands, peaking in late	-	Migratory	Cetacean	Breeding known to occur	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		July (Jenner et al. 2001). The southern migratory route follows a relatively narrow track between the Dampier Archipelago and Montebello Islands, south of the Project Area. In particular, Exmouth Gulf is where cow/calf pairs may stay for up to two weeks during September (Jenner et al. 2001).					
Mesoplodon bowdoini	Andrew's Beaked Whale	Very little is known of Andrew's beaked whale, with very few observations of this species in the wild. Most information on the species has been collected from stranded individuals. Strandings have been recorded in Chile, the Falkland Islands, southern Australian and southern New Zealand, suggesting a circumpolar distribution in the Southern Ocean (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Mesoplodon densirostris	Blainville's Beaked Whale, Dense-beaked Whale	Blainville's beaked whale is found in tropical and subtropical waters in all ocean basins. It is one of the most widely distributed beaked whales. The latitudinal range in Australia	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		may be extended by the warm south-flowing Leeuwin and East Australian currents (Bannister et al. 1996). Most sightings occur in continental slope waters (more than 200 m water depth), with diving depths of more than 900 m recorded (Baird et al. 2006), indicating a preference for waters much deeper than the continental shelf.					
Mesoplodon ginkgodens	Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale	The ginkgo-toothed whale has a broad tropical and subtropical distribution in the Indian and Pacific oceans but has not been recorded in the Atlantic Ocean. It is thought to be more common in the western North Pacific Ocean, where it has occasionally been caught by whalers. Records in Australia are from a small number of stranding events in Victoria and New South Wales. The species is capable of deep dives and is thought to prefer deepwater habitats as do other	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		ziphiid species (Bannister et al. 1996).					
Mesoplodon grayi	Gray's Beaked Whale, Scamperdown Whale	Gray’s beaked whale has a circumpolar distribution at higher latitudes in the southern hemisphere. Observations of the species at sea are most common in deep water (more than 2,000 m), indicating a preference for outer continental shelf and deep ocean waters. Most recorded strandings have occurred in New Zealand (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Mesoplodon hectori	Hector's Beaked Whale	Hector's beaked whale is primarily a Southern Hemisphere cool temperate species. The records are from southern South America, South Africa, Australia, and New Zealand. Recently, there have been several strandings and possible sightings off southern California, but it is unknown whether these represent extralimital strays or normal occurrences.	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Mesoplodon layardii	Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale	The strap-toothed beaked whale has a circumpolar distribution in sub-Antarctic and temperate waters in the Southern Ocean. Analysis of the stomach contents of stranded strap-toothed whales found prey items were primarily deepwater squid, indicating the species forages in outer continental shelf and oceanic waters (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Mesoplodon mirus	True's Beaked Whale	True's beaked whale is distributed in deep circumpolar temperate and sub-Antarctic waters in the southern hemisphere. There is a population in the north Atlantic, although this may be a separate species given the geographic separation from the southern hemisphere population. Strandings have been recorded in South Africa, Australia and New Zealand (Bannister et al. 1996).	-	-	Cetacean	-	Species or species habitat may occur
Neophoca cinerea	Australian Sea Lion	The Australian sea lion is the only endemic pinniped in Australia, with only 76 known breeding colonies ranging from the Abrolhos Islands	Endangered	-	-	-	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		off Western Australia to the Page Islands, South Australia (DSEWPaC 2012b). The estimated total population of Australian sea lion is approximately 14,700, with only 14% found in Western Australia (DSEWPaC 2012b). On the west coast of Western Australia, rookeries are found on low-lying limestone islands that are well protected by perimeter reefs. Females typically travel less than 60 km from their natal site, while males may disperse approximately 200 km from natal sites to other breeding colonies or haul-out sites (Campbell 2003; Campbell et al. 2008). The breeding cycle of the species is approximately 17 to 18 months, leading to breeding and pupping timings that are not strongly correlated with season, with the pupping season at individual colonies ranging between five and					

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		nine months (Goldsworthy et al. 2009).					
Orcaella brevirostris	Irrawaddy Dolphin	The Irrawaddy dolphin is very closely related to the Australian snubfin dolphin and was recognised as a separate species relatively recently. Some authorities still consider the species synonymous with *O. heinsohni*. The species is distributed in southern Asia, southeastern Asia and northern Australia in shallow (less than 20 m) coastal and estuarine waters. In Western Australia, it is recorded north of Broome to the Brisbane River in Queensland (Bannister et al. 1996).	-	Migratory	Cetacean	-	Species or species habitat known to occur
Orcaella heinsohni	Australian Snubfin Dolphin	The Australian snubfin dolphin shares similar habitat preferences with the Indo-Pacific humpback dolphin, occurring in shallow coastal and estuarine tropical waters (typically less than 20 m deep). However, as with the Indo-Pacific humpback dolphin, the species has also been recorded up to 23 km	-	Migratory	Cetacean	-	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		offshore. In Australia, the species distribution covers the coastal waters of Queensland, the Northern Territory and northern Western Australia (Bannister et al. 1996). The population in Australian waters is thought to be continuous with the Papua New Guinea species but separate from populations in Asia.					
Orcinus orca	Killer Whale	The killer whale is widespread from polar to equatorial regions of all oceans and has been recorded off all states of Australia (Bannister et al. 1996). Killer whales appear to be more common in cold, deep waters; however, they have been observed along the continental slope and shelf (Bannister et al. 1996).	-	Migratory	Cetacean	Species or species habitat may occur	Species or species habitat may occur
Peponocephala electra	Melon-headed Whale	Melon-headed whales occur in deep tropical or subtropical oceanic waters in all ocean basins, between 40° N and 35° S. The species is gregarious, with groups of 150 to 1,500 animals recorded. Mass strandings have been recorded in New South Wales, Queensland and	-	-	Cetacean	-	Species or species habitat may occur within area

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Western Australia. It is primarily a pelagic and oceanic species that rarely occurs in continental shelf waters (Bannister et al. 1996).					
Physeter macrocephalus	Sperm Whale	Sperm whales are the largest of the toothed whales and are distributed worldwide in deep waters (deeper than 200 m) off continental shelves and sometimes near shelf edges (Bannister et al. 1996). Sperm whales have been recorded in all Australian state waters. The species is known to migrate northwards in winter and southwards in summer, but detailed information on the distribution and migration patterns of sperm whales off the Western Australian coast is not available (Bannister et al. 1996).	-	Migratory	Cetacean	-	Foraging, feeding or related behaviour known to occur
Pseudorca crassidens	False Killer Whale	False killer whales are found worldwide in deep tropical and temperate waters. They are distributed circumglobally between 45° S and 45° N. Strandings have been recorded in several locations	-	-	Cetacean	Species or species habitat likely to occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		around the Australian coast, including Western Australia (Bannister et al. 1996). The species has been recorded both in deep oceanic waters and continental shelf waters, although it appears to prefer deep offshore waters, with observations in relatively shallow waters made around oceanic islands, such as the Hawaiian Islands (Culik 2004).					
Sousa chinensis	Indo-Pacific Humpback Dolphin	The Indo-Pacific humpback dolphin is now recognised as two distinct species: the Indo-Pacific humpback dolphin (*Sousa chinensis*) and the Australian humpback dolphin (*S. sahulensis*) (Jefferson and Rosenbaum 2014). Distribution of the Indo-Pacific humpback dolphin in Australia is tropical, occurring north of 29° S and 24° S off the east and west coasts of Australia respectively (Bannister et al. 1996). Humpback dolphins inhabit shallow coastal, estuarine habitats in tropical and subtropical regions	-	Migratory	Cetacean	-	Breeding known to occur

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Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		generally in depths of less than 20 m (Corkeron et al. 1997; Jefferson 2000; Jefferson and Rosenbaum 2014).					
Stenella attenuata	Spotted Dolphin, Pantropical Spotted Dolphin	The spotted dolphin is distributed in tropical waters in all ocean basins. It is the second most-populous dolphin species, after the bottlenose dolphin. It occurs in deep oceanic waters, as well as on the continental slope and outer continental shelf waters (Bannister et al. 1996). The species associates with schooling tuna and was subject to historical high levels of mortality due to bycatch in tuna fisheries.	-	-	Cetacean	Species or species habitat may occur	Species or species habitat may occur
Stenella coeruleoalba	Striped Dolphin, Euphrosyne Dolphin	The striped dolphin occurs in tropical and temperate waters in all ocean basins from approximately 40° N to 30 °S. Like other species of *Stenella*, the striped dolphin is known to form large aggregations (more than 1,000 individuals) (Culik 2004). The species is generally considered to be pelagic and appears to prefer continental shelf	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		and oceanic waters (more than 200 m water depth) (Bannister et al. 1996; Culik 2004).					
Stenella longirostris	Spinner Dolphin, Long-snouted Spinner Dolphin	The spinner dolphin is distributed in tropical and temperate waters from 40° N to 40° S. It occurs in continental shelf, continental slope and oceanic waters. Like other species of *Stenella*, spinner dolphins may form large congregations and may associate with tuna and seabirds in pursuit of prey (Bannister et al. 1996; Culik 2004).	-	-	Cetacean	-	Species or species habitat may occur
Steno bredanensis	Rough-toothed Dolphin	The rough-toothed dolphin occurs in tropical and temperate waters in all ocean basins. The species is most often observed far offshore, usually well beyond the continental shelf (Culik 2004). The species often congregates in schools of less than 50 animals but may form larger groups up to 300 animals (Bannister et al. 1996; Culik 2004).	-	-	Cetacean	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Cetacean	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Tursiops aduncus	Spotted Bottlenose Dolphin (Arafura / Timor Sea populations)	The spotted bottlenose dolphin is generally considered to be a warm-water subspecies of the common bottlenose dolphin. Distribution is primarily inshore waters, often in depths of less than 10 m (Bannister et al. 1996). They are known to occur from Shark Bay north to the western edge of the Gulf of Carpentaria.	-	Migratory	Cetacean	Species or species habitat may occur	Species or species habitat known to occur
Ziphius cavirostris	Cuvier's Beaked Whale, Goose-beaked Whale	Cuvier's beaked whale is the only member of the monotypic genus *Ziphius* within the beaked whale (ziphiid) family. The species has a cosmopolitan distribution ranging from tropical to temperate waters in all ocean basins. The species is the deepest-diving mammal, with dives of almost 3,000 m recorded and with most animals recorded in more than 1,000 m water depth (Bannister et al. 1996; Culik 2004; Schorr et al. 2014).	-	-	Cetacean	-	Species or species habitat may occur

Table 3-3 outlines the management plans, recovery plans and conservation advice relevant to those species identified as potentially occurring or having habitat within the Project Area and summarises the key threats to those species as described in the relevant plans and advice.

Table 3-3: Summary of EPBC management plans, recovery plans and conservation advice relevant to the Project Area

Species	Recovery Plan/ Conservation advice	Key threats identified in the Recovery Plan/ Conservation advice	Relevant Conservation Action
Sei Whale	Conservation advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b)	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of sei whales is further defined, assess the impacts of increasing anthropogenic noise (including from seismic surveys, port expansion, and coastal development) on this species.
		Vessel disturbance	Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
Blue Whale	Conservation management plan for the blue whale: *A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999* 2015–2025 (Commonwealth of Australia 2015a) Guidance on key terms within the Blue Whale Conservation Management Plan (DAWE, 2021)	Noise interference	Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area. Ensure EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a) is applied to all seismic surveys.
		Vessel disturbance	Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
Fin Whale	Conservation advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee 2015c)	Noise interference	Once the spatial and temporal distribution (including BIAs) of fin whales is further defined, assess the impacts of increasing anthropogenic noise (including seismic surveys, port expansion, and coastal development) on this species.
		Vessel disturbance	Develop a national vessel strike strategy that investigates the risk of vessel strikes on fin whales and identifies potential mitigation measures.

			Ensure all vessel strike incidents are reported in the National Vessel Strike Database.

3.3.3.1.1 Whale Migration

Humpback whales traverse waters off the west coast of Australia as they migrate annually from summer feeding grounds in Antarctica to the nearshore waters of the Kimberley region where they breed and calve during winter. Humpback whales are likely to be present in the Project Area during the northbound migration. They appear to remain on or within the 200-m isobath near the Montebello Islands and then move closer to shore as they head further north to the calving grounds in the Kimberley. The humpback whale migration corridor is not an identified aggregation area or critical habitat: the whales are in transit and are migrating from their southern polar 'summer' feeding grounds to their northern tropical 'winter' calving and breeding grounds.

Peak northward migration across the NWS is approximately from late July to early August, and peak southward migration is approximately from late August to early September (Jenner et al. 2001) . Data collected between 1995 and 1997 by the Centre for Whale Research indicates that the period for peak northern migration into the calving grounds in the Kimberley is mid to late July (**Table 3–3**). The peak for southern migration is in the first half of September (Jenner et al. 2001).

Figure 3-13 shows the overlap of the Project Area with the humpback whale migration BIA. Satellite tracking data (Double et al. 2010, 2012a; Gales et al. 2009) for northbound and southbound humpback whales indicated that the tagged whales migrated in a consistently narrow inshore path along the northwest coast of Western Australia, with the satellite tracks greater than 50 km from the WHP site.

Based on migration data presented in Thums et al. (2018), it is possible that a small number of migrating individuals will traverse the Project Area (**Figure 3-14**). This migration data, collected over 2008, 2009 and 2011 for tagged humpback whales, shows there are no migration paths that overlap with the Project Area. The different tag numbers correlate to tags on each individual whale, data from 39 tagged whales is plotted. The data also shows that if the humpback whales were to migrate through the Project Area during their northern migration it would be for hours rather than days (i.e. less than 0.5 days, **Figure 3-16**).

Table 3-4: Critical periods for migrating humpback whales in the vicinity of the Project Area

Migrations	Description	Timing
Northbound migration: Port Hedland to Broome	Peaks July and tapers off by August (may vary by 3 weeks from year to year). Extends further compared to southern migration route.	Late July to early August
Southbound migration: Broome to Port Hedland	Southerly migration in this area is contracted in a narrower band than the northerly migration route, generally occurring closer to the coast within the 50-m isobath and generally in waters less than the 35 m deep.	Late September to early October

Sources: Jenner et al. (2001); Threatened Species Scientific Committee (2015a).

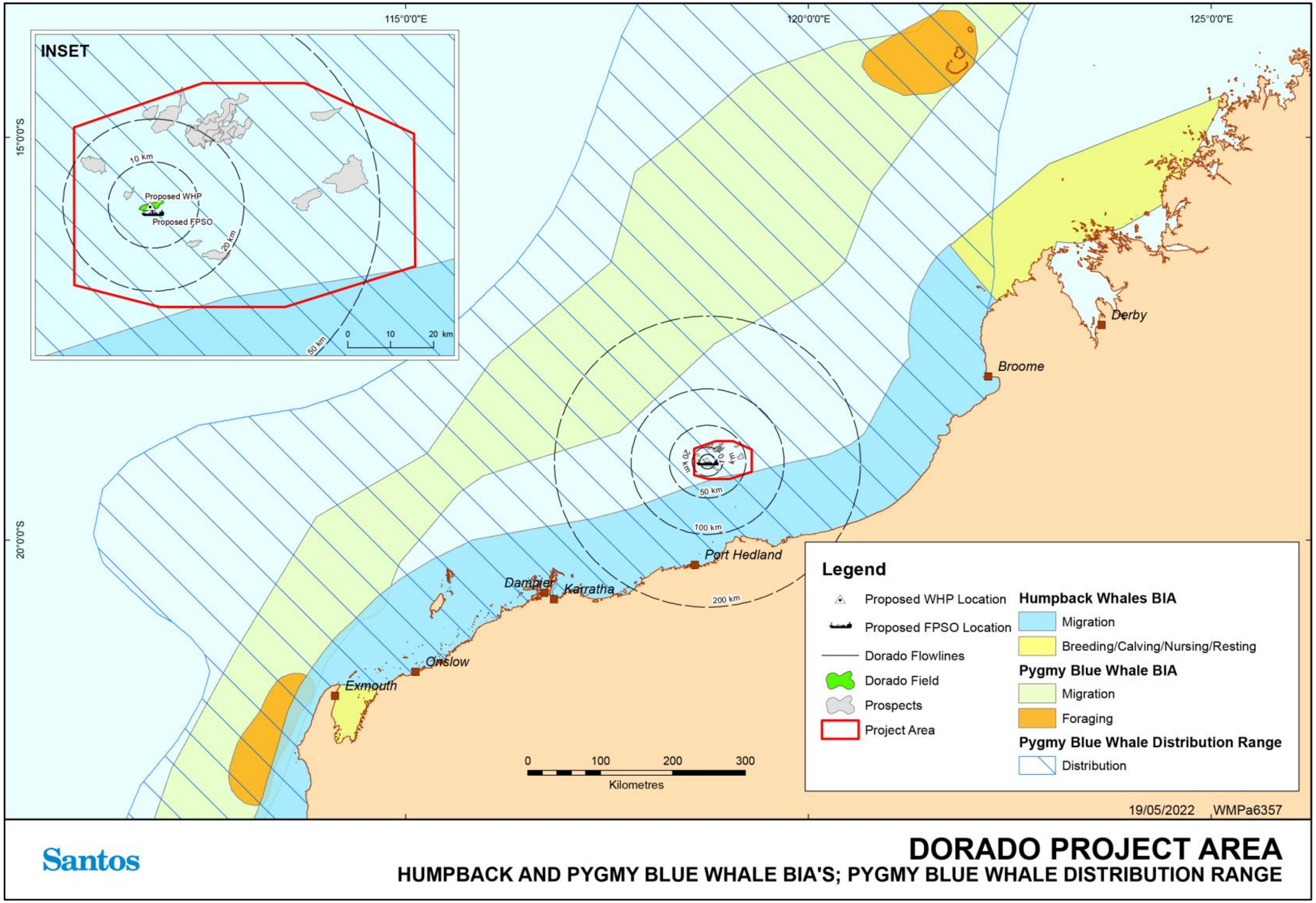
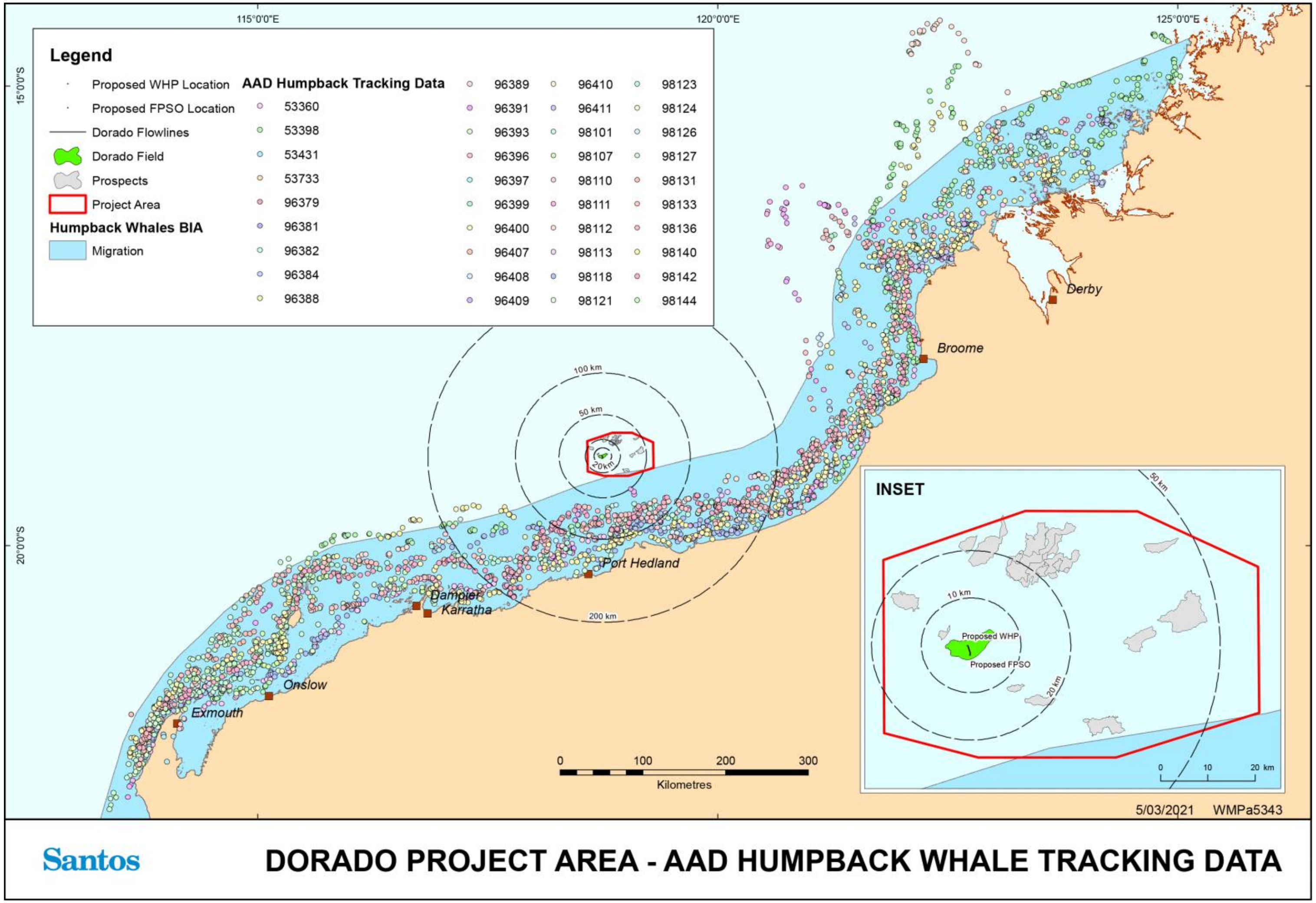
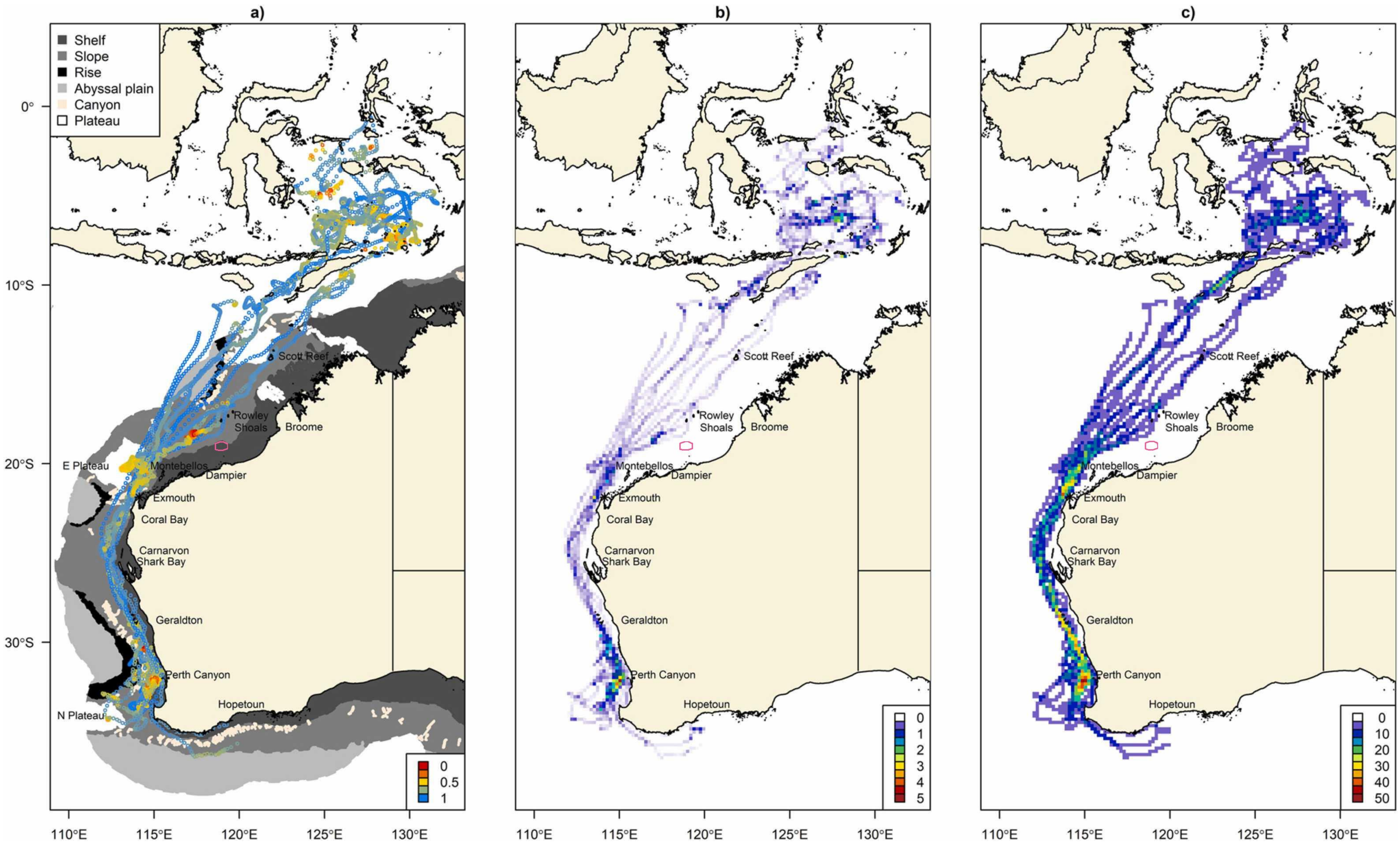


Figure 3-13: Project Area overlap with humpback whale BIAs, pygmy blue whale BIA and pygmy blue whale distribution range



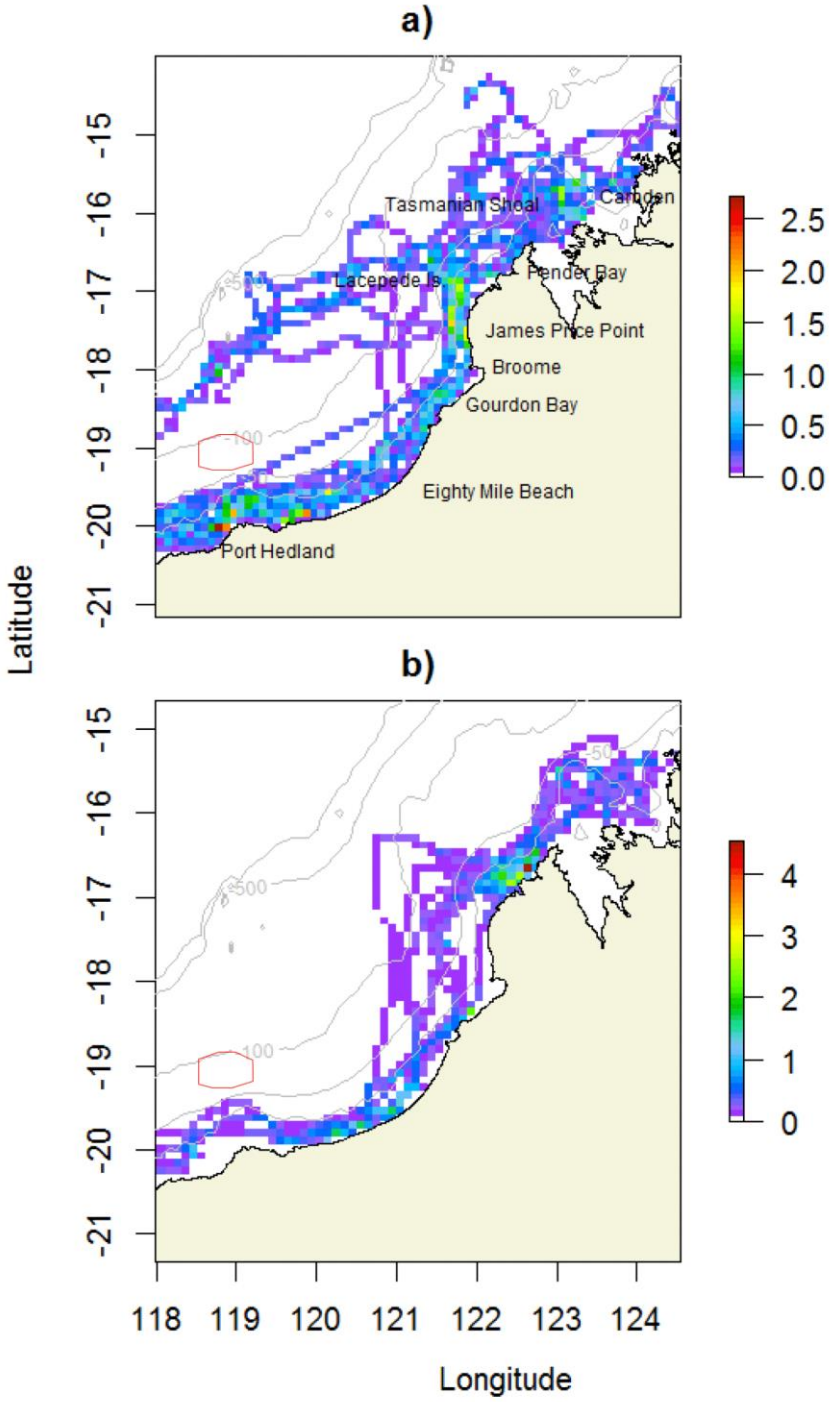
Sources: Double et al. (2012a); Gales et al. (2010).

Figure 3-14: Project Area overlap with humpback whale migration BIA and Australian Antarctic Division whale tracking data



Sources: Thums et al, 2022. a) Pygmy blue whale (n = 16) state space modelled position estimates are colour coded by move persistence with cooler colours indicating high move persistence (indicative of migration) and warmer colours indicating low move persistence (indicative of foraging, and/or resting/ breeding). b) shows the distributions calculated using the modelled position estimates with occupancy (time spent per grid cell in days), and c) shows percentage of pygmy blue whales per grid cell. Satellite tag deployment locations marked with an asterisk, including NW Cape (n = 6), Perth Canyon (n = 15), Bonney Upwelling, SA (n = 1), noting that only data from Hopetoun WA to Indonesia is shown for the latter deployment. Geomorphic features of the Australian EEZ are also shown, including the Exmouth (E) Plateau and the Naturaliste (N) plateau

Figure 3-15: Project Area overlap with pygmy whale tracking data



Number of days spent by northbound (a) and southbound (b) humpback whales per 10 km × 10 km grid cell for the Kimberley Region, within proximity of the Dorado project area, from tagged humpback whales from 2008, 2009 and 2011 (source Thums et al, 2018).

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NORTHBOUND AND SOUTHBOUND HUMPBACK WHALES MIGRATION DURATIONS (2008-2011)

Figure 3-16: Northbound (a) and southbound (b) humpback whale migration durations (2008, 2009 and 2011) and overlap with Project Area

3.3.3.2 Biologically Important Areas and Critical Habitat

BIAs are not defined under the EPBC Act, but there are areas that are particularly important for the conservation of protected species and where aggregations of individuals display biologically important behaviour such as calving, foraging, resting or migration (DAWE, 2021). BIAs have been identified using expert scientific knowledge about species distribution, abundance and behaviour (DAWE, 2021). A number of BIAs for marine mammals that cover biologically important behaviours overlap the EMBA beyond the Project Area. These are summarised in **Table 3-5** along with distance from the WHP and the closest Project Area boundary.

Whilst it is not currently possible to define habitat critical to the survival of blue whales, the best information relates to biologically important areas where foraging occurs (DAWE, 2021). The distribution range of pygmy blue whales overlaps the Project Area, however based on data presented in Thums et al, 2022, and no observed pygmy blue whales during multiple drilling and seismic campaigns within the project area since 2015, pygmy blue whales are not expected to frequent the project area. No critical habitats for marine mammals were identified within the Project Area and EMBA.

Of the BIAs listed in **Table 3-5**, one overlaps the Project Area: the humpback whale migration (north and south) BIA, noting that the humpback whale is no longer a threatened species under the EPBC Act, and as such there are no conservation advice or conservation management plan requirements for the humpback whale migration BIA. This BIA partially overlaps approximately 3% of the Project Area and lies approximately 26 km south of the proposed Dorado Phase 1 WHP location. The portion of the BIA in the Project Area is approximately 0.065% of the total area of the BIA. The migration activities that formed the ecological reason for the designation of this BIA are described above in **Section 3.3.3.1.1**.

Table 3-5: Closest BIAs for marine mammals within the EMBA

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)	Shortest Distance from Project Area Boundary (km)
Balaenoptera musculus	Blue and Pygmy Blue Whale	Possible Foraging Area (CMP)/ Foraging Area (NCVA) “Scott Reef”	567	527
		Possible Foraging Area (CMP)/ Foraging Area (NCVA) “off Ningaloo”	593	569
		Migration	109	84
Dugong dugon	Dugong	Foraging	304	244
		Migration likely	362	301

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)	Shortest Distance from Project Area Boundary (km)
		Foraging (high-density seagrass beds)	523	494
		Breeding	523	494
		Nursing	523	494
		Calving	523	494
		Migration	888	863
Eubalaena australis	Southern Right Whale	Calving buffer	1,454	1,380
		Seasonal calving habitat	1,519	1,395
Megaptera novaeangliae	Humpback Whale	Migration (north and south)	26	Intersects
		Resting	436	380
		Calving	436	380
		Nursing	436	380
Neophoca cinerea	Australian Sea Lion	Foraging (male)	1,143	1,117
		Foraging (male and female)	1,171	1,146
Orcaella heinsohni	Australian Snubfin Dolphin	Breeding	369	308
		Calving	369	308
		Foraging (high-density prey)	369	308
		Foraging likely	441	383
		Resting	676	606
		Foraging	829	772
Physeter macrocephalus	Sperm Whale	Foraging (abundant food source)	1,468	1,445
Sousa chinensis	Indo-Pacific Humpback Dolphin	Calving	369	308
		Foraging (high-density prey)	369	308
		Breeding	369	383
		Foraging	441	308
		Significant Habitat	956	899

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)	Shortest Distance from Project Area Boundary (km)
		Significant Habitat – unknown behaviour	875	817
Tursiops aduncus	Spotted Bottlenose Dolphin	Foraging	369	308
		Breeding	369	308
		Calving	369	308
		Foraging likely	473	415
		Migration likely	473	415

3.3.3.3 Conservation Advice and Recovery Plans

Material published by the Commonwealth under the EPBC Act for the conservation of threatened marine mammals, such as recovery plans, conservation advice, and threat abatement plans, is summarised in **Table 3-6**. Threats identified in this material that may credibly arise from Dorado Phase 1 are also listed, along with cross-references to the relevant assessment of environmental impacts and risks in **Section 7**.

Table 3-6: Summary of material published by the Commonwealth for the conservation of threatened marine mammals relevant to Dorado Phase 1

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
-	All marine mammal species	Threat abatement plan for the impacts of marine debris on vertebrate marine life (Commonwealth of Australia 2018)	Marine debris	**Section 7.3.2**
Balaenoptera borealis	Sei Whale	Conservation advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b)	Noise interference	**Section 7.2.5**
			Vessel disturbance	**Section 7.3.4**
			Climate change	**Section 7.2.6**
			Oil pollution	**Section 7.3.1**
Balaenoptera musculus	Blue Whale	Conservation management plan for the blue whale: A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2015-2025 (Commonwealth of Australia 2015a) Guidance on key terms within the Blue Whale Conservation Management Plan (DAWE, 2021)	Noise interference	**Section 7.2.5**
			Vessel disturbance	**Section 7.3.4**
			Climate change	**Section 7.2.6**
Balaenoptera physalus	Fin Whale	Approved conservation advice for *Balaenoptera physalus* (fin whale) (Threatened Species Scientific Committee 2015c)	Noise interference	**Section 7.2.5**
			Vessel disturbance	**Section 7.3.4**
			Climate change	**Section 7.2.6**
Eubalaena australis	Southern Right Whale	Conservation management plan for the southern right whale: a recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2011-2021 (DSEWPaC 2012c)	Noise interference	**Section 7.2.5**
			Vessel disturbance	**Section 7.3.4**
			Climate change	**Section 7.2.6**
			Marine debris	**Section 7.3.2**
	Australian Sea Lion		Oil pollution	**Section 7.3.1**

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
Neophoca cinerea		Recovery plan for the Australian sea lion (*Neophoca cinerea*) (DSEWPaC 2013a)	Noise interference	**Section 7.2.5**
			Marine debris	**Section 7.3.2**
			Climate change	**Section 7.2.6**
			Disease and parasites from Wastewater	**Section 7.2.3**

3.3.4 Fishes

Historical data for fish diversity has identified 370 species that have the potential to occur within the Project Area (Keesing et al. 2020). The benthic habitat survey undertaken by RPS (2020d) has shown that demersal fish, including commercially important species, were uncommon in the Project Area. This observation is consistent with the relatively flat and featureless benthic habitat within the Project Area. The most common fish observed within the Project Area were small fish (e.g. flatfish, gurnards), which were commonly observed living or burrowing in sediment habitats. Large pelagic fish, including marlin and sharks, were observed at the sea surface (upper 40 m of water column) but not at the seabed (RPS 2020d).

Several fish assemblages occur within the EMBA beyond the Project Area. These include a wide range of demersal and pelagic fish species, many of which are distributed along a latitudinal gradient from tropical waters in the north to temperate waters in the south.

Many species of demersal fish occur within the EMBA beyond the Project Area, including species that support valuable commercial fisheries (**Section 3.4.3**). Areas of complex habitats within the EMBA, such as reefs and shoals, typically exhibit the highest levels of species diversity and abundance. While this may result in species distributions that are constrained within particular habitats, most species are widely distributed (i.e. species ranges of hundreds to thousands of km). The continental slope between North West Cape and the Montebello Trough has more than 500 demersal fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in Australia (Last et al. 2005). Recent surveys of the demersal fish on and off the Ancient Coastline KEF at 125 m water depth have indicated that while some surveyed sections of this KEF had hardbottom substrate and supported enhanced fish diversity, including over half of the total species observed, species richness and abundance overall were not greater on this KEF than on adjacent seabed. Instead, depth, seafloor complexity and habitat type explained patterns in richness and abundance and in structured fish assemblages at both local and broad spatial scales (Currey-Randall et al. 2021).

Like demersal fish, many species of pelagic fish occur within the EMBA beyond the Project Area, including commercially important species, such as mackerel. Relatively large pelagic species, such as billfish, pelagic sharks and tuna, have extensive Indo-Pacific species distributions. Pelagic fishes include species of smaller baitfish, which are an important food source for larger fish species, marine mammals and birds. Pelagic fish within the EMBA are also targeted by commercial and recreational fisheries (**Section 3.4.3**).

3.3.4.1 Threatened and Migratory Fishes

Several species of fish, including cartilaginous fish (e.g. sharks and rays), listed as threatened or migratory under the EPBC Act were identified from PMST reports in **Attachment 1** as potentially occurring within the Project Area and EMBA beyond the Project Area. The full list of fishes including the species that are classified as threatened or migratory are presented in **Table 3-7.**

Santos

Table 3-7: Fish species (including sharks and rays) that may occur within the Project Area and EMBA

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Acentronura australe	Southern Pygmy Pipehorse	Endemic to southern Australia, from Cape Jarvis and the SA Gulfs, and the Perth area, Western Australia. Inhabits shallow algal-covered reefs, sheltering among algae and seagrasses. Individuals may be site attached, remaining in the same area for several years.	-	-	-	Species or species habitat known to occur
Acentronura larsonae	Helen's Pygmy Pipehorse	Endemic to tropical waters of the Montebello Islands, north Western Australia. The species is known only from 2 specimens found clinging to Sargassum sp. attached to isolated coral rock on a sandy coral rubble bottom in a sheltered coral reef in 3 m at Alpha Island, Montebello Islands.	-	-	Species or species habitat known to occur	Species or species habitat may occur within area
Bhanotia fasciolata	Corrugated Pipefish, Barbed Pipefish	Recorded in Australia from Scott Reef, WA. Found elsewhere in the tropical East Indo-West Pacific, from the Andaman Sea to Vanuatu, including Northwestern Australia; inhabits inshore coral reefs, tide-pools and mudflats at 3-25 m.	-	-	-	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Anoxypristis cuspidata	Narrow Sawfish, Knifetooth Sawfish	The narrow sawfish is a marine or marginal (brackish water) species found from inshore waters to a depth of 40 m. Though details of its ecology are not precisely known, it probably spends most of its time on or near the bottom in shallow coastal waters and estuaries. Its Australian distribution is unclear although it is most common in the Gulf of Carpentaria with southward ranges extending to Broad Sound in Queensland and the Pilbara Coast, Western Australia.	-	Migratory	Species or species habitat may occur	Species or species habitat known to occur
Bulbonaricus brauni	Braun's Pughead Pipefish, Pug-headed Pipefish	A small eel-like reddish-brown pipefish with white dots peppering the body and a short white 'pug-faced' snout. Adults lack dorsal and pectoral fins, and have a pointed frontal process overhanging the mouth. Recorded from off North West Cape, Western Australia. Elsewhere the species is known to occur in the tropical East-Indo-west Pacific - Indonesia, Western Australia, Palau and Japan. Inhabits coral reefs at 1-20 m, living in association with dendrophyllid corals, including those of the genus Galaxea.	-	-	Species or species habitat known to occur	Species or species habitat may occur within area

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Campichthys galei	Gale's Pipefish	Gulf St Vincent, South Australia, to Shark Bay, Western Australia. Usually inhabits shallow shelly or rubble substrates, and sparse seagrass beds to about 18 m; occasionally on rocky reefs	-	-	-	Species or species habitat known to occur
Campichthys tricarinatus	Three-keel Pipefish	Endemic to tropical northern Australia from the Montebello Islands, WA to Thursday Island, Torres Strait, Qld; inhabits inshore coral reef and rubble areas at about 2-11 m.	-	-	-	Species or species habitat known to occur
Carcharias taurus (west coast population)	Grey Nurse Shark	The grey nurse shark occurs in tropical and temperate seas of the north and south Atlantic, Indian, and western Pacific oceans (Compagno 2001). In Australia, it is recorded from all States except Tasmania; it is rare in the Northern Territory (Last and Stevens 1994). The current distribution is now mainly confined to coastal waters of southern Queensland, the entire New South Wales coast and southwestern waters of Western Australia (Bruce et al. 2005). The species has been recorded at	Vulnerable	-	-	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		varying depths but is generally found between 15 and 40 m.				
Carcharodon carachariasi	Great White Shark	The great white shark is a wide-ranging but mostly temperate and coastal species; it has a global distribution and at times occurs in oceanic environments, in the tropics, and down to depths of at least 1,200 m (Bruce et al. 2005). It is most common over the continental shelf (often close inshore) of southern Australia, South Africa, northern California and the northeast United States (Compagno 2001). There are no known aggregation sites for great white sharks in the North-west Marine Region, but the species has been recorded in NWS waters during humpback migrations.	Vulnerable	Migratory	Species or species habitat may occur	Foraging, feeding or related behaviour known to occur
Carcharhinus longimanus	Oceanic Whitetip Shark	As the common name suggests, the oceanic whitetip shark is primarily an epipelagic, oceanic species of shark found in temperate and tropical waters more than 18° S. The shark is typically distributed between the sea surface and 150 m water depth. While primarily	-	Migratory	Species or species habitat may occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		oceanic, the species is known to occur in continental shelf waters (Bonfil et al. 2008). The fins of the oceanic whitetip shark are highly valued for shark fin soup, leading to concerns that the species is overfished.				
Centrophorus zeehaani	Southern Dogfish, Endeavour Dogfish, Little Gulper Shark	A small uniformly light greyish-brown deepwater shark (200-700 m), which may be darker above and paler on the belly. Juveniles have dark posterior margins on the dorsal fins and the tail, which fade in intensity in adults. Southern Dogfish have greenish eyes, and a relatively short and bulky snout compared with other gulper shark species.	Conservation Dependent	-	-	Species or species habitat likely to occur
Choeroichthys brachysoma	Pacific Short-bodied Pipefish, Short-bodied Pipefish	Exmouth Gulf and offshore reefs of north Western Australia, and Ashmore Reef in the Timor Sea, to Moreton Bay, Queensland; also Christmas Island in the eastern Indian Ocean. Elsewhere the species is widespread in the tropical, Indo-west-central Pacific: Red Sea and East Africa to the Marshall and Society Islands, north to the Philippines and Japan and south to Australia.	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Inhabits tide pools, seagrass areas, coral reef lagoons and seaward reefs, in depths to 27 m.				
Choeroichthys latispinosus	Muiron Island Pipefish	Endemic to Western Australia, from Port Denison to Brecknock Island in the east Kimberley; inhabits coral reef rubble slopes in 1-10m	-	-	-	Species or species habitat may occur
Choeroichthys sculptus	Sculptured Pipefish	Widespread in the tropical Indo-West Pacific from East Africa to the Tuamotos and Line islands, north to southern Japan and south to Australia. The Sculptured Pipefish is known in Australia from off northwestern Australia and the Great Barrier Reef, Queensland. The species inhabits coral reef flats, lagoons, seagrass beds and seaward reefs in 2-6m.	-	-	-	Species or species habitat may occur
Choeroichthys suillus	Pig-snouted Pipefish	Tropical, subtropical, known from northern Australia and Papua New Guinea; from Jurien Bay (WA) to Moreton Bay (Qld); in rubble habitats of inshore coral reefs to 15 m.	-	-	-	Species or species habitat may occur
Corythoichthys amplexus	Fijian Banded Pipefish, Brown-banded Pipefish	Known from the Dampier Archipelago and Scott Reef, Western Australia, and the northern Great Barrier Reef and	-	-	-	Species or species

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Ashmore Reef, Coral Sea, to Lady Musgrave Island, Queensland. Elsewhere, the species is widespread in the tropical Indo-west Pacific, from the Gulf of Oman and East Africa to Samoa, the Philippines, north to southern Japan. Inhabits coral reef lagoons and seaward reef areas, usually in caves and crevices in 3-30 m.				habitat may occur
Corythoichthys flavofasciatus	Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish	Offshore reefs of Western Australia - Rowley Shoals and Scott Reef, and the Great Barrier Reef, Queensland. Elsewhere the species is widespread in the tropical Indo-west-central Pacific, from the Red Sea to French Polynesia. Inhabits seagrass beds or sandy and rubble areas on sheltered reefs at depths of 1-25 m; often seen in pairs or small groups	-	-	-	Species or species habitat may occur
Corythoichthys haematopterus	Reef-top Pipefish	Tropical Indo-west Pacific, from East Africa to Vanuatu and Fiji, southern Japan and northern Australia; inhabits protected rubble and sandy areas in shallow reef lagoons, reef flats and fore-	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		reef slopes at 1-21 m, mostly above 5 metres.				
Corythoichthys intestinalis	Australian Messmate Pipefish, Banded Pipefish	Tropical Western Central Pacific, known from Indonesia, northern Australia, the Philippines to Samoa, and Micronesia; inhabits sheltered sponge and coral reefs in shallow lagoons and harbours at 3-12 m.	-	-	-	Species or species habitat may occur
Corythoichthys schultzi	Schultz's Pipefish	Widespread in the tropical Indo-Pacific from the Red Sea and East Africa to Tonga, north to southern Japan and south to the offshore islands of north Western Australia and throughout the Great Barrier Reef, Queensland; also Christmas Island in the eastern Indian Ocean. Schultz's Pipefish usually inhabits coarse sand and rubble areas along reef edges in lagoons and on seaward reefs at 1-30m.	-	-	-	Species or species habitat may occur
Cosmocampus banneri	Roughridge Pipefish	Clerke Reef, Rowley Shoals, Western Australia, Ashmore Reef, Timor Sea; also Cocos (Keeling) Islands and Christmas Island in the eastern Indian Ocean. Elsewhere the species is widespread in	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		the tropical, Indo-west-central Pacific from the Red Sea and East Africa to Fiji and the Marshall Islands, north to southern Japan. Rough-ridge Pipefish usually live amongst rubble or in crevices mostly on outer reefs, at 2-30 m				
Cosmocampus maxweberi	Maxweber's Pipefish	Tropical Indo-west-central Pacific, Red Sea, Indonesia, Great Barrier Reef, to Micronesia, Tonga and Samoa; inhabits inshore reefs among rubble to 35 m, although more common on shallow reefs to 4 m.	-	-	-	Species or species habitat may occur
Doryrhamphus baldwini	Redstripe Pipefish	Dunckerocampus baldwini is found in caves, rocky crevices, and the seaward slopes of coral reefs and it is an active cleaner which has been recorded cleaning small parasitic crustaceans on cave cardinal fish (Zapogon evermanni) and a moray eel (Gymnothorax sp.).	-	-	-	Species or species habitat may occur
Doryrhamphus dactyliophorus	Banded Pipefish, Ringed Pipefish	Tropical Western Pacific, from Indonesia, the Ryukyu Islands, Japan, to Australia, the Coral Sea, and east to Marshall and Society Islands, Tonga and Samoa; in Australian waters, known from Clerke	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Reef, WA, the Northenr Territory and the Great Barrier Reef, Queensland; inhabits protected reefs and lagoons, usually in caves and crevices to 10 m.				
Doryrhamphus excisus	Bluestripe Pipefish	Widespread throughout the tropical Indo-Pacific region, from the Persian Gulf and east Africa to the west coast of the Americas in the Eastern Pacific. Recorded in Australian waters from north of Clerke Reef (Western Australia) and the entire length of the Great Barrier Reef (Queensland).	-	-	-	Species or species habitat may occur
Doryrhamphus janssi	Cleaner Pipefish, Janss' Pipefish	Tropical East Indo-west Pacific from the Andaman Sea and Gulf of Thailand, to the Solomon Islands, Micronesia, the Philippines and northern Australia. Inhabits sheltered inshore coral reefs where pairs usually maintain cleaning stations in caves and crevices with sponges, and below large plate corals.	-	-	-	Species or species habitat may occur
Doryrhamphus multiannulatus	Many-banded Pipefish	Common among coral and in reef caves and crevices; usually found in pairs. Occurs at depths of at least 45 m	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Doryrhamphus negrosensis	Flagtail Pipefish, Masthead Island Pipefish	Tropical Western Pacific, Borneo to Micronesia, Vanuatu, northern Australia; inhabits sheltered inner reef flats, muddy areas and lagoons, usually within rubble habitats or associated with sea urchins to 10 m.	-	-	-	Species or species habitat may occur
Festucalex scalaris	Ladder Pipefish	Endemic to subtropical waters of Western Australia; inhabits intertidal algae or sargassum beds to 20 m.	-	-	-	Species or species habitat may occur
Filicampus tigris	Tiger Pipefish	Relatively common in subtropical waters of Australia's east and west coasts. A relic population also occurs in the warmer waters of Spencer Gulf, South Australia. Inhabits shallow seagrass beds and sponge, mud, sand, rock, and rubble areas in depths of 2-30 m.	-	-	-	Species or species habitat may occur
Galeorhinus galeus	School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark	The School Shark occurs throughout the temperate coastal waters of southern Australia. They are found from Moreton Bay, in southern Queensland, to Perth, Western Australia. This species is mainly found in demersal waters, over the continental and insular shelves, but also	Conservation Dependent	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		over the upper slopes, in depths from near shore to 550 m.				
Halicampus brocki	Brock's Pipefish	Recorded in Australia from scattered locations in north Western Australia, the Northern Territory and Queensland. Found elsewhere in the tropical Western Pacific – from the Philippines and north to the Ryuk–u Islands, japan, south to northern Australia, the Coral Sea, eastwards to Micronesia. Usually inhabits patches of coral and macro-algae on coastal reefs at 3-45 m.	-	-	-	Species or species habitat may occur
Halicampus dunckeri	Red-hair Pipefish	Exmouth, and offshore reefs of northern Western Australia, Ashmore Reef, Timor Sea, to the northern Great Barrier Reef, Queensland, and possibly to the Capricorn-Bunker Group, Queensland. Elsewhere, the species is widespread in the tropical, Indo-west-central Pacific A reef associated species usually found on sandy and algal-rubble habitats.	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Halicampus grayi	Mud Pipefish, Gray's Pipefish	Widespread in the tropical Indo-west Pacific, from the Gulf of Aden across the Indian Ocean to northern Australia, north to Japan; inhabits silty and muddy soft bottoms on the continental shelf from inshore bays to deep offshore areas to 100 m.	-	-	-	Species or species habitat may occur
Halicampus macrorhynchus	Whiskered Pipefish, Ornate Pipefish	Rowley Shoals, Western Australia, and off Lizard Island, Great Barrier Reef, Queensland. Elsewhere, the species is widespread in the tropical Indo-west Pacific. Whiskered Pipefish live on sandy, rubble and weedy areas in lagoons and coastal reefs in 3-40 m. One specimen was reportedly trawled in 180-300 m.	-	-	-	Species or species habitat may occur
Halicampus mataafae	Samoan Pipefish	Northern Great Barrier Reef and reefs in the Coral Sea. Elsewhere the species is widespread in the tropical Indo-west Pacific, from the Red Sea and East Africa, across the Indian Ocean to Tonga and Samoa, north to Taiwan, south to northern Australia.	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Found in crevices, under rocks and rubble on shallow coastal, lagoon and outer reefs in depths to 15 m.				
Halicampus nitidus	Glittering Pipefish	Tropical Western Pacific, Vietnam to Fiji, north to the Ryukyu Islands, south to Rowley Shoals and New Caledonia, eastwards to Micronesia. Glittering Pipefish live in crevices and under rocks and rubble on coastal, lagoon and outer coral reef areas to 20 m.	-	-	-	Species or species habitat may occur
Halicampus spinirostris	Spiny-snout Pipefish	Known from the tropical Indo-west Pacific – Indonesia, northern Australia, the South China Sea, Vietnam across to American Samoa; inhabits shallow coral rubble areas in lagoons and intertidal zones of inshore coral reefs in 5-10 m.	-	-	-	Species or species habitat may occur
Haliichthys taeniophorus	Ribboned Pipehorse, Ribboned Seadragon	Shark Bay, Western Australia, to Cape York, Queensland. Elsewhere the species occurs in West Papua, Indonesia, and Papua New Guinea. Inhabits a variety of inshore shallow water areas including weedy regions bordering open substrates, coral reefs, rocky, gravel, sandy and muddy substrates; also	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		associated with sponges, macroalgae, hydroids, shells and seagrasses usually from 1-18 m.				
Heraldia nocturna	Upside-down Pipefish	Endemic to temperate waters of southern and southeastern Australia, from about Seal Rocks, New South Wales, around the southern half of Australia to Geographe Bay, Western Australia, and to Port Davey on the west coast of Tasmania. Upside-down Pipefish inhabit sheltered inshore reefs in harbours, bays and coves where they are usually seen beneath ledges, in holes, crevices and small caves at depths of 2-30 m.	-	-	-	Species or species habitat may occur
Hippichthys cyanospilos	Blue-speckled Pipefish	Widespread in the tropical Indo-West Pacific; Red Sea and east African coast to Fiji, Philippines and Australia; inhabiting brackish shallow-water environments in estuaries and lower reaches of coastal rivers and streams, often amongst mangroves to 4 m.	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Hippichthys heptagonus	Madura Pipefish	Widespread in the tropical Indo-West Pacific, from East Africa to Melanesia and north to Japan; inhabits inshore mangrove estuaries, tidal creeks and the lower reaches of freshwater streams.	-	-	-	Species or species habitat may occur
Hippichthys penicillus	Beady Pipefish	Carnarvon, Western Australia, to Woy Woy, New South Wales. Elsewhere the species occurs in the tropical, Indo-west Pacific, from western Persian Gulf (Kuwait, Saudi Arabia), north central Indian Ocean, and eastward to Japan and Australia.	-	-	-	Species or species habitat may occur
Hippichthys spicifer	Belly-barred Pipefish	In Australia, the species is known from Cape York, Queensland. Elsewhere the species is widespread in the Indo-west Pacific from east Africa and the Red Sea, eastwards to Kiribati and American Samoa.	-	-	-	Species or species habitat may occur
Hippocampus angustus	Western Spiny Seahorse	Endemic to tropical waters of Western Australia, from Shark Bay, north to the Dampier Archipelago. Inhabits sheltered algal-covered reefs and seagrass beds to about 10 m, although the species has been recorded from depths to 30 m	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Hippocampus breviceps	Short-head Seahorse	Endemic to temperate southern Australian waters from Port Welshpool, Victoria, eastern Tasmania, and west to at least Venus Bay, South Australia. The species may also occur in the eastern part of the Great Australian Bight, South Australia.	-	-	-	Species or species habitat may occur
Hippocampus histrix	Spiny Seahorse, Thorny Seahorse	Recorded in Australia from south of Ashmore Reef, Timor Sea, the Great Barrier Reef, Queensland, and in Port Stephens, New South Wales. Elsewhere the species occurs in the tropical and subtropical Western Pacific, from Bali, Indonesia, Papua New Guinea, New Caledonia and Japan. Inhabits areas with both hard and soft bottoms, often attached to soft corals or sponges at 10-95 m, usually below 15 m. The Thorny Seahorse may also be found on shallower algae-rubble or rocky reef areas in about 10 m.	-	-	-	Species or species habitat may occur
Hippocampus kuda	Spotted Seahorse, Yellow Seahorse	Hippocampus kuda is strictly a marine species, widely distributed throughout the Indo-Pacific region, from the Indian	-	-	-	Species or species

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Ocean to the northwestern, western central, and eastern central areas of the Pacific Ocean ("Project Seahorse", 2003; Foster et al., 2003). Approximately 23 countries have confirmed the native presence of H. kuda, ranging from Australia to China (Lourie et al., 2004).				habitat may occur
Hippocampus planifrons	Flat-face Seahorse	Endemic to Western Australia, from Dirk Hartog Island to Broome. Inhabits tidepools, macroalgal and rubble reefs in shallow bays from the intertidal to a depth of about 20 m.	-	-	-	Species or species habitat may occur
Hippocampus spinosissimus	Hedgehog Seahorse	Endemic to tropical waters of north-eastern Australia, from Princess Charlotte Bay to Southport, Queensland; benthic in inner reef waters on rubble substrates and in sponge and seagrass habitats near coral reefs at 20-63 m; often attached to corals in deep current-prone channels between reefs or islands.	-	-	-	Species or species habitat may occur
Hippocampus subelongatus	West Australian Seahorse	Endemic to subtropical and temperate waters of Western Australia, from about Cape Leeuwin to Shark Bay. Often found amongst macroalgae, sponges and sea	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		squirts in muddy and silty habitats in sheltered bays, and on jetty pylons and moorings at 1-25 m.				
Hippocampus trimaculatus	Three-spot Seahorse	he flat-faced seahorse, longnose seahorse, low-crowned seahorse or three-spot seahorse is a species of fish in the family Syngnathidae. It is found in Australia, Cocos Islands, French Polynesia, Hong Kong, India, Indonesia, Japan, the Philippines, Singapore, Taiwan, Thailand, and Vietnam.	-	-	-	Species or species habitat may occur
Histiogamphelus cristatus	Rhino Pipefish	Endemic to southern Australia, from Off Victor Harbour, South Australia, to Green Head, Jurien Bay, Western Australia. Inhabits seagrass beds and adjacent open sandy and rubble areas with patches of seagrass and detritus in estuaries and shallow protected waters, at depths of 1-17 m.	-	-	-	Species or species habitat may occur
Hoplostethus atlanticus	Orange Roughy, Deep-sea Perch, Red Roughy	The Orange Roughy is a deep-bodied bright red demersal fish with large, rough scales. Found in deep offshore waters (100-300 m).	Conservation Dependent	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Leptoichthys fistularius	Brushtail Pipefish	Endemic to temperate waters of southern Australia, from northern Tasmania and Corner Inlet, Victoria, to Albany, Western Australia. Inhabits inshore sheltered seagrass beds, mainly Zostera, but also Posidonia beds.	-	-	-	Species or species habitat may occur
Lissocampus caudalis	Australian Smooth Pipefish	Endemic to southern Australia, from Corner Inlet, Victoria, northern Tasmania and the Bass Strait Islands, across southern Australia, to Cervantes, north of Perth, Western Australia.	-	-	-	Species or species habitat may occur
Lissocampus fatiloquus	Prophet's Pipefish	Endemic to western and northern Australia, from about Rockingham in the south, to the southern Bonaparte Archipelago in the Kimberley, Western Australia, and Sweers Island, Gulf of Carpentaria, Queensland.	-	-	-	Species or species habitat may occur
Lissocampus runa	Javelin Pipefish	Endemic to temperate waters of southern and eastern Australia; known from northern New South Wales, south to Port Arthur, Tasmania, and west to about Perth, Western Australia. Inhabits bay and estuaries, including tidepools, often sheltering amongst seagrass	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		(usually Zostera spp.), in algal beds, and on rubble areas near reefs, at depths to about 20 m.				
Maroubra perserrata	Sawtooth Pipefish	Endemic to temperate southern Australian waters from southern Queensland to Rottnest Island, Western Australia. Inhabits coastal reefs at depths of 3-25 m, sheltering beneath ledges and in caves during day.	-	-	-	Species or species habitat may occur
Micrognathus brevirostris	thorntail Pipefish	In Australian waters, known from Cocos (Keeling) and Christmas islands, the Timor Sea, North West Cape, WA, and from the Great Barrier Reef, Cape York to Southport, Queensland. Elsewhere in the tropical western Pacific, from eastern Indonesia, Australia, Papua New Guinea, New Caledonia, Marshall Island, Bikini Atoll and the Ryukyu Islands, Japan.	-	-	-	Species or species habitat may occur
Micrognathus micronotopterus	Tidepool Pipefish	Tropical East-Indo-west Pacific, known from Singapore, Indonesia, northern Australia and the Philippines; recorded in Australian waters from Exmouth Gulf, WA, to the Gulf of Carpentaria near	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Yirrkala, Northern Territory. Usually inhabits shallow inshore reefs and tidepools, amongst sparse seagrasses and algae-rubble, in depths from 1-5m, although individuals have been collected from depths to 10m.				
Mitotichthys meraculus	Western Crested Pipefish	Endemic to temperate waters of southwestern Australia; only known from two specimens collected at Flinders Bay, Augusta and Perth, Western Australia; reportedly inhabits sheltered seagrass beds (Posidonia coriaceal) in 2m.	-	-	-	Species or species habitat may occur
Nannocampus subosseus	Bonyhead Pipefish	Endemic to Western Australia, from Point Dempster, Esperance, at the western edge of the Great Australian Bight, to Shark Bay. Occurs on shallow coastal and offshore coral and rocky reefs, in a range of habitats including rockpools, ledges, seagrass beds, coral, macroalgae and sandy areas at depths to 14 m.	-	-	-	Species or species habitat may occur
Notiocampus ruber	Red Pipefish	Endemic to southern Australia from Copacabana, New South Wales, to the Recherche Archipelago, Western Australia, including Tasmania. Usually	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		inhabits rocky reefs, often in crevices, in association with sponges and encrusting and filamentous red algae at depths to 20 m.				
Phoxocampus belcheri	Black Rock Pipefish	Widespread in the tropical Indo-West Pacific from the Red Sea and east and South Africa, Madagascar and the Seychelles, eastwards to Fiji and Tonga, north to China, Taiwan, southern Japan, south to Western Australia and New Caledonia; known in Australian waters from the Monte Bello Islands, Western Australia. Inhabits tidepools and shallow intertidal reefs, usually among coral rubble.	-	-	-	Species or species habitat may occur
Phycodurus eques	Leafy Seadragon	Endemic to temperate waters of southern Australia, from about Victor Harbor, South Australia, westwards Yanchep Beach, Western Australia, including Kangaroo Island, South Australia. Victorian records have not been verified. Leafy Seadragons usually inhabit sheltered bays where they are found in seagrass beds especially (Posidonia), and	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		around rocky reefs amongst kelp (Ecklonia) and other macroalgae, at depths of 4-50 metres.				
Phyllopteryx taeniolatus	Common Seadragon	Endemic to temperate coastal waters of southern Australia, from about Newcastle (New South Wales) south to Actaeon Island (Tasmania) and across southern Australia to about Geraldton (Western Australia). Common seadragons inhabit shallow estuaries to deeper offshore reefs, living seagrass beds and on rocky reefs covered in macroalgae, especially kelp beds, in depths of 1-50 m. Individuals usually remain within a broad home range.	-	-	-	Species or species habitat may occur
Pugnaso curtirostris	Pugnose Pipefish	Endemic to southern Australia, from Corner Inlet, Wilsons Promontory (Victoria), northern Tasmania and the Bass Strait islands, to Jurien Bay and the Houtman Abrolhos Islands (Western Australia). Uncommon in Gulf St Vincent and Spencer Gulf, South Australia; inhabits shallow seagrass, eelgrass and algal habitats in sheltered bays and	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		estuaries to about 11m. Juveniles often found amongst decaying seagrass leaves.				
Seriolella brama	Blue Warehou	A steely-blue to greenish-blue medusa-fish becoming slightly paler below, with a large black blotch above the pectoral-fin base, and a silvery-pinkish hue on the gill cover and lower jaw. Found in sahllow to deep offshore waters (3-550 m).	Conservation Dependent	-	-	Species or species habitat may occur
Solegnathus hardwickii	Pallid Pipehorse	Northeast of the Monte Bello Islands, Western Australia to north of Cartier Island, Timor Sea, to the Arafura Sea north of Maningrida, Northern Territory. Inhabits areas with hard substrates, in association with gorgonian corals, black corals, algae and sponges.	-	-	-	Species or species habitat may occur
Solegnathus lettiensis	Gunther's Pipehorse	Recorded in Australia from Rottnest Is, WA (32º00´E) to N of Bathurst Is, NT (130º09'S). Found elsewhere in the Indo-west Pacific.	-	-	-	Species or species habitat may occur
Solenostomus cyanopterus	Robust Ghostpipefish	Shark Bay region to NE of the Monte Bello Islands, Western Australia, and the northern Great Barrier Reef, Queensland, to Shellharbour, New South Wales; also Christmas Island in the eastern Indian	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Ocean. Elsewhere the species is widespread in the tropical Indo-west Pacific, from East Africa and the Red Sea, eastwards to Fiji and southern Japan, and south to Australia.				
Sphyrna lewini	Scalloped Hammerhead	The scalloped hammerhead is a coastal pelagic species; it occurs over continental and insular shelves and in nearby deeper water. It is found in warm temperate and tropical waters, worldwide from 46°N to 36°S. It can be found down to depths over 500 m (1,600 ft), but is most often found above 25 m (82 ft).	Conservation Dependent	-	Species or species habitat may occur	Species or species habitat may occur
Stigmatopora argus	Spotted Pipefish,	Seal Rocks, New South Wales, southwards to Dongara, Western Australia, including around Tasmania. Elsewhere the species occurs in New Zealand. Commonly inhabits seagrass beds in inshore bays and estuaries to depths of at least 8 m. Individuals are occasionally found among floating Sargassum sp.	-	-	-	Species or species habitat may occur
Stigmatopora nigra	Widebody Pipefish	Mooloolaba, Queensland, to Shark Bay, Western Australia, including around	-	-	-	Species or species

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Tasmania. Elsewhere the species occurs in New Zealand. Commonly inhabits sheltered seagrass and algal beds from the intertidal to depths of 35 m.				habitat may occur
Syngnathoides biaculeatus	Double-end Pipehorse	In Australian waters, known from Geraldton to Shark Bay, and north to Ashmore and Cartier Reefs, Western Australia, and from the Timor Sea, the Northern Territory, eastwards to Queensland and south to Batemans Bay (New South Wales). Elsewhere, widespread in the tropical Indo-West-Central Pacific from the Red Sea and East Africa, across the Indian Ocean to Samoa and Tonga.	-	-	-	Species or species habitat may occur
Thunnus maccoyii	Southern Bluefin Tuna	Southern Bluefin Tuna in Australian waters, ranges widely from northern Western Australia (WA) to the southern region of the continent. Southern bluefin tuna are highly migratory, occurring globally in waters between 30–50° S, though the species is mainly found in the eastern Indian Ocean and in the south-west Pacific Ocean.	Conservation Dependent	-	Species or species habitat may occur	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Trachyrhamphus bicoarctatus	Bentstick Pipefish	Widespread in the tropical Indo-west Pacific. Bentstick Pipefish are known in Australian waters from the central coast of Western Australia, northwards throughout the waters of the Northern Territory and Queensland to central New South Wales. They live in sheltered coastal lagoon and reef areas on sandy and rubble habitats amongst seagrasses and macroalgae at 1– 30 m.	-	-	-	Species or species habitat may occur
Trachyrhamphus longirostris	Straightstick Pipefish	Tropical Indo-west Pacific, known from the Red Sea and East Africa, eastwards to the Western Pacific (including Indonesia, the Philippines, Australia, Papua New Guinea, the South China Sea, Japan). Recorded in Australian waters from North West Cape, Western Australia, northwards around the tropical north to about Magnetic Island, Queensland. Most specimens have been trawled or dredged from muddy to sandy-bottom habitats in depths of 16-91m, in association with sand, rubble, seagrasses, algae, sponges, sea pens and hydroids.	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Urocampus carinirostris	Hairy Pipefish	Flynn Reef, Queensland, to the lower Swan River, Perth, Western Australia, including northern Tasmania. Elsewhere the species occurs in Papua New Guinea. The species is uncommon in South Australia.	-	-	-	Species or species habitat may occur
Vanacampus margaritifer	Mother-of-pearl Pipefish	Endemic to sub-tropical and temperate Australia, from North Stradbroke Island, QLD, southwards to Jurien Bay, WA, absent from Tasmania. Inhabits shallow estuarine and coastal waters where it occurs in seagrass beds (including Heterozostera, Zostera, Posidonia and Halophila), macroalgae (Ecklonia and other brown algae), rocky reef, boulder, rubble, sandy and muddy habitats between 2–15 m.	-	-	-	Species or species habitat may occur
Vanacampus phillipi	Port Phillip Pipefish	Jervis Bay, New South Wales, around southern Australia, to Ceduna, South Australia, including northern and eastern Tasmania (the species may occur further west to Cottesloe, Perth, Western Australia). Commonly inhabits seagrass beds (including Halophila, Heterozostera, Posidonia, Ruppia and Zostera) and	-	-	-	Species or species habitat may occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		macroalgae in shallow estuaries, coastal lagoons, and protected bays at depths to 25 m.				
Vanacampus poecilolaemus	Longsnout Pipefish	Endemic to temperate waters of southern Australia, from east of Flinders Island, Bass Strait, Tasmania, and Wilsons Promontory, Victoria in the east, to Cottesloe, Western Australia. Inhabits shallow seagrass and macroalgal beds in estuaries and other quiet, silty, clear-water areas to about 18 m.	-	-	-	Species or species habitat may occur
Glyphis garricki	Northern River Shark, New Guinea River Shark	The northern river shark is one of the rarest species of shark in the world. Adults have only been recorded in coastal waters, whereas neonates, juveniles and subadults have been recorded in freshwater, estuarine and marine environments. The distribution of the species is associated with tidal rivers and estuaries in northern Australia and Papua New Guinea; most records in Western Australia are from King Sound in the Kimberley (Morgan et al. 2010).	Endangered	-	-	Breeding likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Isurus oxyrinchus	Shortfin Mako	The shortfin mako is an oceanic pelagic species, although it has occasionally been recorded in coastal waters. Its distribution is throughout temperate seas, but it is rarely found in waters colder than 16°C. Tagging data has indicated a preference for the upper part of the water column, with occasional dives up to 880 m (Abascal et al. 2011; Stevens et al. 2010)	-	Migratory	Species or species habitat likely to occur	Species or species habitat likely to occur
Isurus paucus	Longfin Mako	The longfin mako is a widely distributed but rarely encountered oceanic shark that ranges from Geraldton around the north coast to at least Port Stephens in New South Wales. Like the shortfin mako, the species occurs in oceanic pelagic habitats. Little information is available regarding the population size and distribution of the longfin mako.	-	Migratory	Species or species habitat likely to occur	Species or species habitat likely to occur
Lamna nasus	Porbeagle, Mackerel Shark	The porbeagle is wide-ranging, typically occurring in oceanic waters off the continental shelf, although it occasionally enters coastal waters. The porbeagle is known to undertake seasonal migrations, although the timing and details of these	-	Migratory	-	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		migratory movements are not well understood (Saunders et al. 2011).				
Manta alfredi	Reef Manta Ray	The taxonomy of the reef manta ray was revised relatively recently (Marshall et al. 2009). The species is commonly sighted inshore but is also found around offshore coral reefs, rocky reefs and seamounts (Marshall et al. 2009). In contrast to the giant manta ray, long-term sighting records of the reef manta ray at established aggregation sites suggest that this species is more resident in tropical waters and may exhibit smaller home ranges, philopatric movement patterns, and shorter seasonal migrations than the giant manta ray (Deakos et al. 2011; Marshall et al. 2009).	-	Migratory	Species or species habitat likely to occur	Species or species habitat known to occur
Manta birostris	Giant Manta Ray	The giant manta ray is broadly distributed in tropical waters of Australia. The species primarily inhabits nearshore environments along productive coastlines with regular upwelling, but it appears to be a seasonal visitor to coastal or offshore sites, including offshore island groups, offshore pinnacles and	-	Migratory	Species or species habitat likely to occur	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		seamounts (Marshall et al. 2009). The Ningaloo Coast is an important area for giant manta rays in autumn and winter (Preen et al. 1997).				
Pristis clavata	Dwarf Sawfish, Queensland Sawfish	The dwarf sawfish is found in Australian coastal waters extending north from Cairns around the Cape York Peninsula in Queensland to the Pilbara coast (Kyne et al. 2013). Dwarf sawfish typically inhabit shallow (2- to 3-m) silty coastal waters and estuarine habitats, occupying relatively restricted areas and moving only small distances (Stevens et al. 2008). Juvenile dwarf sawfish utilise estuarine habitats in northwestern Western Australia as nursery areas and migrate to deeper waters as adults (Thorburn et al. 2008). The majority of capture locations for the species in Western Australian waters have occurred within King Sound and the lower reaches of the major rivers that enter the sound, including the Fitzroy, Mary and Robinson rivers (Morgan et al. 2010).	Vulnerable	Migratory	Species or species habitat known to occur	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Pristis pristis	Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish	The freshwater sawfish inhabits both riverine and marine environments in northern Australia. While primarily associated with rivers, tidal creeks and estuaries, the largetooth sawfish has been recorded up to 100 km offshore (Commonwealth of Australia 2015b). Riverine habitats are particularly important as pupping habitats. In Western Australia, the species is known from riverine and coastal environments in the Kimberley region.	Vulnerable	Migratory	Species or species habitat known to occur	Species or species habitat known to occur
Pristis zijsron	Green Sawfish, Dindagubba, Narrowsnout Sawfish	The green sawfish was once widely distributed in coastal waters along the northern Indian Ocean, although it is believed that northern Australia may be the last region where significant populations exist (Stevens et al. 2005). Within Australia, green sawfish are currently distributed from about the Whitsundays in Queensland across northern Australian waters to Shark Bay in Western Australia (Commonwealth of Australia 2015b). Despite records of the species in deeper offshore waters, green	Vulnerable	Migratory	Species or species habitat known to occur	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		sawfish typically occur in the inshore fringe with a strong association with mangroves and adjacent mudflat habitats (Stevens et al. 2005). Movements within these preferred habitats are correlated with tidal movements (Stevens et al. 2008).				
Rhinocodon typus	Whale Shark	The whale shark is a large pelagic shark that has a global tropical distribution. Whale sharks aggregate annually to feed in the waters of the Ningaloo Coast from March to July with the largest numbers recorded in April and May (Sleeman et al. 2010). The aggregation has been estimated to range between 300 and 500 individuals (Meekan et al. 2006). Timing of the whale shark migration to and from Ningaloo coincides with the coral mass spawning period when there is an abundance of food in the waters adjacent to Ningaloo Reef. After the aggregation period, the distribution of the whale shark is largely unknown. Tagging, aerial and vessel surveys suggest that the group disperses	Vulnerable	Migratory	Foraging, feeding or related behaviour known to occur	Foraging, feeding or related behaviour known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		widely, up to 1,800 km away. Satellite tracking has shown that the sharks may follow three migration routes from Ningaloo (Meekan and Radford 2010; Wilson et al. 2006): + northwest, into the Indian Ocean, + directly north, towards Sumatra and Java, and + northeast, passing through the NWS Province travelling along the shelf break and continental slope.				

3.3.4.2 Biologically Important Areas and Critical Habitat

BIAs are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour, such as breeding, foraging, resting or migration. BIAs for fishes that overlap the Project Area and the EMBA beyond the Project Area are summarised in **Table 3-8.** No critical habitats for fishes were identified within the EMBA.

The Project Area (including the Dorado Phase 1 WHP and FPSO locations) overlaps a foraging BIA for whale sharks shown in the National Conservation Values Atlas (DAWE 2020). Whale sharks are known to congregate around geomorphic features to feed, such as reefs and islands, with steeply sloping seabeds in close proximity to relatively deep water (Copping et al. 2018). These congregations are particularly notable during periods of high food availability, such as coral spawning off Ningaloo Reef and land crab spawning off Christmas Island (Meekan et al. 2009; Taylor and Pearce 1999). The Project Area does not exhibit the geomorphic or biological features associated with whale shark aggregations (**Section 3.3.1.1**), and tagging studies of whale sharks congregating off Ningaloo Reef do not show whale sharks congregating near or migrating through the Project Area (Meekan and Radford 2010; Wilson et al. 2006). Based on the foraging habitat preferences of whale sharks and the results of tagging studies, the foraging BIA is unlikely to represent critical foraging habitat. The BIA may be used by migrating whale sharks moving to and from Ningaloo Reef; however, tagging studies indicate most tagged whale sharks do not use the majority of the BIA when moving away from Ningaloo Reef (**Figure 3-17**).

Table 3-8: Closest BIAs for fishes (including sharks and rays) within the EMBA

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
Rhincodon typus	Whale Shark	Foraging (high-density prey)	0 (overlaps WHP)
Pristis zijsron	Green Sawfish	Nursing	134
		Foraging	134
		Pupping	134
Pristis pristis	Freshwater Sawfish	Pupping	140
		Foraging	140
		Juvenile	372
		Nursing	521
Pristis clavata	Dwarf Sawfish	Foraging	140
		Juvenile	522
		Nursing	140
		Pupping	140
Carcharodon carcharias	White Shark	Foraging	1149

3.3.4.3 Conservation Advice and Recovery Plans

Material published by the Commonwealth under the EPBC Act for the conservation of threatened fishes, such as recovery plans, conservation advice, and threat abatement plans, is summarised in **Table 3-9**. Threats identified in this material that may credibly arise from Dorado Phase 1 are also listed, along with cross-references to the relevant assessment of environmental impacts and risks in **Section 7**.

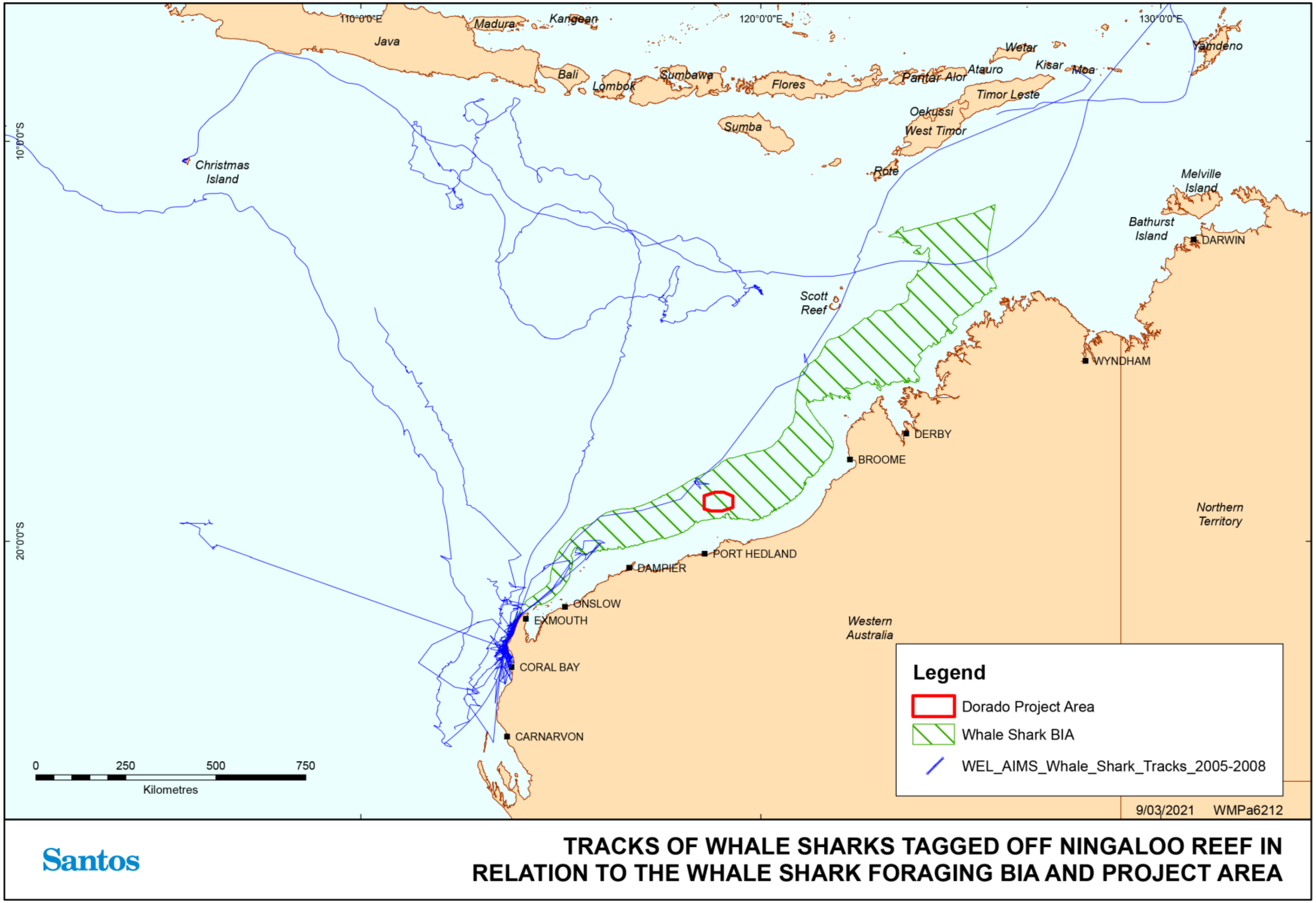

Figure 3-17: Tracks of whale sharks tagged off Ningaloo Reef in relation to the whale shark foraging BIA and Project Area

Table 3-9 Summary of material published by the Commonwealth for the conservation of threatened fishes relevant to Dorado Phase 1

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
-	All shark species	Threat abatement plan for the impacts of marine debris on vertebrate marine life (Commonwealth of Australia 2018)	Marine debris	**Section 7.3.2**
Carcharias taurus (west coast population)	Grey Nurse Shark	Recovery plan for the grey nurse shark (*Carcharias taurus*) (Department of the Environment 2014)	Marine debris	**Section 7.3.2**
			Pollution and disease	**Section 7.2.3**
			Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
			Climate change	**Section 7.2.6**
Carcharodon caracharias	Great White Shark	Recovery plan for the white shark (*Carcharodon carcharias*) (DSEWPaC 2013b)	Marine debris	**Section 7.3.2**
			Climate change	**Section 7.2.6**
Glyphis garricki	Northern River Shark, New Guinea River Shark	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
		Approved conservation advice for *Glyphis garracki* (northern river shark) (Threatened Species Scientific Committee 2014a)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
			Marine Debris	**Section 7.3.2**
Pristis clavata	Dwarf Sawfish, Queensland Sawfish	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
		Approved conservation advice for *Pristis clavata* (dwarf sawfish) (Threatened Species Scientific Committee 2009)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
Pristis pristis	Freshwater Sawfish, Largetooth Sawfish, River	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**

	Sawfish, Leichhardt's Sawfish, Northern Sawfish	Approved conservation advice for *Pristis pristis* (largetooth sawfish) (Threatened Species Scientific Committee 2014b)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
Pristis zijsron	Green Sawfish, Dindagubba, Narrowsnout Sawfish	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b)	Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
		Approved conservation advice for green sawfish (Threatened Species Scientific Committee 2008a)	Habitat degradation/ modification	**Sections 7.2.8** & **7.3.1**
Rhinocodon typus	Whale Shark	Approved Conservation Advice for Rhincodon typus (whale shark) (Threatened Species Scientific Committee 2015d)	Vessel disturbance	**Section 7.3.4**
			Habitat degradation/ modification	**Sections 7.2.8** & **7.3.1**
			Marine Debris	**Section 7.3.2**
			Climate change	**Section 7.2.6**

3.3.5 Reptiles

Six species of marine turtles have been recorded in northern Australia, all of which have a high conservation value. Of these six species, five (green turtle, flatback turtle, hawksbill turtle, loggerhead turtle and olive ridley turtle) are known to regularly breed in northern Australia; leatherback turtles are the exception. Sandy beaches along the Western Australian Pilbara and Kimberley coastlines and nearshore islands are important nesting sites for marine turtles, particular flatback, green and hawksbill turtles. The nearest turtle nesting beach to the Project Area is Bedout Island, which lies approximately 97 km south of the WHP.

One internesting BIA for flatback turtles intersects the Project Area and is located at North Turtle Island 10 km from the WHP location. However, there is no habitat critical to the survival of flatback turtles or other marine turtles within the Project Area. Benthic habitats within the Project Area do not constitute turtle foraging habitat due to the lack of suitable foods (e.g. soft corals, sponges, algae and seagrasses) (**Section 3.3.1.1**). Turtles that prey on pelagic fauna (e.g. leatherback turtles), such as jellyfish, may be present in the Project Area, along with turtles transiting the area; however, these are only expected to occur in low numbers.

Sea snakes of the families *Hydrophiidae* and *Laticaudidae* are widespread throughout tropical waters off northern Australia in both offshore and nearshore waters. They occupy diverse habitats including coral reefs, turbid water habitats and deeper water (Guinea et al. 2004). Species exhibit habitat preferences depending on water depth, benthic habitat, turbidity and season (Heatwole and Cogger 1993). An olive sea snake was observed in waters deeper than 100 m within the Project Area during the marine environmental studies campaign (RPS 2020d).

Saltwater crocodiles may occur within the EMBA beyond the Project Area in coastal and estuarine areas of the Kimberley.

3.3.5.1 Threatened and Migratory Marine Reptiles

A number of species of marine reptiles listed as threatened or migratory under the EPBC Act were identified from PSMT reports in **Attachment 1** as potentially occurring within the Project Area and EMBA beyond the Project Area. The full list of marine reptiles including the species that are classified as threatened or migratory are presented in **Table 3-10**.

Table 3-10: Threatened and migratory marine reptile species identified within the EMBA

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Acalyptophis peronii	Horned Seasnake	Gulf of Siam, Vietnam, Thailand, China (South Chinese sea, coast of Guangdong and Strait of Taiwan), Indonesia, Philippines, Papua New Guinea, New Caledonia, Australia (Northern Territory, Queensland, Western Australia).	-	-	Species or species habitat known to occur	Species or species habitat known to occur
Aipysurus apraefrontalis	Short-nosed Sea Snake	The short-nosed sea snake has primarily been recorded at Ashmore Reef and Cartier Island. The species has also been recorded along the Pilbara coast between Exmouth Gulf and Broome (Threatened Species Scientific Committee 2010a). Like all sea snakes, the short-nosed sea snake must come to the surface to breathe. The species has been recorded primarily in reef flats or in shallow waters (less than 10 m deep).	Critically endangered	-	-	Species or species habitat known to occur
Aipysurus duboisii	Dubois' Seasnake	Marine waters off New Guinea and the Coral Sea east to New Caledonia; the Continental Shelf off northern Australia (northwestern Western Australia to the Great Barrier Reef).	-	-	Species or species habitat known to occur	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Aipysurus eydouxii	Spine-tailed Seasnake	A. eydouxii is found in Western Australia, Northern Territory, Queensland, the South China Sea, the Gulf of Thailand, Indonesia, Peninsular Malaysia, Vietnam, and New Guinea.	-	-	Species or species habitat known to occur	Species or species habitat known to occur
Aipysurus foliosquama	Leaf-scaled Sea snake	The leaf-scaled sea snake has primarily been recorded at Ashmore Reef and Cartier Island. A single specimen was recorded in the Northern Territory (Threatened Species Scientific Committee 2010b). The species has been recorded primarily in reef flats or in shallow waters (less than 10 m deep) on the outer edges of reefs.	Critically endangered	-	-	Species or species habitat known to occur
Aipysurus fuscus	Dusky Seasnake	A. fuscus primarily inhabits reefs in shallow marine habitats. It has occasionally been recorded at depths of up to 30 metres (98 ft).The only reliable reports of this species in the wild are from the Timor Sea, from the reefs of Ashmore, Cartier and Hibernia of the Ashmore and Cartier Islands, and the reefs of Scott and Seringapatam.	-	-	-	Species or species habitat known to occur
Aipysurus laevis	Olive Seasnake	The olive sea snake is the most common sea snake along the northern coast of Australia and nearby island groups. It is a true snake	-	-	Species or species habitat known to occur	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		and gets its common name from the color of its skin. Like all reptiles, olive sea snakes breathe air, but unlike the sea turtles, crocodiles, sea kraits, and other marine reptiles – which must nest on shore – the olive sea snake's entire life cycle occurs in the ocean.				
Aipysurus pooleorum	Shark Bay Seasnake	The species' distribution is restricted to the mid-west coast of Western Australia, especially Shark Bay. Despite this, isolated specimens have been found further south (Storr et al. 1986).	-	-	-	Species or species habitat known to occur
Aipysurus tenuis	Brown-lined Seasnake	The Brown-lined Seasnake is large and elongate with a brown head and paler body. The dorsal scales have dark brown tips which form longitudinal lines on the back and cross-bars on the flanks. Head scales are more or less regular and symmetrical with some fragmentation of the frontal and parietal scales. Body scales are imbricate (overlapping) and smooth in 19 rows at the mid-body. There are 185–195 ventral scales and these are broad, notched and tuberculate (bumpy), especially in males. A	-	-	Species or species habitat known to occur	Species or species habitat known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		small tubercle is present on the lowest body scales of males.				
Astrotia stokesii	Stokes' Seasnake	The Stokes' Seasnake inhabits the tropical seas of northern Australia, including Western Australia, the Northern Territory and Queensland (Cogger 2000).	-	-	Species or species habitat known to occur	Species or species habitat known to occur
Caretta	Loggerhead Turtle	The loggerhead turtle is distributed throughout tropical, subtropical and temperate waters in all ocean basins. In Australia, the species ranges along most of the coastline but is rare in temperate waters (Commonwealth of Australia 2017a). Loggerhead turtles are carnivorous and mainly feed on benthic invertebrates in a wide range of habitats ranging from nearshore to 55 m in depth (Commonwealth of Australia 2017a). Nesting in Western Australia is concentrated from Shark Bay to the North West Cape. Foraging areas are more widely distributed with the Western Australia stock foraging from Shark Bay through to Arnhem Land, Gove and into the Java Sea of Indonesia (Limpus 2008a).	Endangered	Migratory	Species or species habitat likely to occur	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Chelonia mydas	Green Turtle	The green turtle is distributed in tropical and subtropical waters in the Pacific, Atlantic and Indian oceans. Within Australian waters, the species is predominately found off the Western Australia, Northern Territory and Queensland coastlines (Commonwealth of Australia 2017a). The species is primarily herbivorous and forages on algae, seagrass and mangroves, including where these habitats exist at offshore coral reef habitats (Commonwealth of Australia 2017a). Tagging studies have shown that green turtles can move considerable distances between nesting, with movements of hundreds to thousands of kilometres recorded (Limpus 2008b).	Vulnerable	Migratory	Species or species habitat likely to occur	Breeding known to occur
Crocodylus porosus	Saltwater Crocodile, Estuarine Crocodile	The saltwater crocodile occurs within the nearshore marine and estuarine waters throughout southern Asia and northern Australia. Large populations exist within the major river systems of the Kimberley.	-	Migratory	-	Species or species habitat likely to occur
Dermochelys coriacea	Leatherback Turtle	The leatherback turtle is distributed in tropical and temperate oceans worldwide. The species is known to forage and migrate	Endangered	Migratory	Species or species habitat likely to occur	Foraging, feeding or related

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		throughout the open offshore waters of Australia, with a distribution that extends further south into temperate waters than other marine turtle species (Limpus 2009a). Leatherback turtles eat jellyfish almost exclusively and are pelagic throughout their life in oceanic waters around Australia (Limpus 2009a). Records of leatherback turtle nesting in Australia are sparse and limited to the Cobourg Peninsula and Queensland coast (Limpus 2009a), far beyond the EMBA.				behaviour known to occur
Disteira kingii	Spectacled Seasnake	The Spectacled Seasnake has only been known to occur in Australia, between Safety Bay in Western Australia (in 2000) (Cogger 2001 pers. Com.) and across the northern coastline of Australia down to Moreton Bay in Queensland as recorded in the mid 1970s (Limpus 1975).	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur
Disteira major	Olive-headed Seasnake	The Olive-headed Seasnake is considered to be a prominent member of the sea snake fauna of sub-tropical Queensland (Limpus 1975). It becomes relatively common in the waters between Bundaberg and Fraser Island each year from August–January.	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Emydocephalus annulatus	Turtle-headed Seasnake	The species occurs from Shark Bay in Western Australia to the southern Great Barrier Reef (Cogger 1975; Storr et al. 1986).	-	-	-	Species or species habitat likely to occur
Enhydrina schistosa	Beaked Seasnake	he species is known from widely scattered localities in northern Australia, including the Hey-Embley River, Mission River, and Repulse Bay in North Queensland. The Beaked Seasnake has not been recorded in Western Australia (Cogger 2000; Limpus 1975; Porter et al. 1997).	-	-	-	Species or species habitat likely to occur
Eretmochelys imbricata	Hawksbill Turtle	The hawksbill turtle has a worldwide distribution in tropical and subtropical waters. In Australia, hawksbill turtles predominately occur along the northern Western Australian, Northern Territory and northern Queensland coastlines (Limpus 2009b). Hawksbill turtles are omnivorous and feed on algae, sponges, soft corals and soft-bodied invertebrates. This species is typically associated with rocky and coral reef habitats.	Vulnerable	Migratory	Species or species habitat likely to occur	Breeding known to occur
Hydrelaps darwiniensis	Black-ringed Seasnake	The Black-ringed Seasnake was known (in 2000) to be endemic to the shallow coastal waters of northern Australia and southern	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Papua New Guinea, west of Torres Strait (Cogger 2000).				
Hydrophis atriceps	Black-headed Seasnake	he Black-headed Seasnake was known to occur in northern Australia, between Darwin and the coast of Papua New Guinea in 2000 (Cogger 2000).	-	-	-	Species or species habitat likely to occur
Hydrophis coggeri	Slender-necked Seasnake	The Slender-necked Seasnake is found in the waters of the northern Australian coast (Cogger 2000). Slender-necked Seasnakes at Ashmore Reef appear to inhabit the deeper (30–50 m) water beyond the reef edges as well as the reef flat. This is in contrast to the populations in Fiji that are often encountered on reef flats and in lagoons, especially where there are seagrasses (Cogger 2000; Guinea 1982; Guinea & Whiting 2005; McCosker 1975).	-	-	-	Species or species habitat likely to occur
Hydrophis czeblukovi	Fine-spined Seasnake	Fine-spined Seasnakes have been recorded as incidental catch from research and commercial trawls in studies undertaken during the 1980s and 1990s. Specimens have been historically collected from the Arafura Sea (Kharin 1984a); Papua New Guinea (close to Lesson Island as H. geometricus, Smith	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		1986); and 84 km, 140 km, and 130 km north west of Dampier, Western Australia (Rasmussen & Smith 1997).				
Hydrophis elegans	Elegant Seasnake	The Elegant Seasnake is widespread in tropical Australia. This includes Queensland, Western Australia and the Northern Territory (Dell & Fry 2003). Its distribution extends from Shark Bay in Western Australia to Moreton Bay in Queensland (Cogger 2000; Storr et al. 1986).	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur
Hydrophis ornatus	Spotted Seasnake,	The Ornate Seasnake occurs in tropical northern Western Australia, the Northern Territory and northern Queensland. The species sometimes occurs further south in summer, extending its range as far as Tasmania (Cogger 1996)	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur
Lapemis hardwickii	Spine-bellied Seasnake	he spine-bellied sea snake, also commonly known as Hardwicke's sea snake and Hardwicke's spine-bellied sea snake, is a species of venomous sea snake in the family Elapidae.	-	-	-	Species or species habitat likely to occur
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle	The olive ridley turtle has a global distribution in tropical waters. In Australia, the species primarily occurs in the Northern	Endangered	Migratory	-	Breeding likely to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		Territory and Queensland (Limpus 2008c). The olive ridley turtle is primarily carnivorous and feeds predominantly on soft-bodied invertebrates (Commonwealth of Australia 2017a). The species is known to feed in water depths between 15 m and 200 m and may make movements of more than 1,000 km between their nesting and foraging grounds (Whiting et al. 2007). Low-density nesting has also been described on the Kimberley coast (Limpus 2008c).				
Natator depressus	Flatback Turtle	The flatback turtle occurs along the Western Australian, Northern Territory and Queensland coastlines and forages widely across the Australian continental shelf and into the continental waters off Indonesia and Papua New Guinea (Commonwealth of Australia 2017a). Unlike other species of marine turtle, the flatback turtle does not have a global tropical distribution, with all recorded nesting beaches within Australian waters (Limpus 2007). Flatback turtles nest throughout tropical Australia, although there are several distinct populations (Limpus 2007). Populations at	Vulnerable	Migratory	Congregation or aggregation known to occur	Breeding known to occur

Scientific Name	Common Name	Description	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
		higher latitudes off central Queensland and Western Australia's Pilbara coast tend to have a nesting peak in summer (Limpus 2007). Internesting flatback turtles have been recorded travelling further from nesting beaches between laying clutches of eggs (Waayers et al. 2011' Whittock et al. 2014). Flatback turtles are primarily carnivorous and feed predominantly on soft-bodied invertebrates in relatively shallow waters (Limpus 2007). Their distribution is largely restricted to continental shelf waters (less than 200 m deep).				
Pelamis platurus	Yellow-bellied Seasnake	Yellow-bellied Seasnake is the most widely distributed of all sea snake species. In the beginning of the 21st century, the species was found to range from the east coast of Africa through the Indian and Pacific Oceans to the west coast of the Americas (Cogger 2000; Kropach 1975). It was found in most Australian waters with the exception of the colder southern coastline (Cogger 2000).	-	-	Species or species habitat likely to occur	Species or species habitat likely to occur

3.3.5.2 Biologically Important Areas and Critical Habitat

No important habitats for marine reptiles overlap the Project Area; however, several habitats important for the survival of marine turtles were identified within the EMBA beyond the Project Area. These are summarised in **Table 3-11**. BIAs for marine reptiles that overlap the Project Area and the EMBA beyond the Project Area are summarised in **Table 3-12**. The BIAs for turtles are shown in **Figure 3-18** to **Figure 3-21**.

The flatback turtle internesting BIA centred around North Turtle Island is the only one that overlaps the Project Area. North Turtle Island is a small sandy island approximately 96 km and 39 km south of the WHP location and the Project Area respectively. The island is known to host nesting flatback turtles. This BIA overlaps approximately 24% of the Project Area and lies approximately 10 km south of the proposed WHP location. The portion of the BIA in the Project Area is approximately 5% of the total area of the BIA.

Internesting flatback turtles may range more widely than other turtle species, with results from tagging studies of internesting flatbacks at the Lacepede Islands showing flatbacks dispersing further than internesting green turtles at the same location (Waayers et al. 2011). The maximum distance of internesting turtles from the nesting beach observed during this study was approximately 48 km (Waayers et al. 2011). Based on available bathymetry, locations of internesting flatback turtles from these studies are consistent with relatively shallow (less than 30 m deep) coastal waters; such behaviour is consistent with observations of internesting behaviour in other species (Hamel et al. 2008; Hays et al. 1999). Analysis of satellite tracking data for green turtles (Ferreira et al. 2020; Hamel et al. 2008; Hays et al. 1999) shows internesting turtles occupied mostly shallow waters at a median depth of 9 m, and 95% of the distribution was in less than 20-m water depth.

Water depths in the portion of the flatback turtle internesting BIA that overlaps the Project Area range from 72 m to 88 m. These water depths are considerably deeper than the diving depths of internesting flatback turtles (Waayers et al. 2011; Whittock et al. 2016), and hence internesting females are unlikely to be present within the Project Area.

The Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) describes protected habitats for flatback turtles in the following way:

+ Habitats critical for the survival of the species were identified by consensus of a panel of experts in marine turtle biology identifying nesting and internesting habitat for each stock. For flatback turtles, a 60-km buffer zone located immediately seaward of designated nesting habitat defines the habitat critical to the survival of this species to capture internesting behaviour; and
+ BIAs for marine turtles are areas where protected species display biologically important behaviour, such as breeding, foraging, resting and migration. These habitats are not yet described for flatback turtles such that habitat critical to the survival of the stock can be identified; however, this knowledge gap is to be addressed during the life of the recovery plan. In the interim, the recovery plan advises consideration of information in the National Conservation Values Atlas (DAWE 2020) and the Species Profile and Threat Database.

Following the Recovery Plan, the BIA and critical habitat for internesting flatback turtles and the BIA for other turtle species provided by the DotEE and represented in the National Conservation Values Atlas (DAWE 2020) is shown in **Figure 3-18** to **Figure 3-21**.

The EMBA overlaps the BIA for flatback, green, hawksbill and loggerhead turtles and the Project Area overlaps the BIA for flatback turtles as shown in **Figure 3-18** to **Figure 3-21**.

Table 3-11: Nesting habitats critical to the survival of marine turtles within the EMBA indicating shortest distance from the WHP

Species Name	Common Name	Nesting habitats	Shortest Distance from WHP (km)
Natator depressus	Flatback Turtle	Nesting – Cemetery Beach, Port Hedland	80
Eretmochelys imbricata	Hawksbill Turtle	Nesting – Dampier Archipelago	213
Chelonia mydas	Green Turtle	Nesting – Dampier Archipelago	213
Lepidochelys olivacea	Olive Ridley Turtle	Nesting – Cape Leveque	512
Caretta caretta	Loggerhead Turtle	Nesting – Exmouth Gulf and Ningaloo Coast	532

Table 3-12: BIAs for marine reptiles within the EMBA indicating shortest distance from the WHP

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
Caretta caretta	Loggerhead Turtle	Foraging – De Grey River area to Bedout Island	55
		Internesting buffer – Cohen Island	231
		Nesting – Cohen Island	253
		Internesting – Dirk Hartog Island	924
Chelonia mydas	Green Turtle	Foraging – De Grey River area to Bedout Island	55
		Internesting buffer – Delambre Island	213
		Nesting – Delambre Island	232
		Internesting – Dampier Archipelago	249
		Mating – Dampier Archipelago	249
		Migration corridor – Dampier Archipelago	249
		Aggregation – Montebello Islands	376
		Basking – Middle Island and Barrow Island	386
Eretmochelys imbricata	Hawksbill Turtle	Foraging – De Grey River area to Bedout Island	55
		Internesting buffer – Delambre Island	213
		Nesting – Delambre Island	232
		Mating – Dampier Archipelago	249

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
		Migration corridor – Dampier Archipelago	249
		Internesting – Dampier Archipelago	249
Natator depressus	Flatback Turtle	Internesting buffer – North Turtle Island	10
		Foraging – De Grey River area to Bedout Island	55
		Nesting – North Turtle Island	89
		Mating – Dampier Archipelago	249
		Internesting – Dampier Archipelago	249
		Migration corridor – Dampier Archipelago	249
		Aggregation – Montebello Islands	376
Lepidochelys olivacea	Olive Ridley Turtle	Foraging – northern Western Australia	1088

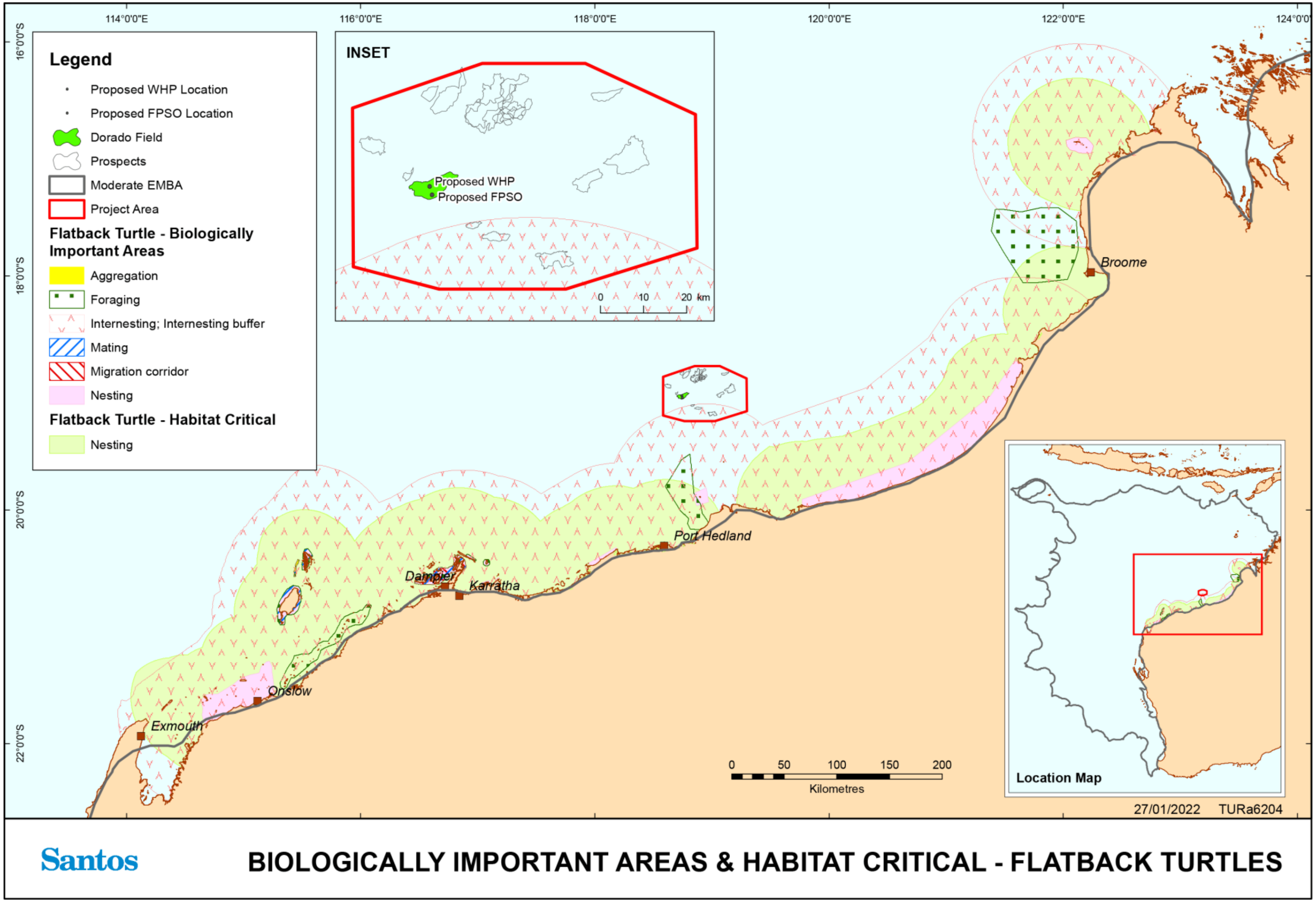

Figure 3-18: Flatback turtle BIAs and habitat critical

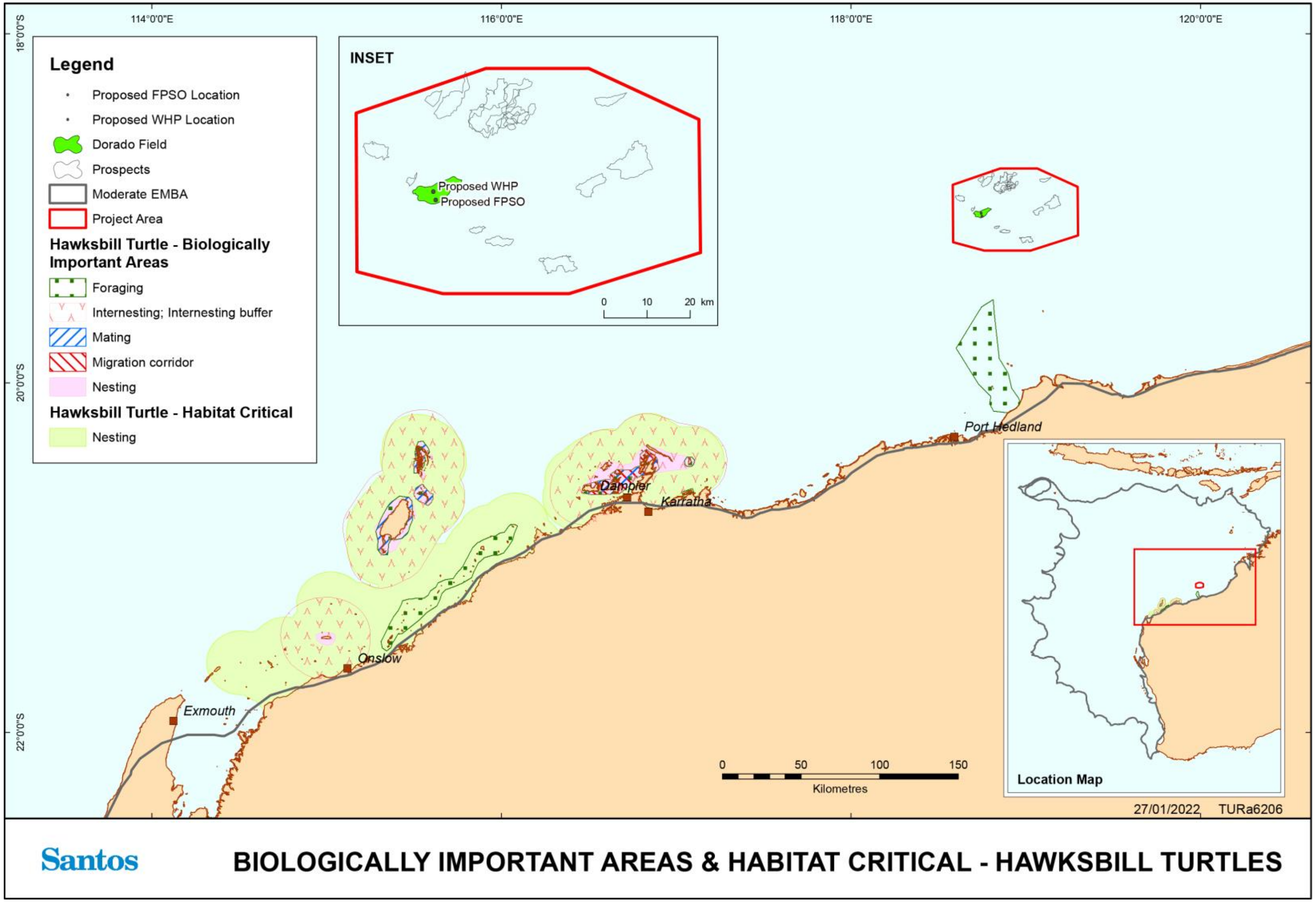

Figure 3-19: Hawksbill turtle BIAs and habitat critical

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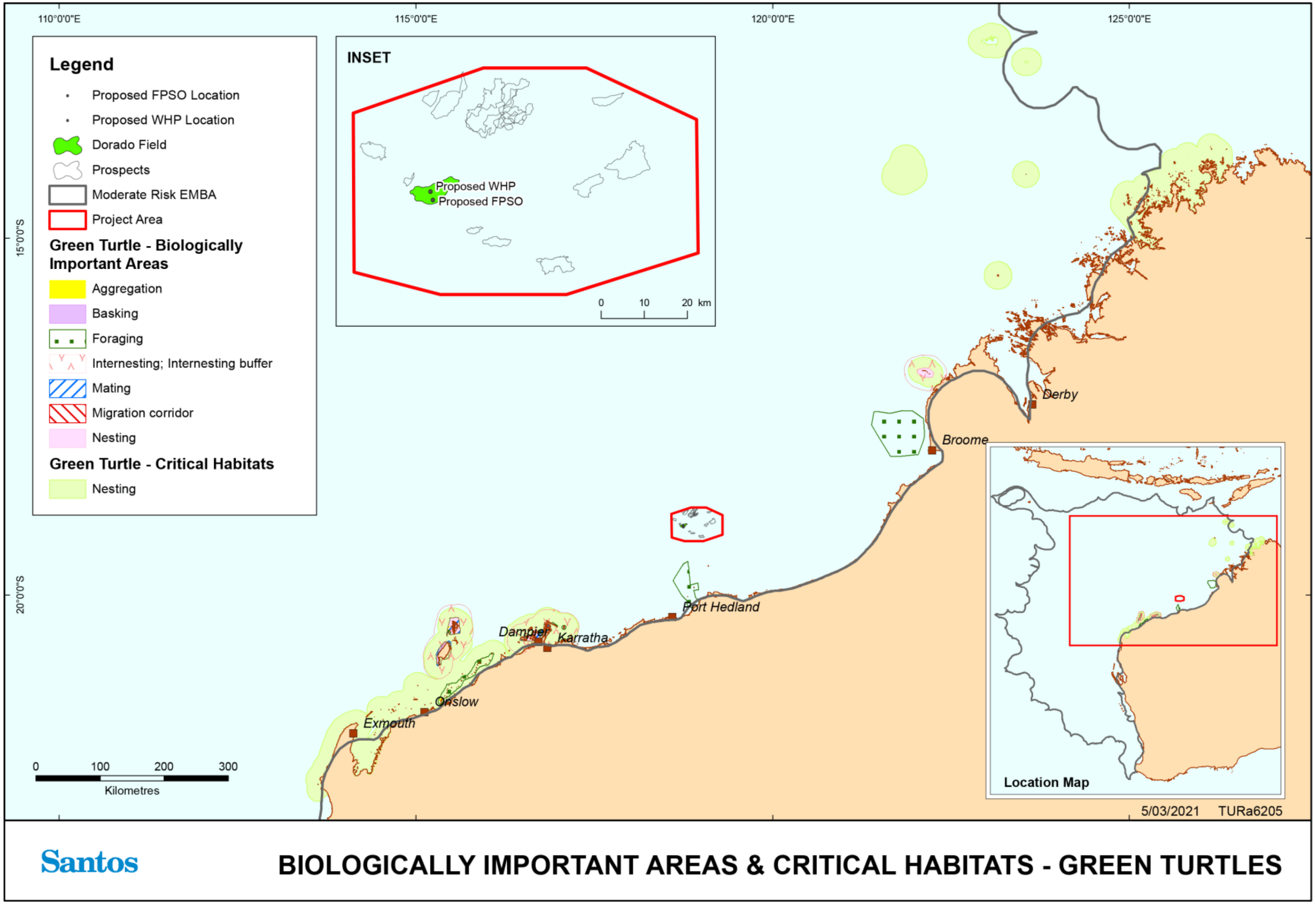

Figure 3-20: Green turtle BIAs and habitat critical

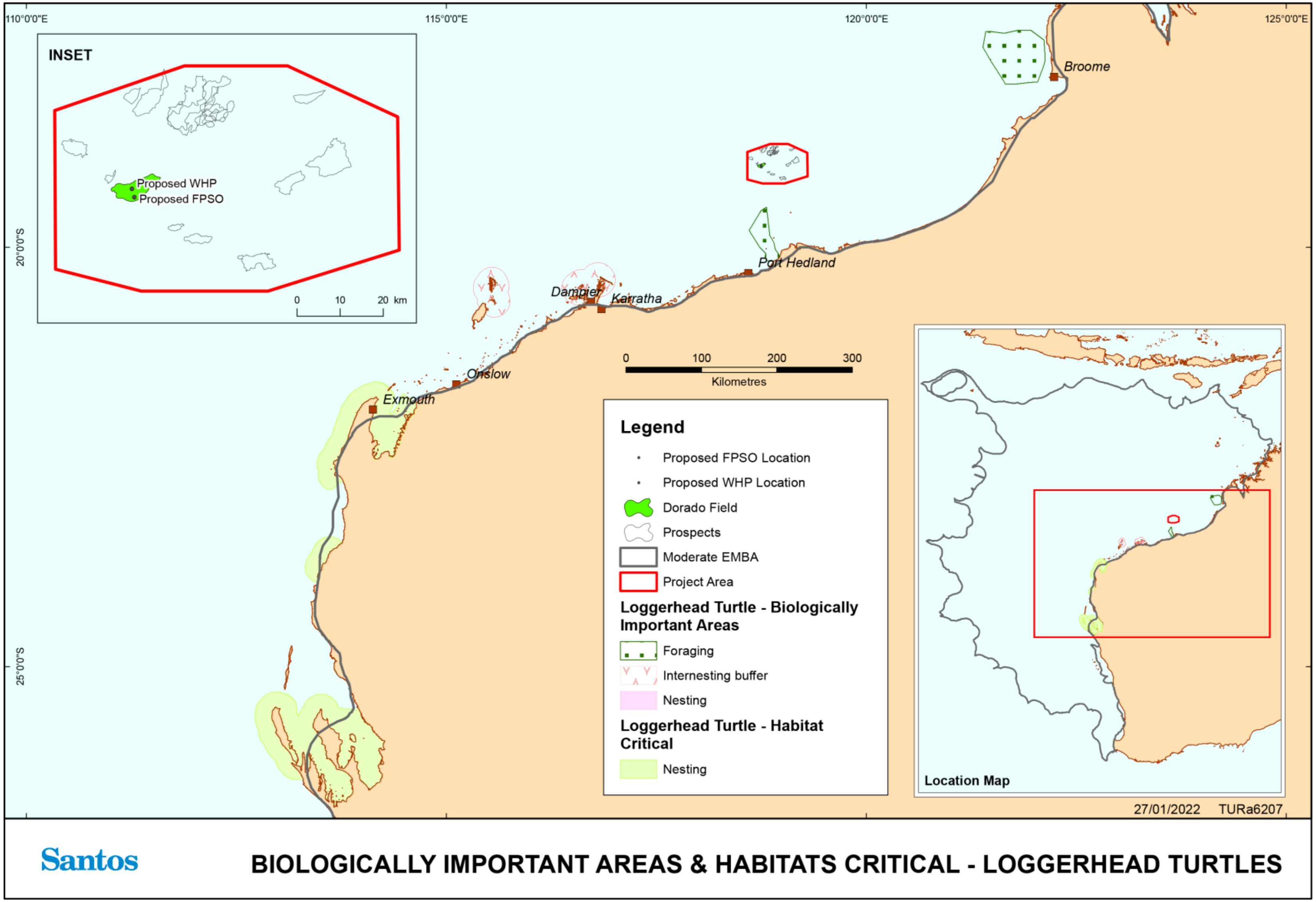

Figure 3-21: Loggerhead turtle BIAs and habitat critical

3.3.5.3 Conservation Advice and Recovery Plans

Material published by the Commonwealth under the EPBC Act for the conservation of threatened marine reptiles, such as recovery plans, conservation advice, and threat abatement plans, is summarised in **Figure 3-13.** Threats identified in this material that may credibly arise from Dorado Phase 1 are also listed, along with cross-references to the relevant assessment of environmental impacts and risks in **Section 7**.

Table 3-13: Summary of material published by the Commonwealth for the conservation of threatened marine reptiles relevant to Dorado Phase 1

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
-	All marine reptile species	Threat abatement plan for the impacts of marine debris on vertebrate marine life (Commonwealth of Australia 2018)	Marine debris	**Section 7.3.2**
-	All marine turtles	National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (DOEE 2020)	Light pollution	**Section 7.3.2**
Aipysurus apraefrontalis	Short-nosed Sea Snake	Approved conservation advice for *Aipysurus apraefrontalis* (short-nosed sea snake) (Threatened Species Scientific Committee 2010a)	Marine debris	**Section 7.3.2**
			Habitat degradation	**Section 7.3.1**
Aipysurus foliosquama	Leaf-scaled Sea Snake	Approved conservation advice for *Aipysurus foliosquama* (leaf-scaled sea snake) (Threatened Species Scientific Committee 2010b)	Marine debris	**Section 7.3.2**
			Habitat degradation	**Section 7.3.1**
Caretta caretta	Loggerhead Turtle	Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a)	Oil pollution	**Section 7.3.1**
			Light pollution	**Section 7.2.4**
			Vessel disturbance	**Section 7.3.4**
			Noise interference	**Section 7.2.5**
			Habitat degradation / modification	**Sections 7.2.8 & 7.3.1**
			Climate change	**Section 7.2.6**
			Disease and pathogens (from wastewater)	**Section 7.2.3**
Chelonia mydas	Green Turtle	Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a)	Oil pollution	**Section 7.3.1**
			Light pollution	**Section 7.2.4**

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
			Vessel disturbance	**Section 7.3.4**
			Noise interference	**Section 7.2.5**
			Habitat degradation / modification	**Sections 7.2.8 & 7.3.1**
			Climate change	**Section 7.2.6**
			Disease and pathogens (from wastewater)	**Section 7.2.3**
Dermochelys coriacea	Leatherback Turtle	Approved conservation advice on *Dermochelys coriacea* (Leatherback Turtle) (Threatened Species Scientific Committee 2008b)	Vessel disturbance	**Section 7.3.4**
			Climate change	**Section 7.2.6**
			Marine debris	**Section 7.3.2**
Eretmochelys imbricata	Hawksbill Turtle	Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a)	Oil pollution	**Section 7.3.1**
			Light pollution	**Section 7.2.4**
			Vessel disturbance	**Section 7.3.4**
			Noise interference	**Section 7.2.5**
			Habitat degradation / modification	**Sections 7.2.8 & 7.3.1**
			Climate change	**Section 7.2.6**
			Disease and pathogens (from wastewater)	**Section 7.2.3**
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle	Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a)	Oil pollution	**Section 7.3.1**
			Light pollution	**Section 7.2.4**

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
			Vessel disturbance	**Section 7.3.4**
			Noise interference	**Section 7.2.5**
			Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
			Climate change	**Section 7.2.6**
			Disease and pathogens (from wastewater)	**Section 7.2.3**
Natator depressus	Flatback Turtle	Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a)	Oil pollution	**Section 7.3.1**
			Light pollution	**Section 7.2.4**
			Vessel disturbance	**Section 7.3.4**
			Noise interference	**Section 7.2.5**
			Habitat degradation / modification	**Sections 7.2.8** & **7.3.1**
			Climate change	**Section 7.2.6**
			Disease and pathogens (from wastewater)	**Section 7.2.3**

3.3.6 Birds

The Project Area does not host a large number or diversity of bird species. There are no emergent features for bird roosting or nesting, and the marine environment does not have high productivity or host consistently high numbers of prey for foraging seabirds. Birds within the Project Area are likely to consist of foraging seabirds and potentially migrating shorebirds (Sage 1979 cited in Ronconi et al. 2015). While migration pathways for species occurring at Eighty Mile Beach (a significant area of intertidal mudflats within the EMBA) are poorly defined, birds may migrate through the Project Area.

The EMBA beyond the Project Area includes a significant number of birds, including many species of seabirds and migratory shorebirds that are listed as threatened or migratory (or both) under the EPBC Act.

Seabirds within the EMBA include shearwaters, boobies, noddies, frigatebirds, terns, petrels and albatrosses. Many of these breed and nest on coastal and offshore islands within the EMBA. Islands hosting notable seabird colonies within the EMBA include:

+ many islands along the Pilbara coast;
+ Ashmore Reef and Cartier Island;
+ Rowley Shoals;
+ Montebello Islands;
+ Barrow Island; and
+ Houtman Abrolhos Islands.

Some, such as petrels and albatrosses, are only likely to be present in the southern temperate areas and are unlikely to breed or nest within the EMBA.

In addition to seabirds, the EMBA beyond the Project Area seasonally hosts large numbers of migratory shorebirds. These species typically nest and breed in Asia in the northern hemisphere summer and migrate to feeding grounds in the southern hemisphere during the southern hemisphere summer. Migratory shorebirds typically aggregate in wetlands, estuaries and coastal mudflat habitats in the EMBA to feed and rest during summer months. Many of these important habitats are recognised by the International Convention on Wetlands of International Importance (Ramsar Convention) and protected under the EPBC Act as wetlands of international importance. These wetlands are described in **Section 3.4.2.4.**

3.3.6.1 Threatened and Migratory Birds

A number of species of birds listed as threatened or migratory under the EPBC Act were identified from PMST reports in **Attachment 1** as potentially occurring within the Project Area and EMBA beyond the Project Area. The full list of birds including species that are classified as threatened or migratory are presented in **Table 3-14.**

Many species of birds listed as migratory within the EMBA undertake long-distance flights to and from Australia along the East Asian–Australasian Flyway, one of several flyways recognised for migratory shorebirds and waders (**Figure 3-22**). Flyways are broad, contiguous corridors between breeding areas in the northern hemisphere and feeding areas in the southern hemisphere. The East Asian–Australasian Flyway extends from Arctic Russia and North America to the southern limits of Australia and New Zealand. It encompasses large parts of East Asia and all of Southeast Asia and includes eastern India and the Andaman and Nicobar Islands. The flyway is used by millions of birds annually, although not all species migrating in the flyway use the full extent of the flyway (BirdLife International n.d.).

Families of migratory birds that use the East Asian-Australasian Flyway include:

+ plovers and lapwings (family *Charadriidae*);
+ sandpipers (family *Scolopacidae*); and
+ pratincoles (family *Glareolidae*).

Resting areas within these flyways are recognised as important for maintaining connectivity between these breeding and feeding areas, and many such habitats are listed under the Ramsar Convention. The EPBC Act gives effect to the Ramsar Convention, with such sites declared as wetlands of international importance under Part 3 of the Act. Ramsar-listed wetlands within the EMBA are described in **Section 3.4.2.4**.

Table 3-14: Bird species that may occur within the Project Area and EMBA

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Acrocephalus orientalis	Oriental Reed-Warbler	-	Migratory	-	Species or species habitat known to occur within area
Actitis hypoleucos	Common Sandpiper	-	Migratory	Species or species habitat may occur within area	Species or species habitat known to occur within area
Anous minutus	Black Noddy	-	-	-	Species or species habitat known to occur within area
Anous stolidus	Common Noddy	-	Migratory	Species or species habitat may occur within area	Breeding known to occur within area
Anous tenuirostris melanops	Australian Lesser Noddy	Vulnerable	-	-	Breeding known to occur within area
Anseranas semipalmata	Magpie Goose	-	-	-	Breeding known to occur within area
Apus pacificus	Fork-tailed Swift	-	Migratory	-	Species or species habitat known to occur within area
Ardea ibis	Cattle Egret	-	-	-	Species or species habitat may occur within area

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Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Ardenna carneipes	Flesh-footed Shearwater, Fleshy-footed Shearwater	-	Migratory	-	Foraging, feeding or related behaviour likely to occur within area
Ardenna grisea	Sooty Shearwater	-	Migratory	-	Species or species habitat may occur within
Ardenna pacifica	Wedge-tailed Shearwater	-	Migratory	-	Breeding known to occur within area
Arenaria interpres	Ruddy Turnstone	-	Migratory	-	Roosting known to occur within area
Calidris acuminata	Sharp-tailed Sandpiper	-	Migratory	Species or species habitat may occur within area	Roosting known to occur within area
Calidris alba	Sanderling	-	Migratory	-	Roosting known to occur within area
Calidris canutus	Red Knot	Endangered	Migratory	Species or species habitat may occur within area	Species or species habitat known to occur within area
Calidris ferruginea	Curlew Sandpiper	Critically endangered	Migratory	-	Species or species habitat known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Calidris melanotos	Pectoral Sandpiper	-	Migratory	Species or species habitat may occur within area	Species or species habitat known to occur within area
Calidris ruficollis	Red-necked Stint	-	Migratory	-	Roosting known to occur within area
Calidris subminuta	Long-toed Stint	-	Migratory	-	Roosting known to occur within area
Calidris tenuirostris	Great Knot	Critically endangered	Migratory	-	Roosting known to occur within area
Calonectris leucomelas	Streaked Shearwater	-	Migratory	Species or species habitat likely to occur within area	Species or species habitat known to occur within area
Catharacta skua	Great Skua	-	-	-	Species or species habitat known to occur within area
Cereopsis novaehollandiae grisea	Cape Barren Goose (south-western),	Vulnerable	-	-	Species or species habitat known to occur within area
Charadrius bicinctus	Double-banded Plover	-	Migratory	-	Roosting known to occur within area
Charadrius dubius	Little Ringed Plover	-	Migratory	-	Roosting known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Charadrius leschenaultii	Greater Sand Plover, Large Sand Plover	Vulnerable	Migratory	Species or species habitat known to occur within area	Roosting known to occur within area
Charadrius mongolus	Lesser Sand Plover, Mongolian Plover	Endangered	Migratory	-	Roosting known to occur within area
Charadrius veredus	Oriental Plover, Oriental Dotterel	-	Migratory	-	Roosting known to occur within area
Diomedea amsterdamensis	Amsterdam Albatross	Endangered	Migratory	-	Species or species habitat likely to occur within area
Diomedea dabbenena	Tristan Albatross	Endangered	Migratory	-	Species or species habitat likely to occur within area
Diomedea epomophora	Southern Royal Albatross	Vulnerable	Migratory	-	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans	Wandering Albatross	Vulnerable	Migratory	-	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi	Northern Royal Albatross	Endangered	Migratory	-	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Fregata andrewsi	Christmas Island Frigatebird, Andrew's Frigatebird	Endangered	Migratory	-	Breeding known to occur within area
Fregata ariel	Lesser Frigatebird	-	Migratory	Species or species habitat likely to occur within area	Breeding known to occur within area
Fregata minor	Greater Frigatebird	-	Migratory	Species or species habitat may occur within area	Breeding known to occur within area
Gallinago megala	Swinhoe's Snipe	-	Migratory	-	Roosting likely to occur within area
Gallinago stenura	Pin-tailed Snipe	-	Migratory	-	Roosting likely to occur within area
Glareola maldivarum	Oriental Pratincole	-	Migratory	-	Roosting known to occur within area
Halobaena caerulea	Blue Petrel	Vulnerable	-	-	Species or species habitat may occur within area
Hydroprogne caspia	Caspian Tern	-	Migratory	-	Breeding known to occur within area
Limicola falcinellus	Broad-billed Sandpiper	-	Migratory	-	Roosting known to occur within area
Limnodromus semipalmatus	Asian Dowitcher	-	Migratory	-	Roosting known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Limosa lapponica	Bar-tailed Godwit	-	Migratory	-	Species or species habitat known to occur within area
Limosa lapponica baueri	Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit	Vulnerable	-	-	Species or species habitat known to occur within area
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri)	Critically endangered	-	-	Species or species habitat known to occur within area
Limosa limosa	Black-tailed Godwit	-	Migratory	-	Roosting known to occur within area
Macronectes giganteus	Southern Giant-Petrel, Southern Giant Petrel	Endangered	Migratory	-	Species or species habitat may occur within area
Macronectes halli	Northern Giant Petrel	Vulnerable	Migratory	-	Species or species habitat may occur within area
Numenius madagascariensis	Eastern Curlew	Critically endangered	Migratory	Species or species habitat may occur within area	Species or species habitat known to occur within area
Numenius minutus	Little Curlew, Little Whimbrel	-	Migratory	-	Roosting known to occur within area
Numenius phaeopus	Whimbrel	-	Migratory	-	Roosting known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Onychoprion anaethetus	Bridled Tern	-	Migratory	-	Breeding known to occur within area
Pachyptila turtur subantarctica	Fairy Prion (southern)	Vulnerable	-	-	Species or species habitat known to occur within area
Pandion haliaetus	Osprey	-	Migratory	Species or species habitat may occur within area	Breeding known to occur within area
Papasula abbotti	Abbott's Booby	Endangered	-	Species or species habitat may occur within area	Species or species habitat known to occur within area
Pelagodroma marina	White-faced Storm-Petrel	-	-	-	Breeding known to occur within area
Pezoporus flaviventris	Western Ground Parrot, Kyloring	Critically endangered	-	-	Species or species habitat known to occur within area
Phaethon lepturus	White-tailed Tropicbird	-	Migratory	-	Breeding known to occur within area
Phaethon lepturus fulvus	Christmas Island White-tailed Tropicbird, Golden Bosunbird	Endangered	-	-	Breeding likely to occur within area
Phaethon rubricauda	Red-tailed Tropicbird	-	Migratory	-	Breeding known to occur within area

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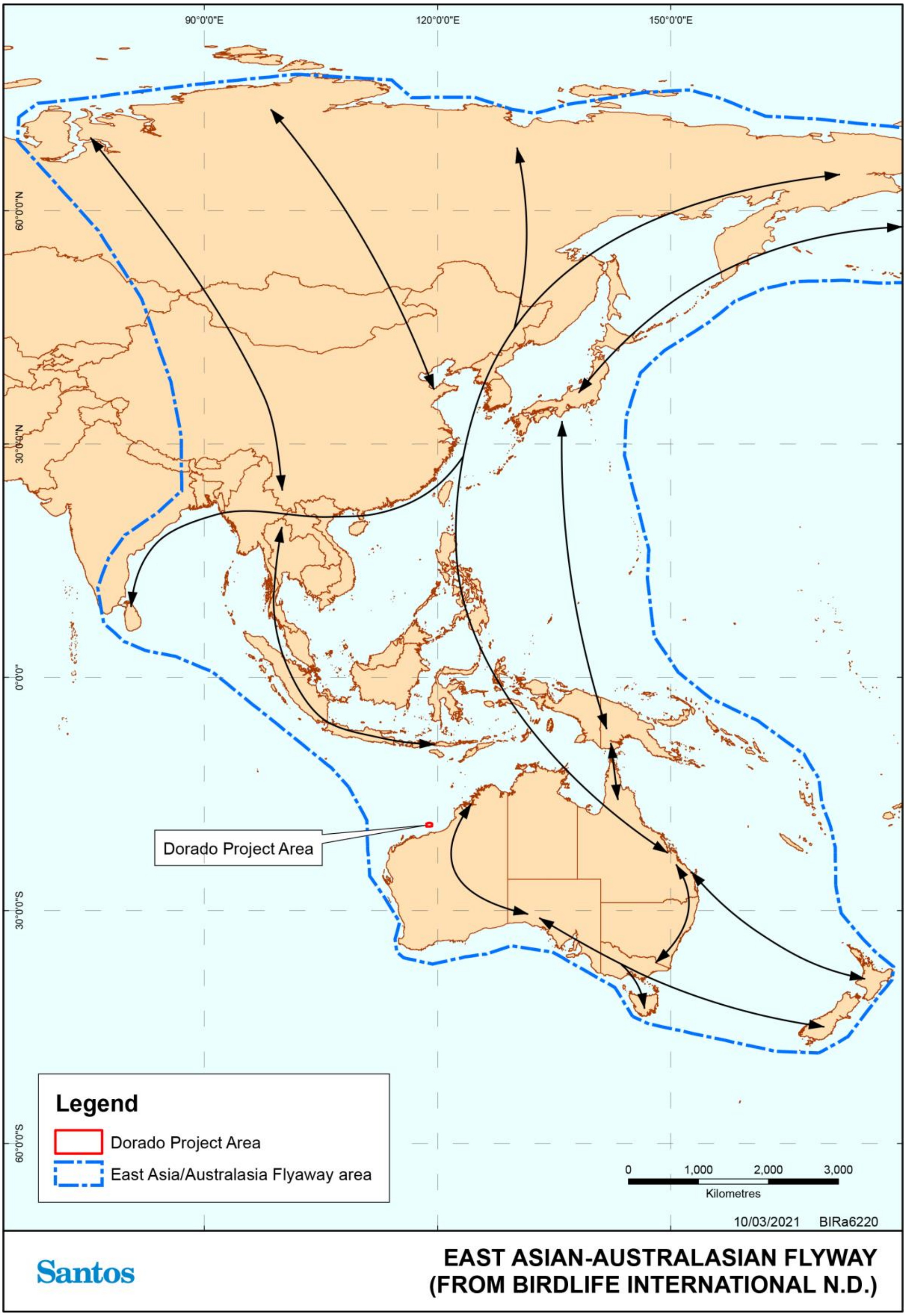
Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Phalacrocorax fuscescens	Black-faced Cormorant	-	-	-	Breeding likely to occur within area
Phalaropus lobatus	Red-necked Phalarope	-	Migratory	-	Roosting known to occur within area
Philomachus pugnax	Ruff (Reeve)	-	Migratory	-	Roosting known to occur within area
Phoebetria fusca	Sooty Albatross	Vulnerable	Migratory	-	Species or species habitat may occur within area
Pluvialis fulva	Pacific Golden Plover	-	Migratory	-	Roosting known to occur within area
Pluvialis squatarola	Grey Plover	-	Migratory	-	Roosting known to occur within area
Pterodroma macroptera	Great-winged Petrel	-	-	-	Breeding known to occur within area
Pterodroma mollis	Soft-plumaged Petrel	Vulnerable	-	-	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis	Little Shearwater	-	Migratory	-	Breeding known to occur within area
Puffinus huttoni	Hutton's Shearwater	-	Migratory	-	Foraging, feeding or related

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
					behaviour known to occur within area
Puffinus tenuirostris	Short-tailed Shearwater	-		-	Breeding known to occur within area
Recurvirostra novaehollandiae	Red-necked Avocet	-	Migratory	-	Roosting known to occur within area
Rhipidura rufifrons	Rufous Fantail		Migratory		Species habitat known to occur within the area.
Rostratula australis	Australian Painted Snipe	Endangered	-	-	Species or species habitat known to occur within area
Sterna dougallii	Roseate Tern	-	Migratory	-	Breeding known to occur within area
Sternula albifrons	Little Tern	-	Migratory	-	Breeding known to occur within area
Sternula nereis nereis	Australian Fairy Tern	Vulnerable	-	-	Breeding known to occur within area
Sula dactylatra	Masked Booby	-	Migratory	-	Breeding known to occur within area
Sula leucogaster	Brown Booby	-	Migratory	Breeding known to occur within area	Breeding known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Sula sula	Red-footed Booby	-	Migratory	-	Breeding known to occur within area
Thalassarche carteri	Indian Yellow-nosed Albatross	Vulnerable	Migratory	-	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta	Shy Albatross	Vulnerable	Migratory	-	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta steadi	White-capped Albatross	Vulnerable	Migratory	-	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida	Campbell Albatross, Campbell Black-browed Albatross	Vulnerable	Migratory	-	Species or species habitat may occur within area
Thalassarche melanophris	Black-browed Albatross	Vulnerable	Migratory	-	Species or species habitat may occur within area
Thalasseus bergii	Crested Tern	-	Migratory	-	Breeding known to occur within area
Thinornis rubricollis	Hooded Plover	-	-	-	Species or species habitat known to occur within area
Tringa brevipes	Grey-tailed Tattler	-	Migratory	-	Roosting known to occur within area

Scientific Name	Common Name	Threatened Status	Migratory Status	Presence within the Project Area (from Attachment 1)	Presence within the EMBA beyond the Project Area (from Attachment 1)
Tringa glareola	Wood Sandpiper	-	Migratory	-	Roosting known to occur within area
Tringa nebularia	Common Greenshank, Greenshank	-	Migratory	-	Species or species habitat known to occur within area
Tringa stagnatilis	Marsh Sandpiper, Little Greenshank	-	Migratory	-	Roosting known to occur within area
Tringa totanus	Common Redshank, Redshank	-	Migratory	-	Roosting known to occur within area
Xenus cinereus	Terek Sandpiper	-	Migratory	-	Roosting known to occur within area



Source: BirdLife International (n.d.).

Figure 3-22: East Asian–Australasian Flyway

3.3.6.2 Biologically Important Areas and Critical Habitats

A number of BIAs for birds overlap the Project Area and the EMBA beyond the Project Area. These are summarised in **Table 3-15**. No critical habitats for birds were identified within the EMBA.

Two BIAs for birds overlap the Project Area, both of which are centred on Bedout Island:

+ a brown booby breeding BIA; and
+ a lesser frigatebird breeding BIA.

The brown booby breeding BIA is centred on Bedout Island (9,576 breeding pairs), which is recognised as one of several offshore islands in the Pilbara and Kimberley regions where this species breeds, including the Lacepede Islands (17,670 breeding pairs), Adele island (7,500 breeding pairs) and White island (4,000 to 5,000 breeding pairs) (Marchant and Higgins 1990 cited in Department of Agriculture, Water and the Environment n.d.). Breeding may be protracted, with egg laying recorded throughout the year at many locations (Marchant and Higgins 1990 cited in DSEWPaC 2012d). Brown boobies may forage widely around nesting islands while breeding (57 km on average, with a standard error of 22 km) and may undertake extensive migrations during non-breeding periods (Miller et al. 2018). Based on this range, brown boobies nesting on Bedout Island may forage in the Project Area and around the proposed WHP and FPSO locations, as well as future tiebacks if a second WHP is installed.

The lesser frigatebird breeding BIA is also centred on Bedout Island. Counts of nesting lesser frigatebirds on Bedout Island observed over 2,000 nesting pairs in June (Burbidge et al. 1987). Breeding at other sites (Ashmore Reef) spans from April to October (Clarke et al. 2011), and the species has a protracted breeding and rearing season due to the relatively high level of parental care for the young. Thus, breeding at Bedout Island may follow similar temporal patterns. Tagging of nesting lesser frigatebirds at Ashmore Reef showed foraging trips from nesting locations were on average 123.2 km, with a standard error of 10.4 km. Based on this range, lesser frigatebirds nesting on Bedout Island may forage in the Project Area and around the proposed WHP and FPSO locations, as well as future tiebacks if these require an additional WHP to be installed.

Table 3-15: Closest BIAs for birds within the EMBA

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
Anous stolidus	Common Noddy	Foraging (provisioning young) – Around Houtman Abrolhos Islands.	1,135
		Foraging – Around Lancelin Island.	1,311
Anous tenuirostris melanops	Australian Lesser Noddy	Foraging (provisioning young) – Houtman Abrolhos Islands.	1,151
Ardenna carneipes	Flesh-footed Shearwater	Aggregation – Foraging from Cape Naturaliste to Eyre, 1 to 150 km offshore. Predeparture zone in some years from Rottnest Island to Bunbury.	1,469
		Foraging (in high numbers) – Foraging from Cape Naturaliste to Eyre, 1 to	1,651

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
		150 km offshore. Predeparture zone in some years from Rottnest Island to Bunbury.	
Ardenna pacifica	Wedge-tailed Shearwater	Breeding – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef. Breeding presence may occur between mid-August to April (Pilbara) or to mid-May (Shark Bay).	45
		Foraging (in high numbers) – Breeding (in hundreds of thousands) off west coast from Ashmore Reef to Carnac Island.	982
Eudyptula minor	Little Penguin	Foraging (provisioning young) – Perth to Bunbury.	1,469
		Foraging (provisioning young) – Southwest Western Australia from Augusta to Twilight Cove.	1,732
Fregata ariel	Lesser Frigatebird	Breeding – Kimberley and Pilbara coasts and islands, also Ashmore Reef. Breeding season March to September.	0
Fregata minor	Greater Frigatebird	Breeding – Kimberley and Ashmore Reef.	498
Hydroprogne caspia	Caspian Tern	Foraging (provisioning young) – In Western Australia found on most coasts, mainly islands (as far offshore as Adele, Bedout, Trimouille and the Houtman Abrolhos) and at Lake Argyle, Lake Gregory and Lake MacLeod; accidental elsewhere in the interior.	1,085
Larus pacificus	Pacific Gull	Foraging (in high numbers) – West coast and islands from Point Quobba (24° 30’ S) south to Wedge I. (formerly south to Warnbro Sound and at Cape Naturaliste); casual further north (Point Cloates and Lake MacLeod).	1,140
Onychoprion anaethetus	Bridled Tern	Foraging (in high numbers) – West coast of Western Australia and around to Recherche Archipelago including offshore waters. Breeding season, late September to late February/early May.	982
Onychoprion fuscatus	Sooty Tern	Foraging – Timor Sea south to 14° 30' S, off northwest coast from Lacepede Island southwest to 117° E including Abrolhos,	1,006

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
		Fisherman and Lancelin Islands; accidental on lower west coast to Hamelin Bay. Breeding visitor (late Augustto early May) Abrolhos & Lancelin Islands; casual winter (November to April) to Fisherman Island.	
Pelagodroma marina	White-faced Storm petrel	Foraging (in high numbers) – Offshore areas of the South-west Marine Region and into the adjacent South-east Marine Region and the North-west Marine Region to north of Shark Bay.	1,076
Phaethon lepturus	White-tailed Tropicbird	Breeding – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef. Breeding recorded between May and October.	47
Pterodroma macroptera	Great-winged Petrel (macroptera race)	Foraging (provisioning young) – Offshore south of Shark Bay, extending around southwest corner of Western Australia and east past Kangaroo Island.	1,646
Pterodroma mollis	Soft-plumaged Petrel	Foraging (in high numbers) – In Western Australia, found in seas north to 21° 30ˈ S.	1,223
Puffinus assimilis tunneyi	Little Shearwater	Foraging (in high numbers) – From Kalbarri to Eucla including offshore waters.	1,036
Sterna dougallii	Roseate Tern	Breeding – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef. Breeding presence may occur mid- March to July.	41
		Resting – Eighty Mile Beach (northern end).	265
		Breeding – North East and North West Twin islands near the mouth of King Sound.	520
		Foraging (provisioning young) – Northwestern and west coasts and islands from Sir Graham Moore Island (13° 50’ S), south to Mandurah (32° 32’ S) and as far offshore as Ashmore Reef, Bedout Island and the Houtman Abrolhos.	1,123
		Foraging – Northwestern and west coasts and islands from Sir Graham Moore Island (13° 50’ S), south to Mandurah (32° 32’ S)	1,258

Species Name	Common Name	Biologically Important Behaviour	Shortest Distance from WHP (km)
		and as far offshore as Ashmore Reef, Bedout Island and the Houtman Abrolhos.	
Sternula albifrons sinensis	Little Tern	Resting – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef.	140
		Breeding – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef. Breeding has been recorded June to October.	149
		Resting – Roebuck Bay Ramsar site.	365
Sternula nereis	Fairy Tern	Breeding – Pilbara and Gascoyne coasts and islands. Breeding may occur late July to September.	235
		Foraging (in high numbers) – Found in the vicinity of lower northwest coast (north to Dampier Archipelago), west coast (south to Peel Inlet) and south coast (from Flinders Bay east to Israelite Bay), including islands as far offshore as Trimouille Island and Houtman Abrolhos Islands.	1,124
Sula leucogaster	Brown Booby	Breeding – Kimberley and northern Pilbara coasts and islands, also Ashmore Reef. Breeding presence may occur February to October.	19
Sula sula	Red-footed Booby	Breeding – Northwest Kimberley and Ashmore Reef. Females lay a single egg every 15 months.	498
Thalassarche chlororhynchos bassi	Indian Yellow-nosed Albatross	Foraging (in high numbers) – Throughout offshore waters of South-west Marine Region, north to Shark Bay and extending east into Bass Strait.	1,737
Thalasseus bengalensis	Lesser Crested Tern	Breeding – Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef. Breeding may occur March to June.	39

3.3.6.3 Conservation Advice and Recovery Plans

Material published by the Commonwealth under the EPBC Act for the conservation of threatened birds, such as recovery plans, conservation advice, and threat abatement plans, is summarised in **Table 3-16**. Threats identified in this material that may credibly arise from Dorado Phase 1 are also listed, along with cross-references to the relevant assessment of environmental impacts and risks in **Section 7**.

In addition to conservation advice and recovery plans for threatened birds, the Commonwealth has also published the Wildlife conservation plan for migratory shorebirds (Commonwealth of Australia 2015c). While this plan considers birds that are listed as migratory, many of the migratory birds considered in this plan are also listed as threatened under the EPBC Act. The plan applies to many species of migratory birds, of which several were identified as potentially occurring within the EMBA. The plan identified habitat modification by acute pollution, such as an oil spill, as a threat to migratory birds. The risk of an oil spill to birds, including migratory birds, is considered in **Section 7.3.1**. No other threats identified in the plan were considered to credibly arise from Dorado Phase 1.

Table 3-16: Summary of material published by the Commonwealth for the conservation of threatened birds relevant to Dorado Phase 1

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
-	All bird species	Threat abatement plan for the impacts of marine debris on vertebrate marine life (Commonwealth of Australia 2018)	Marine debris	**Section 7.3.2**
-	Seabirds and Migratory Shorebirds	National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (DOEE 2020)	Light pollution	**Section 7.3.2**
			Habitat degradation / modification	**Section 7.3.1**
			Climate change	**Section 7.2.6**
-	Seabirds	Draft Wildlife Conservation Plan for Seabirds (DoEE 2019)	Habitat degradation / modification	**Section 7.3.1**
			Invasive species	**Section 7.3.3**
			Climate change	**Section 7.2.6**
			Marine debris	**Section 7.3.1**
			Light pollution	**Section 7.2.4**
			Water pollution	**Section 7.2.3**
-	Migratory Shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (DoE 2015)	Habitat degradation / modification	**Section 7.3.1**
			Anthropogenic disturbance	**Section 7.3.1**
			Climate change	**Section 7.2.6**
Diomedea amsterdamensis	Amsterdam Albatross	National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)	Pollution (oil spill)	**Section 7.3.1,**

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
Diomedea dabbenena	Tristan Albatross			
Diomedea epomophora	Southern Royal Albatross			
Diomedea exulans	Wandering Albatross			
Diomedea sanfordi	Northern Royal Albatross		Parasites and disease	**Section 7.3.3**
Macronectes giganteus	Southern Giant-Petrel, Southern Giant Petrel			
Macronectes halli	Northern Giant Petrel			
Phoebetria fusca	Sooty Albatross			
Thalassarche carteri	Indian Yellow-nosed Albatross			
Thalassarche cauta cauta	Shy Albatross		Climate change	**Section 7.2.6**
Thalassarche cauta steadi	White-capped Albatross			
Thalassarche impavida	Campbell Albatross, Campbell Black-browed Albatross			

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
Thalassarche melanophris	Black-browed Albatross			
Anous tenuirostris melanops	Australian Lesser Noddy	Conservation advice Anous tenuirostris melanops Australian lesser noddy (Threatened Species Scientific Committee 2015e)	Habitat degradation / modification	**Section 7.3.1**
Calidris canutus	Red Knot	Conservation Advice Red Knot (Calidris canutus) (DOE 2016)	Habitat degradation / modification	**Section 7.3.1**
			Pollution / contamination	**Section 7.2.3**
			Anthropogenic disturbance	**Section 7.3.1**
			Direct mortality (bird strike – helicopters, chemical spills and oil spills)	**Section 7.3.1, 7.3.4**
			Climate change	**Section 7.2.6**
Calidris ferruginea	Curlew Sandpiper	Conservation advice Calidris ferruginea curlew sandpiper (Threatened Species Scientific Committee 2015f)	Acute pollution	**Section 7.2.3**
Calidris tenuirostris	Great Knot	Conservation advice Calidris tenuirostris great knot (Threatened Species Scientific Committee 2016a)	Habitat degradation / modification	**Section 7.3.1**
Cereopsis novaehollandiae grisea	Cape Barren Goose	Approved Conservation Advice for Cereopsis novaehollandiae grisea (Cape Barren Goose (south-western)) (DEWHA 2008)	Habitat degradation / modification	**Section 7.3.1**
			Disease	**Section 7.3.3**
Charadrius leschenaultii	Greater Sand Plover, Large Sand Plover	Conservation advice Charadrius leschenaultii greater sand plover (Threatened Species Scientific Committee 2016b)	Habitat degradation / modification	**Section 7.3.1**

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
Charadrius mongolus	Lesser Sand Plover, Mongolian Plover	Conservation Advice Charadrius mongolus lesser sand plover (Threatened Species Scientific Committee 2016c)	Habitat degradation / modification	**Section 7.3.1**
Halobaena caerulea	Blue Petrel	Conservation advice Halobaena caerulea blue petrel (Threatened Species Scientific Committee 2015g)	Habitat degradation / modification	**Section 7.3.1**
Limosa lapponica baueri	Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit	Conservation advice Limosa lapponica baueri bar-tailed godwit (western Alaskan) (Threatened Species Scientific Committee 2016d)	Habitat degradation / modification	**Section 7.3.1**
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri)	Conservation advice Limosa lapponica menzbieri bar-tailed godwit (northern Siberian) (Threatened Species Scientific Committee 2016e)	Habitat degradation / modification	**Section 7.3.1**
Fregata andrewsi	Christmas Island Frigatebird, Andrew's Frigatebird	Conservation advice Fregata andrewsi Christmas Island frigatebird	Habitat degradation / modification	**Section 7.3.1**
			Disease	**Section 7.3.3**
			Pollution	**Section 7.2.3**
			Marine debris	**Section 7.3.1,**
Numenius madagascariensis	Eastern Curlew	Conservation Advice for Numenius madagascariensis (Eastern Curlew) (DoE 2015)	Habitat degradation / modification	**Section 7.3.1**
Pachyptila turtur subantarctica	Fairy Prion (southern)	Conservation advice Pachyptila tutur subantarctica fairy prion (southern) (Threatened Species Scientific Committee 2015h)	Habitat degradation / modification	**Section 7.3.1**
Papasula abbotti	Abbott’s Booby		Climate change	**Section 7.2.6**

Santos

Scientific Name	Common Name	Recovery Plan / Conservation Advice	Credible Threats arising from Dorado Development identified in Plan / Advice	Relevant Assessment of Impacts and Risks
		Conservation Advice for the Abbott's Booby - Papasula abbotti (DAWE 2020)	Disease	**Section 7.3.3**
			Marine debris	**Section 7.3.1**
Pezoporus flaviventris	Western Ground Parrot, Kyloring	Approved Conservation Advice for Pezoporus wallicus flaviventris (Western Ground Parrot) (DSEWPC, 2013e)	Habitat degradation / modification (oil spill)	**Section 7.3.1**
Phaethon lepturus fulvus	Christmas Island White-tailed Tropicbird, Golden Bosunbird	Conservation advice Phaethon lepturus fulvus white-tailed tropicbird (Christmas Island) (Threatened Species Scientific Committee 2014c)	Habitat degradation / modification (oil spill)	**Section 7.3.1**
Pterodroma mollis	Soft-plumaged Petrel	Conservation advice Pterodroma mollis soft-plumage petrel (Threatened Species Scientific Committee 2015i)	Habitat degradation / modification	**Section 7.3.1**
Rostratula australis	Australian Painted Snipe	Approved conservation advice for Rostratula australis (Australian painted snipe) (Threatened Species Scientific Committee 2013)	Habitat degradation / modification	**Section 7.3.1**
Sternula nereis nereis	Australian Fairy Tern	Conservation advice for Sterna nereis nereis (Fairy tern) (Threatened Species Scientific Committee 2011)	Habitat degradation / modification (marine pollution)	**Section 7.3.1**
Thalassarche cauta	Shy Albatross	Conservation Advice Thalassarche cauta Shy Albatross (DAWE 2020)	Climate change	**Section 7.2.6**
			Disease	**ection 7.3.3**
			Marine debris	**Section 7.2.3**

Santos

3.4 Socio-economic Environment

3.4.1 Regional Centres

The nearest town to the Project Area is Port Hedland, which lies approximately 145 km south of the WHP. Other notable coastal population centres in the Pilbara and Kimberley regions are Dampier (280 km from the WHP) and Broome (387 km from the WHP). These population centres for the region provide important services for mining, offshore petroleum, tourism and fishing industries.

3.4.2 Protected Areas

A number of areas in the EMBA are protected under Commonwealth and Western Australian legislation. These include:

+ Commonwealth AMPs;
+ Western Australian marine protected areas;
+ Western Australian terrestrial protected areas; and
+ wetlands of international importance (Ramsar wetlands).

These areas are shown in **Figure 3-23** and **Figure 3-24.**

A number of heritage sites were also identified within the EMBA. Many of these lie within protected areas (e.g. WHAs). Heritage sites are described in **Section 3.4.4**.

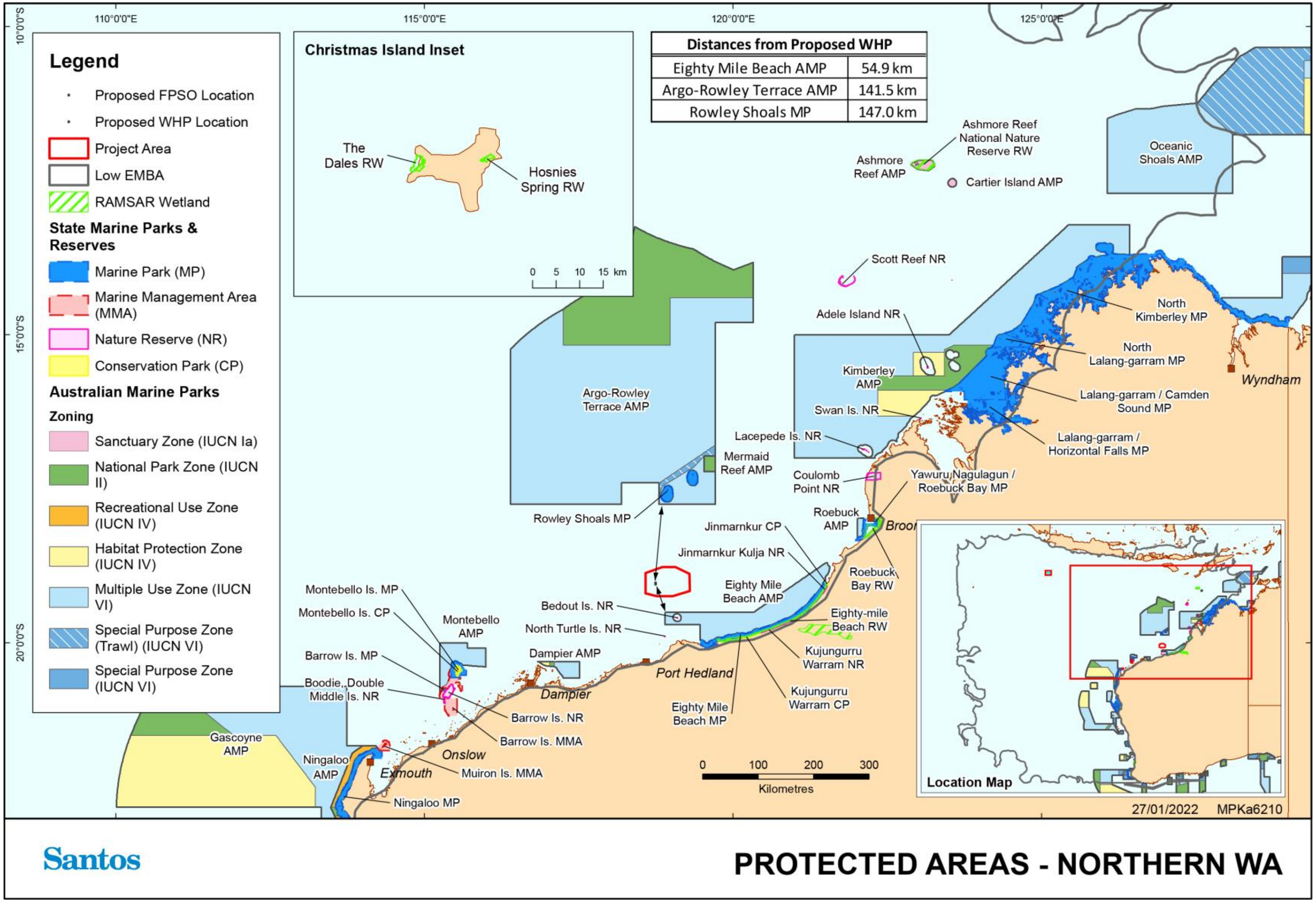


Figure 3-23: Protected areas that overlap the EMBA within Northern WA

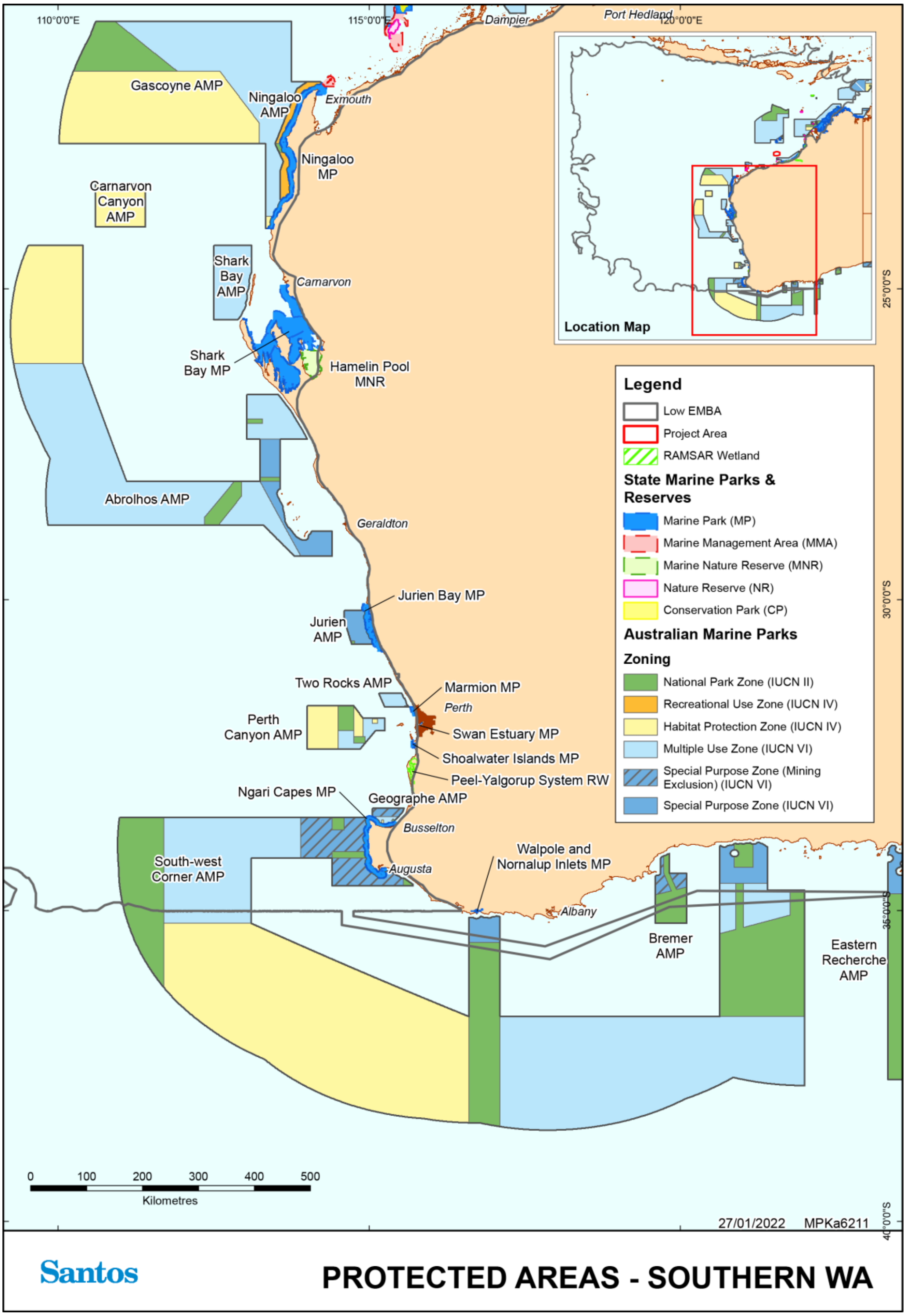


Figure 3-24: Protected areas that overlap the EMBA within Southern WA

3.4.2.1 Australian Marine Parks

In November 2012, the Commonwealth Marine Reserves Network was proclaimed under the EPBC Act with the purpose of protecting the biological diversity and sustainable use of the marine environment (Director of National Parks 2012). A series of AMPs were established within each of the six marine regions - the Coral Sea, the South-west, the Temperate East, the South-east, the North, and the North-west. Each AMP is managed under a marine region–based management plan.

The EPBC Act requires each management plan to assign an IUCN category to each marine park. Additionally, the Act also allows for the management plan to divide a marine park into zones and to assign a category to each zone, which may differ from the overall category of the marine park. Zoning considers the purposes for which the marine parks were declared, the objectives of the relevant management plans, the values of the marine park, and the requirements of the EPBC Act and EPBC Regulations.

The Project Area does not overlap any AMPs; however, the EMBA overlaps a number of them. Summaries of the environmental values of these AMPs, along with their distance from the WHP, are provided in **Table 3-17**.

Table 3-17: Summary of environmental values and sensitivities of AMPs within the EMBA (Director of National Parks 2018a, 2018b)

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
Eighty Mile Beach	55/ 29	VI - Multiple Use Zone (100%)	+ Breeding, foraging and resting habitat for seabirds (one of the world's most important feeding grounds for migratory shorebirds and waders and is listed under the Ramsar Convention); + Internesting and nesting habitat for marine turtles (it supports a significant nesting population of flatback turtles, which are endemic to northern Australia); + Foraging, nursing and pupping habitat for sawfish; + Migratory pathway for humpback whales; + Coastal waters provide critical habitat for several shark and ray species at varying life stages; + The Nyangumarta, Karajarri and Ngarla people's sea country extends into Eighty Mile Beach Marine Park. Access to sea country by families is important for cultural traditions, livelihoods and future socio-economic development opportunities; and + Three known shipwrecks listed under the *Underwater Cultural Heritage Act 2018*: *Lorna Doone* (wrecked in 1923), *Nellie* (wrecked in 1908), and *Tifera* (wrecked in 1923).	The marine park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province; its shallow shelf habitats include terraces, banks and shoals. The marine park is adjacent to the Eighty Mile Beach Ramsar site, recognised as one of the most important areas for migratory shorebirds in Australia, and the Western Australian Eighty Mile Beach Marine Park, providing connectivity between offshore and inshore coastal waters of Eighty Mile Beach.
Argo-Rowley Terrace	142/ 113	II - National Park Zone (25%) VI - Multiple Use Zone (75%)	+ Foraging areas that are important for migratory seabirds, as well as the endangered loggerhead turtle; + Important habitat and foraging for sharks; + Migratory pathway for pygmy blue whales;	The Argo–Rowley Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Transition and Timor Province. It includes two key ecological features: canyons linking the Argo Abyssal Plain with the Scott Plateau (valued for high productivity and aggregations of

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
		VI - Special Purpose Zone (Trawl) (1%)	+ Protection for communities and habitats of the deeper offshore waters (220 m to over 5,000 m) of the region; + Seafloor features, including aprons and fans, canyons, continental rise, knolls or abyssal hills, and the terrace and continental slope; + Communities and seafloor habitats of the Northwest Transition and Timor Province provincial bioregions; + Connectivity between the existing Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park and the deeper waters of the region; + Two KEFs in the reserve include: The canyons linking the Argo Abyssal Plain with the Scott Plateau (unique seafloor feature with enhanced productivity and feeding aggregations of species); and + Mermaid Reef and the Commonwealth waters surrounding Rowley Shoals (an area of high biodiversity with enhanced productivity and feeding and breeding aggregations).	marine life) and Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (valued for enhanced productivity, aggregations of marine life and high species richness). The marine park is the largest in the North-west Network, surrounding the existing Mermaid Reef Marine Park and reefs of the Western Australian Rowley Shoals Marine Park. It includes the deeper waters of the region and a range of seafloor features, such as canyons on the slope between the Argo Abyssal Plain, Rowley Terrace and Scott Plateau. These are believed to be up to 50 million years old and are associated with small, periodic upwellings that result in localised higher levels of biological productivity.
Dampier	191/ 166	II - National Park Zone (6%) IV - Habitat Protection Zone (8%) VI - Multiple Use Zone (86%)	+ Foraging areas for migratory seabirds that are adjacent to important breeding grounds; + Important foraging areas for marine turtles adjacent to significant nesting sites; + Part of the migratory pathway of the protected humpback whale; + Protection for offshore shelf habitats and shallow shelf habitats adjacent to the Dampier Archipelago; and	The Dampier Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. The marine park provides protection for offshore shelf habitats adjacent to the Dampier Archipelago, as well as the area between Dampier and Port Hedland, and is a hotspot for sponge biodiversity. The marine park contains several submerged coral reefs and shoals, including Delambre Reef and Tessa Shoals.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Includes communities and seafloor habitats of the Northwest Shelf Province provincial bioregion, as well as the Pilbara (nearshore) and Pilbara (offshore) mesoscale bioregions.	
Mermaid Reef	217/ 179	II - National Park Zone (100%)	+ Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF is valued for its high productivity, aggregations of marine life and high species richness; + Mermaid Reef, Clerke Reef and Imperieuse Reef are biodiversity hotspots and key topographic features of the Argo Abyssal Plain; + Rowley Shoals present some of the best geological examples of shelf atolls in Australian waters and are ecologically significant in that they are considered ecological steppingstones for reef species originating in Indonesian/western Pacific waters, are one of a few offshore reef systems on the North West Shelf, and may also provide an upstream source for recruitment to reefs further south; + Breeding habitat for seabirds; + Migratory pathway for the pygmy blue whale; and + One known shipwreck listed under the *Underwater Cultural Heritage Act 2018*: Lively (wrecked in 1810).	The marine park is significant because it contains habitats, species and ecological communities associated with the Northwest Transition and includes one KEF. Mermaid Reef is one of three reefs forming the Rowley Shoals; the others are Clerke Reef and Imperieuse Reef and occur to the southwest of the marine park. The Rowley Shoals have been described as the best geological examples of shelf atolls in Australian waters. The reefs of the Rowley Shoals are ecologically significant in that they are considered ecological stepping stones for reef species originating in Indonesian/western Pacific waters, are one of a few offshore reef systems on the North West Shelf, and may also provide an upstream source for recruitment to reefs further south.
Montebello	311/ 288	VI - Multiple Use Zone (100%)	+ Foraging areas for migratory seabirds that are adjacent to important breeding areas; + Areas used by vulnerable and migratory whale sharks for foraging;	The Montebello Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. The marine park includes one KEF, the ancient coastline at the 125-m depth contour. The marine park provides connectivity between deeper waters of the continental shelf and slope

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Foraging areas for marine turtles that are adjacent to important nesting sites; + Section of the north- and southbound migratory pathway of the humpback whale; + Shallow shelf environments with depths ranging from 15 to 150 m that provide protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features; + Seafloor habitats and communities of the Northwest Shelf Province provincial bioregion as well as the Pilbara (offshore) mesoscale bioregion; and + One KEF for the region is the ancient coastline at 125-m depth contour (a unique seafloor feature that provides areas of enhanced biological productivity).	and the adjacent Western Australian Barrow Island and Montebello Islands marine parks. A prominent seafloor feature in the marine park is Trial Rocks, which has two close coral reefs; these reefs are emergent at low tide.
Kimberley	328/ 275	II - National Park Zone (9%) IV - Habitat Protection Zone (8%) VI - Multiple Use Zone (84%)	+ Diverse benthic and pelagic fish communities; + Migratory pathway for humpback whales; + High levels of species diversity; + Reefs and islands of the bioregion are regarded as biodiversity hotspots; + High endemism in demersal fish communities of the continental slop (two distinct communities have been identified on the upper and mid slopes); + Ancient coastline at the 125 m depth contour where rocky escarpments are thought to provide biologically important habitats in areas otherwise dominated by soft sediments;	The Kimberley Marine Park is significant because it includes habitats, species and ecological communities associated with the Northwest Shelf Province, Northwest Shelf Transition and Timor Province and includes two KEFs. The marine park provides connectivity between deeper offshore waters and the inshore waters of the adjacent Western Australian North Kimberley and Lalang-garram/Camden Sound Marine Parks.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Continental slope demersal fish communities characterised by high diversity of demersal fish assemblages; + Breeding and foraging habitat for seabirds; + Internesting and nesting habitat for marine turtles; + Breeding, calving and foraging habitat for inshore dolphins; + Calving, migratory pathway and nursing habitat for humpback whales; + Migratory pathway for pygmy blue whales; + Foraging habitat for dugong and whale sharks; + The Wunambal Gaambera, Dambimangari, Mayala, Bardi Jawi and the Nyul Nyul people's sea country extends into the Kimberley Marine Park. Access to sea country by families is important for cultural traditions, livelihoods and future socio-economic development opportunities, and + More than 40 known shipwrecks listed under the *Underwater Cultural Heritage Act 2018*.	
Roebuck	356/ 295	VI - Multiple Use Zone (100%)	+ Foraging habitat area for migratory seabirds adjacent to important breeding areas; + Foraging area adjacent to important nesting sites for flatback turtles; + Parts of the migratory pathway of the protected humpback whale; + Habitat adjacent to important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish;	The marine park includes examples of ecosystems representative of the Northwest Shelf Province—a dynamic environment influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities ancient coastline thought to be an important seafloor feature, and migratory pathway for humpback whales. The marine park supports a range of species, including species listed as threatened,

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Foraging and calving areas for Australian snubfin, Indo-Pacific humpback and Indo-Pacific bottlenose dolphins; + Foraging habitat for dugong; + Protection for shallow shelf habitats ranging in depth from 15 to 70 m; + Ecosystem examples of the Northwest Shelf Province provincial bioregion and the Canning mesoscale bioregion, and + Sea country valued for indigenous cultural identity, health and well-being for the Yawuru people.	migratory, marine or cetacean under the EPBC Act. Biologically important areas within the marine park include breeding and resting habitat for seabirds, foraging and internesting habitat for marine turtles, a migratory pathway for humpback whales, and foraging habitat for dugong.
Gascoyne	555/ 532	II - National Park Zone (11%) IV - Habitat Protection Zone (48%) VI - Multiple Use Zone (41%)	+ Important foraging areas for: migratory seabirds, threatened and migratory hawksbills and flatback turtles, and vulnerable and migratory whale shark; + A continuous connectivity corridor from shallow depths around 15 m out to deep offshore waters on the abyssal plain at over 5,000 m in depth; + Seafloor features including canyon, terrace, ridge, knolls, deep hole/valley and continental rise. It also provides protection for sponge gardens in the south of the reserve adjacent to Western Australian coastal waters; + Ecosystems examples from the Central Western Shelf Transition, the Central Western Transition and the Northwest Province provincial bioregions, as well as the Ningaloo mesoscale bioregion; + Four KEFs for the region:	The Gascoyne Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, and Northwest Province and includes four KEFs. The marine park includes some of the most diverse continental slope habitats in Australia, in particular the continental slope area between the North West Cape and the Montebello Trough. Canyons in the marine park link the Cuvier Abyssal Plain to the Cape Range Peninsula and are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (enhanced productivity, aggregations of marine life and unique sea-floor feature); Exmouth Plateau (unique sea-floor feature associated with internal wave generation); Continental slope demersal fish communities (high species diversity and endemism – the most diverse slope bioregion in Australia with over 500 species found with over 64 of those species occurring nowhere else); and + Commonwealth waters adjacent to Ningaloo Reef.	
Ningaloo	555/ 532	II - National Park Zone (5%) IV - Recreational Use Zone (95%)	+ Important habitat (foraging areas) for vulnerable and migratory whale sharks; + Areas used for foraging by marine turtles adjacent to important internesting sites; + Part of the migratory pathway of the protected humpback whale; + Foraging and migratory pathway for pygmy blue whales; + Breeding, calving, foraging and nursing habitat for dugong; + Shallow shelf environments that provide protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features; + Seafloor habitats and communities of the Central Western Shelf Transition; + Three KEFs; and	The Ningaloo Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, Northwest Province, and Northwest Shelf Province and contains three KEFs. The marine park provides connectivity between deeper offshore waters of the shelf break and shallower coastal waters. It includes some of the most diverse continental slope habitats in Australia, in particular the continental slope area between the North West Cape and the Montebello Trough. Canyons in the Marine Park are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef. The marine park is located in a transition zone between tropical and temperate waters and sustains tropical and temperate flora and fauna, with many species at the limits of their distributions.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ The Ningaloo Coast World Heritage Property, the Ningaloo Coast National Heritage listing and the Ningaloo Marine Area Commonwealth Heritage Listing.	
Shark Bay	825/ 800	VI - Multiple Use Zone (100%)	+ Foraging areas adjacent to important breeding areas for several species of migratory seabirds; + Part of the migratory pathway of protected humpback whales; + Internesting habitat for marine turtles; + Waters that are adjacent to the largest nesting area for loggerhead turtles in Australia; + Marine park and adjacent coastal areas important for shallow-water snapper; + Protection to shelf and slope habitats, as well as a terrace feature; + Examples of the shallower ecosystems of the Central Western Shelf Province and Central Western Transition provincial bioregions, including the Zuytdorp mesoscale bioregion; and + Connectivity between the inshore waters of the Shark Bay WHA and the deeper waters of the area.	The Shark Bay Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Province and Central Western Transition. The marine park provides connectivity between deeper Commonwealth waters and the inshore waters of the Shark Bay world heritage property.
Ashmore Reef	873/ 830	Ia - Sanctuary Zone (94%) IV - Recreational Use Zone (6%)	+ Ecosystems, habitats and communities associated with; the NWS, Timor Province, and emergent oceanic reefs; + Nesting and internesting habitat for green turtles (including one of three genetically distinct breeding populations in the North-west Marine Region). Low-level nesting activity by loggerhead turtles has also been recorded;	The Ashmore Reef Marine Park is significant because it includes habitats, species and ecological communities associated with the Timor Province. It includes two key ecological features: Ashmore Reef and Cartier Island and surrounding Commonwealth waters (valued for high productivity and breeding aggregations of birds and other marine life); and continental slope demersal fish

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Populations of green, hawksbill and loggerhead turtles occur around the reefs (it is estimated that approximately 11,000 marine turtles feed in the area throughout the year); + Supports a small dugong population of less than 50 individuals that breed and feed around the reef. This population is thought to be genetically distinct from other Australian populations; + Migratory pathway for pygmy blue whales; + Important seabird rookeries on the NWS, including colonies of bridled terns, common noddies, brown boobies, eastern reef egrets, frigatebirds, tropicbirds, red-footed boobies, roseate terns, crested terns and lesser crested terns; + important staging point or feeding area for many migratory seabirds; + significant for its abundance and diversity of sea snakes; + Two KEFs: Ashmore Reef and Cartier Island and surrounding Commonwealth waters; and Continental slope demersal fish communities; + Cultural and heritage sites, including; Ashmore lagoon as a rest/staging area for traditional Indonesian fishers; Indonesian artefacts; and Grave sites; and.	communities (valued for high levels of endemism). Ashmore Reef is the largest of three emergent oceanic reefs in the region and the only one with vegetated islands. The marine park is an area of enhanced biological productivity and a biodiversity hotspot supporting a range of pelagic and benthic marine species and an important biological stepping stone facilitating the transport of biological material to the reef systems along the Western Australian coast via the south-flowing Leeuwin Current, which originates in the region. The Ashmore Reef Ramsar site is located within the boundary of the marine park. The site was listed under the Ramsar Convention in 2002 and is a wetland of international importance under the EPBC Act. An ecological character description that sets out the Ramsar listing criteria met by the site, the key threats and the knowledge gaps is available on the DAWE's website.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Commonwealth heritage listing – Ashmore Reef.	
Carnarvon Canyon	899/ 847	IV - Habitat Protection Zone (100%)	+ A single channel canyon with seabed features that include slope, continental rise and deep holes and valleys; + Ranges in depth from 1,500 to 5,000 m, thereby providing habitat diversity for benthic and demersal species; and + Contains Central Western Transition provincial bioregion ecosystem examples, which are characteristic of the biogeographic faunal transition between tropical and temperate species.	The Carnarvon Canyon Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Transition. This includes deepwater ecosystems associated with the Carnarvon Canyon. The marine park lies within a transition zone between tropical and temperate species and is an area of high biotic productivity.
Oceanic Shoals Marine Park	1060/ 1150	Multiple Use Zone - IUCN Category VI (57%) Special Purpose Zone – IUCN VI (43%)	The marine park protects the following conservation values (DoE 2014): + Important resting area for turtles between egg laying (internesting area) for the threatened flatback turtle and olive ridley turtle; + Important foraging area for the threatened loggerhead turtle and olive ridley turtle; + Examples of the ecosystems of two provincial bioregions: the Northwest Shelf Transition Province (which includes the Bonaparte, Oceanic Shoals, and Tiwi meso-scale bioregions) and the Timor Transition Province; + KEFs represented in the park are (Director of National Parks 2018c): – Carbonate bank and terrace system of the Van Diemen Rise (unique sea-floor feature);	The Oceanic Shoals Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Transition. It contains four key ecological features: carbonate bank and terrace systems of the Van Diemen Rise; carbonate bank and terrace systems of the Sahul Shelf; pinnacles of the Bonaparte Basin; and shelf break and slope of the Arafura Shelf (all valued as unique seafloor features with ecological properties of regional significance). The Marine Park is the largest marine park in the North Network.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			– Carbonate banks and terrace system of the Sahul Shelf (unique sea-floor feature); – Pinnacles of the Bonaparte Basin (enhanced productivity, unique sea-floor feature); and – Shelf break and slope of the Arafura Shelf (unique sea-floor feature). No heritage listings apply to the marine park. Commercial fishing and mining are important socio-economic values for the park (Director of National Parks 2018c). A spatial predictive benthic habitat model of the Oceanic Shoals Marine Park has been developed by AIMS, as part of the Australian National Environmental Science Programme, to determine the spatial heterogeneity of the benthic environment and key classes of organisms within the reserve. The benthic habitat model maps the 10 broad classes of benthic organisms; alcyons, gorgonians, soft corals, hard corals, halimeda, macroalgae, seagrass, filterers (e.g. sponges), burrowers (e.g. sea urchins) and no biota detected (Radford and Puotinen 2016).	
Abrolhos	1,003/ 1,019	IV - Habitat Protection Zone (26%) II - National Park Zone (3%) VI - Multiple Use Zone (64%)	+ Important foraging areas for the: - Threatened Australian lesser noddy; - Northernmost breeding colony of the threatened Australian sea lion; - Great white shark; and - Migratory common noddy, wedge-tailed shearwater, bridled tern, Caspian tern and roseate tern. + Important migration habitat for the protected humpback whale and pygmy blue whales;	The Abrolhos Marine Park is significant because it contains habitats, species and ecological communities associated with four bioregions: Central Western Province; Central Western Shelf Province; Central Western Transition; and South-west Shelf Transition. It includes seven KEFs: the Commonwealth marine environment surrounding the Houtman Abrolhos Islands (valued for high levels of biodiversity and endemism); western demersal slope and associated fish communities (in the Central Western Province and valued as a species group that is nationally or regionally important to

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
		VI - Special Purpose Zone (7%)	+ The second largest canyon on the west coast, the Houtman Canyon; + Examples of the northernmost ecosystems of the Central Western Province and South-west Shelf Transition (including the Central West Coast mesoscale bioregion); + Examples of the deeper ecosystems of the Abrolhos Islands mesoscale bioregion; + Examples of the shallower, southernmost ecosystems of the Central Western Shelf Province provincial bioregion, including the Zuytdorp mesoscale bioregion; + Examples of the deeper ecosystems of the Central Western Transition provincial bioregion; + Examples of diversity of seafloor features, including southernmost banks and shoals of the North-west marine region; deep holes and valleys; slope habitats; terrace and shelf environments; and + Seven KEFs.	biodiversity); mesoscale eddies (valued for high productivity and aggregations of marine life); Perth Canyon and adjacent shelf break, and other west-coast canyons (valued for high biological productivity and aggregations of marine life and unique seafloor features with ecological properties of regional significance); western rock lobster (valued as a species that plays a regionally important ecological role); ancient coastline between 90 m and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism); and Wallaby Saddle (valued for high productivity and aggregations of marine life). The southern shelf component of the marine park partially surrounds the Western Australian Houtman Abrolhos Islands Nature Reserve. The islands and surrounding reefs are renowned for their high level of biodiversity, due to the southward movement of species by the Leeuwin Current. The marine park contains a number of seafloor features, including the Houtman Canyon, the second largest submarine canyon on the west coast (the Perth Canyon being the largest).
Jurien	1,294/ 1,272	II - National Park Zone (2%) VI - Special Purpose Zone (98%)	+ Important foraging areas for the: - Threatened soft-plumaged petrel; - Threatened Australian sea lion; - Threatened white shark; and - Migratory roseate tern, bridled tern, wedge-tailed shearwater, and common noddy.	The Jurien Marine Park is significant because it includes habitats, species and ecological communities associated with two bioregions: South-west Shelf Transition and Central Western Province. It includes three KEFs: ancient coastline between 90 and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism); demersal slope and associated fish communities of the Central

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Important migration habitat for the protected humpback whale; + Examples of the ecosystems of two provincial bioregions: the central part of the South-west Shelf Transition (which includes the Central West Coast mesoscale bioregion) and small parts of the Central Western Province; + Three KEFs; and + Heritage values represented by the *Cambewarra* and *Oleander* historic shipwrecks.	Western Province (valued as a species group that are nationally or regionally important to biodiversity); and western rock lobster (valued as a species that plays a regionally important ecological role). The marine park contains a mixture of tropical species carried south by the Leeuwin Current and temperate species carried north by the Capes Current. The marine park's shelf habitats are defined by distinct ridges of limestone reef with extensive beds of macroalgae. Inshore lagoons are inhabited by a diverse range of invertebrates and fish. Seagrass meadows occur in more sheltered areas, as well as in the inter-reef lagoons along exposed sections of the coast. The marine park includes habitats connecting to and complementing the adjacent Western Australian Jurien Bay Marine Park.
Two Rocks	1,425/ 1,397	II - National Park Zone (2%) VI - Multiple Use Zone (98%)	+ Important foraging areas for the: - Threatened soft-plumaged petrel; - Threatened Australian sea lion; and - Migratory roseate tern, bridled tern, Caspian tern, wedge-tailed shearwater, and common noddy. + Important migratory areas for protected humpback whales and pygmy blue whales; + Seasonal calving habitat for the threatened southern right whale; + Examples of the ecosystem of the southernmost parts of the South-west Shelf Transition (including the Central West Coast mesoscale bioregion); and + Three KEFs.	The Two Rocks Marine Park is significant because it includes habitats, species and ecological communities associated with the South-west Shelf Transition. It includes three KEFs: the Commonwealth marine environment within and adjacent to the west-coast inshore lagoons (valued for high productivity and aggregations of marine life and high levels of biodiversity and endemism); western rock lobster (valued as a species that plays a regionally important ecological role); and ancient coastline between 90 m and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism). The marine park is shallow and provides connectivity between offshore waters and the west

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
				coast inshore lagoons, which are key areas for the recruitment of rock lobster and other commercially and recreationally important fish species.
Perth Canyon	1,460/ 1,437	IV - Habitat Protection Zone (59%) II - National Park Zone (17%) VI - Multiple Use Zone (25%)	+ Globally important seasonal feeding aggregation for the threatened blue whale; + Important foraging areas for the: - Threatened soft-plumaged petrel; - Migratory sperm whale; and - Migratory wedge-tailed shearwater. + Important migratory areas for protected humpback whales and blue whales; + Seasonal calving habitat for the threatened southern right whale; + Examples of the ecosystems of the southernmost parts of the Central Western Province and South-west Shelf Transition (including the Central West Coast mesoscale bioregion), and the northernmost parts of the South-west Transition and Southwest Shelf Province (including the Leeuwin-Naturaliste mesoscale bioregion); and + Four KEFs.	The Perth Canyon Marine Park is significant because it includes habitats, species and ecological communities associated with four bioregions: Central Western Province; South-west Shelf Province; Southwest Transition; and South-west Shelf Transition. It includes four key ecological features: Perth Canyon and adjacent shelf break, and other west-coast canyons (valued for high biological productivity and aggregations of marine life and unique seafloor features with ecological properties of regional significance); demersal slope and associated fish communities of the Central Western Province (valued as a species group that are nationally or regionally important to biodiversity); western rock lobster (valued as a species that plays a regionally important ecological role); and mesoscale eddies (valued for high productivity and aggregations of marine life). The marine park includes the majority of the Perth Canyon, Australia's largest submarine canyon, which is home to the largest feeding aggregations of blue whales in Australia. This unique feature is also of particular significance because it cuts into the continental shelf at approximately 150 m depth west of Rottnest Island, linking the shelf with deeper ecosystems at depths of up to 5,000 m. The Marine Park represents the southern end of the transition area from tropical to temperate marine environments.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
Geographe	1,627/ 1,596	IV - Habitat Protection Zone (2%) II - National Park Zone (2%) VI - Multiple Use Zone (30%) VI - Special Purpose Zone (Mining Exclusion) (67%)	+ Important foraging areas for the: - Threatened soft-plumaged petrel; and - Migratory wedge-tailed shearwater. + Important premigration aggregation area for the migratory flesh-footed shearwater; + Important migratory habitat for the protected humpback whale and blue whale; + Seasonal calving habitat for the threatened southern right whale. + Representation of the South-west Shelf Province on the continental shelf, as well as the Leeuwin-Naturaliste mesoscale bioregion; + Two KEFs; and + Representation of the seagrass habitats of the Geographe Bay KEF, which in this location extends the furthest into Commonwealth waters.	The Geographe Marine Park is significant because it contains habitats, species and ecological communities associated with the South-west Shelf Province. It includes two KEFs: the Commonwealth marine environment within and adjacent to Geographe Bay (valued for high productivity and aggregations of marine life and high levels of biodiversity and endemism); and western rock lobster (valued as a species that plays a regionally important ecological role). The marine park contains an area of high productivity supported by extensive and diverse seagrass beds that cover approximately 60% of Geographe Bay. Tropical and temperate seagrass species account for 80% of the benthic primary production in the area. These meadows provide habitat for fish and invertebrates. Geographe Bay provides important nursery habitat, resting areas and foraging habitats for sharks, whales and seabirds. The marine park includes habitats connecting to and complementing the adjacent Western Australian Ngari Capes Marine Park.
South-west Corner	1,647/ 1,625	IV - Habitat Protection Zone (35%) II - National Park Zone (20%) VI - Multiple Use Zone (39%)	+ Important migratory area for protected humpback whales and blue whales; + Important foraging areas for the: - Threatened white shark; - Threatened Australian sea lion; - Threatened Indian Yellow-nosed albatross and soft-plumaged petrel; - Sperm whale; and	The South-west Corner Marine Park is significant because it contains habitats, species and ecological communities associated with three bioregions: Southern Province; South-west Transition; and South-west Shelf Province. It includes six KEFs: Albany Canyon group and adjacent shelf break (valued for high productivity, aggregations of marine life and unique seafloor features with properties of regional significance); Cape Mentelle upwelling (valued for high productivity and aggregations

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
		VI - Special Purpose Zone (2%) VI - Special Purpose Zone (Mining Exclusion) (4%)	- Migratory flesh-footed shearwater, short-tailed shearwater and Caspian tern; + Seasonal calving habitat for the threatened southern right whale; + Representation of three provincial bioregions (the South-west Transition and Southern Province in the off-shelf area and the South-west Shelf Province on the continental shelf) and two mesoscale bioregions (southern end of the Leeuwin-Naturaliste mesoscale bioregion and western and central parts of the Western Australia South Coast mesoscale bioregion); + Representation of the Donnelly Banks, east of Augusta, characterised by higher productivity and including nursery habitats; and + Six KEFs.	of marine life); Diamantina Fracture Zone (valued as a unique seafloor feature with ecological properties of regional significance); Naturaliste Plateau (valued as a unique seafloor feature with ecological properties of regional significance); western rock lobster (valued as a species that plays a regionally important ecological role); and ancient coastline between 90 m and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism). As the largest marine park in the South-west Network, it contains a wide range of important ecosystems in both shallow and deep water, reaching abyssal depths, including the Diamantina Fracture Zone, Naturaliste Plateau and Donnelly Banks, along with many reefs and canyons. The marine park contributes to a transect that extends from coastal land (Leeuwin–Naturaliste and D’entrecasteaux national parks) to coastal waters (Ngari Capes Marine Park) and the deep ocean.
Eastern Recherche Marine Park	1570/ 1525	II – National Park Zone (76%) VI - Special Use Zone (24%)	The Eastern Recherche Marine Park is part of the South-West Marine Park Network. It lies adjacent to the Recherche Archipelago about 135km east of Esperance and includes important foraging areas for: + Threatened white shark; + Threatened Australian sea lion + Pygmy blue whales are distributed across the marine park; and	The Eastern Recherche Marine Park is significant because it contains habitats, species and ecological communities associated with three bioregions: South-west Shelf Province; Southern Province; and the Great Australian Bight Shelf Transition. It includes three key ecological features: mesoscale eddies (valued for high productivity and aggregations of marine life); ancient coastline between 90 m and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism); and the

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			+ Southern right whales migrate through the region to important nursery areas in coastal waters. The marine park does not contain any international, Commonwealth or National heritage listings (Director of National Parks 2018a) but it is adjacent to the Recherche Archipelago which is home to the only breeding population of great-winged petrels in Australia.	Commonwealth marine environment surrounding the Recherche Archipelago (valued for aggregations of marine life and high levels of biodiversity and endemism). The Marine Park includes representative examples of habitats adjacent to the Recherche Archipelago, an area recognised globally for its biodiversity. The Archipelago contains over 150 islands stretching over 200 km^2 of ocean and represents the most extensive area of rocky reef environments in the region. Its reef and seagrass habitats support a high diversity of warm temperate species. The Marine Park captures one of the few areas where the reef extends into Commonwealth waters and includes Chester and Pollock reefs which are located south of Salisbury Island about 60–70 km offshore
Bremer Marine Park	1495/ 1458	II – National Park Zone (70%) VI – Special Purpose Zone (Mining exclusion) (30%)	The Bremer Marine Park protects the following conservation values (Director of National Parks 2018a): + Contains habitats, species and ecological communities associated with two bioregions: Southern Province and South-west Shelf Province; + Two key ecological features (Albany Canyon group and adjacent shelf break and ancient coastline between 90 m and 120 m depth); + Important foraging areas for: – Threatened white shark; – Threatened Australian sea lion;	The Bremer Marine Park is significant because it contains habitats, species and ecological communities associated with two bioregions: Southern Province and South-west Shelf Province. It includes two key ecological features: Albany Canyon group and adjacent shelf break (valued for high productivity, aggregations of marine life and unique seafloor features with properties of regional significance); and ancient coastline between 90 m and 120 m depth (valued for relatively high productivity, aggregations of marine life and high levels of biodiversity and endemism). The Marine Park contains the Bremer Canyon and significant calving and aggregation area for whales as well as important foraging areas for sharks, sea lions, and a range of seabirds.

Name	Distance from the WHP (km)/ Project Area Boundary (km)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities	Statement of Significance
			– Threatened Indian yellow-nosed albatross, Australian fairy tern and soft-plumaged petrel; and – Migratory flesh-footed shearwater, short-tailed shearwater, bridled tern and Caspian tern. – Important migratory pathway for humpback whales; – Significant calving habitat for the threatened southern right whale; and – Important aggregation area for killer whales The marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). Commercial tourism, fishing, shipping and recreation are important supported socio-economic activities in the park.	

3.4.2.2 Western Australian Marine Protected Areas

In addition to the AMPs described in **Section 3.4.2.1**, a number of Western Australian marine protected areas were identified as overlapping the EMBA beyond the Project Area. These are described in **Table 3-18** and shown in **Figure 3-23** and **Figure 3-24**.

No Western Australian marine protected areas overlap the Project Area. The Western Australian marine protected areas that overlap the EMBA comprise two categories:

- marine parks; and
- marine protected areas.

Marine parks are created to protect natural features and aesthetic values while allowing recreational and commercial uses that do not compromise conservation values. Marine parks are multiple-use reserves that cater for a wide range of activities. Marine parks are zoned in accordance with the IUCN categories for protected areas. Each marine park has a “management plan” that contains strategies to protect the high-value assets in the park, as well as permitted-activities tables.

Marine management areas provide an integrated management structure over areas that have high conservation value and intensive multiple-use.

Table 3-18: Summary of environmental values and sensitivities of State marine protected areas within the EMBA

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
Eighty Mile Beach Marine Park	128/90	VI - Multiple Use Zone (100%)	+ Aboriginal cultural heritage; + Intertidal sand and mudflat communities supporting a high abundance and diversity of invertebrate life; + Diverse subtidal filter-feeding communities; + Macroalgal and seagrass communities; + High-diversity intertidal and subtidal coral reef communities; + Mangrove communities and adjacent saltmarshes; + High-diversity and abundance of shorebirds and waders (including migratory species); + Flatback turtles nesting; + Dugongs and several whale and dolphin species; and + Recreational and commercial fishing.
Rowley Shoals Marine Park	147/117	II - National Park (0.14%) VI - Multiple Use Zone (99.86%)	+ Reefs form part of a series of important ecological "steppingstones" for biota originating in Indonesian/western Pacific waters; + Provides an important upstream source for recruitment to reefs further south; + Marine biota, including: - 184 species of corals, primarily Indo-West Pacific species; - 264 species of molluscs; - 82 species of echinoderms, and - 389 species of finfish.

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
Montebello Islands Marine Park	357/334	VI - Multiple Use Zone (100%)	+ Important habitats including: - corals reefs and bommies; - mangroves; - seagrass and macroalgae meadows; - rocky shorelines and hard substrate, and - intertidal sand and mudflat communities. + Large diversity of species, including dugongs, turtles, whales, other protected cetaceans and birds, as well as sea snakes and fish. + Socio-economic values including: - hydrocarbon exploration and production; - pearling; - nature-based tourism; and - commercial and recreational fishing.
Barrow Island Marine Management Area	371/347	IV - Habitat / Species Management Area (100%)	+ Regionally significant coral reefs; + Diversity of tropical marine fauna; + Seabirds and migratory shorebirds; + Unique mangrove communities; + Green, hawksbill and flatback turtles nesting and breeding; and + Nature-based tourism.
Barrow Island Marine Park	401/377	VI - Multiple Use Zone (100%)	+ Biggada Reef, an ecologically significant fringing reef; + Turtle Bay, an important turtle aggregation and breeding area; and + Representative areas of seagrass, macroalgal and deepwater habitat.

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
Muiron Islands Marine Management Area	533/509	IV - Habitat / Species Management Area (100%)	+ Immediately adjacent to the northern end of the Ningaloo Marine Park and Ningaloo WHA; + Sandy beaches, macroalgae and seagrass beds in the shallow waters (particularly on the eastern sides); and + Coral reef up to depths of 5 m, which surrounds both sides of South Muiron Island and the eastern side of North Muiron Island.
Ningaloo Marine Park	553/529	VI - Multiple Use Zone (100%)	+ Aligns with the Ningaloo WHA in Western Australian waters; + Over 217 species of coral (representing 54 genera); + Over 600 species of mollusc (clams, oysters, octopus, cuttlefish, snails); + Over 460 species of fish; + Ninety-seven species of echinoderms (sea stars, sea urchins, sea cucumbers); + Habitat for numerous threatened species, including whales, dugong, whale sharks and turtles; and + Habitat for over 25 species of migratory birds.
Lalang-garram/ Camden Sound Marine Park	607/549	VI - Multiple Use Zone (100%)	+ Aboriginal cultural heritage values, including three recognised traditional owner groups; + Species of special conservation interest, including: - humpback whales, which calve and rest within the park; - dolphins; - dugongs; - marine turtles; - crocodiles; - fish (including sharks and rays); - birds; and

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
			- benthic invertebrates (molluscs, crustaceans, echinoderms and sponges). + Geology and geomorphic features; + Habitats and communities; + Nature-based tourism; and + Fishing.
Lalang-garram/ Horizontal Falls Marine Park and North Lalang-garram Marine Park	612/553	VI - Multiple Use Zone (100%)	+ Cultural heritage values and sites of the Dambimangari traditional owners; + Habitats and communities, including: - mangroves and saltmarshes; - coral reefs; - seagrass and macroalgae; - estuaries; and - pelagic habitat. + A range of coastal geomorphologies; + Fauna of special conservation interest, including: - marine turtles; - dugongs; - dolphins; - crocodiles; - fish (including sharks and rays); - whales (particularly humpback whales); - sea snakes; and - birds. + Recreation and nature-based tourism values.

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
North Kimberley Marine Park	754/697	VI - Multiple Use Zone (100%)	+ Four separate management areas including, Uunguu, Balanggarra, Miriuwung Gajerrong, and Wilinggin traditional owners; + Species of special conservation interest, including: - dolphins; - dugongs; - marine turtles; - crocodiles; - fish (including sharks and rays); and - birds. + Habitats and communities; + Nature-based tourism; and + Fishing.
Shark Bay Marine Park	835/810	VI - Multiple Use Zone (100%)	+ 323 fish species, comprising: - 83% tropical species; - 11% warm temperate species; and - 6% cool temperate species. + 218 species of bivalves, comprising: - 75% with a tropical range; and - 10% with a southern Australian range. + 12 species of seagrass, making it one of the most diverse seagrass assemblages in the world; + An estimated population of about 11,000 dugongs, one of the largest populations in the world;

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
			+ Humpback and southern right whales use the bay as a migratory staging post; + Bottlenose dolphins occur in the bay, and green turtle and loggerhead turtle nest on the beaches; + Large numbers of sharks including whaler, tiger shark and hammerhead are present, as well as an abundant population of rays, including the manta ray; + Hamelin Pool in Shark Bay contains the most diverse and abundant examples of stromatolite forms in the world, representative of life forms that lived some 3,500 million years ago; and + Aligns with the Shark Bay WHA.
Jurien Bay Marine Park	1,281/1,258	VI - Multiple Use Zone (100%)	+ Ecological values: - geomorphology, such as intertidal reef platforms; - water and sediment quality; - seagrass meadows and macroalgal communities; and - fauna such as seabirds, invertebrate communities, finfish, sea lions, cetaceans and turtles. + Social values: - indigenous heritage and maritime heritage; - commercial fishing, recreational fishing and aquaculture; - coastal use; - seascapes; - marine nature-based tourism and water sports; - petroleum drilling and mineral development; and - scientific research and education.

Name	Distance from the WHP/ closest Project Area Boundary (km) (approximate)	IUCN Zones and Areas (% of park total)	Summary of Values and Sensitivities
Shoalwater Islands Marine Park	1,507/1,472	VI - Multiple Use Zone (100%)	+ Representative rocky shoreline habitats; + Roosting and nesting areas for birds, including little penguins; + Seagrass meadows; + Marine fauna, such as: - fishes (including sharks and rays); - bottlenose dolphins; - sea lions; - crustaceans (including western rock lobster); - worms; and - shellfish.
Ngari Capes Marine Park	1,643/1,619	VI - Multiple Use Zone (100%)	+ Aboriginal cultural heritage values; + Seagrass communities; + Intertidal, shallow subtidal and deep reef communities; + Coral communities; + Finfish; + Marine mammals, including sea lions; + Seabirds and shorebirds; + Recreational uses; and + Scientific research.

3.4.2.3 Western Australian Terrestrial Protected Areas

The Western Australian terrestrial protected areas that overlap the EMBA comprise two categories:

- nature reserves; and
- conservation parks.

Nature reserves and conservation parks are intended to protect and conserve flora and fauna.

The hydrocarbon spill modelling studies (**Attachment 8**) identified several Western Australian terrestrial reserves as potentially having shoreline accumulation of oil above impact thresholds. These are described in **Table 3-19**.

Table 3-19: Nature reserves and conservation parks within the EMBA

Reserve Name	Distance from the WHP (km)	Distance from Closest Project Area Boundary (km)
Nature Reserves		
Bedout Island Nature Reserve	72	38
North Turtle Island Nature Reserve	96	71
Kujungurru Warrarn Nature Reserve	170	117
Jinmarnkur Kulja Nature Reserve	152	105
Coulomb Point Nature Reserve	406	345
Lacepede Islands Nature Reserve	429	372
Barrow Island Nature Reserve	389	365
Boodie, Double Middle Islands Nature Reserve	412	389
Swan Island Nature Reserve	545	487
Adele Island Nature Reserve	609	553
Scott Reef Nature Reserve	625	582
Conservation Parks		
Kujungurru Warrarn Conservation Park	176	121
Jinmarnkur Conservation Park	292	234
Montebello Islands Conservation Park	363	340

3.4.2.4 Wetlands of International Importance (Ramsar Wetlands)

Wetlands of international importance, commonly called Ramsar sites, are protected under the EPBC Act as wetlands of international importance. The Project Area does not overlap any wetlands of international importance; however, a number are overlapped by the EMBA (potentially impacted in the unlikely event of a hydrocarbon spill). These are listed in **Table 3-20**, along with the shortest distance between the WHP and the AMP.

Table 3-20: Ramsar wetlands within the EMBA

Wetland	Distance from Dorado WHP (km)	Distance from Closest Project Area Boundary (km)
Eighty-mile Beach	146	99
Roebuck Bay	366	305
Ashmore Reef National Nature Reserve	873	829
Peel-Yalgorup System	1,526	1,503
Hosnies Spring	1,700	1,676
The Dales	1,712	1,687

These sites are recognised as being critically important to migratory bird species that utilise habitats in more than one country. Descriptions of each of these Ramsar sites are in the following sections. Refer to **Section 3.3.6** for a summary of migratory birds that may occur within the EMBA.

3.4.2.4.1 Eighty-mile Beach

The Eighty-mile Beach Ramsar site is located between Port Headland and Broome and is made up of Eighty Mile Beach and Mandora Salt Marsh (about 40 km inland from the beach). Eighty Mile Beach is a long (220 km) relatively uninterrupted sand coast and associated mudflats, ranging in width from 1 km to 4 km (Hale and Butcher 2009). The boundary of the Ramsar site along the beach is defined by the tide, extending from mean low water to 40 m above mean high water. The intertidal zone is comprised of a large expanse of intertidal mudflats (up to 4 km wide at the lowest tides) and a narrow strip at the landward edge of coarser quartz sands. Mandora Salt Marsh includes two large seasonal wetlands and a series of small permanent mound springs. A summary of the environment and ecological character of the Ramsar site is provided in **Table 3-21**.

Table 3-21: Environmental and ecological character description of the Eighty-mile Beach Ramsar site (from Hale and Butcher 2009)

Ecosystem Components and Processes	
Climate	Semi-arid monsoonal with a prolonged dry period, more than 80% of rainfall in the wet season (December to March). High interannual variability. High occurrence of tropical cyclones.
The Beach	+ Geomorphology: Extensive intertidal mudflats comprised of fine-grained sediments. Site is backed by steep dunes comprised of calcareous sand. + Hydrology: Macro-tidal regime. No significant surface water inflows. Groundwater interactions unknown (knowledge gap). + Primary production and nutrient cycling: Data deficient, but organic material deposited from ocean currents driving the system through bacterial or microphytobenthos-driven primary production. + Invertebrates: Large numbers and diversity of invertebrates within the intertidal mudflat areas. + Fish: Data deficient, but anecdotal evidence of marine fish (including sharks and rays) using inundated mudflats.

	+ Waterbirds: Significant site for stopover and feeding by migratory shorebirds. Regularly supports more than 200,000 shorebirds during summer and more than 20,000 during winter. High diversity with 97 species of waterbird recorded from the beach. Regularly supports more than 1% of the flyway population of 20 species. + Marine turtles: Significant breeding site for the flatback turtle.
Mandora Salt Marsh	+ Geomorphology: Wetland formation dominated by alluvial processes. Wetlands were once a part of an ancient estuary. Freshwater springs have been dated at 7,000 years old. + Hydrology: Walyarta, East Lake and the surrounding intermittently inundated paperbark thickets are inundated by rainfall and local run-off. Extensive inundation occurs following large cyclonic events. Salt Creek and the mound springs are groundwater-fed systems through the Broome Sandstone Aquifer. + Water quality: Most wetlands are alkaline, reflecting the influence of soils and groundwater. Salinity is variable: mound springs are fresh, Salt Creek is hypersaline, and Walyarta is variable with inundation. Nutrient concentrations in groundwater and groundwater-fed systems are high. + Primary production and nutrient cycling: Data deficient. However, evidence of boom and bust cycle at Walyarta with seasonal inundation. + Vegetation: Inland mangroves (*Avicennia marina*) lining Salt Creek are one of only two occurrences of inland mangroves in Australia. Paperbark thickets dominated by the saltwater paperbark (*Melaleuca alsophila*) extend across the site on clay soils, which retain moisture longer than the surrounding landscape. Samphire (*Tecticornia* spp.) occurs around the margins of the large lakes. Freshwater aquatic vegetation occurs at Walyarta when inundated and at the mound spring sites year-round. + Invertebrates: Data limited, but potentially unique species. + Waterbirds: Significant site for waterbirds and waterbird breeding, particularly during extensive inundation events. 66 waterbirds recorded. Supports more than 1% of the population of at least two species. Breeding recorded for at least 24 species.
Ecosystem Services	
Provisioning service	+ Freshwater: The freshwater springs at Mandora Salt Marsh provide drinking water for livestock. + Genetic resources: Plausible, but as yet no documented uses. + Climate regulation: Plausible, but data deficient.
Regulating service	+ Biological control of pests: Evidence that many of the shorebirds feed on the adjacent pastoral land and that the incidence of 2.88 million oriental pratincole coincided with locusts in almost plague proportions, upon which the birds fed.
Cultural Services	+ Recreation and tourism: The beach portion of the site is important for recreational fishing, tourism, bird watching and shell collecting. + Spiritual and inspirational: Spiritually significant for the Karajarri and Nyangumarta and contains a number of specific culturally significant sites. The site has inspirational, aesthetic and existence values at regional, state and national levels.

	+ Scientific and educational: Mandora Salt Marsh and Eighty Mile Beach have been the sites of a number of significant scientific investigations. In addition, Eighty Mile Beach is a significant site for migratory shorebird monitoring and is currently part of the Shorebirds 2020 program.
Supporting services	As evidenced by the listing of the Eighty-mile Beach Ramsar site as a wetland of international importance. The system provides a wide range of biodiversity-related ecological services critical for the ecological character of the site, including: + containing a diversity of wetland types; + supporting significant numbers of migratory shorebirds; + supporting significant wetland bird breeding; and + supporting flatback turtle breeding.

3.4.2.4.2 Roebuck Bay

The Roebuck Bay Ramsar site covers an area of 34,119 hectares and is primarily comprised of intertidal mudflats. The site extends from Campsite (a location on the northern shore of Roebuck Bay) east of the town of Broome to south of Sandy Point. The site was listed for several reasons including, most notably, outstanding shorebird values. The high biomass of benthic invertebrates at Roebuck Bay (for a tropical mudflat) is a key characteristic that makes it such an important shorebird habitat. The soft-bottom intertidal mudflats of the northern and eastern shores of Roebuck Bay and high tide roosts at Bush and Sandy points are the most biologically significant parts of the site (Bennelongia 2009).

The site regularly supports over 100,000 waterbirds. It is the fourth most important site for waders in Australia in terms of absolute numbers and the most important in terms of the number of species it supports in internationally significant numbers. A summary of the environment and ecological character of the Ramsar site is provided in **Table 3-22**.

Table 3-22: Environmental and ecological character description of the Roebuck Bay Ramsar Site (from Bennelongia 2009)

Ecosystem Components and Processes	
Climate	Semi-arid monsoonal with hot, wet summers and warm, dry winters. Mean monthly temperature ranges from a maximum of approximately 35°C to a minimum of 13.6°C, and average daily sunshine is around 15 hours. Winters are mild, with overnight temperatures rarely falling below 5°C. Mean annual rainfall at Broome is 601 mm, mostly falling from December to March
Tides	Semi-diurnal tides with an amplitude up to 10 m. Spring tides occur every fortnight. These flood low-lying salt marshes behind the mangrove woodlands fringing the bay at high tide and expose about 190 km^2 of mudflat (45% of the bay area) at low tide. The twice daily tidal flushing across the mudflat is a driving factor in the ecology of most life forms in the extensive intertidal zone of the bay.
Roebuck Bay	+ Wetland values: The site is an example of a tropical marine embayment within the Northwest bioregion. It is one of only a dozen intertidal flats worldwide where benthic food sources are found in sufficient densities that they regularly support internationally significant numbers of waders.

	+ Threatened species/communities: Loggerhead and green turtles regularly use the site as a seasonal feeding area and as a transit area on migration. Flatback turtles regularly nest in small numbers around Cape Villaret during the summer months. Sawfish regularly use the tidal creeks and mangrove areas for breeding and refuge. + Regional biodiversity: The site supports a significant component of the regional intertidal and shallow marine biodiversity in terms of the marine mammals, marine invertebrate infauna, and avian fauna across the site. The total density of macrobenthic animals is high by global standards for a tropical mudflat, and species richness is very high (estimated to be between 300 and 500 species). + Key habitat in life cycle. The site is one of the most important migration stopover areas for shorebirds both in Australia and globally. It is the arrival and departure point for large proportions of the Australian populations of several shorebird species, notably the bar-tailed godwit and great knot. The site provides essential energy replenishment for many migrating species, some of which fly non-stop between continental east Asia and Australia.
Primary Determinants of Ecological Character	
Sedimentary and Geomorphic Processes	+ Geomorphology: A megascale irregular curved embayment that contains a wide expanse of intertidal mud and sand flats indented by microscale linear tidal creeks. + Sedimentology: Three main sediment provinces have been identified: northern sands province, eastern silt and clay province and southern sands province.
Nutrient Processes and Carbon Supply	Nitrogen and phosphorus are frequently the most important because their biological availability limits rates of growth of marine plants. There are probably several sources of carbon supply to the intertidal flats of Roebuck Bay, namely in situ fixation by microalgae, phytoplankton deposits during flooding tides, detritus from adjacent mangrove systems, and some transport of macroalgal and seagrass material. There may also be input of terrestrial carbon, particularly after major rainfall events following the passage of cyclones.
Groundwater Movements	The only available measurements of the relationship between groundwater and the coastal systems of Roebuck Bay are from Vogwill (2003) who used a series of piezometers to record changes in groundwater levels in mudflats behind Crab Creek and Dampier Creek. Groundwater levels in both systems were affected by tidal movement and rainfall, with each being dominant close to the coast and hinterland respectively.
Tides and Water Exchange	The daily ebb and flow of the tides in Roebuck Bay are a significant factor in determining the ecological character of the bay, as are the lunar and annual tidal regimes.
Intrinsic Ecological Factors	Within a systems approach to describing the ecological character of a geographical area, there is a need to include those intrinsic ecological factors, such as recruitment, trophic structure, resources depletion and other attributes of habitat utilisation. It is not possible to describe all of the intrinsic attributes of Roebuck Bay here as many of them are species specific and not documented.

3.4.2.4.3 Ashmore Reef National Nature Reserve

The Ashmore Reef Ramsar site is located within the Commonwealth Ashmore Reef Marine Park. Ashmore Reef is located on the outer continental shelf, approximately 320 km off the northwest coast of mainland Australia. The site was listed in 2002. In addition to providing an important site for migratory shorebirds, Ashmore Reef also hosts regionally important populations of migratory and non-migratory seabirds.

A summary of the environmental and ecological character of the Ashmore Reef Ramsar site is provided in **Table 3-23**.

Table 3-23: Environmental and ecological character description of the Ashmore Reef Ramsar Site (from Hale and Butcher 2013)

Ecosystem Components and Processes	
Climate	+ Arid tropical monsoonal climate. + Located outside the main belt of tropical cyclones in the Timor Sea.
Geomorphic Setting	+ Located in an area of high oil and gas reserves, with active hydrocarbon seeps. + Geomorphic groups within the site include reef slope, reef crest, reef flat, back reef sands, lagoons and islands.
Tides and Currents	+ Strong seasonal influences of the Indonesian Throughflow and Holloway currents. + Internal waves are a feature of the region, and Ashmore Reef may act to break these resulting in increased nutrients from bottom waters. + High-energy environment with spring tides over 4.5 m and large flushing on tidal cycles.
Water Quality	+ Seasonal variations in temperature and salinity in ocean and lagoon water. + Water clarity, turbidity and other water quality parameters remain a knowledge gap.
Vegetation	+ Five species of seagrass recorded with *Thalassia hemprichii* dominant, comprising over 85% of total cover. + Total cover of 470 hectares, but much of this is sparse, and there is only 220 hectares with a mean cover of greater than 10%. + Over 3,000 hectares of macroalgae, mostly on the reef slope and crest areas + Algae dominated by turf and coralline algae with fleshy macroalgae comprising typically less than 10% of total algal cover.
Ecosystem Services	
Supports Near Natural Wetland Types	Contains examples of the following wetland types: + Permanent shallow marine waters. + Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows. + Coral reefs. + Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks. + Intertidal mud, sand or salt flats.
Supports Biodiversity	The Ashmore Reef Ramsar site is considered a hotspot of biodiversity with the highest species richness of many groups of fauna in the bioregion and more broadly across the North West Shelf. This includes many groups of invertebrates, such as

	coral, molluscs, echinoderms and crustaceans, as well as finfish and sea snakes. Biodiversity at the site is supported by the habitat provided by the near-natural wetland types and the interactions between the biota within the atoll environment, such as trophic relationships and the transfer of energy.
Provides Physical Habitat for Breeding Waterbirds	Twenty species of wetland bird have been recorded breeding within the Ashmore Reef Ramsar site, the majority of which are seabirds. The species recorded breeding at the site utilise a range of different habitats within the system. This includes the shrubby and grassy vegetation, the ground beneath shrub vegetation, and the sandy beaches. Maintaining this diversity of habitat is essential to maintaining this service.
Supports Migratory Birds	Ashmore Reef Ramsar site supports a diversity and abundance of migratory shorebirds in the East Asian–Australasian Flyway. The majority of birds in the flyway migrate from breeding grounds in northeast Asia and Alaska to non-breeding grounds in Australia and New Zealand, covering the journey of 10,000 km twice in a single year.
Supports Threatened Species	Supports a range of species that are of ecological significance, several of which are listed as threatened under the EPBC Act. Taxa include: + corals; + sea cucumbers; + fishes; + sea snakes; + marine turtles; and + dugong.

3.4.2.4.4 Peel-Yalgorup System

The Peel-Yalgorup System Ramsar site is composed of the Peel-Harvey estuary and a series of lakes. The estuary and lakes were designated as a Ramsar site in 1990. Of these components, only the Peel-Harvey estuary (approximately 1526 km from the Dorado WHP) could credibly be at risk of impacts from Dorado Phase 1; hence, the Peel-Harvey estuary is the only component of the Ramsar site described here.

A summary of the environmental and ecological character of the Peel-Harvey estuary component of the Peel-Yalgorup System Ramsar site is provided in **Table 3-24**.

Table 3-24: Environmental and ecological character description of the Peel-Harvey estuary component of the Peel-Yalgorup Ramsar site (from Hale and Butcher 2013)

Ecosystem Components and Processes	
Geomorphology	+ Geomorphology: estuary formed since last glacial period. Formerly a natural bar-built estuary that would intermittently open to the sea; currently permanently open to the sea via the Mandurah Channel that was dredged and is maintained at 1.9 m water depth. Peel-Harvey estuary is relatively shallow, with much of the estuary having less than 0.5 m water depth.
Hydrology	+ Water derived from: - direct rainfall; - surface water flows from catchment via Serpentine, Murray and Harvey rivers (the primary source of inflows into the estuary); and

	- groundwater inflows. + Tidal exchange historically limited, but currently facilitated by permanently opened channel.
Water Quality	+ Strong seasonal patterns in salinity: - low in winter (less than 5 ppt) due to freshwater inputs from rainfall and rivers; and - high in summer (more than 35 ppt) due to evaporation and lack of freshwater input. + Waters generally well oxygenated due to shallow nature of estuary facilitating diffusion of atmospheric oxygen into the water column, but high biological oxygen demand may lead to local, short-term deoxygenation. + Historically severe eutrophication due to agricultural practices in river catchments.
Vegetation	+ Phytoplankton: seasonal patterns linked to nutrient availability and hydrology. Dominated by diatoms during autumn and winter, cyanobacteria becoming conspicuous in spring and early summer, particularly in the Harvey estuary. Historical eutrophication has contributed to phytoplankton blooms. + Benthic plants: dominated by macroalgae, with higher abundance in the Peel estuary due to relatively shallow waters depths compared to Harvey estuary. Historical eutrophication results in high macroalgae biomass. Seagrass growth of *Ruppia* and *Halophila* is seasonal, with senescence during winter. + Littoral vegetation: tidal saltmarsh communities are common in the littoral environment around the Peel-Harvey estuary.
Fauna	+ Invertebrates: significant invertebrate population supported by high levels of primary productivity. Invertebrates such as polychaetes, crustaceans and molluscs support birds. + Fish: most species in the estuary are considered marine or estuarine species that recruit as larvae or juveniles. + Marine mammals: anecdotal evidence of small numbers of bottlenose dolphins moving between the Peel-Harvey estuary and the ocean. + Birds: 86 species of waterbirds recorded in the Peel-Harvey estuary. Up to 150,000 birds recorded, which is the highest number recorded for wetlands in southwestern Australia. The site has been recorded supporting more than 1% of the populations of waterbirds, including several migratory species utilising the East Asia–Australasia Flyway.
Determinants of Ecological Character	
Nutrients	Eutrophication in the Peel-Harvey estuary resulting from nutrient inputs from river catchments has altered the ecosystem. Increased primary productivity supports higher biomass of plants and invertebrates, which in turn supports migratory bird and waterbird populations. Negative effects may include smothering of intertidal flats due to high levels of macroalgae.
Salinity	Salinity limits the range of aquatic organisms that may survive in the estuary due to osmotic stress. The salinity in the estuary varies significantly on an annual cycle from brackish (less than 5 ppt) to higher than marine (more than 35 ppt).

	The continuous intrusion of marine water due to the permanent channel has altered the natural salinity regime.
Habitat	The estuary provides a range of habitats: + open water; + mudflats; + aquatic plants; + samphire; + paperbark; and + sedgeland. The diversity of habitats is reflected in the relatively high species richness and diversity of migratory birds and waterbirds that use the estuary.

3.4.2.4.5 Hosnie's Spring

Hosnie's Spring Ramsar site is located on the eastern side of Christmas Island in the Indian Ocean approximately 2,800 km west of Darwin, Australia, and 1700 km from the Dorado WHP. At the time of listing (1990) Hosnie's Spring comprised less than one hectare of freshwater spring. In 2010, the boundary of Hosnie's Spring was expanded from 0.33 hectares to 202 hectares (Hale and Butcher 2010).

A summary of the environmental and ecological character of the Hosnie's Spring Ramsar site is provided in **Table 3-25.**

Table 3-25: Environmental and ecological character description of the Hosnie's Spring Ramsar site (from Hale and Butcher 2010)

Ecosystem Components and Processes	
Climate	+ Warm tropical climatic zone; warm to hot year round. + High rainfall (2,000 mm/year).
Geomorphic setting	+ Site is located within the shore terrace on an area of gravel overlying phosphoric soils. + Spring is situated at the base of the inland cliffs where spring water flows over a limestone flowstone.
Water quality	+ Limited information (two snapshot surveys only). + Typical of limestone karst systems with alkaline conditions and relatively high concentrations of calcium. + Trace elements and metals are all low. + Nitrogen is predominantly in the form of nitrate. + High concentrations of sulphate result in a sulphurous odour.
Critical Components and Processes	
Hydrological Regime	+ Groundwater dominant. + Source for Hosnie's Spring is a perched, unconfined aquifer that discharges where impermeable volcanic rocks are close to the surface. + Flow rate is not known but expected to be low.

	+ Spring is perennial.
Mangroves	+ Stand of mangroves from the genus *Bruguiera* covers the majority of the wetland. + Comprises a range of age classes with evidence of active regeneration. + A number of very large trees (large than typical for the species), with the largest tree measuring 82 cm diameter at breast height and exceeding 40 m in height. + Between 300 and 600 trees in total (more than 2.5 cm diameter at breast height) and a density of between 10 and 20 trees per 100 m^2.
Land Crabs	+ Supports large populations of at least three species: - red crabs (*Gecarcoidea natalis*); - robber crabs (*Birgus latro*); and - blue crabs (*Discoplax hirtipes*).
Cultural and Supporting Services	
Recreation and Tourism	While the site is open to the public, tourism to the site is not promoted. Rather, the site is managed to provide a limited number of visitors an opportunity to visit a unique wetland that is largely undisturbed by humans.
Scientific and Educational	The unique nature of the site and the pristine condition provide excellent opportunities for research.
Supports Near-natural Wetland Types	The spring at the Ramsar site is in near-natural condition and significant within the bioregion. It is the only area on Christmas Island that supports freshwater mangroves.
Biodiversity	Supports a variety of wetland species, communities and habitats, including marine, terrestrial and freshwater-dependent species.
Food Webs	Interactions between land crabs and mangroves form an important food web at the site.
Distinct Wetland Species	Blue crabs are reliant on the few permanent freshwater sites on Christmas Island (including Hosnie's Spring) for reproduction and for survival in the dry season.
Ecological Connectivity	Red crabs migrate from the plateau to the ocean to breed each year.

3.4.2.4.6 The Dales, Christmas Island

The Dales, Christmas Island Ramsar site is located on Christmas Island in the Indian Ocean approximately 2,800 km west of Darwin, and approximately 1712km from the Dorado WHP. The Dales Ramsar site is located entirely within the Christmas Island National Park, in the west of the island, with the western boundary of the site extending to 50 m seaward from the low water mark. The site was listed as a Ramsar site in 2002. The Dales Ramsar site comprises a system of seven watercourses collectively known as "The Dales". Three of the Dales support permanent springs, while the remaining Dales support intermittent streams during the wet season (Butcher and Hale 2010).

A summary of the environmental and ecological character of The Dales Ramsar site is provided in **Table 3-26.**

Table 3-26: Environmental and ecological character description of The Dales Ramsar site (from Butcher and Hale 2010)

Ecosystem Components and Processes	
Climate	+ Warm tropical climatic zone; warm to hot year round. + High rainfall (2,000 mm/year).
Geomorphic Setting	+ Site is located within the shore terrace on an area of gravel overlying phosphoric soils. + Springs are situated at the base of the inland cliffs where spring water flows over a limestone flowstone.
Water Quality	+ Limited site-specific data – information from one survey in 2003 for Hugh's Dale may provide baseline data for time of listing. + Water quality is good, with higher concentrations of some trace metals and major ions compared to upstream reference sites, due to the presence of volcanic rocks and significant crab populations.
Terrestrial Vegetation	+ Limited site-specific data; descriptions of the vegetation are limited.
Coral reef	+ The coral reef is limited and dominated by abiotic and hard corals of low diversity.
Fish	+ Community predominantly of Indo-Pacific origin. + Endemism is low, but a number of species are at the western extent of their range at Christmas Island; and there is evidence of hybridisation. One endemic freshwater species recorded from the site.
Invertebrates (Excluding Crabs)	+ The site supports a low diversity of benthic marine invertebrates but may also support anchialine fauna, although no site-specific data has been sourced to confirm this.
Critical Components and Processes	
Geomorphic Setting	+ The island is a karstic landscape with key geomorphic features including the terrace formations, sea cliffs, and caves and other karst features, such as tufa at Hugh's Dale.
Hydrology	+ Karstic drainage system of groundwater and surface ephemeral streamflow post heavy rainfall events during the wet season. + Spring outflow of groundwater at three of the Dales is permanent.
Land Crabs	+ All 20 species of land crab occur within the boundary of the site. + The Dales provide a major migration pathway for crabs to and from the ocean during spawning. + The site is important for blue crabs in particular.
Waterbirds	+ Eleven waterbirds, including nine endemic species, one nationally listed vulnerable and one endangered species are found at the site. + The site supports breeding seabirds, including Abbott's booby and red-footed booby.
Cultural and Supporting Services	

Recreation and Tourism	The Dales are a popular recreational area for both tourists and locals. Two timber boardwalks have been installed at No. 1 Dale and Hugh's Dale. The Dales are the most popular sightseeing destination on the island with the waterfall at Hugh's Dale being the greatest attraction.
Science and Education	Parks Australia undertakes and supports a range of research programs across the Christmas Island National Park, many of which are directly relevant to The Dales. For example, research investigations include impacts of the yellow crazy ant, land crab ecology, and Abbott's booby.
Food Webs	Crab spawning provides a rich food supply to marine biota, including whale sharks. In addition, the land crabs play a significant role in the energy dynamics of the forest, affecting seedling recruitment and ultimately the structure of the forest. The invasion of the yellow crazy ant has significantly affected trophic relationships on Christmas Island.
Provides Physical Habitat (for Breeding Waterbirds).	Terrestrial vegetation provides roosting and breeding sites for several species of waterbirds.
Biodiversity	Supports a variety of wetland species, communities and habitats, including marine, terrestrial and freshwater-dependent species.
Special Ecological, Physical or Geomorphic Features	Provides critical habitat for the blue crabs and freshwater crabs, provides examples of karst features such as tufa deposits at the Hugh's Dale waterfall, and possibly provides anchialine cave communities.
Distinct or Unique Wetland Species	Red crabs are considered keystone species on the island.
Threatened Wetland Species, Habitats and Ecosystems	The Dales Ramsar site supports nesting sites for the endangered Abbott's booby. The Christmas Island frigatebird has also been recorded from the site.
Priority Wetland Species	Christmas Island supports a number of vagrant species listed under various international agreements
Supports Near-natural Wetland Types	Springs and karst systems are representative of the bioregion and considered in near natural condition at the time of listing.
Ecological Connectivity	The streams of The Dales provide critical migration pathways for downward migration of red, blue and robber crabs and return pathways for juvenile blue crabs in particular.

3.4.3 Fisheries

The waters off Western Australia support a range of commercial, recreational and traditional fisheries. These provide employment, food and recreation for thousands of people and drive important economic activities, especially in coastal regional centres.

3.4.3.1 Commercial Fishing

Commercial fisheries within the EMBA can be considered in two categories:

- Western Australian (state) managed fisheries, and
- Commonwealth managed fisheries.

State managed fisheries are shown in **Figure 3-25**, and Commonwealth managed fisheries are shown in **Figure 3-26**. Identification of relevant fisheries within the Bedout Sub-basin has been ongoing since 2008 through consultation with the Department of Primary Industries and Regional Development (DPIRD) and Western Australian Fishing Industry Council (WAFIC). A review of available fishery management information for pelagic and demersal finfish fisheries indicated that while fisheries management measures include annual quotas and closure of specific areas all the time, none of the fisheries have specific time periods of closure for spawning or aggregation.

Both fishery categories are considered, with fisheries that overlap the Project Area described in more detail.

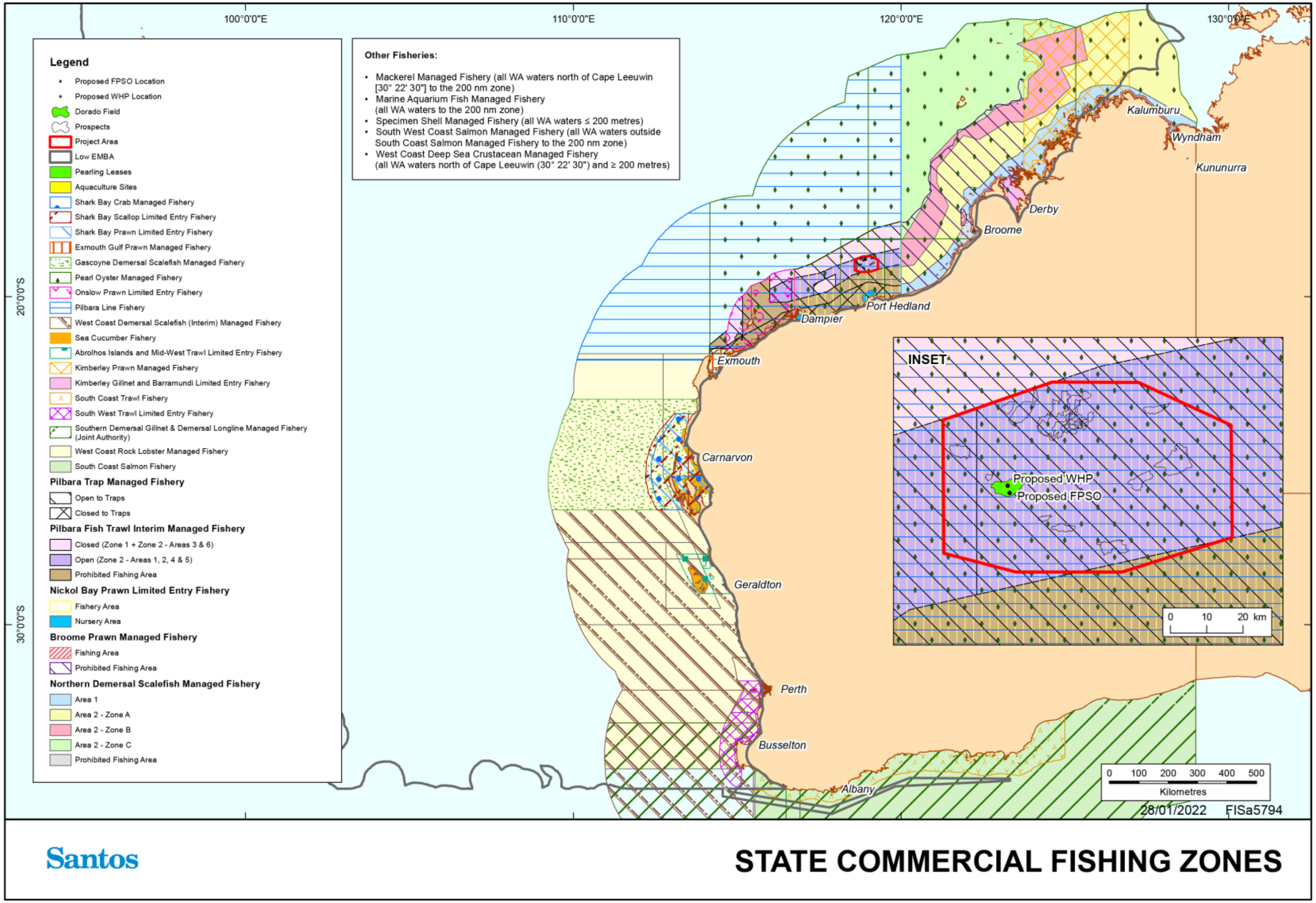


Figure 3-25: Western Australian (state) managed fisheries within the EMBA

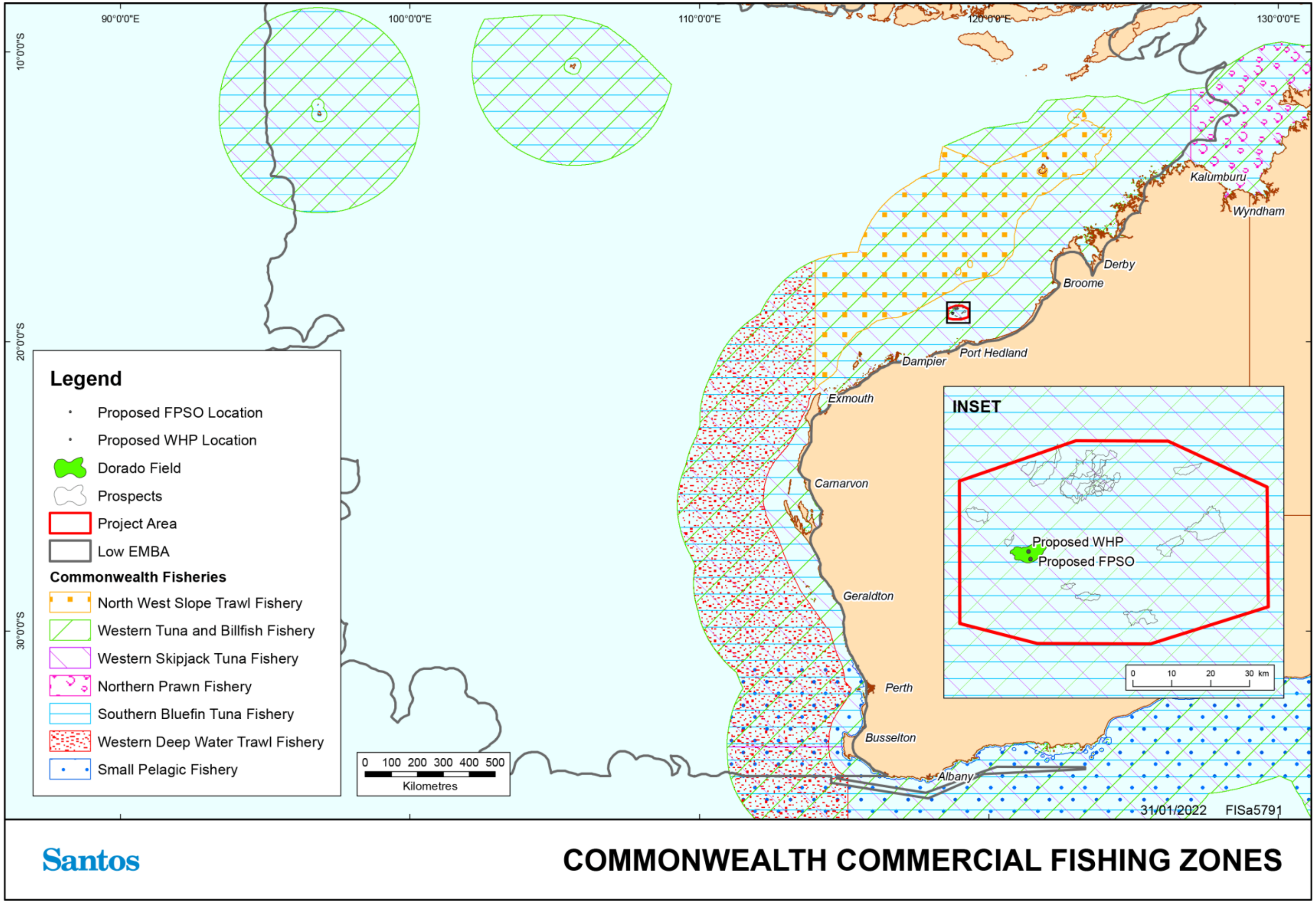


Figure 3-26: Commonwealth managed fisheries within the EMBA

3.4.3.1.1 State Managed Fisheries

State fisheries are managed by DPIRD (formerly Department of Fisheries) with specific management plans, regulations and a variety of subsidiary regulatory instruments under the Western Australian *Fish Resources Management Act 1994*. The information on state managed fisheries has been derived from Status reports of the fisheries and aquatic resources of Western Australia 2017/18: state of the fisheries (Gaughan et al. 2019) and direct consultation with DPIRD. Santos consults regularly with state fisheries relevant to activity operational areas, mainly by distribution of an Annual Consultation Update by post. Santos has undertaken engagement with the State Managed Fishers, via WAFIC, to support recent drilling and seismic activities within the Bedout Sub-basin (refer accepted Environment Plans for Archer 3D Marine Seismic Survey - https://info.nopsema.gov.au/activities/432/show_public , Keraudren Extension Survey - https://info.nopsema.gov.au/activities/404/show_public , and more recently the Bedout Multi-Well Drilling, accepted by NOPSEMA - https://info.nopsema.gov.au/environment_plans/535/show_public). Santos bases its understanding of the fisheries on reviews of annual status of the fishery reports published by DPIRD and the Australian Bureau of Agricultural and Resource Economics and Sciences, on other relevant fisheries management publications, and on fishery catch and effort data (**Section 7.2.8.2.1)**.

Santos requested annual catch and effort data (FishCube data) from DPIRD for fisheries understood to operate within or near to the Project Area. Data was assessed for 60 nautical mile (nm) x 60 nm Catch and Effort System (CAES) blocks and for 10 nm x 10 nm CAES blocks for the following:

+ catch and effort data for the most recent 10 years (2009 to 2018, aggregated); and
+ annual catch and effort data for each of the most recent five years (2014, 2015, 2016, 2017, 2018).

Data was assessed to identify where the greatest fishing effort in each fishery occurred and the relative importance of waters within the Project Area.

Data provided by DPIRD included:

+ weight (kg) – a measure of fish catches per CAES block during the period of interest;
+ vessel count – a measure of the number of vessels that fished in a CAES block during the period of interest; and
+ fishing day count – a measure of fishing effort, represented by the number of days when one or more vessels fished in a CAES block during the period of interest.

Due to confidentiality reasons, DPIRD do not release catch and effort data for CAES blocks where less than three vessels fished during the period of interest (i.e. less than three vessels per year or less than three vessels over the complete 10-year period). Where this applies, the Vessel Count is marked 'Less than 3', while Weight and Fishing Day Count are marked as 'N/A'. CAES blocks where the results are provided in this way confirm that fishing effort did occur within the block during that period, but the associated catch and effort values are not available. CAES blocks where no fishing is recorded do not return any data.

FishCube data has been mapped for the following fisheries (refer **Section 7.2.8.2.1**), to determine the spatial overlap and/or recorded fishing effort within the Project Area:

+ Mackerel Managed Fishery (Area 2 - Pilbara) (**Figure 7-30**);
+ Pilbara Fish Trawl (Interim) Managed Fishery (**Figure 7-31**);

- Pilbara Line Fishery (**Figure 7-32**);
- Pilbara Trap Managed Fishery (**Figure 7-33**);
- Nickol Bay Prawn Managed Fishery;
- Pilbara Crab Managed Fishery;
- Specimen Shell Managed Fishery; and
- Western Australian North Coast Shark Fishery.

Figure 3-27 shows the specific state managed within proximity of the Project Area. A summary of the state managed fisheries intersecting or within proximity of the Project Area is provided in **Table 3-27**. In addition to the fisheries that overlap the Project Area, a range of state managed fisheries overlap the EMBA beyond the Project Area. These are summarised in **Table 3-28**.

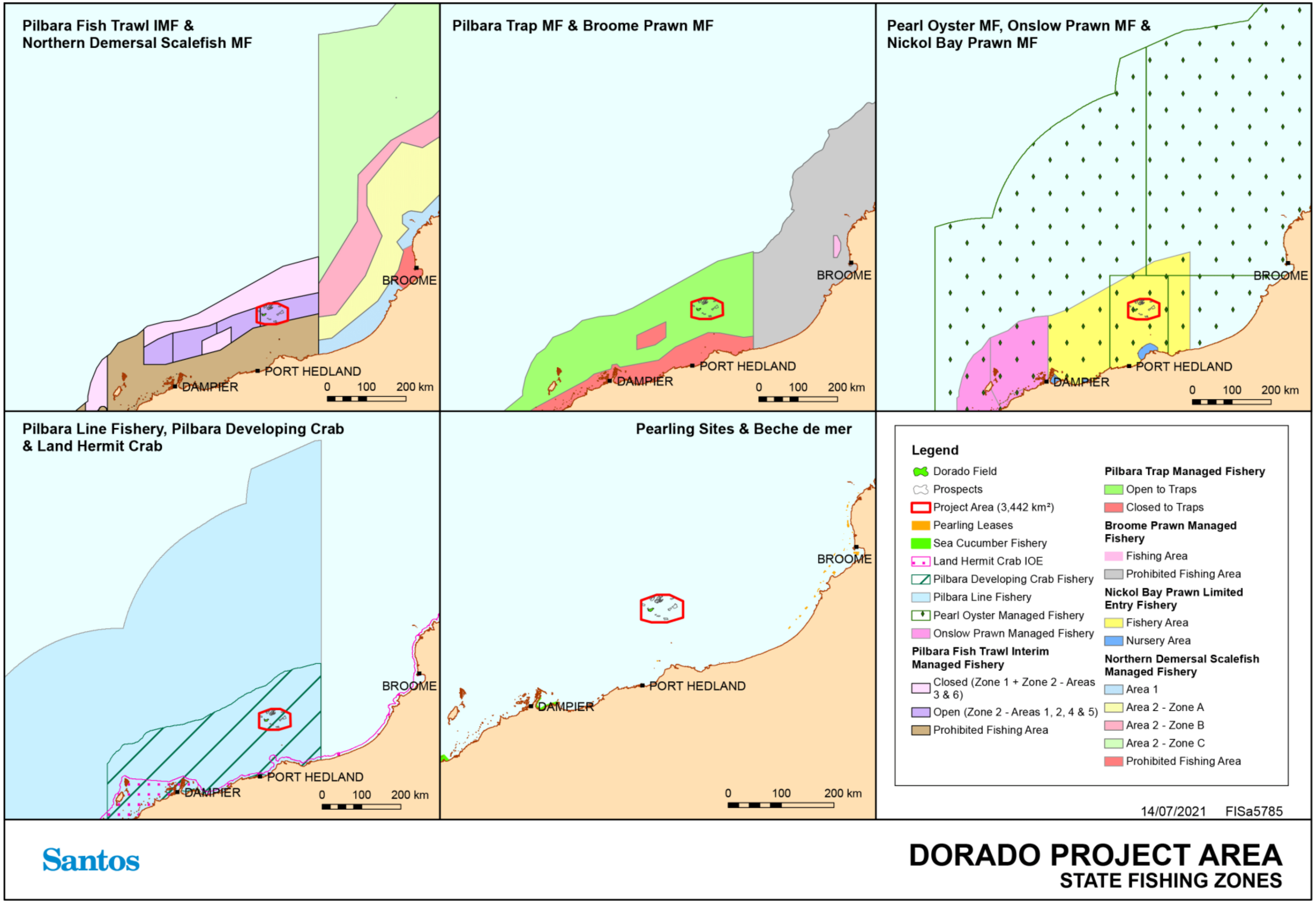


Figure 3-27: State managed fisheries in proximity of the Project Area

Table 3-27: Western Australian (state) commercial fisheries within the Project Area

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Pilbara Fish Trawl Interim Managed Fishery (IMF) Newman et al. (2019a)	The Pilbara Fish Trawl Interim Managed Fishery is situated in the Pilbara region in the northwest of Australia. It occupies the waters north of latitude 21°35ˈ S and between longitudes 114° 9ˈ 36" E and 120° E. The fishery is seaward of the 50-m isobath and landward of the 200-m isobath. The fishery consists of two zones: Zone 1 in the southwest of the fishery (which is closed to trawling) and Zone 2 in the north, which consists of six management areas, Areas 1 to 6. Areas 1, 2, 4 and 5 are open to trawl fishing all year round. The total area of these areas is 6,900 nm^2 (23,666 km^2).	Demersal trawl	Bluespotted emperor (*Lethrinus punctulatus*) Red emperor (*Lutjanus sebae*) Rankin cod (*Epinephelus multinotatus*) Goldband snapper (*Pristipomoides multidens*) Other demersal snapper, emperor, cod and grouper species are also caught.	In 2018, the total catch for the fishery was 1,975 tonnes (Gaughan et al. 2019), making up 75% of the total catch by the Pilbara Demersal Scalefish Fisheries, which is comprised of the trawl, trap and line fisheries. In the 2018 season, there were 11 licences in this fishery held by four licence holders. According to FishCube data, up to four vessels were active during the 2018 season. Fishing occurs year-round.	Fishing activity and target species occur in the Project Area. FishCube data shows fishing effort in the last 10 years occurs over an area of 23,058 km^2. The Project Area overlaps with 3,389 km^2 (15%) of the area of fishing effort. Fishing effort has occurred consistently within the Project Area each year for the last five years.

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Pilbara Trap Managed Fishery (MF) Newman et al. (2019a)	The Pilbara Trap MF lies north of latitude 21° 44' S and between longitudes 114° 9.6' E and 120°00'E on the landward side of a boundary approximating the 200-m isobath and seaward of a line generally following the 30-m isobath.	Demersal fish traps	Bluespotted emperor (*Lethrinus punctulatus*) Red emperor (*Lutjanus sebae*) Rankin cod (*Epinephelus multinotatus*) Goldband snapper (*Pristipomoides multidens*) Other demersal snapper, emperor, cod and grouper species are also caught.	In the 2018 season, there were six licenses in the Pilbara Trap MF, held between two operators. According to FishCube data, less than three vessels were active for the majority of the season, with a third vessel active only in July. In 2018, the total catch for the fishery was 562 tonnes (Gaughan et al. 2019), making up 21% of the total catch by the Pilbara Demersal Scalefish Fisheries, which is comprised of the trawl, trap and line fisheries. Fishing occurs year-round.	Fishing activity and target species occur in the Project Area. The fishery operates primarily from Onslow. Traps are limited in number with the greatest effort in waters less than 50 m depth. Given the water depth, fishing activity is not expected to occur within the Project Area. Fishing effort occurs over an area of 86,006 km^2. The Project Area overlaps with 3,442km^2 (4 %) of the area of fishing effort. Less than three vessels have operated in the Project Area each year for the last 5 years.
Pilbara Line Fishery Newman et al. (2019a)	The Pilbara Line Fishery fishing boat licensees are permitted to operate anywhere within "Pilbara waters", bounded by a line commencing at the intersection of 21° 56' S latitude and the high water	Demersal longline	Goldband snapper (*Pristipomoides multidens*) Ruby snapper (*Etelis carbunculus*) Other demersal snapper, emperor, cod and grouper	In the 2018 season nine individual licences were held in the Pilbara Line Fishery, held by seven operators. According to FishCube data, less than three vessels were active during the season.	Fishing activity and target species occur in the Project Area. FishCube data shows fishing effort in the last 10 years has occurred over an area of 146,414 km^2. The Project

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
	mark on the western side of the North West Cape on the mainland of Western Australia;,west along the parallel to the intersection of 21° 56' S latitude and the boundary of the 200-nm Australian Fishing Zone (AFZ), and north to longitude 120° E.		species are also caught.	The total catch in 2018 for the Pilbara Line Fishery was 95 tonnes (Gaughan et al. 2019), making up 4% of the total catch by the Pilbara Demersal Scalefish Fisheries, which is comprised of the trawl, trap and line fisheries. Fishing occurs year-round.	Area overlaps with 2,787 km^2 of the area of effort (2%). FishCube data reports that less than three vessels have operated in the Project Area each year for the last five years, compared with greater fishing effort located to the west of the Project Area between Exmouth and Dampier.
Mackerel Managed Fishery (Area 2 – Pilbara) Lewis and Brand-Gardner (2019) Mackie et al. (2010)	The Mackerel Managed Fishery licence area extends from Cape Leeuwin in the southwest of Western Australia to the Western Australian–Northern Territory border. Management Area 1 of the fishery (Kimberley sector) extends from 121° E to the Western Australian–Northern Territory border. Management Area 2 of the fishery (Pilbara sector) extends from 114° E near the North West Cape to 121° E.	Primarily surface or mid-water trolling by line. Jigging methods are also used.	Spanish mackerel (*Scomberomorus commerson*) Grey mackerel (also called broad-barred Spanish mackerel), school mackerel, spotted mackerel, shark mackerel and other pelagic species are also caught as bycatch species.	Most fishing efforts focused in Pilbara and Kimberley waters. Mackerel fishers troll for mackerel in nearshore waters. The fishery mainly relies on near-surface trolling and jig fishing around coastal reefs, shoals and headlands. FishCube data (**Attachment 1**) shows that fishing effort in the vicinity of the Project Area occurs in less than 60 m water depth, which is corroborated by	Considering the habitats and features that the fishery targets (reefs, shoals and headlands) are absent from the Project Area, participants in the fishery are not expected to be present in the Project Area. FishCube data for the last 10 years shows the Mackerel Managed Fishing effort within Area 2 is 51,526 km^2. The Project Area overlaps with 523 km^2 of the area of effort (1%). Fishing effort is restricted to the southern portion of the Project Area.

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
	Management Area 3 of the fishery (Gascoyne/West Coast sector) extends south from 114° E to Cape Leeuwin. The Project Area overlaps Area 2 – Pilbara sector.			consultation with fishing stakeholders for previous Bedout Sub-basin activities. The fishery operates year-round; however, most fishing effort occurs from April/May to October/November. In the Pilbara sector, about 65% of effort has historically occurred from July to August. The commercial catch of Spanish mackerel from all sectors of the fishery has been 270 to 330 tonnes (Gaughan et al. 2019) per year since 2006.	
Pearl Oyster Managed Fishery Hart et al. (2016, 2019)	The Pearl Oyster Managed Fishery licence area extends from 114° 10ˈ E near Exmouth to the Western Australian–Northern Territory border and out to the edge of the AFZ (200 nautical miles). The licence	Drift diving in waters up to 35 m depth	Indo-Pacific, silver-lipped pearl oysters (*Pinctada maxima*).	Drift diving, with divers towed behind vessels, allows collection of legal-sized pearl oysters from the seabed by hand. Following collection, pearl oysters are kept in wire mesh panels on the seabed at holding sites	The Project Area overlaps with Zones 1 and 2 of the fishery. However, pearl collection, holding and farming activities are limited to nearshore waters. Recent literature suggests more than 90% of individuals occurred shallower than 40 m

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
	area is subdivided into four zones. Zone 1 extends from 114° 10' E to 119° 30' E. Zone 2 extends from 118° 10' E and includes the Eighty Mile Beach region out to 18° 14' S. Zone 3 includes waters offshore from Broome and the North Kimberley coast, north of 18° 14' S and between 119° 00' E and 125° 20' E. Zone 4 extends from 125° 20' E to the Western Australian–Northern Territory border.			near fishing grounds. After 2 to 3 months, oysters are transferred from holding sites to pearl farm leases for cultivating pearls. The principal fishing grounds for pearl oyster collection are located off Eighty Mile Beach within water depths of approximately 20 m. A deeper water collection site called 'Compass Rose' lies offshore from Eighty Mile Beach in water depths of approximately 35 m. Holding sites are located near the fishing grounds in water depths up to 30 m (Hart et al. 2016). Fishing usually commences in March/April and ceases in June/July. Seeding of the pearl oysters is undertaken during winter months (June to August).	and less than 2% were found deeper than 50 m, supporting that extensive populations do not extend into deep water in the region (Whalan et al 2021). Pearl diving activities do not intersect the Project Area. FishCube data shows no effort within the Project Area, due to the restriction of pearl diving operational activities to shallow diving depths below 35 m. The nearest pearl diving activities in the last 10 years have occurred near Port Hedland, North Turtle Island, Little Turtle Islet and the DeGrey River mouth (approximately 50 km south of the Project Area). No fishing has been undertaken at these sites since 2016. The principal pearl oyster fishing grounds are located off Eighty Mile Beach approximately 120 km from the Project Area.

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
				This may occur at holding sites or at pearl farms. The principal fishing grounds, holding sites and pearl farms are in waters off Eighty Mile Beach and Broome. A single approved pearl farm lease is located near North Turtle Island, and pearl diving activities have previously occurred in coastal waters near Port Hedland and the De Grey River mouth.	
Nichol Bay Prawn Managed Fishery Kangas et al. (2019)	The boundaries of the Nichol Bay Prawn MF are all the waters of the Indian Ocean and Nickol Bay between 116° 45' E longitude and 120° E longitude on the landward side of the 200-m isobath. The fishery incorporates the Nickol Bay, Extended Nickol Bay, Depuch and De Grey River size-managed fish grounds.	Trawl	Banana prawns Brown tiger prawns	Fishing effort is concentrated in waters less than 50 m depth. The total landings of major penaeids for the 2017 season were 227.1 tonnes. Fishing effort in 2017 increased to 281 boat days, well up on the low effort of 43 boat days in 2016 (Kangas et al. 2017).	Prawn trawling activities are unlikely to occur in the Project Area. FishCube data shows effort in the fishery does not intersect the Project Area.

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Western Australia North Coast Shark Fishery Department of Fisheries (2005)	The fishery includes Australian waters north of Broome, from longitude 120° E to 123° 45' E (Koolan Island).	Longline	Dusky whaler shark Sandbar shark Gummy shark Whiskery shark	This fishery is currently closed to protect the breeding grounds of the resource that supports the two southern shark fisheries. No fishing effort since 2008/09.	The fishery is currently closed. Target species may occur in the Project Area.
Pilbara Crab Managed Fishery Johnston et al. (2019)	The boundaries of the fishery are consistent with the boundaries of the Nickol Bay Prawn Managed Fishery and the Onslow Prawn Fishery, which include waters between 114° 39.9' E and 120° E, and on the landward side of the 200-m depth isobath.	Traps	Blue swimmer crab	Crabbing activity along the Pilbara coast is centred largely on the inshore waters from Onslow through to Port Hedland, with most commercial and recreational activity occurring in and around Nickol Bay. Blue swimmer crabs are targeted by the fishery within inshore waters around Nickol Bay using hourglass trap (Gaughan and Santoro 2018).	Fishery activities are not expected to intersect the Project Area due to the distance from inshore waters. FishCube data shows no fishing effort within the Project Area. Consultation with WAFIC has indicated that while they do mostly fish nearshore (less than 50 m of water) they may venture into deeper waters.

Fishery	License Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Specimen Shell Managed Fishery Hart et al. (2019b)	This fishery occurs in all Western Australian state waters. Effort is concentrated in the area adjacent to the largest population centres, such as Broome, Karratha, Shark Bay, Mandurah, Exmouth, Cape region, Albany and Perth.	Hand collection, wading, diving in shallow coastal waters. One licence exemption permits the use of ROV.	The fishery targets the collection of specimen shells for display, collection, cataloguing and sale.	The main method of specimen shell collection is by hand, by a small group of divers operating from small boats in shallow coastal waters or by wading along coastal beaches below the high water mark. A current exemption permits the use of an ROV at depths of up to 300 m. This is a limited entry fishery with 23 active licences in 2016. A maximum of 2 divers are allowed in the water per licence at any one time, and specimens may only be collected by hand. ROVs were limited to one per license in 2016.	FishCube data for the last 10 years (**Section 7.2.8.2.1**) shows the Specimen Shell Managed Fishing effort area is 43,320km^2. The Project Area overlaps. The Project Area overlaps with 1,358km^2 of the area of effort (3%). Fishing effort to date is along the eastern extent of the Project Area.

Table 3-28: Western Australian (state) commercial fisheries within the EMBA and not the Project Area

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
Abalone Managed Fishery Strain et al. (2019)	Roe's abalone Brownlip abalone Greenlip abalone		Hand collection, diving	Abalone are collected by hand in shallow coastal waters in the southwest of Western Australia. Fishing effort from the dive-based fishery is restricted to shallow coastal waters off the southwest and south coasts of Western Australia, particularly around the Perth metropolitan area. Abalone is harvested by divers, limiting the fishery to shallow waters. The target species do not occur in tropical waters. The management area covering waters north of Moore River (near Perth) is closed.
Abrolhos Islands and Mid-West Trawl Managed Fishery	Saucer scallops (*Ylistrum balloti*), with a small component targeting the western king prawn (*Penaeus latisulcatus*).	2017/2018: 651 tonnes	Operates using low- opening otter trawl systems.	All the waters of the Indian Ocean adjacent to Western Australia between 27° 51ˈ S latitude and 29° 03ˈ S latitude on the landward side of the 200-m isobath.
Broome Prawn Managed Fishery Kangas et al. (2019)	Western king prawns (*Penaeus latisulcatus*) and coral prawns (a combined category of small penaeid species).	Extremely low fishing effort occurred. Only trial fishing was undertaken by one boat during 2016 to investigate whether commercial fishing was warranted. This resulted in negligible landings.	Otter trawl	The fishery operates in a designated trawl zone off Broome. The boundaries of the fishery are all Western Australian waters of the Indian Ocean lying east of 120° E longitude and west of 123° 45' E longitude on the landward side of the 200- m isobath. The actual trawl area is contained within a delineated small area northwest of Broome. The majority of the fishery is permanently closed to trawling and is not fished.

[11] Sources for catch data: Department of Agriculture 2019; Gaughan et al., 2019; DPIRD 2018.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
Cockburn Sound Mussel Managed Fishery	Blue mussels (*Mytilus galloprovincialis*)	2015: Unspecified.	Aquaculture	Main mussel farming occurs in southern Cockburn Sound.
Cockburn Sound Crab Managed Fishery	Blue swimmer crab (*Portunus armatus)*	2017/2018: closed to commercial and recreational fishing since April 2014.	Drop nets, scoop nets, diving	Encompasses the inner waters of Cockburn Sound, from South Mole at Fremantle to Stragglers Rocks, through Mewstone to Carnac Island and Garden Island, along the eastern shore of Garden Island and back to John Point on the mainland.
Cockburn Sound Line and Pot Managed Fishery	Southern garfish (*Hyporhamphus melanochir*), Australian herring (*Arripis geogianus*)	2017/2018: 257 tonnes.	Line (fish) Shelter and trigger pots (octopus)	Encompasses the inner waters of Cockburn Sound, from South Mole at Fremantle to Stragglers Rocks, through Mewstone to Carnac Island and Garden Island, along the eastern shore of Garden Island and back to John Point on the mainland.
Exmouth Gulf Prawn Managed Fishery	Western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus* spp.) and banana prawns (*Penaeus merguiensis*).	2017/2018: 713 tonnes.	Low-opening otter trawls.	Sheltered waters of Exmouth Gulf. Essentially the western half of the Exmouth Gulf (eastern part is a nursery ground). The Muiron Islands and Point Murat provide the western boundary; Serrurier Island provides the northern limit.
Gascoyne Demersal Scalefish Managed Fishery	Targets pink snapper (*Pagrus auratus*) and goldband snapper (*Pristipomoides multidens*). Other demersal species caught include the rosy snapper (*P. filamentosus*), ruby snapper (*Etelis carbunculus*), red emperor (*Lutjanus sebae*), emperors (Lethrinidae, including	2017/2018: Snapper: 133 tonnes. Other demersals: 144 tonnes.	Mechanised handlines	The fishery operates in the waters of the Indian Ocean and Shark Bay between latitudes 23° 07' 30" S and 26° 30' S. Vessels are not permitted to fish in inner Shark Bay.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
	spangled emperor (*Lethrinus nebulosus*) and redthroat emperor (*L. miniatus*)), cods (Epinephelidae, including Rankin cod (*Epinephelus multinotatus*) and goldspotted rockcod (*E. coioides*)), pearl perch (*Glaucosoma burgeri*), mulloway (*Argyrosomus japonicas*), amberjack (*Seriola dumerili*) and trevallies (Carangidae).			
Hermit Crab Fishery	Australian land hermit crab (*Coenobita variabilis*)	2017/2018: 58,643 (lowest reported in the last 10 years (2008 to 2017); catch range 58,643 to 118,203)).	Activity is land-based and occurs on beaches along large areas of the Western Australian coastline.	Operates in Western Australian waters north of the Exmouth Gulf (22° 30' S).
Kimberley Developing Mud Crab Managed Fishery	Mud crab (*Scylla serrata*)	2017/2018: 60 tonnes (also includes catch data from Pilbara Developmental Crab Fishery).	Mud crab traps	This fishery operates between Broome and Cambridge Gulf. Three commercial operators are permitted to fish from King Sound to the Northern Territory border, with closed areas around communities and fishing camps. One Aboriginal Corporation is permitted to fish in King Sound, with the other Aboriginal Corporation permitted to fish in a small area on the western side of the Dampier peninsula, north of Broome.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
				Notices issued under the *Fish Resources Management Act 1994* prohibit all commercial fishing for mud crabs in Roebuck Bay and an area of King Sound near Derby.
Kimberley Gillnet and Barramundi Managed Fishery	Barramundi *(Lates calcarifer)* King threadfin *(Polydactylus macrochir)* Blue threadfin *(Eleutheronema tetradactylum)*	2017/2018: 79.9 tonnes.	Gillnet in inshore waters	Nearshore and estuarine zones of the North Coast Bioregion from the Western Australian–Northern Territory border (129° E) to the top end of Eighty Mile Beach, south of Broome (19° S). The waters of the Kimberley Gillnet and Barramundi Managed Fishery are defined as all Western Australian waters north of 19° S latitude and west of 129° E longitude and within three nautical miles of the high water mark of the mainland of Western Australia and the waters of King Sound south of 16° 21.47ˈ S latitude.
Kimberley Prawn Managed Fishery	Banana prawns (*Penaeus merguiensis*) Tiger prawns (*Penaeus esculentus*) Endeavour prawns (*Metapenaeus endeavouri*) Western king prawns (*Penaeus latisulcatus*)	2017/2018: 269 tonnes.	Trawl	The Kimberley Prawn Managed Fishery operates off the north of the state between Koolan Island and Cape Londonderry. The boundaries of the Kimberley Prawn Managed Fishery are all Western Australian waters of the Indian Ocean lying east of 123° 45ˈ E longitude and west of 126° 58ˈ E longitude. It abuts the western boundary of the Commonwealth Northern Prawn Fishery.
Mandurah to Bunbury Developing Crab Fishery	Blue swimmer crab (*Portunus armatus)*	2017/2018: 5.2 tonnes.	Drop nets, scoop nets, diving	Fishery extends from south of the Shoalwater Islands Marine Park (32° 22ˈ 40" S) to Point McKenna near Bunbury (33° 16ˈ S) and offshore to 115° 30ˈ E. The fishery is divided into two zones with crab fishing historically being permitted within Area 1, Comet Bay between 32° 22ˈ 40" S and 32° 30ˈ S, and Area 2, Cape Bouvard to the southern boundary of the fishery. In 2015, crab fishing within Area 2 ceased.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
Marine Aquarium Fish Managed Fishery	Over 250 target species of finfish. (228 species caught in 2012). Fishermen can also take coral, live rock, algae, seagrass and invertebrates. The main fish species landed in 2012 were scribbled angelfish (*Chaetodontoplus duboulayi*) and green chromis (*Chromis cinerascens*) The main coral species landed in 2012 were the coral-like anemones of the Corallimorpharia.	2017/2018: Total catch of 150,544 fishes; 21.9 tonnes of coral, live rock and living sand; and 322 litres of marine plants.	Hand harvest while diving or wading. Handheld nets	Dive-based fishery operating all year throughout Western Australian waters (to 200 nM), but restricted by diving depths. The Marine Aquarium Fish Managed Fishery is able to operate in all state waters (between the Northern Territory border and South Australian border). The fishery is typically more active in waters south of Broome, with higher levels of effort around the Capes region, Perth, Geraldton, Exmouth and Dampier. Operators in the Marine Aquarium Fish Managed Fishery are also permitted to take coral, live rock, algae, seagrass and invertebrates under the Prohibition on Fishing (Coral, 'Live Rock' and Algae) Order 2007 and by way of Ministerial Exemption (Gaughan and Santoro 2018).
North Coast Trochus Fishery	Trochus (*Tectus niloticus*)	2017/2018: Unspecified.	Harvested with handheld levers or chisels	Indigenous fishery operating within King Sound.
Northern Demersal Scalefish Managed Fishery	Red emperor (*Lutjanus sebae*) Goldband snapper (*Pristipomoides multidens*)	2017/2018:1317 tonnes (total). Goldband snapper (not including other jobfish): 473 tonnes. Red emperor: 34 to 47 tonnes.	The permitted means of operation within the fishery include handline, dropline and fish traps, but since 2002 it has essentially been a trap-based fishery that uses gear,	The Northern Demersal Scalefish Managed Fishery operates off the northwest coast of Western Australia in the waters east of 120° E longitude. These waters extend out to the edge of the AFZ (200 nautical miles). The fishery consists of three zones: Zone A is an inshore area, Zone B comprises the area with most historical fishing activity and Zone C is an offshore deep-slope developmental area. The fishery is further divided into two fishing areas: an inshore sector and an offshore sector. The inshore waters in the vicinity of Broome are closed to commercial fishing.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
			time of access and spatial zones as the primary management measures (State of the Fisheries 2014-15).	The fishery is located to the east of the Project Area. Therefore, no fishing activity will occur overlapping the Project Area. Target species occur in the Project Area.
Octopus Interim Managed Fishery	*Octopus cf. tetricus*, with occasional bycatch of *O. ornatus* and *O. cyanea* in the northern parts of the fishery and *O. maorum* in the southern and deeper sectors.	2017/2018: Commercial: 257 tonnes Recreational: 1 tonne	Line and pots Trawl and trap (land octopus as byproduct)	Fishery is in the development phase. Four main categories in Western Australian waters. Octopus are primarily caught in the Developing Octopus Interim Managed Fishery (largest fishery) area is limited to the boundaries of the developmental fishery, which is an area bounded by the Kalbarri Cliffs (26° 30ˈ S) in the north and Esperance in the south. Passive and by-product harvests of octopus occur in both the Cockburn Sound Line and Pot Managed Fishery and the West Coast Rock Lobster Managed Fishery.
Onslow Prawn Managed Fishery Kangas et al. (2019)	Western king prawns (*Penaeus latisulcatus*) Brown tiger prawns (*Penaeus esculentus*) Endeavour prawns (*Metapenaeus* spp.)	2017/2018: Negligible (Minimal fishing occurred in 2017). Only 5 days of fishing effort was undertaken (one boat) in 2017.	Trawl	Operates along the western part of the North West Shelf with most prawning activities concentrated in the shallower water off the mainland. The boundaries of the fishery are 'all the Western Australian waters between the Exmouth Prawn Fishery and the Nickol Bay prawn fishery east of 114°39.9' on the landward side of the 200 m depth isobath'.
Roe's Abalone	Western Australian Roe's abalone (*Haliotis roei*)	2017/2018: Commercial: 49 tonnes Recreational: 23 tonnes	Dive and wade The commercial fishery harvest method is a single diver working off a "hookah" (surface-supplied breathing	Operating in shallow coastal waters along the Western Australian western and southern coasts from Shark Bay to the South Australian border. Divided into eight management areas. Commercial fishing for Roe's abalone is managed in six separate regions from the South Australian border to Busselton Jetty: Areas 1, 2, 5, 6, 7 and 8. Area 8 of the fishery was not fished in 2013.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
			apparatus) using an abalone "iron" to prise the shellfish off rocks. Abalone divers operate from small fishery vessels (generally less than 9 m in length).	
Shark Bay Crab Interim Managed Fishery	Blue swimmer crab (*Portunus armatus*)	2017/2018: 443 tonnes total Crab: 153 tonnes	Trawl and trap	Waters of Shark Bay north of Cape Inscription, to Bernier and Dorre Islands and Quobba Point. In addition, two fishers with long-standing histories of trapping crabs in Shark Bay are permitted to fish in the waters of Shark Bay south of Cape Inscription.
Shark Bay Prawn Managed Fishery	Western king prawn (*Penaeus latisulcatus*) Brown tiger prawn (*Penaeus esculentus*) Variety of smaller prawn species including endeavour prawns (*Metapenaeus* spp.) and coral prawns (various species).	2017/2018: 1,608 tonnes	Low-opening otter trawls	The boundaries of the Shark Bay Prawn Managed Fishery are located in and near the waters of Shark Bay.
Shark Bay Scallop Limited Entry Fishery	Saucer scallop (*Ylistrum balloti*)	2017/2018: 1,632 tonnes	Low-opening otter trawls	The boundaries of the Shark Bay Scallop Limited Entry Fishery are located in and near the waters of Shark Bay.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
South Coast Open Access Netting Fishery	Insufficient information	Insufficient information	Insufficient information	Bunbury to the South Australian border.
South Coast Salmon Managed Fishery	Western Australian salmon (*Arripis truttaceus*)	2017: 50 tonnes	Beach seine net, rod and line	Licensees operate from 18 designated beaches within the South Coast Bioregion, many of which have huts that are referred to as salmon camps.
South West Coast Salmon Managed Fishery	Western Australian salmon (*Arripis truttaceus*)	Insufficient information	Beach seine nets	The fishery includes all Western Australian waters north of Cape Beaufort (south coast) except Geographe Bay. The South West Coast Salmon Managed Fishery operates on various beaches south of the metropolitan area.
South West Coast Beach Net	Insufficient information	Insufficient information	Insufficient information	Insufficient information
South West Trawl Limited Entry Fishery	Saucer scallops (*Ylistrum balloti*)	2017/2018: 460 t meat weight (2,301 t whole weight)	Otter trawls	Waters between 31° 34ˈ 27" S and 115° 8ˈ 8" E where the fishery intersects with the high water mark at Cape Leeuwin and on the landward side of the 200-m isobath.
Temperate Demersal Gillnet and Demersal Longline Fisheries	Gummy shark (*Mustelus antarcticus*) Dusky shark (*Carcharhinus obscurus*) Whiskery shark (*Furgaleus macki*) Sandbar shark (*Carcharhinus plumbeus*)	2017/2018: Sharks and rays: 936 tonnes Scalefish: 133 tonnes	Demersal gillnets and power-hauled reels (to target sharks) Demersal longline	The Temperate Demersal Gillnet and Demersal Longline Fisheries consist of Zone 1 of the Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery and the West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery. The Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery spans the waters from 33° S latitude to the Western Australian–South Australian border and comprises three management zones. Zone 1 extends southwards from 33° S to 116° 30ˈ E longitude off the south coast. Zone 2 extends from 116° 30ˈ E to the Western Australian–South Australian border (129° E). A small number of Zone 3 units permit fishing throughout Zone 1 and eastwards to 116° 55ˈ 40" E.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
				The West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery technically extends northwards from 33° S latitude to 26° S latitude. However, the use of shark fishing gear has been prohibited north of 26° 30' S (Steep Point) since 1993. Demersal gillnet and longline fishing inside the 250-m depth contour has been prohibited off the metropolitan coast (between latitudes 31° S and 33° S) since November 2007.
Warnbro Sound Crab Managed Fishery	Blue swimmer crab (*Portunus armartus)*	2017/2018: closed to commercial and recreational fishing	Drop nets, scoop nets, diving	Includes Warnbro sound and adjacent water, extending from Becher Point to John Point.
West Coast Deep Sea Crustacean (Interim) Managed Fishery	Crystal (snow) crabs (*Chaceon albus*) Giant (king) crabs (*Pseudocarcinus gigas*) Champagne (spiny) crabs (*Hypothalassia acerba*)	2017/2018: 164.4 tonnes	Baited pots operated in a longline formation in the shelf edge waters (more than 150 m deep)	North of latitude 34° 24' S (Cape Leeuwin) and west of the Northern Territory border on the seaward side of the 150-m isobath out to the extent of the AFZ, mostly in 500 to 800 m of water.
West Coast Demersal Scalefish Interim Managed Fishery	West Coast inshore demersals: West Australian dhufish (*Glaucosoma hebraicum*), pink snapper (*Pagrus auratus*) with other species captured including redthroat emperor (*Lethrinus miniatus*), bight redfish (*Centroberyx gerrardi*) and baldchin groper (*Choerodon rubescens*).	2017/2018: 248 tonnes	Handline and dropline	The fishery encompasses the waters of the Indian Ocean just south of Shark Bay (at 26° 30' S) to just east of Augusta (at 115° 30' E) and extends seaward to the 200-nm boundary of the AFZ. The commercial fishery is divided into five management areas comprising four inshore areas and one offshore area. The inshore areas, i.e. Kalbarri, Mid-West, Metropolitan and South-West, extend outwards to the 250-m depth contour, while the Offshore Area extends the entire length of the fishery from the 250-m depth contour to the boundary of the AFZ.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
	West Coast offshore demersals: Eightbar grouper (*Hyporthodus octofasciatus*), hapuku (*Polyprion oxygeneios*), blue-eye trevalla (*Hyperoglyphe antarctica*) and ruby snapper (*Etelis carbunculus*).			
West Coast Estuarine Managed Fishery	Blue swimmer crab (*Portunus armartus)*	2017/2018: Commercial: 353 tonnes (blue swimmer crab) Recreational: 58 to 77 tonnes	Drop nets, scoop nets, diving (crabs)	Includes the waters of the Swan and Canning Rivers (Area 1), the waters of the Peel Inlet and Harvey Estuary, together with the Murray Serpentine, Harvey and Dandalup Rivers (Area 2) and waters of the Hardy Inlet (Area 3). Of these areas only Areas 1 and 2 are permitted for crab fishing.
West Coast Nearshore and Estuarine Finfish Fisheries	Nearshore: whitebait (*Hyperlophus vittatus*), western Australian salmon (*Arripis truttaceus*), Australian herring (*Arripis georgianus*), sourthern school whiting (*Sillago bassensis*), yellowfin whiting (*Sillago schomburgkii*), yelloweye mullet (*Aldrichetta forsteri*), tailor (*Pomatomus saltarix*), southern garfish	2017/2018: 353 tonnes	Haul, beach seine and gill netting (commercial). Line fishing (recreational)	Five commercial fisheries target nearshore and/or estuarine finfish in the West Coast Bioregion. Nearshore: Cockburn Sound Fish Net Managed Fishery operating within in Cockburn sound, South West Coast Salmon Managed Fishery operating on various beaches south of the Perth Metropolitan area, West Coast Beach Bait Managed Fishery operating on beaches spanning from Moore River to Tim's Thicket and the South West Beach Seine Fishery operating on various beaches from Tim's Thicket southwards to Port Geographe Bay Marina. Estuarine*:* West Coast Estuarine Managed Fishery operating in the Swan/Canning and Peel Harvey estuaries, and in the Hardy Inlet.

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
	(*Hyporhamphus melanochir*), silver trevally (*Pseudocaranx georgianus*) and King George whiting (*Sillaginodes punctate*). Estuarine*:* sea mullet (*Mugil cephalus*), estuary cobbler (*Cnidoglanis macrocephalus*) and black bream (*Acanthopagrus butcheri*).			
West Coast Nearshore Net Managed Fishery	Southern garfish (*Hyporhamphus melanochir*) Australian herring (*Arripis georgianus*)	Insufficient information	Insufficient information	Insufficient information
West Coast Purse Seine Fishery	Scaly mackerel (*Sardinella lemuru*) Pilchard (*S. sagax*) Australian anchovy (*Engraulis australis*) Yellowtail scad (*Trachurus novaezelandiae*) Maray (*Etrumeus teres*)	2017/2018: 1,095 tonnes	Purse seine gear	Waters between Ningaloo and Cape Leeuwin including three separate zones: Northern Development (22° 00' S to 31° 00' S), Perth Metropolitan (31° 00' S to 33° 00' S) and Southern Development Zone (33° 00' S to Cape Leeuwin).
West Coast Rock Lobster Managed Fishery	Western rock lobster (*Panulirus cygnus*)	2016: 272 to 400 tonnes (346 to 481 tonnes based on updated average weight)	Baited traps (pots) Pots and diving (recreational catch)	The fishery is situated along the west coast of Australia between Latitudes 21° 44' S to 34° 24' S. The fishery is managed in three zones: Zone A – Abrolhos Islands, north of latitude 30° S excluding the Abrolhos Islands (Zone B) and south of latitude 30° S (Zone C).

Fishery	Target Species	Catch[11]	Fishing Method	Area Description
West Coast Demersal Gillnet and Demersal Longline	Gummy shark (*Mustelus antarcticus*) Dusky shark (*Carcharhinus obscurus*) Whiskery shark (*Furgaleus macki*) Sandbar shark (*C. plumbeus*)	2016/2018: 936 tonnes of sharks and rays	Demersal gillnets and demersal longline (not widely used)	Operates between 26° S and 33° S.
Western Australian Sea Cucumber Fishery (formerly known as Beche-de-mer Fishery) Gaughan et al. (2019)	Sandfish (*Holothuria scabra*) Deepwater redfish (*Actinopyga echinites*).	2016: 93 tonnes	Hand-harvest fishery, with animals caught principally by diving and a smaller amount by wading.	The fishery is primarily based in the northern half of the state, from Exmouth Gulf to the Northern Territory border. The Western Australian Sea Cucumber Fishery is permitted to operate throughout Western Australian waters with the exception of a number of specific closures around the Dampier Archipelago, Cape Keraudren, Cape Preston and Cape Lambert, the Rowley Shoals and the Abrolhos Islands (Gaughan and Santoro 2018).

3.4.3.1.2 Commonwealth Managed Fisheries

Commonwealth managed fisheries are those within the 200-nm AFZ managed by Australian Fisheries Management Authority. In some cases, by agreement with the states and territory, Commonwealth fisheries also extend to the low water mark. Information on Commonwealth managed fisheries has been derived from 'Fishery Status' Report 2019 (Department of Agriculture 2019).

Commonwealth managed fisheries that overlap the Project Area are described in **Table 3-29:**

+ Southern Bluefin Tuna Fishery;
+ Western Skipjack Tuna Fishery; and
+ Western Tuna and Billfish Fishery.

Commonwealth fisheries that have permits to operate in the EMBA are described in **Table 3-30** and include:

+ North West Slope Trawl Fishery;
+ Northern Prawn Fishery;
+ Small Pelagic Fishery;
+ Southern and Eastern Scalefish and Shark Fishery; and
+ Western Deepwater Trawl Fishery.

Table 3-29: Commonwealth managed commercial fisheries within the Project Area

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Southern Bluefin Tuna Fishery Patterson and Nicol (2018)	Fishery includes all waters of Australia, out to 200 nm from the coast. Young fish move from spawning grounds in the northeast Indian Ocean into the Australian exclusive economic zone and southward along the Western Australian coast (Patterson et al. 2019).	Purse seine vessels primarily in Great Australian Bight all year round Pelagic longline off southern New South Wales in winter	Southern bluefin tuna	Most of the Australian catch has been taken by purse seine, targeting juvenile tuna in the Great Australian Bight. Australian domestic longliners operating along the east coast catch some tuna, and recreational fishing has increased (Patterson et al. 2019). No current effort occurs on the NWS; fishing activity is concentrated in the Great Australian Bight and off southeast Australia (Patterson et al. 2019).	Although the fishery boundaries encompass the Project Area, the lack of effort outside the Great Australian Bight and the east coast of Australia means activity within the Project Area is not expected.
Skipjack Tuna Fishery	This fishery extends around the whole of Australia in waters out to 200 nm from the coast.	Purse seine fishing gear (98%) and some pole-and-line effort	Skipjack Tuna	There has been no fishing effort in the fishery since the 2008–09 fishing season.	Given the lack of fishing effort across the whole fishery, activity within the Project Area is not expected.

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Project Area Presence
Western Tuna and Billfish Fishery	This fishery has a wide area of operation, extending from the tip of Cape York around Western Australia to the border of Victoria and South Australia within both the AFZ and further offshore within the high seas, with major landing ports for the fishery being in Fremantle and Geraldton.	Pelagic longline fishing methods and some use of minor line fishing methods	Bigeye tuna (*Thunnus obesus*) Yellowfin tuna (*Thunnus albacares*) Albacore tuna (*Thunnus alalunga*) Broadbill Swordfish (*Xiphias gladius*) Striped marlin (*Kajikia audax*)	Fishing occurs in both the AFZ and adjacent high seas of the Indian Ocean. Fishing occurs year-round. In recent years, fishing effort has concentrated off southwest Western Australia and South Australia with no current effort on the NWS (Department of Agriculture 2019). Between 2014 and 2018, fishing effort has consistently focused on waters west of Carnarvon and south of southwest Western Australia. The main landing ports are Geraldton and Fremantle. Since 2005, fewer than five vessels have been active in the fishery each year (three vessels in 2016; four vessels in 2017).	Although the fishery boundaries encompass the Project Area, in recent years, effort has concentrated off southwest Western Australia and South Australia and therefore activity within the Project Area is not expected.

Table 3-30: Commonwealth managed commercial fisheries within the EMBA but not the Project Area

Fishery	Key Target/ Indicator Species	Summary of Fishing Activities	Gear Type?	License Area Description
North West Slope Trawl Fishery	Scampi (crayfish): velvet scampi (*Metanephrops velutinus*) and boschmai scampi (*Metanephrops boschmai*). Deepwater prawns (penaeid and carid): pink prawn (*Parapenaeus longirostris*), red prawn (*Aristaeomorpha foliacea*), striped prawn (*Aristeus virilis*), giant scarlet prawn (*Aristaeopsis edwardsiana*), red carid prawn (*Heterocarpus woodmasoni*) and white carid prawn (*Heterocarpus sibogae*). Snapper.	There has been no fishing effort in the Project Area. Fishing effort occurs within the EMBA. Fishing occurs on the continental slope in water depths greater than 200 m. Fishing effort has typically occurred along the slope offshore from the Pilbara region, in the Rowley Shoals area and northeast towards and around Scott Reef. Fishing occurs year-round. The number of vessels involved in the fishery has been one or two vessels each year since 2008/2009. The primary landing ports are Point Samson in Western Australia and Darwin in the Northern Territory. Four fishing permits and two vessels were active in the fishery during the 2016-17 fishing season. Total catch in the 2016-17 fishing season was 57.8 tonnes over 114 days of fishing effort. Fishing effort increased in the 2017-2018 season. Total catch was 79.7 tonnes over 219 days.	Demersal crustacean trawl seaward of the 200-m isobath.	Extends from 114° E to approximately 125° E off the Western Australia coast between the 200-m isobath and the outer limit of the AFZ.
Western Skipjack Tuna Fishery Australian Fisheries Management Authority (2019)	Skipjack tuna (*Katsuwonus pelamis*)	2017-18: None in either zone. Fishing in the Western Skipjack Tuna Fishery is opportunistic and highly dependent on availability and the domestic cannery market. Currently, no domestic cannery has active contracts for skipjack tuna.	Purse seine Some pole and line	The Skipjack Tuna Fishery is split into two sectors: east and west. The Western Skipjack Tuna Fishery is located in all Australia waters west of 142° 30ʹ 00" E, out to 200 nm from the coast. There has been no fishing effort in the Skipjack Tuna Fishery since the 2008-09 season, and in that season activity

				concentrated off South Australia (Department of Agriculture 2019).
Small Pelagic Fishery	Australian sardine (*Sardinops sagax*) Blue mackerel (*Scomber australasicus*) Jack mackerel (*Trachurus declivis*) Redbait (*Emmelichthys nitidus*).	2018-19: 9,424 tonnes	Purse seine and midwater trawling	Extends from Queensland to southern Western Australia.
Western Deepwater Trawl Fishery	A diverse range of species are caught, ranging from tropical and ruby snappers on the shelf edge to orange roughy (*Hoplostethus atlanticus*), oreo dories and bugs (*Ibacus* spp.) in the deeper temperate waters.	2017-18: 101.9 tonnes	Demersal fish trawl seaward of the 200-m isobath	The fishery's northernmost point is from the boundary of the AFZ to longitude 114° E, and its southernmost point is from the boundary of the AFZ to longitude 115° 08ˈE. Deep water off Western Australia, from the 200-m isobath to the edge of the AFZ.

3.4.3.2 Recreational Fishing

Consultation for previous petroleum activities undertaken by Santos in the Project Area has confirmed that no charter boats operate out of Port Hedland.

Similarly, consultation with Recfishwest identified that recreational fishing often occurs around the Port Hedland port marker buoys. In consultation with the Port Hedland Game Fishing Club and Port Hedland Volunteer Marine Rescue, it was identified that recreational fishing activity may occur 50 nm offshore, with some locals targeting game fish up to the 50-m water depth and the area surrounding Bedout Island. Therefore, no interaction with recreational fishers is anticipated in the Project Area but may occur in the EMBA.

3.4.3.2.1 North Coast Bioregion

The North Coast Bioregion (Pilbara/Kimberley) runs from the Ashburton River to the Western Australia–Northern Territory border. The oceanography of this region includes waters of Pacific Ocean origin that enter through the Indonesian archipelago, bringing warm, low-salinity waters polewards via the Indonesian throughflow and Holloway currents, which flow seasonally and interact with Indian ocean waters. Recreational fishing is experiencing a significant growth in this region, with a distinct seasonal peak in winter when the local population increases by significant numbers of metropolitan and interstate tourists. This has been added to by the increased recreational fishing by those involved in the construction or operation of major developments in this region. Owing to the high tidal range, much of the angling activity is boat-based with beach fishing limited by periods of flood tides and high water. Numerous creek systems, mangroves, rivers and ocean beaches provide shore and small-boat fishing for a variety of species, including barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin, mud crabs and cods. Offshore islands, coral reef systems and continental shelf waters provide species of major recreational interest, including saddletail snapper and red emperor, cods, coral and coronation trout, sharks, trevally, tuskfish, mackerels and billfish.

3.4.3.2.2 Gascoyne Coast Bioregion

The Gascoyne Coast Bioregion extends from just north of Kalbarri to the Ashburton River, south of Onslow. The marine environment of this region represents a transition between the fully tropical waters of the northwest shelf of the North Coast Region and the temperate waters of the West Coast Region. This region has been identified as one of the 18 world "hotspots" in terms of tropical reef endemism and the second most diverse marine environment in the world in terms of tropical reef species. This region is a focal point for winter recreational fishing and is a key component of many tourist visits. Angling activities include beach and cliff fishing (e.g. Steep Point and Quobba), embayment and shallow-water boat angling (e.g. Shark Bay, Exmouth Gulf and Ningaloo lagoons), and offshore boat angling for demersal and larger pelagic species (e.g. off Ningaloo). The predominant target species include the tropical species, such as emperors, tropical snappers, groupers, mackerels, trevallies and other game fish. Temperate species at the northern end of their ranges, such as pink snapper, tailor and whiting, also provide significant catches, particularly in Shark Bay.

3.4.3.2.3 West Coast Bioregion

The marine environment of the West Coast Bioregion, which lies between Kalbarri and Augusta, is predominantly a temperate oceanic zone, but it is heavily influenced by the Leeuwin Current, which transports warm tropical water southward along the edge of the continental shelf. This region contains the state's major population centres and is the most heavily used bioregion for recreational fishing (Fletcher and Santoro 2015). The range of recreational fishing opportunities includes estuarine fishing, beach fishing and boat fishing either in embayments or offshore for demersal and pelagic game species often around the islands and out to the continental shelf.

3.4.3.3 Traditional Fishing

Within the northern and northwestern extent of the EMBA is a defined area where a Memorandum of Understanding exists between the Australian and Indonesian Governments. The Agreement between the Government of Australia and the Government of the Republic of Indonesia Relating to Cooperation in Fisheries (1992 Fisheries Cooperation Agreement) provides the framework for fisheries and marine cooperation between Australia and Indonesia and facilitates information exchange on research, management and technological developments; complementary management of shared stocks; training and technical exchanges; aquaculture development; trade promotion; and cooperation to deter illegal fishing.

Cooperation under the agreement today takes place under the auspices of the Working Group on Marine Affairs and Fisheries. Established in 2001, the Working Group on Marine Affairs and Fisheries is the primary bilateral forum to enhance collaboration across the spectrum of marine and fisheries issues relevant to the areas of the Arafura and Timor seas. The working group brings together the fisheries, environment and scientific research portfolios and agencies from both countries.

The fishers focus their activities in and around the shallow water lagoons of Scott Reef, primarily targeting trepang and opportunistically gathering trochus shells. They also catch fish largely for subsistence purposes although the average fish catch per *lete-lete* (traditional Indonesian fishing vessel) in 2008 increased to commercial volumes. Although deeper waters are more plentiful in trepang, deep diving is generally not undertaken by the fishers due to the Memorandum of Understanding stipulation on the exclusive use of traditional equipment only.

3.4.3.4 Aquaculture

3.4.3.4.1 North Coast Bioregion

Aquaculture development in this region is dominated by the production of pearls from the species *Pinctada maxima*. A large number of pearl oysters for seeding are obtained from wild stocks and supplemented by hatchery-produced oysters with major hatcheries operating at Broome and the Dampier Peninsula. Pearl farm sites are located mainly along the Kimberley coast, particularly in the Buccaneer Archipelago, in Roebuck Bay and at the Montebello Islands. Developing marine aquaculture initiatives in this region include growing trochus and barramundi.

The Pearl Oyster Fishery of Western Australia operates in shallow coastal waters (Fletcher et al. 2006). All the leases are within the 35-m diving depth. Through consultation, the Pearl Producer's Association have raised concern that spawning stock is found to the 100-m depth contour. However, this is not supported in the study by Condie et al. (2006), who modelled oyster larva transport in the Eighty Mile Beach region and found that, while some larvae travelled more than 60 km, most were transported less than 30 km. The model results suggest that spawning in the Eighty Mile Beach region is concentrated around the 8- to 15-m depth range, with potential smaller contributions from the northeast. These spawning events are likely to lead to successful recruitment locally and alongshore to the southwest.

The spawning events also feed larvae into neighbouring shallow coastal environments (through tidal oscillations) and deeper waters to the west (more than 20 m deep). However, spat (juvenile pearl oysters) abundance seems to be low in these areas, suggesting that recruitment is strongly limited by habitat availability and possibly high mortality rates in shallow water. High local abundances of brood stock and spat observed occasionally in deeper water (less than 30 m deep) seem to be supported by intermittent larval transport from inshore populations. Spawning in this area seems to contribute little to recruitment in the inshore populations.

3.4.3.4.2 Gascoyne Coast Bioregion

Hatchery production of oysters is the core of the pearling industry in the Gascoyne region. Hatcheries in Carnarvon and Exmouth supply spat to pearl farms in the northwest, and several hatcheries supply juveniles to the developing black-lip pearl oyster farms in the region. Pearl production is carried out on a small scale in Shark Bay and Exmouth Gulf. The local aquaculture sector is also focusing on the production of aquarium species.

3.4.3.4.3 West Coast Bioregion

The principal aquaculture development activities in this region are the production of mussels (*Mytilus galloprovincialis*) and marine algae (*Dunaliella salina*) and the emerging black pearl industry based on the production of *Pinctada margaritifera* at the Abrolhos Islands. The main mussel farming area is in southern Cockburn Sound, where conditions are sheltered and the nutrient and planktonic food levels are sufficient to promote good growth rates.

3.4.4 Heritage

3.4.4.1 World Heritage Places

There are two WHAs located within the EMBA: the Ningaloo Coast (533 km from the Dorado WHP) and Shark Bay (835 km from the Dorado WHP).

3.4.4.1.1 The Ningaloo Coast

The Ningaloo Coast was included on the World Heritage List in 2011 and was inscribed for outstanding natural universal values as follows:

- an example of superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance;
- outstanding examples representing major stages of Earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features; and
- the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

The Ningaloo Coast WHA includes:

- Ningaloo Marine Park (Commonwealth waters);
- Ningaloo Marine Park (Western Australian state waters);
- Muiron Island Marine Management Area (including the Muiron Islands);
- Jurabi Coastal Park;
- Bundegi Coastal Park;
- Cape Range National Park; and
- Learmonth Air Weapons Range.

The Ningaloo Coast WHA (including the Muiron Islands) is managed under a plan that is consistent with the World Heritage Convention and Australia's World Heritage management principles. World Heritage management principles are set out in regulations and cover matters relevant to the preparation of management plans, the environmental assessment of actions that may affect the property and community consultation processes.

The Australian World Heritage management principles are outlined under Schedule 5 of the Environment Protection and Biodiversity Conservation Regulations 2000. The objective is to ensure that any likely impact of an action on the World Heritage values of the property should be considered. Any action should be consistent with the protection, conservation, presentation or transmission to future generations of the World Heritage values of the property.

The marine environment of the Ningaloo Coast WHA is protected as a Commonwealth marine park and state marine park and is discussed further in **Section 3.4.2**.

3.4.4.1.2 Shark Bay

Shark Bay was included on the World Heritage List in 1991 and is one of the few properties inscribed for all four outstanding natural universal values:

- an outstanding example representing the major stages in the earth's evolutionary history;
- an outstanding example representing significant ongoing ecological and biological processes;
- an example of superlative natural phenomena; and
- containing important and significant habitats for in situ conservation of biological diversity.

Since 1997, an agreement established the joint management of the Shark Bay WHA by the Australian Government and the Western Australian state government, with the operational responsibility by the Western Australian agencies. This agreement also created a Community Consultative Committee and a Scientific Advisory Committee, both of which provide advice as required. The entire WHA encompasses islands and peninsulas, with an area of approximately 2.2 million hectares (70% of which is marine waters), and includes the following areas:

- Hamelin Pool Marine Nature Reserve;
- Francois Peron National Park;
- Shell Beach Conservation Park;
- Monkey Mia Reserve;
- Monkey Mia Conservation Park;
- Zuytdorp Nature Reserve;
- Bernier, Dorre and Koks Islands Nature Reserves;
- Dirk Hartog Island National Park; and
- Various pastoral leases.

The marine environment of the Shark Bay WHA is protected as a state marine reserve and is discussed further in **Section 3.4.2**.

3.4.4.2 Commonwealth Heritage Places

The Commonwealth Heritage Places List comprises natural, indigenous and historic heritage places that are either entirely within a Commonwealth area or are outside the Australian jurisdiction and owned or leased by the Commonwealth or a Commonwealth Authority (**Table 3-31**). Eight natural Commonwealth Heritage Places were identified within the EMBA, none of which lie within the Project Area. Three of these places (Ashmore Reef, Mermaid Reef and the Ningaloo Marine Area – Commonwealth Waters) are found in marine parks and are discussed further in **Section 3.4.2**. The HMAS *Sydney II* and HSK *Kormoran* Shipwreck Sites is listed under both National and Commonwealth Heritage Lists.

Table 3-31: Commonwealth heritage places within the EMBA

Commonwealth Heritage Place	Place Type	Distance from WHP (km) (approximate)
Mermaid Reef - Rowley Shoals	Natural	226
Ningaloo Marine Area - Commonwealth Waters	Natural	555
Yampi Defence Area	Natural	570
Scott Reef and Surrounds - Commonwealth Area	Natural	632
Learmonth Air Weapons Range Facility	Natural	635
Ashmore Reef National Nature Reserve	Natural	873
HMAS *Sydney II* and HSK *Kormoran* Shipwreck Sites	Historic	1,111
Christmas Island Natural Areas	Natural	1,697

3.4.4.3 National Heritage Places

Natural, historic and indigenous places that are of outstanding heritage value to the Australian nation are recorded as National Heritage Places. Nine National Heritage Places are found in waters from the South Australian border to the Northern Territory border, with nine of these occurring within the EMBA (**Table 3-32**). Shark Bay and The Ningaloo Coast are listed as both WHAs and National Heritage Places and are discussed in **Section 3.4.4.1**.

Table 3-32: National heritage places within the EMBA

National Heritage Place	Place Type	Distance from WHP (km) (approximate)
Dampier Archipelago (including Burrup Peninsula)	Indigenous	248
The West Kimberley	Natural	318
Barrow Island and the Montebello-Barrow Islands Marine Conservation Reserves	Natural	357

National Heritage Place	Place Type	Distance from WHP (km) (approximate)
The Ningaloo Coast	Natural	533
Shark Bay, Western Australia	Natural	835
Dirk Hartog Landing Site 1616 - Cape Inscription Area	Historic	928
HMAS *Sydney II* and HSK *Kormoran* Shipwreck Sites	Historic	1,111
Batavia Shipwreck Site and Survivor Camps Area 1629 - Houtman Abrolhos	Historic	1,159
Christmas Island Natural Areas	Natural	1,698

3.4.4.4 Marine Archaeology

All historic shipwrecks older than 75 years are protected under the *Underwater Culture Heritage Act 2018*. Details of historic shipwreck sites are available on the Australian National Shipwreck Database, although precise locations of the wrecks are sometimes unknown. A search of the Australian National Shipwreck Database indicated there are no historic shipwrecks within the Project Area, nor has Santos observed any debris or wreckage from ships within the Project Area. There are no historic sunken aircraft (older than 75 years) located within the Project Area. There are, however, 25 historic shipwrecks located in the EMBA, the closest being the Twin Screw Steamer (1912), approximately 13 km from the Project Area. There is also one sunken aircraft located in the EMBA off Eighty Mile Beach, the Dornier Do-24 X-36 (1942), located approximately 210 km southeast of the Project Area.

3.4.4.5 Indigenous Heritage

Indigenous people have a strong ongoing association with the area that extends from the beginning of human settlement in Australia some 50,000 years ago. The close, long-standing relationship between Indigenous peoples and the coastal and marine environments of the area is evident in Indigenous culture today, in addition to archaeological sites such as the Burrup Peninsula. The traditional owners of the northwest continue to rely on coastal and marine environments and resources for their cultural identity, health and wellbeing, as well as their domestic and commercial economies.

Marine resource use by Indigenous people is generally restricted to coastal waters. Fishing, hunting and the maintenance of maritime cultures and heritage through ritual, stories and traditional knowledge continue as important uses of the nearshore region and adjacent areas. However, while direct use by Indigenous people of deeper offshore waters is limited, many groups continue to have a direct cultural interest in decisions affecting the management of these waters. The cultural connections Indigenous people maintain with the sea may be affected, for example, by offshore fisheries and industries. In addition, some Indigenous people are involved in commercial activities such as fishing and marine tourism, so have an interest in how these industries are managed in offshore waters with respect to their cultural heritage and commercial interests (Department of the Environment, Water, Heritage and the Arts 2008b).

A search of the Department of Planning, Lands and Heritage's Aboriginal Heritage Inquiry System was undertaken to identify registered Aboriginal sites (Registered Sites) as outlined under Section 5 of the Aboriginal Heritage Act 1972 (WA). A total of 194 Registered Sites were identified within the EMBA.

Identified Registered Sites have been designated for a number of aspects including (but not limited to) artefact scatters; ceremonial, mythological, and camp sites; water sources; engravings; and burial. In addition to Registered Sites, there are a number of other Heritage Places along the northwest coastline of Western Australia (refer to **Attachment 1**).

3.4.5 Tourism

The Kimberley, Pilbara and Gascoyne regions are popular visitor destination for Australian and international tourists. Tourism is concentrated in the vicinity of population centres including Broome, Dampier, Exmouth, Coral Bay and Shark Bay.

Marine and coastal use is also clustered around major population centres along the Western Australian coastline including Perth, Bunbury, Geraldton, Jurien Bay and Margaret River.

Tourism contributes to local economies in terms of both income and employment; and tourists include local, interstate and international visitors. Popular water-based activities include fishing, swimming, snorkelling, diving, surfing, windsurfing/kiting, and boating, while popular land-based activities include bushwalking, camping, bird watching and four-wheel driving.

Seasonal nature-based tourism, such as humpback whale watching, whale shark encounters and tours of turtle hatching, mainly occurring around Ningaloo Reef, Cape Range National Park, Broome and Perth. Seasonal aggregations of whale sharks, manta rays, sea turtles and whales, as well as the annual mass spawning of coral, attract large numbers of visitors to Ningaloo each year. There is no tourism activity with the Project Area. A low level of recreational diving may occur in the waters surrounding Bedout Island, located approximately 38.8 km south of the Project Area.

3.4.6 Maritime Industry

3.4.6.1 Ports

The two largest ports within the Pilbara region are Port Hedland (located approximately 143 km south of the proposed FPSO) and the Port of Dampier. Port Hedland is Australia's second largest port and exports bulk commodities of iron ore and salt. Total throughput at Port Hedland for 2019 was recorded to be approximately 521 million tonnes (Pilbara Ports Authority n.d.). The Port of Dampier is one of the major tonnage ports in Australia, with prime export commodities of iron ore, LNG and salt.

3.4.6.2 Shipping

The Project Area is subject to considerable shipping activity, particularly bulk carriers transiting to and from the Port of Port Hedland (**Figure 3-28**). AMSA has established a network of shipping fairways off the northwest coast of Australia to manage traffic patterns. The shipping fairways are designed to keep shipping traffic away from offshore infrastructure and aim to reduce the risk of collision. Use of the fairways is strongly recommended but not mandatory. The International Regulations for Preventing Collisions at Sea 1972 apply to all vessels navigating within or outside the shipping fairways. The use of these fairways does not give vessels any special right of way.

The Dorado WHP is located 13.2 km west and 17.5 km east of the closest commercial shipping fairways.

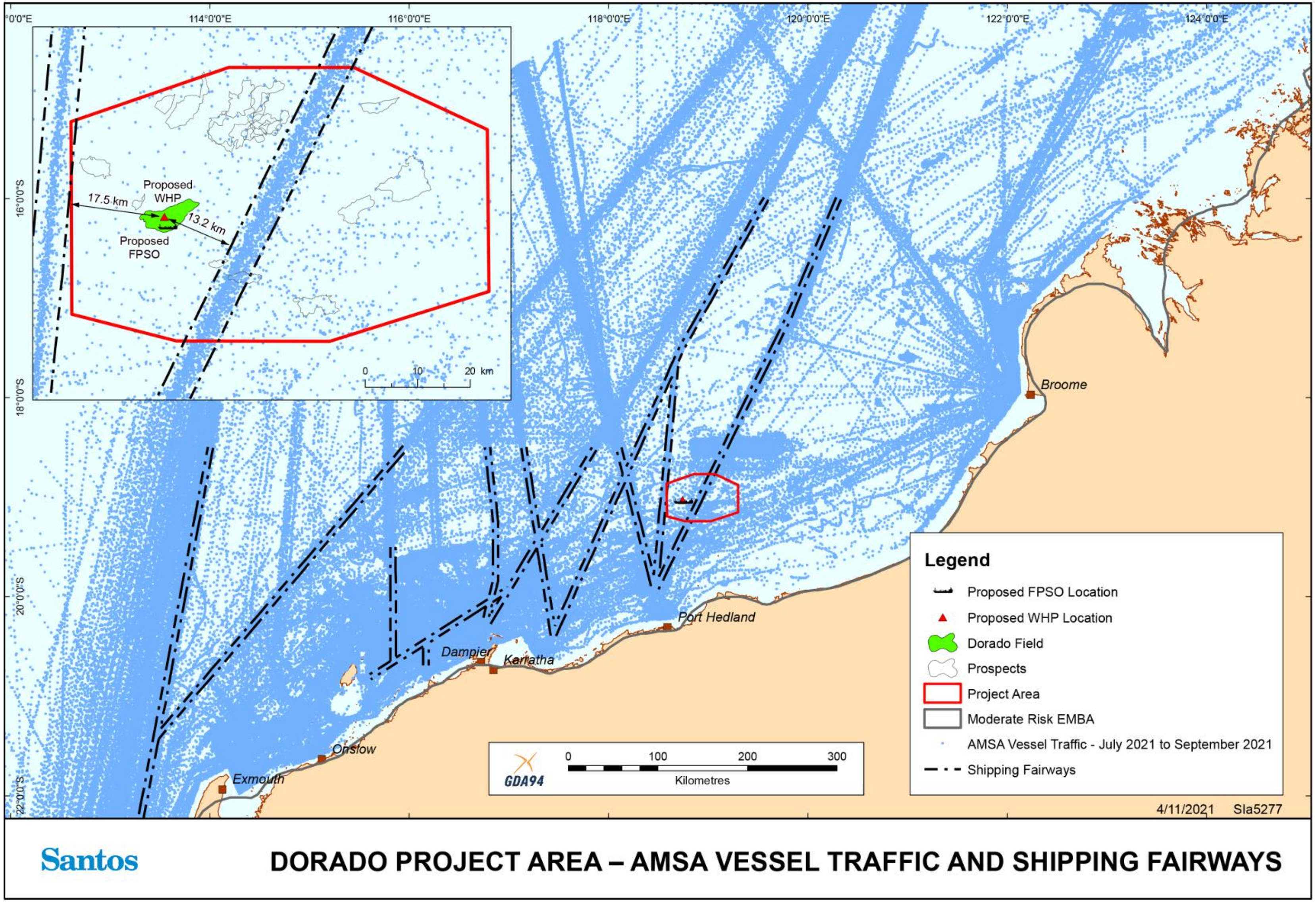


Figure 3-28: AMSA ship locations and shipping fairways

3.4.6.3 Petroleum

In 2018/19, Western Australia's petroleum industry was worth $38.4 billion per annum. The petroleum sector accounted for 26% of the total value of Western Australia's mineral and petroleum sales in 2018/19, with 20% of all mineral and petroleum sales coming from LNG. Currently Western Australia has four operating LNG projects: the NWS, Gorgon, Pluto and Wheatstone. There are also a number of FPSO facilities on the NWS, as shown in **Figure 3-29**. There are also domestic gas plants on Varanus Island in the NWS, Devil Creek Onshore Gas Plant and Macedon Gas Plant in the Pilbara region and an oil facility near Dongara called Cliff Head.

There are several exploration and production permits and leases throughout Western Australian and Commonwealth waters in the EMBA. Existing petroleum infrastructure, permits and licences are shown in **Figure 3-29**.

The Project Area occurs in a particularly isolated area of the NWS with respect to the main oil and gas operational and exploratory fields. There are currently no existing facilities in the Project Area. The nearest operating facility is Woodside's Angel oil field and associated infrastructure, located approximately 250 km from the WHP.

One optical submarine telecommunication cable traverses the western edge of the Project Area (refer to **Figure 3-29**), the North West Cable System, which connects offshore oil and gas facilities in the Browse, Bonaparte and Carnarvon Basins to onshore locations. The JASURAUS cable system, which connects Port Hedland to Jakarta, is adjacent to and west of the Project Area.

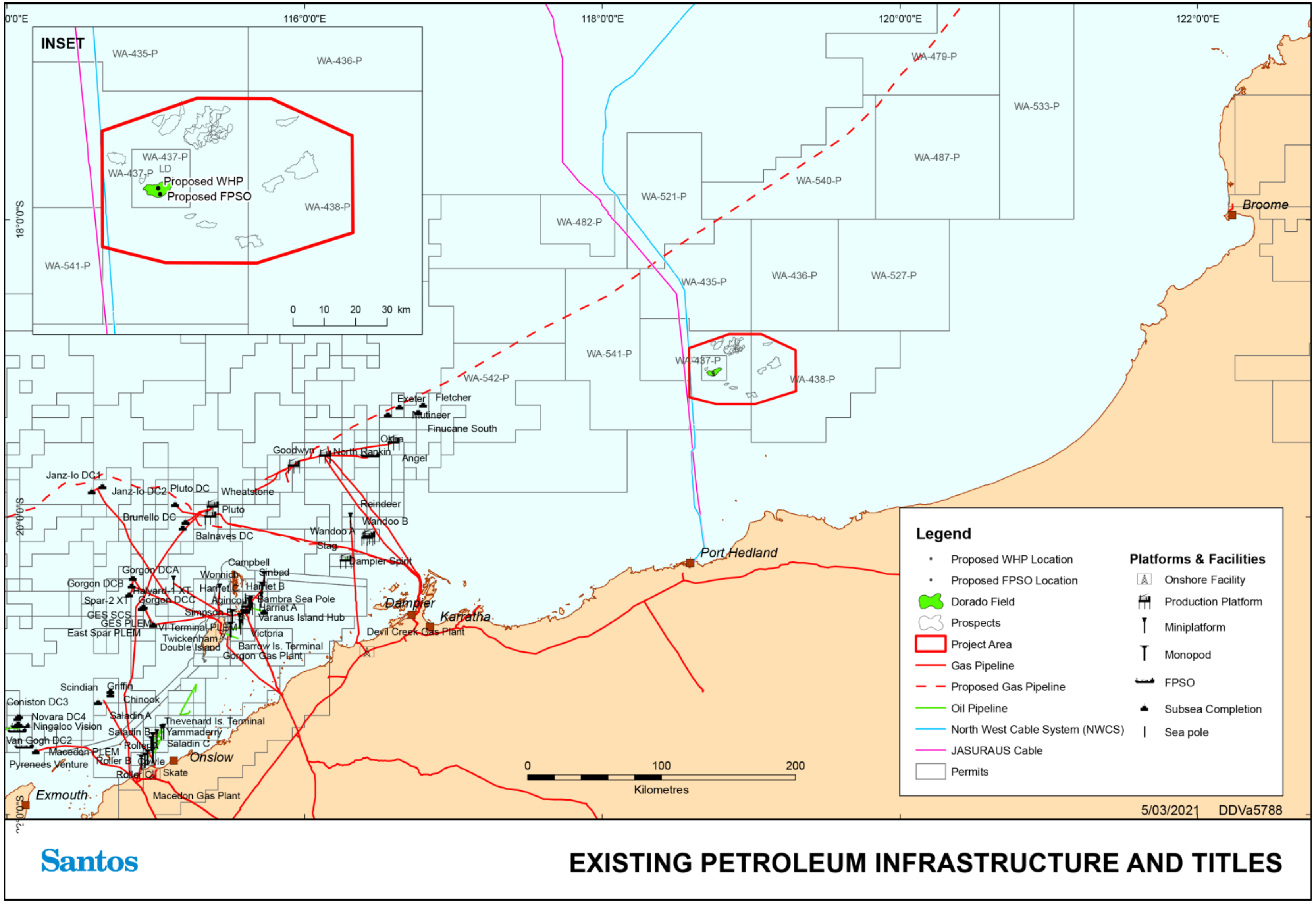


Figure 3-29: Existing petroleum infrastructure, permits and licences

3.4.7 Defence

The Naval Communication Station Harold E. Holt is located on the northwest coast of Australia, 6 km north of Exmouth. The town of Exmouth was built at the same time as the communications station to provide support to the base and to house dependent families of United States Navy personnel (Shire of Exmouth 2014; DoE 2014).

No designated Department of Defence areas overlap the Project Area. Two Royal Australian Air Force (RAAF) bases are located in the northwest of Western Australia: Learmonth RAAF Base (approximately 602 km from the WHP near Exmouth) and Curtin RAAF Base (approximately 561 km from the WHP near Derby) (RAAF 2014). The EMBA overlaps these bases.

Designated military exercise areas occur over waters and airspace of the northwest of Western Australia and may be activated following the required notifications. There are two training and practice areas located near the Learmonth RAAF Base, approximately 363 km (training area) and 538 km (practice area) southwest of the Project Area. These overlap with the EMBA.

Additional defence activities that occur within the EMBA include:

+ Broome training depot;
+ Exmouth admin and high-frequency transmitting;
+ Exmouth very low–frequency transmitting station;
+ Geraldton training depot “A” Company 16th Battalion;
+ HMAS *Stirling*-Rockingham;
+ HMAS *Stirling*-Garden Island;
+ Karratha training depot;
+ Learmonth – air weapons range;
+ Learmonth radar site – Vlaming Head, Exmouth; and
+ Yampi Sound training area.

Key defence bases and facilities are illustrated in **Figure 3-30**.

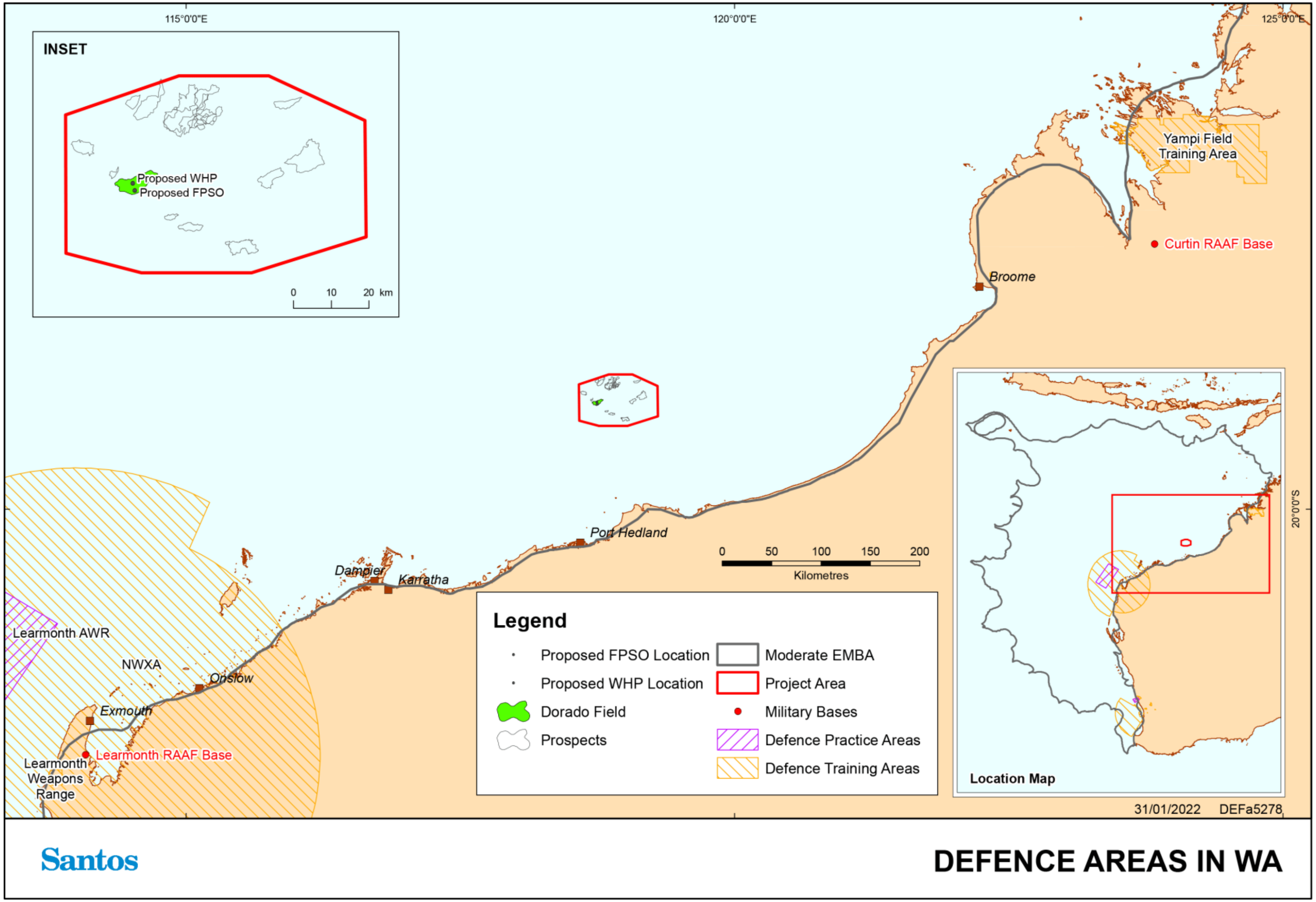


Figure 3-30: Defence areas in Western Australia

4 Acceptable Levels of Impacts and Risks

The OPGGS (E) Regulations require that the Dorado Development OPP demonstrate that the environmental impacts and risks associated with Dorado Phase 1 are of an acceptable level. Santos has defined acceptable levels of impacts and risks for the environmental receptors that may credibly be impacted by Dorado Phase 1 to address this requirement. The predicted environmental impacts and risks from all aspects of Dorado Phase 1 were then compared to the predefined acceptable levels to evaluate whether the impacts and risks associated were below the acceptable level.

The following criteria were considered by Santos when developing receptor-specific acceptable levels of impacts and risks:

+ the environmental value of the receptor;
+ the principles of ESD;
+ relevant requirements (**Section 2**), such as:
  - legislation;
  - policies;
  - conventions; and
  - material published under the EPBC Act, including recovery plans, conservation advice and the Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013);
+ internal context, including Santos' environment policy, environmental risk management framework, technical guidance material and expert technical advice from internal stakeholders; and
+ external context, such as advice provided by stakeholders and subject matter experts.

The acceptable levels of impacts and risks were developed independently of the environmental impact and risk assessments. This was done to ensure that the acceptable levels were based on the criteria outlined above, rather than the predicted impacts of Dorado Phase 1.

A description of how the criteria were considered in developing receptor-specific acceptable levels of impacts and risks is provided below.

4.1 Considerations when Defining Acceptable Levels of Impacts

4.1.1 Environmental Value of Receptors

The environmental value of each receptor was considered when developing receptor-specific acceptable levels of impact. The determination of the environmental value of a receptor considered attributes such as:

+ uniqueness – uniqueness is the quality of an environmental value or sensitivity being particularly remarkable, special or unusual. Impacts to receptors that are unique are less acceptable than impacts to receptors that are common within the environment. For example, impacts to a rare, endangered species are less acceptable than the same impacts to a common species;
+ connectedness – connectedness is the quality of an environmental value or sensitivity being joined to or linked with other features of the environment. Impacts to receptors that are highly connected to other receptors are more likely to result in effects to ecosystems and are

hence less acceptable than impacts to receptors that are not highly connected to other receptors; and
- socio-economic value – Socio-economic value is the value of an environmental value or sensitivity to society, including social, cultural and economic value. Impacts to receptors that have a high socio-economic value (including receptors that are of particular conservation, cultural or economic value) are less acceptable than impacts to receptors that have a low socio-economic value.

The uniqueness, connectedness and socio-economic value for each receptor was assessed on a qualitative basis. This assessment was informed by the description of environmental values and sensitivities in **Section 3**. The concepts of uniqueness, connectedness and socio-economic value were assessed qualitatively to provide an aggregated environmental value for each receptor.

The environmental value of many receptors is reflected by the relevant requirements that apply to the receptors. Receptors that have a high environmental value typically have a high degree of protection by relevant requirements, such as WHAs, marine protected areas and species listed as threatened under the EPBC Act. The degree of protection provided by relevant requirements is typically correlated to the environmental value of the receptor.

4.1.2 Principles of Ecologically Sustainable Development

The principles of ESD stated in the EPBC Act have been considered by Santos in defining acceptable levels of impacts and risks. These principles were also considered in progressing the concept for the Dorado Development and management of environmental impacts and risks. These principles are:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- the principle of intergenerational equity — that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and
- improved valuation, pricing and incentive mechanisms should be promoted.

Energy is fundamental to societies and their sustainable development. The UN has a 2030 Agenda for Sustainable Development (2030 Agenda) which establishes 17 Sustainable Development Goals (SDGs) and 169 targets that build on the Millennium Development Goals. The SDGs and targets are integrated and indivisible and balance three dimensions of sustainable development: economic, social and environmental. This was considered for evaluating acceptability for those potential impacts which extend outside of Australia's jurisdiction.

4.1.3 Relevant Requirements

The requirements identified in **Section 2** that are relevant to environmental receptors were considered when developing receptor-specific acceptable levels of impact. Santos has included the acceptability of impacts and risks to matters protected under Part 3 of the EPBC Act as this forms part of NOPSEMA's assessment for the Dorado Development OPP. Several international agreements are given effect by Part 3 of the EPBC Act, such as the Ramsar Convention (Wetlands of International

Importance); the World Heritage Convention (WHAs); and the Bonn Convention, CAMBA, ROKAMBA and JAMBA (migratory species).

Santos considered the Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013) when defining acceptable levels of impacts and risks. While these guidelines are intended to assist proponents in determining whether an action may have a significant impact upon a matter of national environmental significance, Santos has used the guidelines to inform the definition of receptor-specific acceptable levels of impact. The significant impact criteria for matters protected under Part 3 of the EPBC Act are summarised in **Table 4-1**. Santos considers significant impacts to matters protected under Part 3 of the EPBC Act to be unacceptable.

Table 4-1: Significant impact criteria relevant for matters protected under Part 3 of the EPBC Act (Department of the Environment 2013)

Category	Significant Impact Criteria
Critically Endangered and Endangered Species	An action is likely to have a significant impact on critically endangered or endangered species if there is a real chance or possibility that it will: + lead to a long-term decrease in the size of a population; + reduce the area of occupancy of the species; + fragment an existing population; + adversely affect habitat critical to the survival of a species; + disrupt the breeding cycle of a population; + modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline; + result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat; + introduce disease that may cause the species to decline; or + interfere with the recovery of the species.
Vulnerable Species	An action is likely to have a significant impact on vulnerable species if there is a real chance or possibility that it will: + lead to a long-term decrease in the size of an important population; + reduce the area of occupancy of an important population; + fragment an existing important population into two or more populations; + adversely affect habitat critical to the survival of a species; + disrupt the breeding cycle of a population; + modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline; + result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat; + introduce disease that may cause the species to decline; or + interfere substantially with the recovery of the species.
Migratory Species	An action is likely to have a significant impact on migratory species if there is a real chance or possibility that it will: + substantially modify, destroy or isolate an area of important habitat for a migratory species;

Category	Significant Impact Criteria
	+ result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species; or + seriously disrupt the lifecycle of an ecologically significant proportion of the population of a migratory species.
Wetlands of International Importance (i.e. Declared Ramsar Wetland)	An action is likely to have a significant impact on a wetland of international importance if there is a real chance or possibility that it will result in: + areas of wetland being destroyed or substantially modified; + a substantial and measurable change in the hydrological regime of the wetland; + the habitat or lifecycle of native species dependent upon the wetland being seriously affected; + a substantial and measurable change in the water quality of the wetland that may adversely impact on the biodiversity, ecological integrity, social amenity or human health; or + an invasive species that is harmful to the ecological character of the wetland being established in the wetland.
Commonwealth Marine Environment	An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that it will: + result in a known or potential pest species becoming established in the commonwealth marine area; + modify, destroy, remove, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity on a commonwealth marine area results; + have a substantial adverse effect on a population of a marine species or cetacean, including its lifecycle and spatial distribution; + result in a substantial change in air quality or water quality that may adversely impact on biodiversity, ecological integrity , social amenity or human health; + result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected; or + have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck.
World Heritage Properties	An action is likely to have a significant impact on the World Heritage values of a declared World Heritage property if there is a real chance or possibility that it will cause: + one or more of the world heritage values to be lost; + one or more of the world heritage values to be degraded or damaged; or

Category	Significant Impact Criteria
	+ one or more of the World Heritage values to be notably altered, modified, obscured or diminished.
National Heritage Places	An action is likely to have a significant impact on the National Heritage values of a National Heritage place if there is a real chance or possibility that it will cause: + one or more of the national heritage values to be lost; + one or more of the national heritage values to be degraded or damaged; or + one or more of the National Heritage values to be notably altered, modified, obscured or diminished.

4.1.4 Internal Context

Santos considers an impact or risk associated with the proposed activity to be acceptable if:

+ the consequence of a planned event is ranked as I or II; or a risk of impact from an unplanned event is ranked Very Low to Medium;
+ an assessment has been completed to determine whether further information or studies are required to support or validate the consequence assessment;
+ assessment and management of risks have addressed the principles of ecologically sustainable development;
+ that the acceptable levels of impact and risks have been informed by relevant species recovery plans, threat abatement plans and conservation advice can be demonstrated;
+ performance standards are consistent with legal and regulatory requirements;
+ performance standards are consistent with the Santos' Environment, Health and Safety Policy and/or Climate Change Policy; and
+ performance standards are consistent with industry standards and best practice guidance (for example, National Biofouling Management Guidance Guidelines for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee, 2018)).

These consequence and risk descriptors are defined in the Santos risk matrix (**Section 7.1**). Environmental consequences greater than Moderate for planned impacts and risks greater than Medium for unplanned events are unacceptable to Santos.

4.1.5 External Context

The external context considered by Santos in establishing acceptable levels of impacts and risks includes any available information provided by stakeholders or from subject matter experts in relation to Dorado Phase 1. Santos understands the OPP public comment period will provide additional external context, in addition to any consultation undertaken during the development of the OPP. Stakeholder comments provided on the OPP during the public comment period will be considered in the revised version of the OPP submitted to NOPSEMA for Stage 2 assessment following the public comment period.

Santos considers an impact or risk associated with the proposed activity to be acceptable if it is consistent with relevant and reasonable stakeholder expectations. In instances where stakeholders object to a proposed activity or expectations are not aligned, Santos may consider the impact or risk acceptable if it can be demonstrated that the objections and expectations are not relevant or are not reasonable.

4.2 Acceptable Levels of Impact for Dorado Phase 1

Based on the considerations outlined in **Section 4.1**, the acceptable levels of impact to environmental values and sensitivities that may be affected by aspects of Dorado Phase 1 are presented in **Table 4-2**.

Some receptors described in **Section 3** will not credibly be impacted by Dorado Phase 1:

+ bathymetry;

- oceanography;
- regional centres; and
- defence.

Table 4-2: Acceptable levels of impact to environmental values and sensitivities for Dorado Phase 1

Key Environmental Values/Sensitivities	Receptor-Specific Acceptable Levels of Impact (RSAL)	Justification for the Acceptable Level
Physical Environment		
Climate	**RSAL1**: No significant[1] impacts to key Australian ecosystems attributable to Dorado Phase 1 GHG emissions. **RSAL2**: Dorado Phase 1 is an insignificant CO_{2-e} emissions contributor to Australian and global CO_{2-e} emissions [1] Significant - As defined by the significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).	To date, the currently observed global warming and the associated anthropogenic climate changes cannot be directly attributed to any one development or activity, as they are the result of net global GHG emissions and GHG sinks that have accumulated in the atmosphere since the industrial revolution began. Despite the uncertainties in linking global warming and associated ecosystem impacts to GHG emissions from an individual project, Santos considers the potential for significant impact to key Australian ecosystems to result from Dorado Phase 1 GHG emissions to be unacceptable if it were to occur, and the basis for RSAL1. RSAL2 is premised on Dorado Phase 1 GHG emissions being an insignificant contributor to Australian and global GHG emissions, thereby reducing the likelihood that Dorado Phase 1 GHG emissions specifically will result in significant ecosystem impacts from climate change.
Water quality	**RSAL3**: Impacts to water quality that do not result in a loss of ecological integrity[2] are acceptable. **RSAL4**: Substantial[3] impacts to water quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable. [2] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010). [3] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.	Water quality is not unique, and the continental shelf waters in the Project Area are very widely represented in the region. Water quality is highly connected to marine ecosystems, and impacts to water quality have the potential to result in impacts to other receptors, such as fauna. A substantial change in water quality may adversely impact on biodiversity, ecological integrity, social amenity or human health. The socio-economic value of water quality in the Project Area is limited, as there are few other users that rely on high water quality in the Project Area. Impacts to water quality from Dorado Phase 1 cannot be avoided; but by limiting substantial impacts to within 1 km of the discharge locations the potential impacts to marine ecosystems will be very low. Given the offshore location and absence of sensitive marine ecosystems within the Project Area, substantial impacts to water quality within 1 km of the discharge location are acceptable.
Sediment quality	**RSAL5**: Impacts to sediment quality that do not result in a loss of ecological integrity[2] are acceptable. **RSAL6**: Substantial[3] impacts to sediment quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable. [2] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010). [3] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) value for sediments for contaminants derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.	Sediment quality is not unique, and the sediments within the Project Area are very widely represented in the region. Sediment quality is connected to marine ecosystems, particularly benthic fauna. The socio-economic value of sediment quality in the Project Area is limited, as there are few other users that rely on high sediment quality in the Project Area. Impacts to sediment quality from Dorado Phase 1 cannot be avoided; but by limiting substantial impacts to within 1 km of sources of potential sediment contamination (e.g. drilling locations) the potential impacts to marine ecosystems will be very low. By limiting potentially substantial impacts to sediment to within 1 km of the WHP, FPSO and drilling activities, the potential for environmental impacts as a result of contaminated sediments will be highly localised. These impacts are considered to be acceptable.
Air quality (excluding GHG emissions)	**RSAL7**: No substantial changes in air quality that may adversely impact on biodiversity, ecological integrity, social amenity or human health as a result of Dorado Phase 1.	Dorado Phase 1 is located in the open ocean and is well-removed from nearest residential or sensitive populations of the Australian mainland. Air quality in the Project Area is high and is widely represented in the offshore Pilbara region; air quality in the Project Area is not unique. Air quality is connected to other environmental values and sensitivities, such as air-breathing fauna and other marine users. The defined acceptable level provides a high degree of confidence that impacts to air quality will not result in substantial impacts to other receptors.

Key Environmental Values/Sensitivities	Receptor-Specific Acceptable Levels of Impact (RSAL)	Justification for the Acceptable Level
Biological Environment		
Benthic habitats	**RSAL8**: No significant[1] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities. [1] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).	Environmental surveys and habitat modelling indicate benthic communities within the Project Area are largely bare sediments interspersed with relatively small areas of hard substrates. These habitats are widely represented in the region and are not considered to be particularly sensitive. Sensitive habitats, such as hard corals, are unlikely to occur within the Project Area and, if they do occur, will be protected from direct disturbance. Santos has not placed a limit on the size of the footprint, as the footprint of potential tiebacks (if any) is currently unknown. Given the widespread nature and low sensitivity of the benthic habitats observed and predicted throughout the Project Area, Santos considers the direct disturbance footprint of the foundation facility and potential tiebacks will not result in substantial impacts to biodiversity, ecological integrity, social amenity or human health. Santos considers the footprint of the foundation facility and any future tiebacks to be acceptable.
Coastal habitats	**RSAL10**: No impacts to coastal habitats.	Coastal habitats would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Santos considers any large-scale hydrocarbon spill to be unacceptable.
KEFs	**RSAL11**: No significant impacts[1] to environmental values of KEFs. [1] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).	KEFs in the region are largely geomorphic features that provide important ecosystem services primarily as a result of their unique physical features (e.g. provision of hard substrates, facilitation of upwelling etc.). These are geographically diverse features that cover a large extent. The Project Area has been designed to exclude KEFs in the region; hence, there will be no direct disturbance of the seabed within a KEF. Impacts to KEFs that do not significantly impact upon the environmental values of the KEF are acceptable.
TECs	**RSAL12**: No impacts to TECs.	TECs would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Santos considers any large-scale hydrocarbon spill to be unacceptable.

Fishes
Marine mammals
Reptiles
Birds
	RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.
	RSAL14: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE.
	RSAL15: No injury to pygmy blue whales in a pygmy blue whale BIA
	RSAL16: No significant[1] impacts to EPBC listed threatened, migratory or cetacean species under the EPBC Act as a result of Dorado Phase 1.
	[1] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).
		Santos considers that significant impacts to threatened or migratory fauna defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013) to be unacceptable. These criteria are specific to the particular threatened and migratory classifications of fauna under the EPBC Act and are provided in **Table 4-1**.
		Santos supports the intent of conservation advice, recovery plans and threat abatement plans for these species, which is to prevent further decline and enhance the recovery of these species. Santos considers any mortality of or significant impact to species listed as threatened or migratory under the EPBC Act as a result of Dorado Phase 1 to be unacceptable.
		Recent clarification of terms in the CMP for the Blue Whale 2021-25 (DAWE, 2015) advise that PTS and TTS do constitute an injury. Acceptable levels of impact with regard to potential for 'injury' to cetaceans from the Dorado Development is limited to protection of threatened cetacean species where 'injury' is a defined term in applicable threatened species conservation advice or conservation management plans and includes potential sources of injury from underwater noise such as PTS or TTS (pygmy blue whales).
		
		Further acceptable levels for turtles relevant to light impacts from the Turtle Recovery Plan and National Light Pollution Guidelines are as followed:
		+ The Dorado Development will not result in disruption within, or displacement from, habitat critical to the survival of marine reptiles identified as potentially affected.
		+ The Dorado Development will not result in impacts which disrupt critical behaviours such as nesting, hatchling orientation, sea finding and dispersal behaviour in marine reptiles identified as potentially affected.
		+ The Dorado Development will not result in significant impacts to marine reptiles identified as potentially affected, defined as a possibility that it will'
		  - have a substantial adverse effect on a population of migratory/marine species, or the spatial distribution of the population.
		  - modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
		  - seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory/marine species.
		  - have an adverse effect on a population of listed threatened species, or the spatial distribution of the population.
		  - modify, destroy or isolate an area of important habitat for a listed threatened species.
		  - disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a listed threatened species.

Key Environmental Values/Sensitivities	Receptor-Specific Acceptable Levels of Impact (RSAL)	Justification for the Acceptable Level
Socio-economic and Cultural Environment		
Protected Areas	**RSAL17**: No impacts to ecological values of Ramsar wetlands. **RSAL18**: No impacts to the values of marine parks.	Protected areas such as Ramsar wetlands, AMPs and Western Australian marine protected areas and terrestrial reserves would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Santos considers any large-scale hydrocarbon spill to be unacceptable.
Fisheries	**RSAL19**: No negative impacts to the economic viability of the commercial fish resources. **RSAL20**: Short-term displacement of commercial fishing activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL21**: Long-term (up to 20 years) exclusion of commercial fishing activities from the gazetted PSZ during production operations is acceptable.	The presence of the Dorado Project infrastructure may result in an increase in the abundance of commercially targeted fish species due to habitat modification. Santos considers the displacement of other users (e.g. commercial fishers) from relatively small areas of the Project Area to be acceptable. Exclusion of fishers from these areas is not expected to affect landings and is required for the safe operation of Dorado Phase 1. Given the widespread nature of fish resources in the region and the limited overlap of the Santos project area with commercial fisheries, Santos considers the impacts to fish will not result in negative impacts to commercially exploited fish resources at a population level.
Heritage	**RSAL22**: No significant[1] impacts to World Heritage properties, National Heritage places, Commonwealth Heritage places or registered Aboriginal heritage sites. [1] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).	The World, National, Commonwealth and Aboriginal heritage properties would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Santos considers any large-scale hydrocarbon spill to be unacceptable.
Tourism	**RSAL23**: No impacts to nature-based tourism resources resulting in demonstrated loss of income. **RSAL24**: Short-term displacement of tourism activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL25**: Long-term (up to 20 years) exclusion of tourism activities from the gazetted PSZ during production operations is acceptable.	There are no known tourist attractions or destinations within the Project Area or surrounding waters. Santos considers the displacement of other users (e.g. tourism operators) from the Project Area, which is a relatively small area of the open ocean environment where existing tourism and recreation use is very low, to be acceptable.
Maritime Industry	**RSAL26**: Short-term displacement of commercial shipping from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL27**: Long-term (up to 20 years) exclusion of commercial shipping from the gazetted PSZ during production operations is acceptable.	Santos considers the displacement of other users (e.g. commercial shipping) from relatively small areas of the open ocean environment in Dorado Phase 1 area to be acceptable. Santos acknowledges there is commercial shipping in the region, which is concentrated in the shipping fairways designated by AMSA.
Defence	**RSAL28**: Short-term displacement of defence activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL29**: Long-term (up to 20 years) exclusion of defence activities from the gazetted PSZ during production operations is acceptable.	Santos considers the displacement of other defence activities from relatively small areas of the open ocean environment in Dorado Phase 1 area to be acceptable. There are no designated defence areas within the Project Area.

5 Analysis of Alternatives

The OPGGS (E) Regulations require that the OPP describe any feasible alternatives to the Dorado Development or to an activity that is part of the Dorado Development, including:

- a comparison of the environmental impacts and risks arising from the project or activity and the alternative; and
- an explanation as to why the alternative was not preferred.

This section of the OPP presents the alternatives considered for the Dorado Development, providing an overview of the advantages and disadvantages of each alternative with an emphasis on environmental impacts and risks. It also provides a justification for the selection of the preferred option. Some decisions will be determined during FEED (preliminary engineering) and others during detailed engineering stages of the Dorado Development. Decisions remaining to be made and their environmental implications are summarised at the end of this section.

The process of assessing the Dorado Development alternatives started in 2018, with an early identification of potential development concepts and understanding of the feasibility of early field development. Upon identifying the technically and commercially viable options, Santos identified the preferred Dorado Development concept. This process was undertaken in two main phases:

- analysis of concept alternatives; and
- analysis of design alternatives.

During the early identification of potential development concepts, only those that were technically and commercially viable and were appropriate for the reservoir type were carried into the concept alternatives analysis (i.e. options considered feasible, refer to **Section 5.1**). Following the determination of the field development option, the following concept alternatives (**Section 5.3)** were considered:

- the type of production trees to be installed (the production tree options); and
- the facilities that would be required to process the hydrocarbons (the facility options).

Once the preferred Dorado Development concept was identified, analysis of design alternatives for the preferred development concept was undertaken (**Section 5.4**). This included technical options for specific utility and processing systems (such as PW management).

5.1 Field Development Options

Immediately following the Dorado discovery, the following development options were considered to recover the light oil, condensate and gas resources:

- no development;
- developing liquids only – producing light oil and condensate, with gas reinjected; and
- developing liquids with gas export– full integrated resource development of light oil, condensate and gas resources.

Developing the petroleum resources aligns with the Australian Government's offshore development policy to explore and develop offshore petroleum resources. The policy recognises that development of these resources provides benefits to the Australian community, including:

- Government royalties and taxation revenue that is used to provide government services;
- employment for Australians;

+ production of petroleum resources to sustain a high standard of living;
+ improved energy resources security; and
+ regional industrial development.

The offshore petroleum policy encourages the development of commercially viable petroleum reserves. This requirement is a feature of the administration of petroleum titles. As the titleholder for WA-437-P and WA-438-P petroleum titles, Santos has an obligation to undertake exploration and develop any commercially viable petroleum resources (refer to **Section 2.1.1**). In this context, the 'no development' alternative is not consistent with the legal obligations and commercial objectives of Santos and was therefore not considered further.

Santos acknowledges that the 'no development' option results in no associated impacts to the environment. However as detailed in this OPP, Santos considers that the environmental impacts of planned activities associated with the Dorado Development can be managed to acceptable levels and the associated petroleum activities are consistent with the principles of ESD.

Dorado Phase 1 was selected as the 'liquids only' development concept, primarily as there is a requirement to enhance the liquids recovery through reinjection of reservoir gas via a phenomena called "miscible flood". Miscible flood is a general term for injection processes that introduce miscible gases into the reservoir. A miscible displacement process maintains reservoir pressure and improves oil displacement because the interfacial tension between oil and water is reduced.

For Dorado Phase 1, the LPG-rich gas (which is produced during recovery of the oil) will be reinjected back into the reservoir at high pressure to ensure miscibility between the injected gas and the in situ oil; thereby, previously immobile oil, trapped in smaller pores of the reservoir rock, will be mobile enough to be extracted and will enhance the overall recoverable liquids from the Dorado field.

The reinjection of the gas avoids flaring and also preserves the option for a future gas export project, a potential Phase 2 of the Dorado Development. If commercially and technically viable, this next phase would be subject to separate approvals and is not included in this Offshore Project Proposal, as further understanding of the recoverable gas resources and development of concept design and facility options is required.

Given the objective of Dorado Phase 1 is to extract the oil, the "liquids with gas export" development option was not selected, as the recovery of oil would be substantially less due to no reinjection of the LPG-rich gas. The following sections provide an overview of the alternatives considered for undertaking Dorado Phase 1.

5.2 Methodology

To assess the concept and design alternatives for Dorado Phase 1 and to understand the merits of each option, a multidisciplinary evaluation of options across the following five criteria was undertaken:

+ technical feasibility;
+ health and safety (H&S);
+ environment;
+ economic; and
+ societal.

To further facilitate the comparisons of options, the above criteria were subdivided into subcriteria. The subcriteria, along with key considerations, are presented in **Table 5-1**.

Table 5-1: Alternatives analysis criteria and subcriteria

Criteria	Subcriteria	Key Considerations
Technical feasibility	Technical complexity	How technically complex the design of the option is
	Proposal execution risk	Level of risk associated with constructing the option
	Management of reservoir performance	How is the reservoir managed – maximum production from the reservoir being preferable
Health and Safety	Safety risk during construction	Level of health and safety risks to construction personnel associated with the option during construction
	Safety risk during operations	Level of health and safety risks to operations personnel associated with the option during operations
Environment	Physical presence and seabed footprint	Extent of the physical presence and seabed footprint associated with the option – as an indicator of the likely seabed disturbance
	Number of vessel movements	What vessel movements and their frequencies are associated with the option – as an indicator of potential disturbance to marine fauna
	Light emissions	Quantity of light emitted by the option – as an indicator of potential impact on marine fauna and migratory birds
	Underwater noise	Level of expected underwater noise from the option – as an indicator of potential impact on marine fauna
	Atmospheric emissions, including GHG	Volume of expected atmospheric emissions associated with the option
	Planned liquid discharges	Types, volume and frequency of expected planned liquid discharges associated with the option
	Planned solid waste generation	Expected volume of solid waste generated from the option
	Risk of IMS translocation	Risk level of IMS translocation associated with the option
	Risk of unplanned discharges	Types and risk of potential unplanned discharges associated with the option
Economic	Schedule risk	How long it would take to construct the option
	Commercial risk	The CAPEX and operating expenses (OPEX) associated with the option
Societal	Socio-cultural impacts	Potential socio-cultural impacts associated with the option – as an indicator of impacts to recreational and cultural activities, such as traditional fishing and marine parks
	Socio-economic impacts	Potential socio-economic impacts associated with the option – as an indicator of impacts to the broader economy, such as job creation, and impacts to commercial operations, such as commercial fisheries

The options were not assessed quantitatively but rather by comparing the options to each other, in each alternative category. During the comparison, a value was assigned to each subcriteria as per **Table 5-2**. As the number of subcriteria is different for each criterion, the average score for each criterion was established. The greater the number, the more desirable the option is. The average scores of all criteria were summed up to establish the option's relative ranking. Similarly, the option with the highest score is the preferred option. The relative ranking can be regarded as the desirability of the option.

Table 5-2: Scoring values

Score	Key Considerations
1	Significantly worse when compared to the other options
2	Marginally worse when compared to the other options
3	All options are equal when compared to each other
4	Marginally better compared to other options
5	Significantly better compared to other options

To establish the desirability ranking, equal weighting was given to each criterion (technical feasibility, health & safety, environment, economic, and societal). This approach ensured that environmental considerations were on an equal footing with the other criteria.

5.3 Concept Alternatives

This section provides the comparative assessment undertaken for the concept alternatives:

- the type of production trees to be installed (the production tree options); and
- the facilities that would be required to process the hydrocarbons (the facility options).

5.3.1 Production Tree Options for Dorado Reservoir

To operate a well, a production tree is required to control the pressure and flow from the reservoir. The type of production trees used can have a significant influence on the facilities required.

The production tree options considered for the Dorado reservoir were:

- wet subsea production trees (i.e. production trees located on the seabed); and
- dry production trees (i.e. production trees located at the surface on the facilities and the wellheads remain on the seabed).

The assessment of the above options is presented in **Table 5-3**.

It is expected that the Dorado field will require significant reservoir management and potential intervention, so reducing the complexity and safety risk of these activities as well as associated costs, were significant drivers in the decision-making.

The "dry production trees" option was identified as the preferred option and adopted as it ranked first for all criteria, including:

  - the production trees on the facility providing better access and visibility and simplified installation and maintenance and repair activities;
  - presenting a lower execution risk profile than wet production trees and also expected to present a lower risk profile during installation activities;
  - reducing the expected seabed disturbance during maintenance and repair activities. It is acknowledged that tubulars would need to be installed to connect the subsea wellheads to the dry production trees and that seabed disturbance will occur during the installation activities;
  - the dry production trees will facilitate inspection (via the WHP) and early detection of potential leaks, reducing the risk of potential escalation and unplanned discharges;
  - the CAPEX and OPEX associated with dry production trees are expected to be less than that of wet production trees; and
  - Response planning considerations are not expected to be affected by the production trees decision.

The societal subcriteria were found not to be differentiators between the two options. The main drawbacks associated with the “wet production trees” were:

- reduced access (which complicates installation and maintenance activities);
- increased safety risks (associated with more complex installation activities, the potential need of divers and limited access/visibility during maintenance operations);
- reduced opportunity to identify and address potential leaks; and
- higher overall CAPEX and OPEX.

The type of production trees required for future tiebacks of additional resource discoveries is not able to be determined at this stage as it requires information on location and reservoir management that is not currently available (**Section 5.5**).

Table 5-3: Production trees options assessment

Criteria	Subcriteria	Production Trees Alternatives			
		Wet Production Trees		Dry Production Trees	
		Score	Justification	Score	Justification
Technical feasibility	Technical complexity	2	The trees being underwater complicates installation and future maintenance and repair operations due to difficult and limited accessibility.	4	Having trees on a facility provides greater accessibility and visibility, which simplifies the installation, maintenance and repair during operations.
	Proposal execution risk	2	Access to the trees is limited and difficult as it requires vessels, ROVs and potentially divers, which increases the execution risks.	4	Due to better tree access and visibility, the activities associated with installation, maintenance and repair are considered easier and have lower execution risks associated with them.
	Management of reservoir performance	2	Well intervention to assist with reservoir performance is more complex for wet production trees than dry production trees.	4	Well intervention to assist with reservoir performance is simpler for dry production trees.
Average technical feasibility		**2**		**4**	
Health and Safety	Safety risk during construction	2	Installation operations will be more complex with wet production trees, which increases the construction safety risk profile.	4	Installation operations will not be as complex with dry production trees, which reduces the construction safety risk profile.
	Safety risk during operations	3	Safety risks during operations are expected to be higher than with dry production trees due to limited access and visibility and the requirement for diving operations to undertake inspection, monitoring, maintenance and repair (IMMR) activities, increasing the safety risk.	3	It is expected that reservoir management and intervention will be required during operations. Having dry production trees will allow for easier access and greater visibility, which reduces the safety risk profile.
Average Health and Safety		**2.5**		**3.5**	

Criteria	Subcriteria	Production Trees Alternatives			
		Wet Production Trees		Dry Production Trees	
		Score	Justification	Score	Justification
Environment	Physical presence and seabed footprint	3	During installation, maintenance and repair operations, diver and/or ROV will be required near or at seabed, which presents an increase in potential seabed disturbance.	3	Potential seabed disturbance will be eliminated during maintenance and repair operations as the trees will be on the facility; however, some seabed disturbance may occur during installation when tubulars are installed to connect the subsea wellheads to the production trees.
	Number of vessel movements	3	The number of vessel movements is not expected to be affected by the production trees decision.	3	The number of vessel movements is not expected to be affected by the production trees decision.
	Light emissions	3	Light emissions are not expected to be affected by the production trees decision as wet production trees would be tied-back to a lit facility.	3	Light emissions are not expected to be affected by the production trees decision. Dry production trees would be either directly tied-back to a lit facility, as per the wet production trees, or tied-back by the intermediary of an unmanned facility. On an unmanned facility, the lighting levels would be kept to minimum navigational safety requirements, and therefore the overall light profile is not expected to be a differentiator between the two options.
	Underwater noise	3	While wet production trees will require subsea maintenance and repair activities, it is not expected that the resultant underwater noise will be a significant addition to the ambient underwater noise.	3	Underwater noise level is not expected to be affected by the production trees decision.
	Atmospheric emissions, including GHG	3	Atmospheric emissions are not expected to be affected by the production trees decision.	3	Atmospheric emissions are not expected to be affected by the production trees decision.
	Planned liquid discharges	3	Planned liquid discharges are not expected to be affected by the production trees decision.	3	Planned liquid discharges are not expected to be affected by the production trees decision.

Criteria	Subcriteria	Production Trees Alternatives			
		Wet Production Trees		Dry Production Trees	
		Score	Justification	Score	Justification
	Planned solid waste generation	3	Planned solid waste generation is not expected to be affected by the production trees decision.	3	Planned solid waste generation is not expected to be affected by the production trees decision.
	Risk of IMS translocation	3	IMS translocation risks are not expected to be affected by the production trees decision.	3	IMS translocation risks are not expected to be affected by the production trees decision.
	Risk of unplanned discharges – during drilling/ well intervention activities	3	Response planning considerations are not expected to be affected by the production trees decision as the same rig type (i.e Jack up) would be used.	3	Response planning considerations are not expected to be affected by the production trees decision as the same rig type (i.e Jack up) would be used.
	Risk of unplanned discharges – during operations	2	The potential risk of unplanned discharges is higher with the trees being subsea, as leaks are not as easy to detect and repair.	4	Having the production trees on the facility will make it easier to identify and repair potential leaks, thereby reducing the potential risk of unplanned discharges.
	Response planning considerations for unplanned LOWC scenario	3	Response planning considerations are not expected to be affected by the production trees decision. Due to the shallow water depth at Dorado (88 m), Santos considers a relief well as the primary source control strategy for a complete LOWC event, therefore the duration and volume of spill associated with a LOWC event is the same for both alternatives considered. Although a wet production tree development may allow for the potential use of subsea direct intervention source control methods, the ability to deploy these methods is not guaranteed.	3	Response planning considerations are not expected to be affected by the production trees decision. The primary source control strategy is still a relief well therefore the duration and volume of spill associated with a LOWC event is the same for both alternatives considered (no change for the wet tree alternative). Direct intervention source control for wells drilled with a jack-up MODU (access by Well Control Specialists to target a well via the platform or jack-up MODU) is common. Although constructing the wells this way precludes the use of subsea direct intervention source control methods (as the well is not being constructed in open water, with wellhead/BOP equipment close to the seabed), this is the case for many existing offshore assets.

Criteria	Subcriteria	Production Trees Alternatives			
		Wet Production Trees		Dry Production Trees	
		Score	Justification	Score	Justification
Average environment		**2.6**		**3.1**	
Economic	Schedule risk	3	The overall schedule risk is not expected to be affected by the production trees decision.	3	The overall schedule risk is not expected to be affected by the production trees decision.
	Commercial risk	2	The overall CAPEX and OPEX associated with wet production trees are expected to be the highest of the two options due to the complexity and additional requirements imposed by subsea activities.	4	CAPEX and OPEX of dry production trees will be less than that of wet production trees. It is expected that less well and equipment downtime due to better accessibility will result in better production.
Average economic		**2.5**		**3.5**	
Societal	Socio-cultural impacts	3	The socio-cultural impacts are not expected to differ between the two options.	3	The sociocultural impacts are not expected to differ between the two options.
	Socio-economic impacts	3	The socio-economic impacts are not expected to differ between the two options.	3	The socio-economic impacts are not expected to differ between the two options.
Average societal		**3**		**3**	
Overall Score (desirability)		**12.6**		**17.1**	

5.3.2 Facility Options

During the early identification of potential development concepts, it was recognised that, should dry trees be required, integrating them directly into an FPSO facility or a central processing platform (CPP) or a gravity-based storage structure (GBSS) (ie gravity-based structure with "liquids" storage cells on the seabed) would have execution risk and associated health & safety risks, fabrication complexity, and operability issues caused by congestion and so were disregarded early as concepts. Taking into consideration the findings of the early identification of potential development concepts, a WHP was therefore required to host the dry production trees.

Following the decisions of liquids only production and dry production trees on a WHP, the next decision was to identify the facility or facilities assemblage that would be required to develop and operate the Dorado field.

The following facility options for Dorado Phase 1 were considered:

- WHP with an FPSO – dry production trees located on a WHP with the production fluids exported to an FPSO for treatment, storage and offloading;
- WHP with a CPP and a floating storage and offloading (FSO) facility – dry production trees located on a WHP with the production fluids exported to a CPP for treatment, with saleable products exported to an FSO for storage and offloading. The CPP would stand separate to the WHP on a conventional steel jacket; and
- WHP with a GBSS – dry production trees located on a WHP with the production fluids exported to a GBSS for storage (in storage cells on the seabed) prior to periodic offloading. The GBSS would be based on a tripod type concrete structure with subsea storage of liquids prior to offloading.

The assessment of the above options is presented in **Table 5-4**. The "WHP with an FPSO" option was identified as the preferred facility option and was adopted because:

- it represents the lowest utilities discharges and solid waste generation;
- it has no subsea hydrocarbon storage cells (such as the "WHP with a GBSS" option), reducing the risk of small undetectable leaks of hydrocarbons to the marine environment; and
- the associated execution and operational risks are the lowest of the three options considered given the experience in the region and similarity of other WHP/FPSO facilities operated by Santos.

The overall score for the "WHP with an FPSO" option was the highest, however this option scored lower on some environment sub-criteria :

- potential environmental impact associated with increased underwater noise associated with the use of thrusters on the FPSO; however, this is not expected to be a significant noise addition in the Project Area, which overlaps with two shipping fairways (background ambient noise elevated by transiting ships) and is assessed in **Section 7.2.5**; and
- potential environmental risk due to an IMS translocation resulting from the FPSO moving off station for significant maintenance (up to every five years); however, this risk is well managed by Santos through operating similar assets in the region and is assessed in **Section 7.3.3.**

As this option performed sufficiently well in the other criteria and given that the associated risks can be managed to acceptable levels, the "WHP with an FPSO" option was adopted as the preferred facility concept. The selected concept for the Phase 1 development of the petroleum resources is therefore a WHP, housing dry production trees, connected to an FPSO producing liquids only.

As presented above, during the assessment a clear preference was identified between the “WHP with an FPSO” option and the “WHP, CPP & FSO” and “WHP with a GBSS” options. This was not the case between the “WHP, CPP & FSO” and “WHP with a GBSS” options, where a very slight preference was identified for the “WHP with a GBSS” option.

For the technical feasibility criterion, the “WHP, CPP & FSO” option performed as well as the “WHP with an FPSO” option while the “WHP with a GBSS” option was the least desirable due to its increased complexity and limited gravity-based structure regional experience. The “WHP, CPP & FSO” and “WHP with a GBSS” options presented an identical level of desirability for the health and safety criterion, with the “WHP, CPP & FSO” option presenting a lower operations safety risk than the “WHP with an FPSO” option (due to not requiring flexible dynamic risers) but a higher construction safety risk (due to higher offshore installation activities).

For the environment criterion, the “WHP with a GBSS” option was identified as preferred over the “WHP with an FPSO” option, with the main advantages being the absence of thrusters (which is associated with a reduction in underwater noise and atmospheric emissions) and a reduction of potential IMS translocation risk. Its main draw backs were the larger footprint and the potential risk of hydrocarbon leaks associated with the storage cells on the seabed within the GBSS. The “WHP, CPP & FSO” option was identified as the least preferred for the environment criterion as it represents the highest levels of light emissions, utility discharges to the marine environment and solid waste generated.

For the economic criterion, the only difference between the “WHP with an FPSO” and the “WHP, CPP & FSO” options is that the “WHP, CPP & FSO” option is associated with a higher schedule risk (due to not being able to refurbish an existing facility). The “WHP with a GBSS” option presented the highest schedule and commercial risks (mostly associated with the lack of regional experience with gravity-based structures).

For the societal criterion, the “WHP with a GBSS” option performed as well as the “WHP with an FPSO” option while the “WHP, CPP & FSO” option was the least preferred due to its potentially larger exclusion zone.

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Table 5-4: Facility options assessment

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
Technical feasibility	Technical complexity	4	The level of technical complexity is not a differentiator between the "WHP with an FPSO" and the "WHP, CPP & FSO" options (comparable hydrocarbons processing and storage systems). The hydrocarbons storage system is less complex than that of the "WHP with a GBSS" option.	4	The level of technical complexity is not a differentiator between the "WHP with an FPSO" and the "WHP, CPP & FSO" options (comparable hydrocarbons processing and storage systems). The hydrocarbons storage system is less complex than that of the "WHP with a GBSS" option.	2	This is the most technically complex option as it requires the integration of the subsea oil storage systems and the topsides of the GBSS.
	Proposal execution risk	4	WHP with FPSO systems are common in the region and are not expected to present a heightened execution risk.	4	WHP, CPP and FSO systems for oil production are less common in the region but are not expected to present a heightened execution risk.	2	Regional industry experience with WHP with a GBSS is limited and generally GBSSs present a higher execution risk, inherent to the substructure itself.
	Management of reservoir performance	3	Reservoir management is not impacted by the choice of facilities.	3	Reservoir management is not impacted by the choice of facilities.	3	Reservoir management is not impacted by the choice of facilities.
Average technical feasibility		**3.7**		**3.7**		**2.3**	
Health and Safety	Safety risk during construction	4	This option is associated with the lowest offshore installation work	2	The construction safety risk profile is similar between this option and the "WHP	2	The construction safety risk profile is similar between this option and the "WHP, CPP & FSO" option, but

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			requirement and as such represents the lowest safety risk during construction. The FPSO will sail down prior to commissioning and be hooked up to the installed DTM.		with GBSS" option, but it represents an increase in construction safety risk compared to the "WHP with an FPSO" option, as there is more offshore installation activity required to install the CPP and the FSO.		it represents an increase in construction safety risk compared to the "WHP with an FPSO" option, as there is more offshore installation activity required to install the GBSS.
	Safety risk during operations	2	Subsea flowlines and loadout lines are common to all three options. Operating flexible dynamic risers (specific to FPSO) introduces a safety risk that is not present with the other options.	4	Subsea flowlines and loadout lines are common to all three options. Not having to operate flexible dynamic risers marginally lowers the safety risk profile.	4	Subsea flowlines and loadout lines are common to all three options. Not having to operate flexible dynamic risers marginally lowers the safety risk profile.
Average Health and Safety		**3**		**3**		**3**	
Environment	Physical presence and seabed footprint	5	In addition to the WHP with gravity-based structure foundation footprint, the FPSO seabed footprint is limited to the anchoring mechanisms. As the WHP is common to all three options, this option has the smallest footprint for	2	In addition to the WHP gravity-based structure foundation footprint, there is the seabed footprint of the CPP steel jacket, loadout line to offtake buoy and the associated FSO anchoring mechanisms.	1	This option has a more complex footprint for removal than the WHP with gravity-based structure foundation due to the large liquids storage structure (on the seabed) of the GBSS.

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			removal at end of field life due to the limited installed infrastructure for the FPSO, i.e. the anchoring mechanisms.		This option has a larger footprint for removal than the FPSO option due to installed CPP infrastructure.		
	Number of vessel movements	3	Vessel movements and frequencies are expected to be similar during construction and operations for all options. The FPSO detaches for cyclone avoidance and five-yearly maintenance activity, resulting in a few additional vessel movements over years so is not considered to be a differentiator.	3	Vessel movements and frequencies are expected to be similar during construction and operations for all options. The FSO (if detachable) might detach for cyclone avoidance. The FSO will detach for five-yearly maintenance activity resulting in a few additional vessel movements over years so is not considered to be a differentiator.	3	Vessel movements and frequencies are expected to be similar during construction and operations for all options. No additional vessel movements such as those associated with detaching FPSO and FSO in other options.
	Light emissions	4	Lighting will be required on two facilities (WHP and FPSO) representing the lowest light emissions.	2	Lighting will be required on three facilities (WHP, CPP and FSO) representing the highest light emissions.	4	Lighting will be required on two facilities (WHP and GBSS) representing the lowest light emissions.
	Underwater noise	2	The use of the FPSO thrusters is a source of underwater noise absent	2	The use of the FSO thrusters is a source of underwater noise absent from the “WHP with a GBSS” option.	4	The absence of thruster noise results in the lowest underwater noise contribution.

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			from the "WHP with a GBSS" option.				
	Atmospheric emissions, including GHG	2	Similar atmospheric emissions levels are expected from production activities; however, the use of FPSO thrusters results in increased fuel consumption and resultant atmospheric emissions.	2	Similar atmospheric emissions levels are expected from production activities; however, the use of FSO thrusters results in increased fuel consumption and resultant atmospheric emissions.	4	The absence of FPSO and FSO thrusters with this option reduces the overall fuel consumption and the level of atmospheric emissions.
	Planned liquid discharges	4	Only the FPSO has utility discharges. Discharges from processing activities are expected to be similar between the three options.	2	The two manned facilities (CPP and FSO) have utility discharges. Discharges from processing activities are expected to be similar between the three options.	4	Only the GBSS has utility discharges. Discharges from processing activities are expected to be similar between the three options.
	Planned solid waste generation	4	Only one manned facility would generate solid waste. Solid waste generated from processing activities are similar for the three options.	2	Two manned facilities would generate solid waste. Solid waste generated from processing activities are similar for the three options.	4	Only one manned facility would generate solid waste. Solid waste generated from processing activities are similar for the three options.
	Risk of IMS translocation	2	It is expected that construction, supply and IMMR vessel requirements will be the same across all three options, and therefore the risk of IMS translocation	2	It is expected that construction, supply and IMMR vessels requirements will be the same across all three options, and therefore the risk of IMS translocation	4	It is expected that construction, supply and IMMR vessels requirements will be the same across all three options, and therefore the risk of IMS

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			from these vessels is not a differentiator. The FPSO will detach for five-yearly maintenance activity in dry dock, likely outside Australian waters. This presents a potential IMS risk if unmanaged.		from these vessels is not a differentiator. The FSO will detach for five-yearly maintenance activity in dry dock, likely outside Australian waters. This presents a potential IMS risk if unmanaged.		translocation from these vessels is not a differentiator. With no detachable facility this option presents the lowest IMS risk.
	Risk of unplanned discharges	4	Not having hydrocarbon subsea storage cells, this option and the “WHP, CPP & FSO” represent a lower risk of small undetected leaks of hydrocarbons in the environment. Other spill risks are expected to be similar between the three options as the subsea piping is similar for all three options.	4	Not having hydrocarbon subsea storage cells, this option and the “WHP with an FPSO” represents a lower risk of small undetected leaks of hydrocarbons in the environment. Other spill risks are expected to be similar between the three options as the subsea piping is similar for all three options.	2	Having subsea hydrocarbon storage cells for this option presents a potential for small undetected leaks of hydrocarbons in the environment from the storage cells. Other spill risks are expected to be similar between the three options as the subsea piping is similar for all three options.
Average environment		**3.3**		**2.2**		**3.3**	
Economic	Schedule risk	4	The potential refurbishment of an existing FPSO or even new build results in a reduced and more predictable construction	2	Without the possibility of refurbishment, this option is expected to present an increased construction timeframe to construct the CPP and FSO compared to	1	Without the possibility of refurbishment, this option is expected to present an increased construction timeframe to construct the GBSS compared to the “WHP with an FPSO” option.

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			timeframe compared with the other options.		the “WHP with an FPSO” option.		There are few hydrocarbon storage GBSSs in operation on the NWS, and there is limited experience in installing and operating GBSS in the region.
	Commercial risk	4	The commercial risk profile is expected to be similar between this option and the “WHP, CPP & FSO” option. A GBSS solution would represent a greater commercial risk due to the limited experience in installing and operating subsea GBSSs in the region.	4	The commercial risk profile is expected to be similar between this option and the “WHP, CPP & FSO” option. A GBSS solution would represent a greater commercial risk due to the limited experience in installing and operating subsea GBSSs in the region.	2	The GBSS has a higher commercial risk for the execution stage associated with installation activity as there is limited experience in installing and operating GBSSs in the region.
Average economic		**4**		**2**		**1.5**	
Societal	Socio-cultural impacts	3	The facility decision is not expected to influence the socio-cultural impacts of Dorado Phase 1.	3	The facility decision is not expected to influence the socio-cultural impacts of Dorado Phase 1.	3	The facility decision is not expected to influence the socio-cultural impacts of Dorado Phase 1.
	Socio-economic impacts	4	With only two facilities, the exclusion zone is expected to be the smallest (along with that of the “WHP with a GBSS”), thereby reducing potential socio-economic	2	With three facilities, the exclusion zone is the larger of the three options, resulting in the greater potential for socio-economic impacts, particularly in	4	With only two facilities, the exclusion zone is expected to be the smallest (along with that of the “WHP with an FPSO”), thereby reducing potential socio-economic

Criteria	Subcriteria	Facility Alternatives					
		WHP with an FPSO		WHP, CPP & FSO		WHP with a GBSS	
		Score	Justification	Score	Justification	Score	Justification
			impacts, particularly in relation to activities such as fisheries.		relation to activities such as fisheries.		impacts, particularly in relation to activities such as fisheries.
Average societal		**3.5**		**2.5**		**3.5**	
Overall Score (desirability)		**17.5**		**13.5**		**13.7**	

5.4 Design Alternatives

The WHP platform function and design were set at the early stage during the concept alternatives analysis as being a gathering facility to house the dry production trees with no processing capacity. Following the decision to progress with the “WHP with an FPSO” option, alternatives in the production system design on the FPSO were evaluated.

5.4.1 Mooring Design

Continuous dynamic positioning of the FPSO is disregarded given the metocean conditions (including cyclone conditions) on the North West Shelf. Given that the FPSO will not use dynamic positioning, the FPSO will have to be secured in position via a mooring system. The mooring system will connect the FPSO to multiple chains anchored to the seabed. The following mooring design options were considered:

+ permanent (the FPSO will remain on station through all weather conditions) – 4 x 6 “leg” system comprising anchor chain and ground chain; and
+ disconnectable turret mooring (DTM – the FPSO will move off station during adverse weather events) – 3 x 4 “leg” system comprising anchor chain, ground chain, subsea buoy and a fairlead chain.

The assessment of the above options is presented in **Table 5-8**. The “disconnectable mooring” option ranked first in all but the economic criterion, wherein the “disconnectable mooring” option was penalised by the potential loss of days of production associated with the FPSO moving off station during cyclonic events.

Overall, the “disconnectable mooring” option was identified as the most desirable mooring design option and adopted because it:

+ has the lower overall health and safety profile for both the installation and operations stages. The FPSO moving off station during cyclonic events reduces the risk profile compared to the FPSO staying on station. It is noted that some health and safety risks persist due to the requirement to shut down, disconnect, move away, return, and resume production prior to and after cyclonic events;
+ presents a lower noise profile due to a shorter installation timeframe; and
+ has the smaller seabed footprint due to a lower number of anchors and anchor legs being required.

While the risk of IMS translocation associated with the “disconnectable mooring” option is greater, due to the FPSO disconnecting for maintenance activities in dry dock (expected approximately every five years), this risk is well understood: and to date, IMS risks have been effectively managed by Santos. It is important to note that, during cyclonic events, the FPSO will disconnect but will remain at sea until safe to connect. Therefore, choosing the “disconnectable mooring” option does not present an unacceptable IMS translocation risk.

The technical feasibility and societal criteria were found not to be differentiators between the two options. The “permanent mooring” option does present a more desirable option as it reduces the potential for IMS introduction, but when considering other environment subcriteria (seabed footprint and atmospheric emissions in particular), there was less preference for the option overall based on the environment criterion. The “permanent mooring” option does present less of a commercial risk, as it does not involve loss of production days when the FPSO has to move off station for cyclones, but this economic advantage was not sufficient to identify the “permanent mooring” option as preferable.

There are no other permanently moored FPSO on the NWS of Australia. Permanently moored floating facilities, such as Montara, Prelude, and Ichthys, are located in the Timor Sea and therefore not subject to the same metocean conditions as on the NWS, i.e. Dorado location.

Table 5-5: Mooring design options assessment

Criteria	Subcriteria	Mooring Design Alternatives			
		Permanent		Disconnectable Mooring	
		Score	Justification	Score	Justification
Technical feasibility	Technical complexity	3	Technical complexity is not expected to be a differentiator between the options. This option will require a simpler but much larger mooring system. The technical difficulties associated with the size of the mooring system will be compensated by being less complex.	3	Technical complexity is not expected to be a differentiator between the options. This option will require a smaller but more complex mooring system. The technical complexity advantages brought by a smaller system will be counterbalanced by the additional difficulty of being removable.
	Proposal execution risk	3	The execution risk profile is not expected to be impacted by the mooring design decision.	3	The execution risk profile is not expected to be impacted by the mooring design decision.
	Management of reservoir performance	3	The management of reservoir performance is not expected to be impacted by the mooring design decision.	3	The management of reservoir performance is not expected to be impacted by the mooring design decision.
Average technical feasibility		**3**		**3**	
Health and Safety	Safety risk during construction	2	The anchor laying and connecting activities are expected to take longer due to the increased number of anchors and mooring “legs”, thus slightly increasing the construction safety risk profile.	4	The construction safety risk profile is lower with this option due to the reduced number of anchors and anchoring “legs” that are to be installed.
	Safety risk during operations	1	The operational safety risk profile is greater with this option due to the FPSO staying on station during cyclonic events. The preparations required for such event will be more complex than those for moving off station.	5	Operational safety risks associated with shutdown, disconnection and resumption of production are considered less risky than preparations for cyclones and severe weather events.

Criteria	Subcriteria	Mooring Design Alternatives			
		Permanent		Disconnectable Mooring	
		Score	Justification	Score	Justification
Average Health & Safety		**1.5**		**4.5**	
Environment	Physical presence and seabed footprint	2	Additional anchors and anchor "legs" (24 anchors on 4 anchor legs instead of 12 anchors on 3 legs) result in the seabed footprint being greater.	4	Fewer anchors and anchor "legs" equates to a smaller seabed footprint.
	Number of vessel movements	3	The number of vessel movements is not expected to be significantly impacted by the mooring design decision.	3	The number of vessel movements is not expected to be significantly impacted by the mooring design decision.
	Light emissions	3	While with this option the FPSO will remain on station and may continue production during cyclonic conditions, the overall light emissions are not different to normal operating conditions and are not impacted by the mooring design decision.	3	The light emissions are not expected to be impacted by the mooring design decision.
	Underwater noise	2	The installation activities are expected to be longer and therefore generate underwater acoustic emissions for a longer period. During operations it is not expected that the noise level will differ between the two options.	4	The installation activities are expected to be shorter and therefore generate underwater noise for a shorter period. During operations it is not expected that the noise level will differ between the two options.
	Atmospheric emissions, including GHG	3	The FPSO will remain on station and may continue production during cyclonic conditions; however, the overall atmospheric emissions are not expected to vary sufficiently to differentiate between the mooring design options.	3	The FPSO will navigate away from the cyclonic conditions on its own power; therefore, the overall atmospheric emissions are not expected to vary sufficiently to differentiate between the mooring design options.
	Planned liquid discharges	3	The planned liquid discharges are not expected to vary significantly between the mooring design options.	3	The planned liquid discharges are not expected to vary significantly between the mooring design options.

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Criteria	Subcriteria	Mooring Design Alternatives			
		Permanent		Disconnectable Mooring	
		Score	Justification	Score	Justification
	Planned solid waste generation	3	The planned solid waste generation is not expected to vary significantly between the mooring design options.	3	The planned solid waste generation is not expected to vary significantly between the mooring design options.
	Risk of IMS translocation	4	The FPSO will remain on station for the duration of the Dorado Phase 1 lifecycle, thus reducing potential IMS translocation risk associated with the FPSO entering non-Australian waters after it is initially mobilised.	2	The FPSO may disconnect for five-yearly maintenance activities in dry dock and represents a potential IMS risk when remobilising back to location. The FPSO will disconnect for cyclones, but does not "dock" in these instances, and remains at sea until safe to reconnect.
	Risk of unplanned discharges	3	The risk of unplanned discharges is not expected to vary significantly between the mooring design options.	3	The risk of unplanned discharges is not expected to vary significantly between the mooring design options.
Average environment		**2.9**		**3.1**	
Economic	Schedule risk	3	Schedule risk is not impacted by mooring design.	3	Schedule risk is not impacted by mooring design.
	Commercial risk	4	As the FPSO remains on station throughout all weather conditions, the option presents slightly less commercial risk than the "disconnectable mooring" option.	2	The FPSO moving off station presents a commercial risk due to loss of production days.
Average economic		**3.5**		**2.5**	
Societal	Socio-cultural impacts	3	The socio-cultural impacts are not expected to differ between the two options.	3	The socio-cultural impacts are not expected to differ between the two options.

Criteria	Subcriteria	Mooring Design Alternatives			
		Permanent		Disconnectable Mooring	
		Score	Justification	Score	Justification
	Socio-economic impacts	3	The socio-economic impacts are not expected to differ between the two options.	3	The socio-economic impacts are not expected to differ between the two options.
Average societal		**3**		**3**	
Overall Score (desirability)		**13.8**		**16.1**	

5.4.2 Power Supply

The operation of the Dorado facilities requires a power supply. The power requirement includes electricity for rotating machinery such as pumps and compressors and power in the form of heat for processing the recovered fluids. The total power demand ie. electrical load, is estimated at approximately 30 MW.

The following alternative options to supply power were identified and considered:

+ import power from the existing mainland grid;
+ import power from existing oil and gas facilities;
+ Photovoltaic (PV) system or wind turbine system adjacent to or on the FPSO;
+ power generation on the FPSO using produced gas; and
+ power generation on the FPSO using diesel fuel.

The options were primarily assessed against energy efficiency criteria and associated potential to reduce the GHG emissions from the Dorado Development; and the technical maturity and practicability of each alternative.

5.4.2.1 Import Power from Mainland Electricity Grid Supply

One option for powering the Dorado Development facilities is via transmission of power from the mainland electricity grid supply. The imported electricity would likely be generated at Port Hedland Power Station (closest power station to Dorado) which is a natural gas-fired power station (where gas is combusted to generate electricity). There would be a requirement to install a subsea transmission line between the FPSO and the mainland (approximately 145km in length) which would incur energy losses during transmission. FPSO process heat requirements of 15 MWh would also need to be transmitted in the form of additional electricity (~15 Mwe) from the mainland, in lieu of captured waste heat from offshore power generation, which incurs further inefficiencies.

5.4.2.2 Import Power from Existing Offshore Oil and Gas Facility

Electricity could also be imported from an existing offshore oil and gas facility. This would require the installation of a transmission line between the FPSO and the power generating facility. The closest offshore oil/ gas facility to the Dorado Development is approximately 200km away. To further consider this option it has to be assumed:

+ that it is possible to identify an offshore oil and gas facility which generates excess power and has power transmission facilities (or its operator is willing to modify the facility so it does);
+ the distance and seabed between the facility and FPSO does not preclude the installation of a subsea transmission line and;
+ a mutually acceptable commercial and contractual agreement can be reached between Santos and the facility operator.

Offshore facilities generating their own power in the region do so by combusting produced gas, in the same manner that power would be generate don the Dorado FPSO given that heat cannot be transmitted from the mainland as for the option of importing power from the mainland, the heat required for hydrocarbon processing would have to be generated on the FPSO.

5.4.2.3 Photovoltaic (PV) System and/or Wind Turbine System

Photovoltaic (PV) and/ or wind turbines also produce electricity and are both available technologies.

PV and wind turbine systems are intermittent generators of electricity such that battery systems would also be required to ensure a continuous and stable supply of power to the FPSO. The size of the supply would require greater than 250 MW of solar panels (1x1 km array) or greater than 25 of the largest wind turbines at the time of preparing this OPP. The size of the battery system required to store generated electricity (for when the PV/wind turbine system is not operational) would likely need to be greater than 1 GW/hr and the mass of this system would be approximately 5,000te.

To further consider this option it has to be assumed the PV system/wind turbine system would be installed offshore, adjacent to the Dorado WHPO and FPSO. If the PV/wind turbine system were constructed onshore then there would be a requirement to build a subsea transmission line between the FPSO and the mainland (approximately 145km in length) as per the "import power" options (**section 5.4.2.1**).

There would be an additional electrical load requirement to generate the heat for hydrocarbon processing on the FPSO.

5.4.2.4 Power Generation on the FPSO using produced gas

Gas turbine generators are commonly used onboard offshore oil and gas facilities. Gas turbines are compact, have high reliability, require relatively little maintenance and can be run using fuel gas produced from the Development reservoirs. The engineering design process for the Development will consider the application of lower emission energy systems for supplementary power loads for the facilities and potential integration of battery storage systems to optimise the efficiency of this solution.

5.4.2.5 Power Generation on the FPSO using diesel

Power can also be generated by diesel-powered turbines.

Should diesel be the only fuel source for power there would be a requirement to transfer, bunker and store large volumes of diesel (approximately 900m^3 for 5 days) to meet the electricity demands of oil production. Typically these engines require frequent maintenance/ service every 500 hours. In the event that a produced gas power generation system is used, the FPSO would still require diesel power generation capacity to support the FPSO operation for commissioning (until the power generation system is commissioned), when the field is not producing gas, or the FPSO is not on station.

Similar to using produced gas, diesel power would utilise onboard heat recovery units for process heat.

5.4.2.6 Preferred Option

The assessment of the options is presented in **Table 5-6**. The "produced gas electricity supply - FPSO" option was identified as the preferred option and was adopted because:

- the associated execution and operational risks are the lowest of the five options considered given the experience in the region and similarity of other WHP/FPSO facilities operated by Santos;

+ this option offers the best reliability for operating;
+ the PV/wind turbine systems options are more technically complex and have not been executed offshore of WA previously; and
+ of the technically feasible power supply alternatives, it offers optimal energy efficiency, particularly when considering the combined electricity and heat requirements for production processing systems.

In both options that "import" electricity to the Dorado facilities, the power most likely will have been generated by combusting gas. The quantity of GHG emissions emitted from either of these options are not expected to be materially different to those generated from gas turbine generators located on the FPSO so these options do not provide a significant GHG emissions reduction benefit for the Dorado Development. The Dorado Development would have to include emissions associated with generation of the imported electricity (Scope 2 emissions) in its annual emissions reporting, which are expected to be comparable to those associated with generating electricity on the FPSO. These options require Santos to depend on a third party to provide power which represents an undesirable position, as Santos would not have control or visibility on potential outages if the facilities were interrupted or shutdown their operations. Both of these options also require installation of a subsea transmission line, increasing the development footprint, with potential to impact sensitive habitat. A subsea transmission line also introduces energy losses which need to be compensated for by additional onshore power generation resulting in additional emissions.

Whilst the PV/ wind turbine system options will result in no GHG emissions to produce electricity, the need for a continuous uninterrupted power supply for safe operations, the quantity of panels/ turbines and additional battery storage required to generate the required power and associated space requirements rendered this option infeasible. This option would also require additional structures to be installed offshore (separate to the WHP/FPSO) to house the equipment, increasing the seabed disturbance footprint of Dorado Phase 1.

Generating power solely from diesel rather than produced gas results in increased GHG emissions. Even if the GHG emissions associated with the transport and storage of diesel to the Dorado facilities are disregarded, the NGER Act GHG emissions calculation methodology for a similar volume indicates combusted diesel emits approximately 30% more GHG emissions than produced gas for power generation. Although technically feasible, this option would represent an increase in GHG emissions relative to the produced gas power supply option and as a result it was not adopted as the primary power supply option. The FPSO will still require diesel power generation for contingent power supply when the field is not producing gas, or the FPSO is not on station.

A benefit of onboard power generation is that the electrical power demand (and associated emissions) is less by at least 15 MW due to the recovery of exhaust heat from gas turbine generators which is used to process the oil. This gives FPSO power generation a GHG emissions efficiency advantage over imported power generated by gas fuels of approximately 27%.

Using produced gas for FPSO power generation was selected as the power generation option for Dorado Phase 1.

Table 5-6: Power Supply options assessment

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
Technical feasibility	Technical complexity	2	Connection of approximately 145km long high voltage power cable via FPSO turret technically challenging due to need to transfer HV power across the rotating swivel of FPSO (required for weathervaning). There would be a requirement to generate heat on the FPSO for processing, (this is typically recovered from the exhaust (waste) heat of the power	2	Connection of approximately 200km (closest offshore facility) long high voltage power cable via FPSO turret technically challenging due to need to transfer HV power across the rotating swivel of FPSO (required for weathervaning). There would be a requirement to generate heat on the FPSO for processing, (this is typically recovered from the exhaust	1	Most technically complex when compared with other options, given the offshore location of the FPSO and locating the system adjacent to the facility. Limited PV structures installed in offshore open water locations so would be constructed onshore, and then transfer of power via subsea power cable. There is insufficient space or weight allowance	4	This option presents a common power supply option utilised for offshore oil and gas facilities. The technology is well advanced and provides the reliability required for operations on the FPSO.	4	Diesel power generation presents a common power supply option utilised for offshore facilities, and typically available as the backup power supply option. The technology is well advanced and provides the reliability required for operations on the FPSO.

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			generation units).		(waste) heat of the power generation units).		available on the FPSO/ WHP to install the required equipment to generate and store (battery would weigh approximately (weighing 5,000te) the order of magnitude of power required.				
	Proposal execution risk	2	This option introduces additional execution risk associated with installing the subsea power cable and introduces 3rd party operational risk as a sole power provider to the	2	This option introduces additional execution risk associated with installing the subsea power cable and introduces 3rd party operational risk as a sole power provider to the	1	This option introduces additional execution risk associated with installing very large grid scale PV system or wind turbine system offshore and associated moorings in	5	No additional execution risk as the generators are installed on the FPSO in the shipyard as part of the FPSO fabrication.	5	No additional execution risk. The proposed power generation units on the FPSO will run on diesel (contingent for when FPSO is disconnected) as well as gas. Additional diesel storage tanks

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			Dorado project would be required.		Dorado project would be required.		remote cyclonic location.				required on the FPSO.
	Management of reservoir performance	2	This option may result in poorer reliability, leading to deferred extraction from the reservoir.	2	This option may result in poorer reliability, leading to deferred extraction from the reservoir.	2	This option may result in poorer reliability, leading to deferred extraction from the reservoir.	4	Power supply options will not impact reservoir management.	4	Power supply options will not impact reservoir management
Average technical feasibility		**2**		**2**		**1.3**		**4.7**		**4.7**	
Health & Safety	Safety risk during construction	2	Construction risk associated with installation of subsea cable from mainland facility to FPSO.	2	Construction risk associated with installation of subsea cable from offshore facility to FPSO.	1	Construction risk associated with installation of PV structure / wind turbines and moorings.	5	No associated construction risk in the Project Area, equipment installed in shipyard.	5	No associated construction risk in the Project Area, equipment installed in shipyard.
	Safety risk during operations	4	Increase H&S risk associated with the requirements for HV power slip rings in the	4	Increase H&S risk associated with the requirements for HV power slip rings in the	1	H&S risk associated with maintenance on PV structure/ wind turbines.	3	H&S risk associated with maintenance activities offshore on power	2	H&S risk associated with maintenance activities offshore on power

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			swivel stack. Third party H&S risk associated with operating mainland facility. Potential for reduced safety due to loss of power events (out of Santos control) and restarting production.		swivel stack. Third party H&S risk associated with operating mainland facility. Potential for reduced safety due to loss of power events (out of project control) and restarting production.		Potential for reduced safety due to loss of power events (out of project control) and restarting production.		generating systems on FPSO		generating systems on FPSO
Average H&S		**3**		**3**		**1**		**4**		**3.5**	
Environ-ment	Physical presence and seabed footprint	2	Subsea cable laid on seabed from mainland to FPSO. Cable route may have to cross over sensitive habitats.	2	Subsea cable laid on seabed from existing facility to FPSO. Cable route may have to cross over sensitive habitats.	1	Insufficient space on WHP and FPSO for PV or wind turbines. Additional seabed disturbance for PV structure or anchors to hold wind turbines on location	5	No seabed disturbance equipment located on FPSO	5	No seabed disturbance equipment located on FPSO

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
							(adjacent to WHP/ FPSO).				
	Number of vessel movements	2	Increased vessel movements associated with installation of subsea powerline	2	Increased vessel movements associated with installation of subsea powerline	2	Increased vessel movements associated with installation of PV/ wind turbines	4	No additional vessel movements associated with installation	3	No additional vessel movements associated with installation offset against additional diesel supply vessel movements.
	Light emissions	2	Minor/ short term light emissions associated with presence of installation vessels for laying subsea cable. No light emissions within Project Area during Operations.	2	Minor/ short term light emissions associated with presence of installation vessels for laying subsea cable. No additional light emissions within Project Area during Operations.	2	Minor/ short term light emissions associated with presence of installation & maintenance vessels for installation of PV/ wind turbines. Light emissions during Operations associated with navigational lighting only.	4	No additional light emissions associated with installation or Operations.	4	No additional light emissions associated with installation or Operations.

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
	Underwater noise	2	Minor/ short term noise emissions associated with installation vessels for laying subsea cable.	2	Minor/ short term noise emissions associated with installation vessels for laying subsea cable.	1	Acoustic emissions associated with foundation piling, as well as installation vessels for installation of wind turbines.	4	No additional noise emissions associated with installation or Operations.	4	No additional noise emissions associated with installation or Operations.
	Energy Efficiency, GHG emissions	2	Produces similar GHG emissions as produced gas electricity supply on FPSO assuming remote power is produced from gas. 27% less efficient than FPSO gas power generation due to FPSO waste heat recovery benefit, and energy losses during	2	Produces similar GHG emissions as produced gas electricity supply on FPSO assuming remote power is produced from gas. 27% less efficient than FPSO gas power generation due to FPSO waste heat recovery benefit, and energy losses	5	Does not produce emissions (but not viable for safe and efficient operations).	2	Produces similar GHG emissions to electricity from mainland or remote facility. Energy efficiency advantage of 27% over onshore power generation due to waste heat recovery benefit.	1	>30% additional GHG emissions than power produced from gas (as presented in the NGER GHG emissions calculation methodology for a similar volume combusted diesel emits more GHG emissions than field gas). Also vessel emissions from transport of diesel to FPSO.

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			transmission from onshore power supply.		during transmission from onshore power supply.						
	Planned liquid discharges	3	There are no associated planned liquid discharges with generation of power supply. Planned discharges associated with presence of installation vessels for laying subsea cable.	3	There are no associated planned liquid discharges with generation of power supply. Planned discharges associated with presence of installation vessels for laying subsea cable.	3	There are no associated planned liquid discharges with generation of power supply. Planned discharges associated with presence of installation vessels for installation of wind turbines.	3	There are no associated planned liquid discharges with generation of power supply.	3	There are no associated planned liquid discharges with generation of power supply.
	Planned solid waste generation	3	There are no associated planned solid discharges with generation of power supply	3	There are no associated planned solid discharges with generation of power supply	3	There are no associated planned solid discharges with generation of power supply	3	There are no associated planned solid discharges with generation of power supply	3	There are no associated planned solid discharges with generation of power supply
	Risk of IMS translocation	2	Potential for IMS	2	Potential for IMS	2	Potential for IMS translocation	4	No additional risk of IMS	4	No additional risk of IMS

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			translocation associated with installation vessels used to install subsea cable.		translocation associated with installation vessels used to install subsea cable.		associated with installation vessels used to install wind turbines		translocation as gas power generation units installed on FPSO during shipyard fabrication		translocation as diesel power generation units installed on FPSO during shipyard fabrication
	Risk of unplanned discharges	2	Potential for unplanned discharges associated with vessels used for subsea cable installation.	2	Potential for unplanned discharges associated with vessels used for subsea cable installation.	2	Potential for unplanned discharges associated with vessels used for installing PV structure/ wind turbine.	5	No associated risk of unplanned discharges from power generation units.	4	No associated risk of unplanned discharges from power generation units. Increased potential for unplanned discharges associated with transport and bunkering diesel to the FPSO.
Average environment		**2.2**		**2.2**		**2.3**		**3.8**		**3.4**	
Economic	Schedule risk	2	Additional schedule risk associated with additional environment	2	Additional schedule risk associated with additional environment	1	PV technology has not been adopted for power supply in an offshore	4	No additional schedule risk, as power supply will be studied during detailed	4	No additional schedule risk, as power supply will be studied during detailed

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			(commonwealth and state) approvals, undertaking baseline route surveys and the installation of subsea cable		(potentially commonwealth and state depending on facility that will supply the power) approvals, undertaking baseline route surveys and the installation of subsea cable		location. There would be a requirement to adapt the technology for the offshore environment. Additional surveys (habitat and geotechnical) for installation of wind turbines. There would be a requirement for a number of PV cells/ wind turbines to meet the power requirements of the FPSO.		engineering, and appropriate units ordered for installation during shipyard scope. No additional approvals required as part of FPSO facility.		engineering, and appropriate units ordered for installation during shipyard scope. No additional approvals required as part of FPSO facility.
	Commercial risk	2	Additional risk associated with power supply during operations stage, as requires Santos	2	Additional risk associated with power supply during operations stage, as requires Santos	1	Reliability of PV or wind turbines would be an issue during operations requiring a large battery to store electricity	4	Reliable power supply, located and controlled on the FPSO, adopts technology used to generate	4	Reliable power supply located and controlled on the FPSO, adopts technology used to generate power for oil and

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
			to depend on a third party to provide power which represents an undesirable position, as Santos does not have control or visibility on potential outages if the facilities are interrupted or have to shutdown their operations. This option has a high capital outlay per unit of energy consumed. Power losses due to transmission conditioning.		to depend on a third party to provide power which represents an undesirable position, as Santos do not have control or visibility on potential outages if the facilities are interrupted or have to shutdown their operations. This option has a high capital outlay per unit of energy consumed. Power losses due to transmission conditioning.		(unable to locate this on the FPSO due to large size and weight) or back up power supply (such as diesel or gas generation) to improve reliability. This option has a high capital outlay per unit of energy consumed.		power for oil and gas facilities globally. Gas is supplied from the reservoir wells.		gas facilities globally. Diesel storage on FPSO and supplied by supply vessel.

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
Average economic		**2**		**2**		**1**		**4**		**4**	
Societal	Sociocultural impacts	2	The sociocultural impacts are not expected to differ between this option, supply from another facility or power supply generated on the FPSO (gas), as all result in GHG emissions.	2	The sociocultural impacts are not expected to differ between this option, supply from mainland facility or power supply generated on the FPSO (diesel or gas), as all result in GHG emissions.	5	The use of PV or wind turbines is likely to be more favourable from a sociocultural aspect given that these represent a lower GHG emission for power supply compared with other options involving use of fossil fuel.	2	The sociocultural impacts are not expected to differ between this option, supply from another facility or power supply generated on the FPSO (gas), as all result in GHG emissions.	1	From a GHG emissions perspective the sociocultural impacts less favourable for diesel generated power on the FPSO compared to all three gas power supply options based on higher GHG emissions associated with use of diesel, and the requirement for diesel to be shipped and bunkered to the FPSO on a regular basis. Noting also that diesel would need to be

Criteria	Sub-criteria	Power Supply									
		Import Power - Mainland Grid Supply		Import Power - existing Offshore Facility		PV/ Wind Turbines Systems Offshore		Power Generation on FPSO - Gas		Power Generation on FPSO - Diesel	
		Score	Justification	Score	Justification	Score	Justification	Score	Justification	Score	Justification
											imported, as Australia is a net importer of diesel.
	Socioeconomic impacts	2	There is potential socioeconomic impact associated with subsea cable on the seabed – creating a potential snagging hazard following initial installation, this will likely be covered with sediment with time.	2	There is potential socioeconomic impact associated with subsea cable on the seabed – creating a potential snagging hazard following initial installation, this will likely be covered with sediment with time.	1	This option has the greatest potential socioeconomic impact with the presence of PV or wind turbines structure as well as the WHP/ FPSO	4	There is no socioeconomic impact associated with this option.	2	This option will result in additional vessel traffic associated with the regular required supply of diesel to the FPSO.
Average societal		**2**		**2**		**3**		**3**		**1.5**	
Overall Score (desirability)		**11.2**		**11.2**		**8.6**		**19.5**		**17.1**	

5.4.2.6.1 FPSO Gas Turbine Power Generation Alternatives

To optimise the energy efficiency for FPSO gas turbine power generation, a number of design alternatives were considered and assessed during engineering design. Key to the assessment of design alternatives for the power generation system, is the combined demand for process electricity and heating. The provision of process heating is often linked to power generation configuration, of which waste heat recovery units (WHRU) are the most efficient means of generating a heat source. Reducing heat or electrical consumption through energy efficient design allows for a reduction in power generation, resulting in a reduction in fuel consumption and GHG emissions. Given the interdependency between power and heat supply systems - the provision of process heating and the configuration of power generation systems needs to be assessed holistically to determine optimal energy efficiency outcomes.

The main sources of electrical power demand for the Dorado facilities includes:

- compressor drivers;
- pumps;
- heat generation and distribution; and
- cooling.

The largest sources of heating requirements for the facility operations include:

- Crude oil heater;
- Fuel gas heating; and
- Glycol regenerator reboiler.

The total process heat requirements are significant, requiring up to 17 Megawatts (MW) heat load. Heat is typically generated in one of three ways:

- through the combustion of fuel in an indirect fired heater;
- using electricity with an electrical heating element; or
- captured from the exhaust of an engine.

The combination of power supply and process heating requirements have trade-offs in terms of energy required, reliability, and associated emissions. Key energy efficiency considerations relevant to design alternatives for the FPSO gas turbine power generation system are assessed in Table 5-7.

Table 5-7: FPSO Gas Turbine Power Generation Design Alternatives and Energy Efficiency Strengths/ Weaknesses – Design Considerations

Design Alternatives	Strengths	Weaknesses
Combined Cycle Gas Turbine System	+ Relatively high efficiency + Reduction in energy requirement and GHG emissions (~6MW of energy and ~5000 tCO_2e/yr of emissions).	+ Heat load already partially captured with waste heat recovery for integrated heat and power system (see Open Cycle Waste heat recovery design alternative).

Design Alternatives	Strengths	Weaknesses
		+ Significantly increases the complexity and utilities requirements of the FPSO. + Increases cost per MW by a factor of 10 for minimal additional benefit (~6MW or a reduction of 5000 tCO2e/yr).
Open Cycle Gas Turbine System Waste Heat Recovery	Recovery of heat from exhaust to meet facility process heating requirements, with zero additional emissions – eliminates need for fired boilers for heating medium and associated emissions ~6,000 tCO2e/yr	Integrates the heat and power system which may cause challenges during startup and upset conditions, potentially leading to a cascade trip and flaring.

Table 5-8: FPSO Gas Turbine Power Generation Design Alternatives and Energy Efficiency Strengths/ Weaknesses – Operations Considerations

Operations Alternatives	Strengths	Weaknesses
Gas Turbine Generator 3 X 50% Approximately 137,000 tCO2e/yr	+ Spinning reserve (3rd turbine) provides optimal power load stability for operations and production + Energy efficiency further optimised when combined with waste heat recovery	+ Additional fuel use degrades overall efficiency + Spinning reserve (3rd turbine) results in an increase of approximately 46,000 tC02e/yr.
Gas Turbine Generator 2 x 50% + 1 x 0% (standby) Approximately 91,000 tCO2e/yr	Decreased fuel use and increased energy efficiency – approximately 33% less CO2e emissions (~46,000 tCO2e/yr) compared with the 3 x 50% configuration Energy efficiency further optimised when combined with waste heat recovery	Reduced power load stability for operations and production

Following the assessment of design and operations alternatives, and associated energy efficiency and emissions reduction considerations, the design basis for the FPSO power generation system includes:

+ 2 x 50% + 1 x 0% (standby) gas turbine generator configuration resulting in a 33% reduction in CO2e emissions (~46,000 tCO2e/yr), due to elimination of emissions from spinning reserve, associated with continuous operation of a 3rd gas turbine generator (3 x 50% alternative);
+ Inclusion of waste heat recovery on open cycle gas turbine system to maximise utilisation of waste heat for process heating resulting in a further reduction of ~6,000 tCO2e/yr. Inclusion of waste heat recovery negates the potential benefits of the combined cycle gas turbine system alternative; and
+ The current operations philosophy for this design basis is to load shed any non-producing electrical load for a duration long enough to start the spare generator.

Potential further optimisations to the design basis and operations philosophy to be considered in the subsequent Project phase, and key decision criteria, are further discussed in **Section 5.5**.

5.4.3 Reservoir Management

The Dorado reservoir is geologically complex, with the recovery of hydrocarbons from a number of reservoirs within the Archer Formation. The requirement to manage the hydrocarbon recovery from the Dorado reservoir drives some of the alternative options assessed for the Dorado Project.

The reservoir development concept and drainage plan is designed to optimise overall liquid hydrocarbon recovery during Dorado Phase 1. Reservoir simulation studies have been undertaken during the concept selection stage to assess recovery factors associated with alternative recovery mechanisms, including natural depletion, along with gas flooding and water flooding or injection (with and without gas lift) schemes to enhance production.

Water flooding is a reservoir displacement process, and therefore miscibility[12] is irrelevant (i.e. miscibility is only produced through the gas flooding process).

Gas flooding is the injection of gas into the reservoir to maintain reservoir pressure and enhance overall liquid recovery. Gas lift is a small injection of gas into the wellbore (not the reservoir) to reduce the density of the fluids within the wellbore (not the reservoir itself) thus allowing them to flow back to the surface more easily. Detailed studies showed that the composition of the gas being reinjected back into the reservoir, coupled with the oil composition and the pressure and temperature conditions of the reservoir, means that the gas flood within the Caley reservoir will be miscible and not immiscible.

Extensive laboratory testing supported by reservoir modelling predicts that reinjection of an LPG-rich gas into the reservoirs will enhance oil recovery through a miscible process. Enhanced oil recovery through miscible gas flooding is a proven technology widely used both onshore and offshore and, in the case of the Dorado field, is expected to achieve high hydrocarbon liquid recovery factors of up to 75% (**Table 5-9**). The miscible flood relies on injected LPG-rich gas contacting the reservoir oil and, through a complex process of component exchange, oil and gas phases mixing to become a single phase, resulting in an enhancement to production and improved recovery factors.

Table 5-9: Hydrocarbon liquids recovery factors by recovery mechanism

Recovery Mechanism	Hydrocarbon Liquids Recovery Factors
Water flood (no gas lift)	43%
Water flood (with gas lift)	68%
Miscible gas flood	Up to 75%

Studies suggest that a development concept utilising water injection for the purpose of enhanced liquids recovery would erode hydrocarbon liquid recovery potential by more than 15 MMbbl. Reinjecting PW into the lower members of the reservoir carries the risk that reinjection may result in the wells watering out earlier, reducing the volume of hydrocarbon liquids that can be recovered.

[12] Miscibility occurs when two fluids with similar polarity (and, therefore, similar intermolecular interactions) are combined and the fluids mix to form a homogeneous solution.

The option of reinjecting the PW into the reservoir for the purpose of oil recovery was disregarded due to the increased risk of water breakthrough in the down-dip oil production wells and the resulting negative impact on overall hydrocarbon liquid recovery.

5.4.4 Flaring Management

Dorado Phase 1 operations will generate GHG emissions. **Section 5.4.2** assesses the power supply options, inclusive of evaluating the associated GHG emissions, adopting fuel gas power generation on the FPSO as the preferred option. **Section 5.4.2.6.1** assesses the options for reservoir management and the requirement for reinjection of the majority of the produced gas back into the Dorado reservoir to enhance oil recovery.

Other sources of GHG emissions throughout the project life requiring assessment are planned flaring during routine operations, as well as flaring from non-routine events during operations i.e process upsets, and the non-routine operational activities including well clean-up/ completions, well workovers and facility commissioning.

For safety reasons, during operations, there is a requirement to continuously flare a small portion of the produced gas, via the flare pilot (further information presented in **Section 6** and **7.2.6**). Flare pilots are a safety feature on flare systems to ensure gas releases are ignited and completely burned. Pilotless flares are available, however these pose increased safety risk in the case where the flare fails to ignite and GHG emissions reduction benefit is eroded with a single unignited methane gas release event.

During well testing, facility commissioning and other non-routine events during operations such as loss of compression, controlled shutdown, emergency conditions, pressure relief events, and start-up after non-routine events, there is a requirement to safely process the associated gas (refer **Table 7-40**). These scenarios occur for limited periods of time over the project life.

The following alternative options were identified to manage the gas from these events:

+ reduced emissions during well testing (Reduced Emissions Completion);
+ compressed natural gas for storage and other users;
+ gas to wire;
+ carbon capture and storage; and
+ flaring the gas.

Table 5-10 describes the options and assesses the technical feasibility for implementation and potential environmental benefit for Dorado Phase 1.

During commissioning, start-up and controlled shutdown of all systems on the FPSO are available (being turned on or off in a predetermined sequence) and therefore limited use of the flaring reduction options would be available. It is not possible to commission/ start-up the reinjection compressor system without first having the separation system and gas treatment system running, therefore this off-spec gas would require flaring. The wells will be operated during this stage to minimise flaring. During planned shutdowns depressurisation of the system or parts of the system might be required which is only possible to achieve with the flare.

Pressure relief events/emergency shutdowns generally escalate rapidly and occur over a short time period. Given the escalation and short notice occurrence of such events it is difficult to activate flare reduction systems (which require ramping up to the required operating conditions).

At the time of preparing the OPP, management of the GHG emissions associated with well testing, facility commissioning and non-routine events during operations via flaring is considered the preferred option.

Table 5-10: Flaring Options Assessment

Option	Description	Feasibility Assessment	
Compressed Natural Gas	The compressed natural gas (CNG) option requires that the gas typically is compressed and stored for future use, such as power generation on the FPSO, or exported for use at other facilities. This option requires the installation of a treatment, compression and export facility on the FPSO, and if the gas is to be exported - a pipeline to transport the gas. Alternatively large storage facilities (high pressure bullets) will be required.	Given the short term nature of well clean-up/ work-overs and commissioning, and the intermittent/ unknown nature of non-routine operational events, as well as the lack of existing infrastructure (no transmission line/ gas export pipeline from Dorado to the mainland or another offshore facility - therefore infrastructure would be required to be installed) the options that included exporting the gas, or power were not considered feasible for the Dorado Project on the basis that they: + increase technical complexity and safety risk (due to the addition of pressurised systems on the FPSO), + result in additional seabed disturbance and additional decommissioning requirements, + would not provide a reliable source of gas or power for the end user (so are not economically viable) due to the short term source from well testing and commissioning and the intermittent nature of non-routine events during operations, and + do not reduce the overall GHG emissions as the end user will likely combust the product. The World Bank (2015) concludes in general that marine Compressed Natural Gas (CNG) is not yet commercially proven, and there are currently no analogues in operation. Storage of the CNG is not possible on the FPSO due to weight, space limitations (large storage bullet) and the associated increased safety risk (storing large volumes of high pressure gas) and complexity. Storage space on the WHP/ FPSO is limited, if there is no associated pipeline available to transfer the gas to onshore or offshore users. Gas to wire would require large offshore and onshore transformers and 150km sub-sea cable, which is not economical for short term nature of the supply of the gas.	Not adopted
Gas to Wire	This requires the combustion of the gas in the FPSO power generation system to generate electricity and the generated electricity to be transmitted onshore or to another offshore facility.		Not adopted
Reduced Emissions	REC is a method that can be used during well clean-up/ completions, where the produced gas is captured, compressed and stored for future	The technology has been typically used for wells involving hydraulic fracturing that have higher rates of flowback compared to normal well completions (USEPA, 2019). This technology is in the early stages of assessing its potential applicability for offshore	Not adopted

Option	Description	Feasibility Assessment	
Completion (REC)	use rather than being flared, therefore reducing GHG emissions during well testing.	conventional wells and is currently not proven for conventional well completions offshore. For REC to work gas treatment, gas compression and gas storage facilities are required on the WHP or MODU. This is not feasible due to space and weight restrictions on both facilities. Additionally, the safety risk is increased due to storage of large volumes of high pressure gas on a small facility.	
Carbon Capture Storage	The CCS option requires the capturing of carbon dioxide (CO_2) for compression, and potentially transportation, prior to being reinjected where it would not enter the atmosphere thereby reducing GHG emissions.	Capturing emissions from the flare is not possible because the flare produces widely variable heat and emissions and is required to be unimpeded and physically separate from process equipment. Carbon capture and storage equipment for capturing and treating exhaust emissions on the FPSO from the gas fired equipment would require a large amount of process equipment exceeding the weight and space allowance on the FPSO. Santos is actively pursuing CCS opportunities in Australia (see **Section 7.2.6.4.1**). The technology is at the conceptual phase regarding application for offshore oil and gas activities. The Dorado LPG-rich gas also has a very low percentage of naturally occurring CO_2, limiting the benefit gained by capturing and reinjecting the CO_2. In view of the complex issues which require resolution prior to CCS being a viable option for GHG emissions management for Dorado Phase 1, and the limited emissions benefit associated with the Dorado gas, this option was disregarded.	Not adopted
Flaring	Flare stacks are used to combust flammable gas released by pressure release valves (referred to as flaring).	Flaring of associated gas is considered feasible for Dorado Phase 1 as the flare system on the FPSO can be designed for maximum process upset gas rate in all cases. No additional process systems are required, and there is no increase in safety risk. This option offers low capital cost as this option utilises the existing flare which is required for safety reasons.	Adopted

5.4.5 Produced Water Management

As with all oil and gas developments, even though PW is not expected to occur in the initial years of production, following initial water production it will gradually increase over time for the remainder of field life. To minimise impacts to oil production, the facilities and well operations teams will manage production across the reservoir to minimise water production where possible. For the purposes of this alternatives assessment and the produced water impact assessment (**Section 7.2.2**) conservative PW rates (based on those expected towards end of field life) are assumed based on maximum rate possible per facility design.

Following separation from hydrocarbons during processing, PW requires disposal. The following PW disposal management alternatives were considered:

+ overboard discharge – the PW is treated to reduce its oil-in-water content to 30 mg/L oil in water (OIW) or less before being discharged overboard to the marine environment; and
+ shallow reinjection – the PW is treated and reinjected into formations such as the Depuch Formation above the Archer formation (Dorado reservoir) as the primary means of disposal. Due to operational constraints, this option may include some occasions (e.g PW injection system not available, insufficient storage capacity to hold the PW onboard the FPSO due to a non-routine event) whereby PW may have to be discharged overboard after treatment to reduce OIW content to 30 mg/L or less.

The assessment of the above options is presented in **Table 5-11.** The "overboard discharge" option was identified as the most desirable PW management option and was adopted because of the following key factors:

+ far field modelling to assess discharge of the produced water to the marine environment determined that a dilution factor of less than 1:1000 (required dilution to achieve background water quality levels) was achieved within a 1km radius of the discharge. This was assessed using the Santos risk matrix as having a negligible environmental impact as the development is not located in a sensitive marine environment, with the closest sensitive receptor being Bedout Island 72km to the south of the discharge location;
+ available produced water treatment technology means that a high standard of treatment can be achieved prior to discharge, ensuring the impact of the discharge stream is within acceptable limits (as demonstrated by far field modelling);
+ overboard discharge results in lower CO_2 emissions by avoiding the emissions associated with installing shallow reinjection wells from MODU drilling operations and drilling support vessel operations;
+ it eliminates drill cuttings discharges to the seabed from reinjection well drilling operations; and
+ overboard discharge is the preferred alternative when considering other non-environmental criteria including lower safety risk, less technically complex, less execution risk, lower reservoir management risk and lower commercial and schedule risk.

Table 5-11: PW management options assessment

Criteria	Sub-criteria	Shallow Reinjection		Overboard Discharge	
		Score	Justification	Score	Justification
Technical feasibility	Technical complexity	2	The drilling of reinjection wells introduces an additional level of complexity compared with the "overboard discharge" option. The reinjection option still requires installation of PW treatment system as "contingent", in event the reinjection system fails, and to avoid shut-in of the facility the PW will require treatment prior to discharge overboard.	4	The technical complexity of this option would be limited to the design and operation of the PW treatment system. PW treatment systems are commonplace in the industry and well understood.
	Proposal execution risk	2	The drilling operation introduces additional execution risk due to the additional time required to drill the wells and install the associated reinjection equipment.	4	As PW treatment systems are common throughout the industry and readily available, it is expected to represent a lower execution risk than the reinjection options. The PW system is installed in the shipyard during FPSO construction.
	Management of reservoir performance	3	The management of reservoir performance is not impacted by shallow reinjection.	3	The management of reservoir performance is not impacted by overboard discharge.
Average technical feasibility		**2.3**		**3.6**	
Health & Safety	Safety risk during construction	2	Drilling additional wells for reinjection increases the overall risk of the drilling activity by extending the drilling activity duration and thereby increasing exposure.	4	With no requirement for additional wells, the construction safety risk profile associated with this option is lower.
	Safety risk during operations	3	The operations safety risk profile is expected to be similar between the options.	3	The operations safety risk profile is expected to be similar between the options.

Criteria	Sub-criteria	Shallow Reinjection		Overboard Discharge	
		Score	Justification	Score	Justification
Average Health & Safety		**2.5**		**3.5**	
Environment	Physical presence and seabed footprint	3	The reinjection wells would be within the footprint of the WHP jacket (up to 16 wells), thus physical presence and footprint are not differentiators.	3	The extent of physical presence and associated seabed footprint are not expected to be differentiators.
	Number of vessel movements	2	Drilling support vessels required during reinjection drilling operations	4	No drilling support vessels required.
	Light emissions	3	The level of light emitted is not impacted by the PW management decision.	3	The level of light emitted is not impacted by the PW management decision.
	Underwater noise	3	Underwater noise is not a differentiator between the options.	3	Underwater noise is not a differentiator between the options.
	Atmospheric emissions, including GHG	2	An increase in atmospheric emissions (~ 3-4000 tCO_2e/yr) is expected due to the additional fuel that would be combusted to provide power to the compression and injection systems.	4	It is expected that the PW system will require minimal electrical or hydraulic power, if any, to be operated. This option is therefore associated with the lowest atmospheric emissions
	Planned liquid discharges	4	Primary disposal method is reinjection; however, contingency discharge of treated PW may occur. These volumes would be substantially less than the volumes involved in the "overboard discharge" option.	2	PW discharges to marine environment will result in elevated contaminants concentrations compared to background level but subject to treatment to acceptable levels (<30 mg/L OIW) prior to discharge, and will achieve dilution to background water quality levels within a 1km radius of the discharge location, avoiding impacts to any sensitive receptors beyond the 1km mixing zone. The extent of the mixing zone where these elevated concentrations are predicted

Criteria	Sub-criteria	Shallow Reinjection		Overboard Discharge	
		Score	Justification	Score	Justification
					to be observed will be managed to ALARP and acceptable levels. The potential for contaminants in the PW to interact with sediment in the Commonwealth Marine area, either directly or through deposition of precipitates or natural suspended sediment with adsorbed contaminants, is very low (**Section 7.2.2.2.2**).
	Planned solid waste generation	3	The planned solid waste generation is not impacted by the PW management decision.	3	The planned solid waste generation is not impacted by the PW management decision.
	Risk of IMS translocation	3	The risk of IMS translocation is not impacted by the PW management decision.	3	The risk of IMS translocation is not impacted by the PW management decision.
	Risk of unplanned discharges	3	The risk of unplanned discharges is associated with the discharge of off-specification PW when the reinjection system is not operational. The system used to reduce OIW to less than 30 mg/L would be similar for both options, and therefore the risk of the system malfunctioning is expected to be similar between all options.	3	While it would be online significantly more frequently with the "overboard discharge" option, the system used to reduce OIW to less than 30 mg/L would be similar for both options and therefore the risk of the system malfunctioning is expected to be similar for all options.
Average environment		**2.9**		**2.9**	
Economic	Schedule risk	2	The additional drilling duration and the associated schedule uncertainty presents a slight increase in schedule risk compared to the "overboard discharge" option.	4	As PW treatment systems are readily available and their installation common practice, the option presents a lower schedule risk than the other two options.
	Commercial risk	2	The CAPEX and OPEX associated with the reinjection options is expected to be higher	4	As this option only requires a PW treatment system, it represents the lowest commercial risk.

Criteria	Sub-criteria	Shallow Reinjection		Overboard Discharge	
		Score	Justification	Score	Justification
			due to the additional drilling cost, the cost of procuring and maintaining the necessary reinjection equipment (such as pumps, flowline, another WHP riser, and another swivel path) and the cost of designing, installing and maintaining a PW discharge system.		
Average economic		**2**		**4**	
Societal	Socio-cultural impacts	3	The socio-cultural impacts are not expected to be impacted by the PW management decision.	3	The socio-cultural impacts are not expected to be impacted by the PW management decision.
	Socio-economic impacts	3	The socio-economic impacts are not expected to be a differentiator between the options.	3	Following treatment of the PW, it is expected that the potential impact on the abundance and quality of commercially targeted fish from the discharge of PW will be undetectable. Therefore, the socio-economic impacts are not expected to be a differentiator between the options
Average societal		**3**		**3**	
Overall Score (desirability)		**12.7**		**17**	

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Against the environment criteria, with consideration for all environment sub-criteria, overboard discharge scored slightly higher compared with shallow reinjection. During the environmental impact assessment, the discharge of PW (based on OIW of 30 mg/L or less) was found to be acceptable (see **Section 7.2.2**). Through supporting studies completed by Santos (**Section 7.2.2**) it has been demonstrated that following treatment prior to discharge to 30 mg/L or less OIW, the mixing/dilution zone to reach no-effects concentrations is limited to a 1km radius, noting that the nearest significant sensitive receptor Bedout Island is 72km to the south. In addition, the shallow reinjection option has GHG and atmospheric emissions and drill cuttings discharges associated with drilling a reinjection well.

Santos will need to actively manage Dorado Phase 1 PW discharges to ensure the extent of the mixing zone (i.e. the area in which elevated concentrations of PW contaminants may be observed) in the marine environment is reduced to ALARP and acceptable levels. Further assessment during engineering and design will be undertaken to evaluate the full range of treatment technologies to reduce the potential levels of contaminants within the PW to ALARP.

Following selection of overboard discharge as the preferred alternative, considerations were directed to the height of the PW outfall from the FPSO. Three heights were considered: 10 m above mean sea level (AMSL), at mean sea level (MSL), and 10 m below mean sea level (BMSL).

Numerical modelling studies were commissioned to inform the height of the PW outfall decision process. PW discharges were modelled for each discharge configuration to predict the likely extent of the discharge plume and the dilution of PW in the marine environment. The modelled findings are based on the combined annualised results (150 simulations per case). Further detail on the modelling studies, the inputs, model, and modelling criteria is included in the modelling report provided in **Attachment 7** and summarised in **Section7.2.2** where modelling is discussed.

Figure 5-1 shows the modelled maximum spatial extents to the 1:1,000 dilution contour for each of the discharge heights. **Table 5-12** summarises the modelling results, providing the annualised maximum distance and area from the Dorado FPSO to achieve a dilution factor of 1:1,000 at the 99th percentile for each of the discharge heights. Discharging the PW at 10 m below sea surface results in the shortest maximum distance and the smallest potential area of impact.

Table 5-12: Annualised maximum distance and area from the Dorado FPSO to achieve a dilution factor of 1:1,000 at the 99th percentile for PW discharge released at 10 m above sea surface, at sea surface (0m) and 10 below sea surface.

Parameter	PW Discharge Depth		
	10 m above sea surface	At Sea Surface (0 m @ MSL)	10 m below sea surface
Maximum Distance to achieve 1:1000 dilution factor	770 m	900 m	590 m
Maximum Area to achieve 1:1000 dilution factor	0.86 km^2	1.37 km^2	0.5 km^2

Discharging the PW below sea surface resulted in enhanced mixing of the PW, resulting in the smallest area of impact compared with above surface and at surface discharge options. Discharge at or below surface also reduces overspray and corrosion risk to the FPSO. Therefore, discharge of PW below sea surface is preferred both technically and environmentally.

The selected overboard discharge option is premised on reducing PW OIW content to 30 mg/L or less before being discharged to the marine environment. To achieve this OIW content, the PW will be subject to primary and secondary phases of treatment. The FPSO design will include provision for a dedicated off-specification storage tank to segregate off-specification produced water for re-treatment if needed, to supplement the primary and secondary treatment processes. The FPSO layout also includes space for future installation of additional tertiary treatment system if required. The Dorado Operations Environment Plan will include provision for adaptive management of overboard discharge in the event that PW composition differs significantly from design assumptions, or if mixing/dilution processes deviate from modelled predictions. Examples of adaptive management may include tertiary treatment to improve treatment performance; or evaluation of alternative process chemicals to reduce potential impact of emulsions on treatment system performance. Based on the acceptability of overboard discharge and the significant safety, technical complexity, execution, reservoir management, commercial and schedule risk associated with shallow reinjection; future consideration of shallow reinjection is not proposed as part of Dorado adaptive management for produced water management.

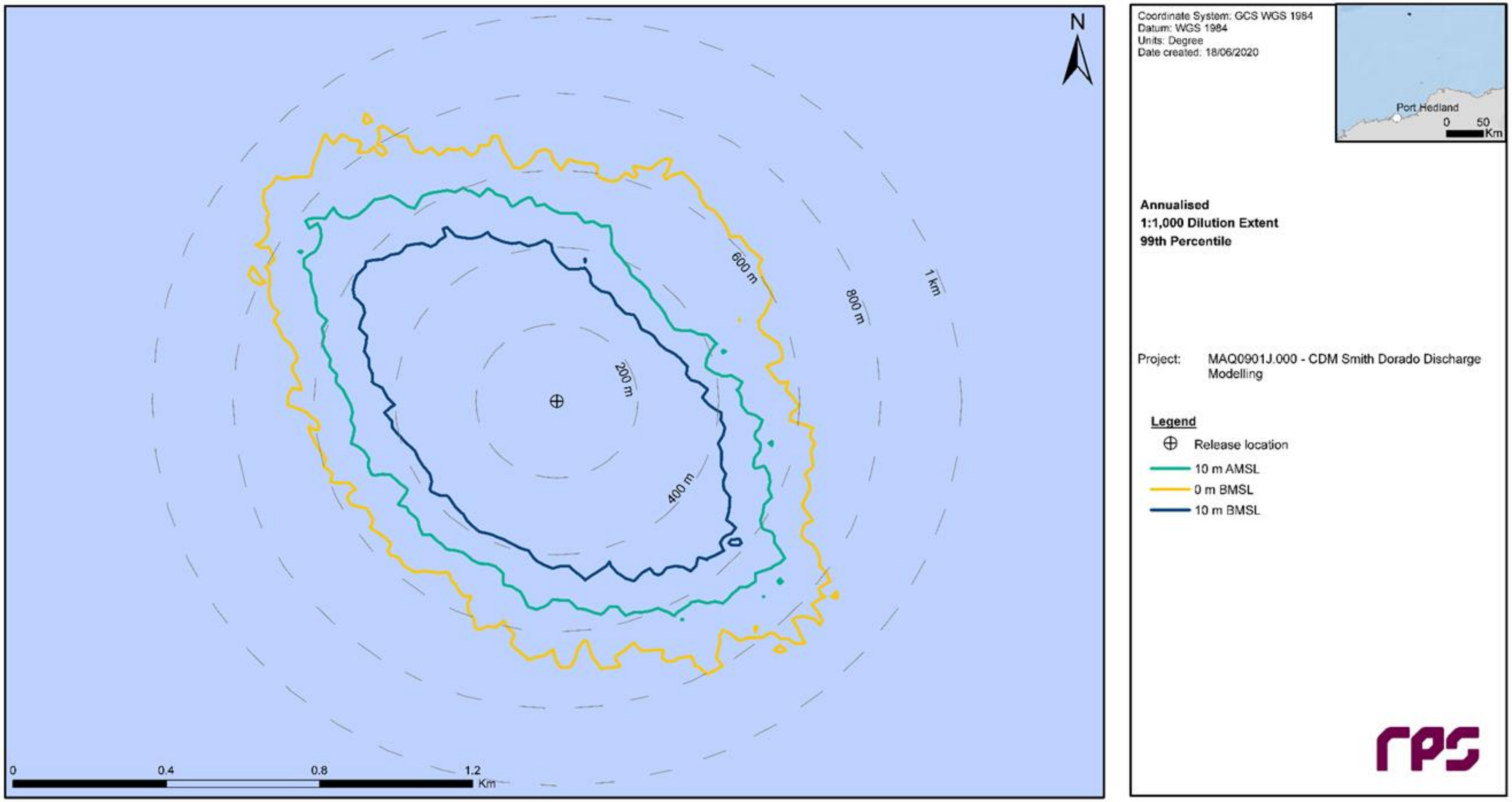

Figure 5-1: Maximum spatial extents to the 1:1,000 dilution contour for a 4,350 m^3/day PW discharge released at 10 m above sea surface (10m AMSL),at sea surface (0 m BMSL) and 10 m below sea surface (10m BMSL) for the 99th percentile analysis.

5.5 Decisions taken and remaining to be made

During this early design stage, some decisions remain for Dorado Phase 1. The decision-making process shown for the above alternatives will be used to determine outcomes in a transparent manner and to meet regulatory requirements and stakeholder expectations. Given that some design decisions are yet to be made and that environmental benefit is one of the factors Santos evaluates during options assessment, for the purpose of this OPP Santos has assessed the option that provides for the worse-case environmental outcome (i.e. conservative assessment). The resulting environmental outcomes of these decisions are presented in the Evaluation of Environmental Impacts and Risk section of this OPP (**Section 7**) including a demonstration of the acceptability of the resultant environment impacts.

Prior to execution of Dorado Phase 1, selected facility design and operating systems will be further assessed in the subsequent activity specific EPs where Santos will be required to demonstrate that the potential environmental risks and impacts from the activities of Dorado Phase 1 have been reduced to ALARP and acceptable levels.

Decisions taken during early design or remaining to be made during detailed design are presented below:

+ Produced Water treatment system – the PW treatment system as described in **Section 5.4.5** will be designed to achieve OIW concentration of 30 mg/L or less during normal operations based on primary and secondary treatment systems, supplemented by inclusion of a dedicated off-specification storage tank for re-treatment of off-specification PW. During detailed engineering and design, there will be further consideration of tertiary treatment systems to inform the ALARP assessment for the Operations EP, which will include consideration of tertiary treatment technologies such as macroporous polymer extraction (where produced water is passed through beds of macroporous polymer particles that attract oil, thus separating oil from the water phase to remove dissolve hydrocarbons). The FPSO layout includes space and weight allowance for additional tertiary treatment systems to be installed in the future if PW composition differs significantly from design assumptions, or if mixing/dilution processes deviate from modelled predictions;
+ Power generation system – the FEED design solution for the power generation system will consist of 2 by 50% and 1 by 0% (standby) gas generator turbines with waste heat recovery as described in **Section 5.4.2**. During detailed engineering and design, further design optimisations for power generation will consider alternative measures to avoid flaring or production outages to manage gas turbine generator outages and mitigate a potential shortfall of electrical power to the facility. Alternative measures could include battery energy storage system technology (BESS) or combining BESS with diesel fuel essential power generators to minimise flaring from load-shedding during outages.
+ Gas Reinjection Compressors – reinjection compressor turbines are planned to be direct drive. An alternative to direct drive compressors is electric motors. Direct drive has advantages over an electric motor driven compressor because there is less equipment required, less associated energy losses and better overall energy efficiency;
+ Further energy-efficiency considerations will also include, at a minimum:
    - Flash gas compressor design to allow for re-wheeling to avoid inefficient operation and unnecessary emissions later in the life of the facility as the flash gas compression load profile changes

  - Flash-gas compressor critical sparing philosophy to minimise compressor downtime and unplanned flaring
  - Vapour recovery unit (VRU) critical sparing philosophy to reduce potential for VRU downtime and associated unplanned flaring
  - Cooling system set-up (i.e. open, closed or once through system; requirements; size and number of variable flow fans and pumps), the use of a heat exchangers system and insulation of the facilities' systems to reduce heating and cooling requirements.
+ Treatment system for drains containing hydrocarbons – the drains' oil and water separation system is still to be finalised. At a minimum deck drainage design will segregate non-contaminated (ie. open deck runoff) from contaminated sources (ie. process system runoff), any hydrocarbon and chemical inventories will be bunded, any contaminated wastewater will be subject to treatment to 30 ppm OIW at a minimum or to a higher standard where required e.g. MARPOL requirement for bilge discharge to be treated to 15 ppm (**Section 7.2.3**).

During FEED, best available techniques or best practicable environmental options studies were undertaken to select the PW and open drains treatment systems, the power generation system, and the energy-efficiency measures to be adopted.

The aim of these studies is in keeping with the twelfth report of the Royal Commission on Environmental Pollution (1988) which defines best practicable environmental option as "*the outcome of a systematic consultative and decision-making procedure which emphasises the protection and conservation of the environment across land, air and water. The...procedure establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long-term as well as the short-term*".

During the studies, the performance of alternative options will be assessed against key objectives, reflected through a range of criteria, to identify the option that performs best overall. A multidisciplinary quantitative comparison across the following four criteria will therefore be undertaken: engineering practicability (which will consider elements such as options' development status, performance, operations and maintenance requirements, and space and weight requirements), environment (which will include elements such as discharges to the marine environment, atmospheric emissions and generated waste to land), health and safety (such as personnel risk exposure change, work limitation or restriction, and training requirements) and cost (such as CAPEX and OPEX, liability and reputation, and cost of future compliance). The outcomes of the FEED studies will be reviewed during detail design to assess, among other factors, potential technology, project and/or legislation changes.

Prior to the development of prospects within the Project Area, the following will need to be determined:

+ Tiebacks to the Dorado WHP or FPSO – arrangements for potential future tiebacks will be designed and operated to meet the environmental performance outcomes, requirements and constraints presented in this OPP; and
+ Tieback flowline installation – the flowlines associated with future tiebacks might be flexible or rigid flowlines (as presented in **Section 6.7.2.2**). This decision will influence the flowline laying method. The design and execution of the activity will be assessed against environmental acceptability criteria; will meet the environmental performance outcomes, requirements and constraints presented in this OPP; and will demonstrate in the EP that the associated environmental risks have been reduced to ALARP.

6 Description of the Development

6.1 Overview

This section of the OPP provides a description of the expected key stages and activities associated with Dorado Phase 1, as relevant to the assessment of environmental impacts and risks. It defines the nature and scale of Dorado Phase 1, which has been used to facilitate an appropriate description of the existing marine environment (**Section 3**). Understanding both the petroleum activities and the existing marine environment allows the sources of impacts and risks to be appropriately evaluated (**Section 7**).

Dorado Phase 1 includes oil production from the Dorado field and future tiebacks (currently identified as prospects in the Dorado Project Area) to augment oil production. In this phase, recovered gas will be reinjected to the Dorado reservoir to enhance oil recovery. Dorado Phase 1 will be designed for liquid handling rates of 100 KSTB/d and gas reinjection capacity of 235 MMscf/d. Dorado Phase 1, including future tiebacks, is estimated to produce a total export volume of 350 MMbbls over 20 years.

6.2 Dorado Development Project Concept

Dorado Phase 1 will develop resources identified in the Bedout Sub-basin, with initial production being light oil[13] from the Caley reservoir, the main target reservoir, and both oil and condensate[14] from the Baxter, Crespin and Milne reservoirs (which underly the Caley). Collectively, these resources are termed the Dorado field. The key characteristics of the proposed Dorado Phase 1 development are summarised in **Table 6-1**. The current development concept (Dorado Phase 1) shown in **Figure 6-1** comprises:

+ a not normally manned WHP, with provisioning for 16 Dorado field wells (oil and gas production and gas reinjection) drilled from a single drill centre that connects to the WHP (dry trees). Gas will be reinjected via the wells into the reservoir to enhance oil recovery. The WHP will be remotely powered and operated from the FPSO;
+ infield flowlines approximately 12 inches in diameter and 2.2 km in length to transport the hydrocarbons and associated production fluids, and an umbilical to provide chemicals, power and communications between the Dorado WHP and the FPSO;
+ an FPSO connected to the seabed via a DTM. The FPSO will include accommodation and processing facilities and will allow for the storage and offloading of the hydrocarbons via an offtake tanker; and
+ the future development of prospects identified in the Dorado Development Project Area (**Figure 6-2)** as tiebacks to either the Dorado WHP or the FPSO enabling ongoing operation of the facilities.

Dorado Phase 1 will produce:

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[13] Oil, also known as petroleum or crude, is a low-American Petroleum Institute (API) gravity unrefined petroleum liquid composed primarily of hydrogen and carbon.

[14] Condensate is a low-density (high-API gravity) liquid hydrocarbon. Its presence as a liquid phase depends on temperature and pressure conditions in the reservoir allowing condensation of liquid from vapour.

- stabilised light oil and condensate. All liquid products will be comingled on the FPSO and sold as a single liquid product – Dorado oil;
- associated produced gas with a high LPG content. The majority of the gas that is not used as fuel gas or for the flare pilot on the FPSO will be reinjected to enhance oil recovery; and
- PW (a combination of condensed and formation water) that will be treated and discharged overboard.

The foundation development targets the Dorado field. There is potential for future tiebacks to the WHP or the FPSO from within the Project Area (**Figure 6-2**) pending exploration success of identified prospects (**Figure 6-3**). The characteristics of these future tie-back reservoirs are expected to be similar to that of the Dorado field (i.e. yielding similar products).

The Dorado field and future tiebacks are expected to produce hydrocarbons over the operating life of 20 years. At the end of the commercial life of the field, Dorado Development infrastructure will be decommissioned in accordance with standard industry practices and relevant legislation at the time of decommissioning (refer to **Section 6.7.7**).

Table 6-1 Key characteristics of the Dorado Phase 1 development

Project Element	Number, Extent, or Range
Project Area	The Dorado Development Project Area is spatially defined in **Figure 6-4.**
Wells	A maximum total of 38 wells, being a combination of oil and gas development wells and gas reinjection wells, located within the Project Area, will be comprised of: + Up to 16 wells with dry trees on the Dorado WHP, being: - 6 x oil production; - 2 x gas production; - 2 x gas reinjection; and - Up to 6 additional wells that are a combination of production and gas reinjection wells. + Up to 22 wells will be future tie-backs located within the project area, with the breakdown of production and gas reinjection wells to be determined by the tieback reservoir characteristics.
WHPs	A maximum of three (3) not normally manned WHPs, comprising: + One gravity based not normally manned WHP located in the Dorado field, in the vicinity of the site described in Table 6-2, with 16 slots for production and gas reinjection wells. + Up to an additional two (2) not normally manned WHP's located in the project area.
FPSO facility	One (1) FPSO located at the Dorado field, in the vicinity of the site described in **Table 6-2**, moored by a DTM system used for processing and treatment of the recovered liquids for export, reservoir gas for power generation, pilot flare, and gas reinjection. FPSO connected to the WHP via flowlines (initially two hydrocarbon production and one gas reinjection), an umbilical and risers.

Project Element	Number, Extent, or Range
Future tie-backs - pipelines and subsea systems	Comprising flowlines, umbilicals and potentially manifolds depending on the tie-back concept, providing for two future tie-backs.
Dorado Phase 1 hydrocarbons	Light oil and condensate as described in **Section 6.4,** with a total volume of 350 MMbbls over 20 years.
Project life	Project life is presented in **Table 6-3,** including operation of the FPSO for a 20-year period.

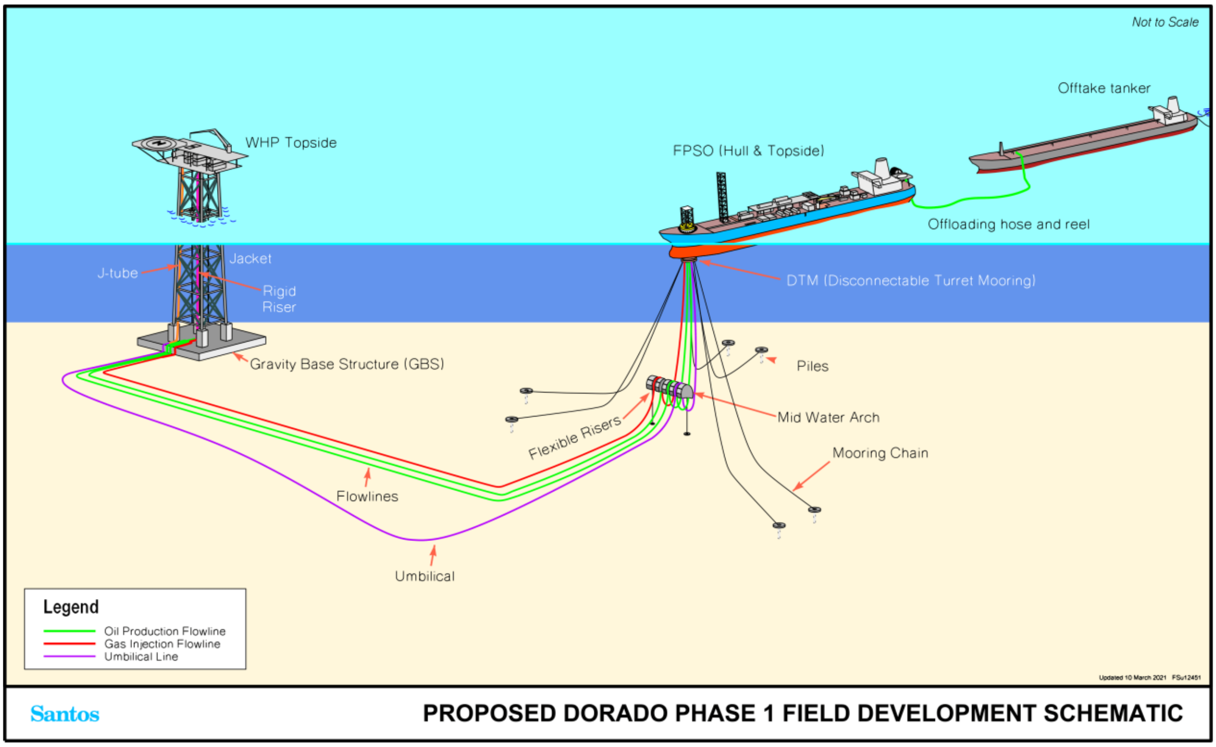


Figure 6-1: Proposed Dorado Phase 1 Development Schematic

6.3 Location

The Dorado Development is located in the offshore Bedout Sub-basin, approximately 140 km offshore of northwest Western Australia (from the centre of the Dorado WHP), in Commonwealth marine waters. The nearest regional centre of Port Hedland is approximately 145 km south of the proposed FPSO location (refer **Figure 6-2**).

The Dorado Development Project Area (as defined in **Section 6.3.1**) does not contain any emergent reefs or islands or submerged shoals or banks. The nearest reef or island to the Dorado WHP is Bedout Island, which is approximately 70 km to the southeast. The nearest shoal or bank is Rowley Shoals, which is approximately 120 km to the north of the Dorado WHP.

The proposed locations of the Dorado WHP and FPSO are presented in **Table 6-1**. The final locations are dependent on further geotechnical studies and detailed engineering.

Table 6-2: Proposed surface locations for Dorado WHP and FPSO infrastructure

Parameter	Coordinates (Datum/Projection: GDA 94 Zone 50)			
	Latitude	Longitude	Easting	Northing
Dorado WHP	19° 01' 38" S	118° 44' 37" E	683,500	7,895,250
FPSO	19° 02' 41" S	118° 44' 55" E	684,000	7,893,314

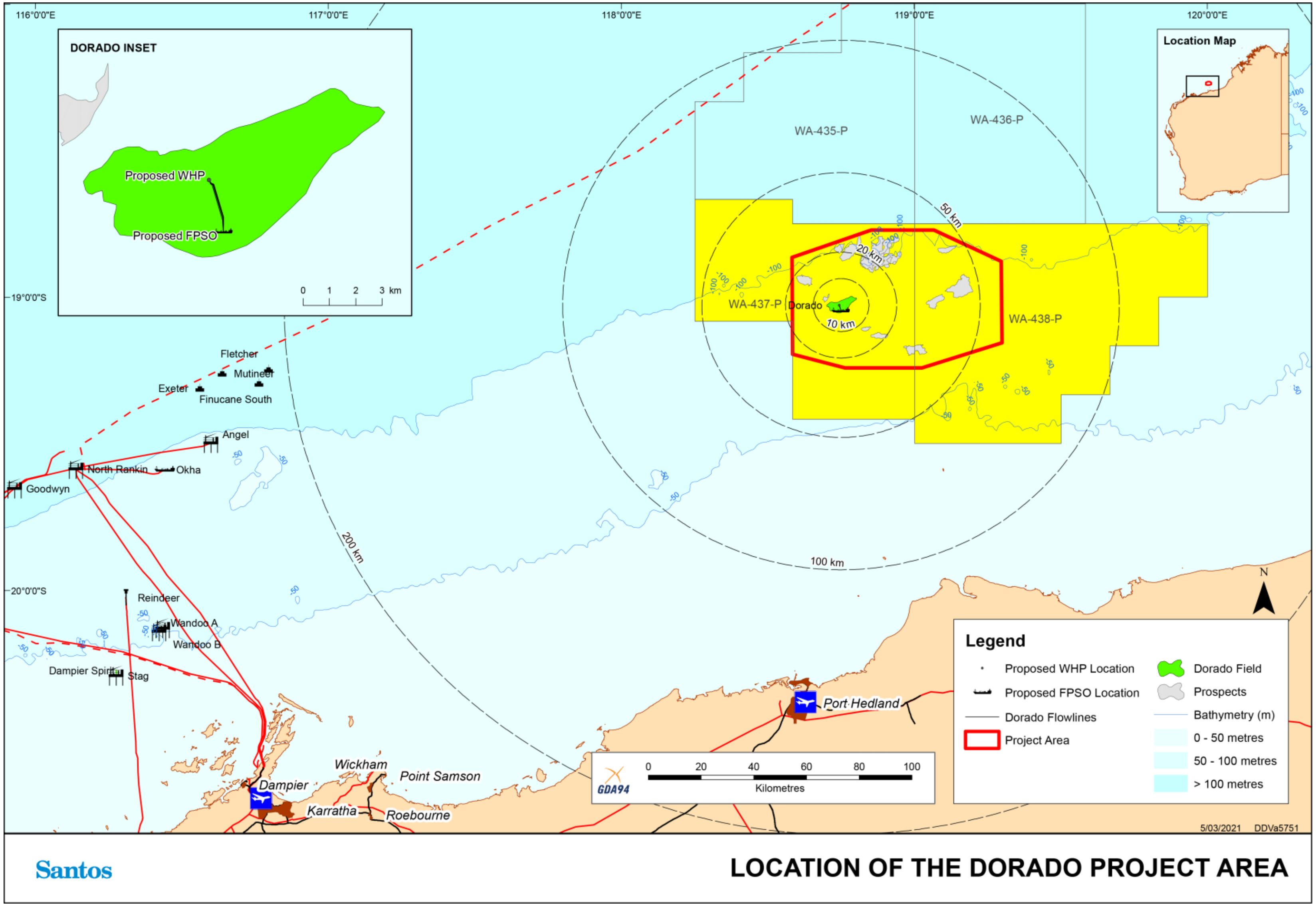


Figure 6-2: Location of the Dorado Development Project Area

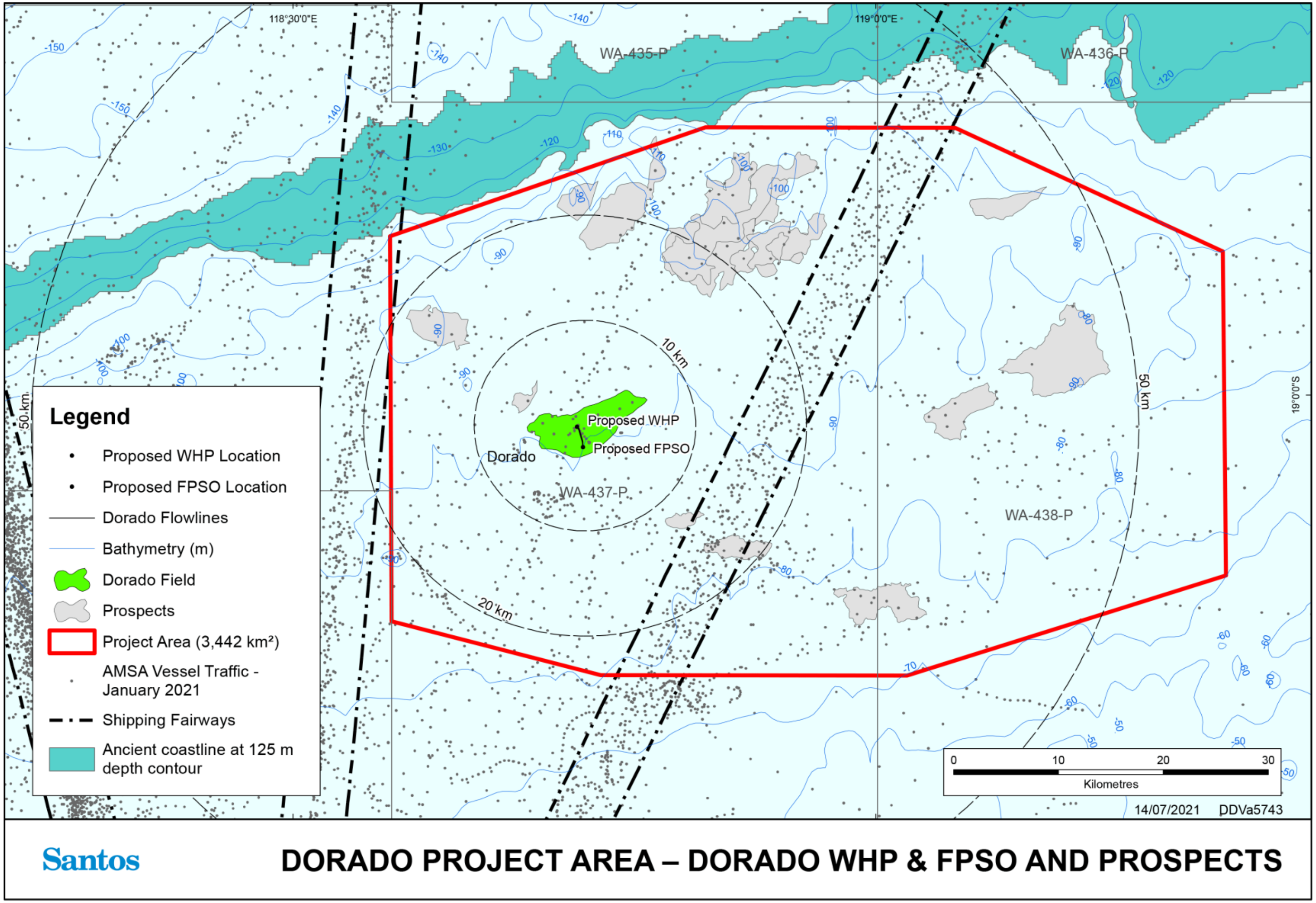


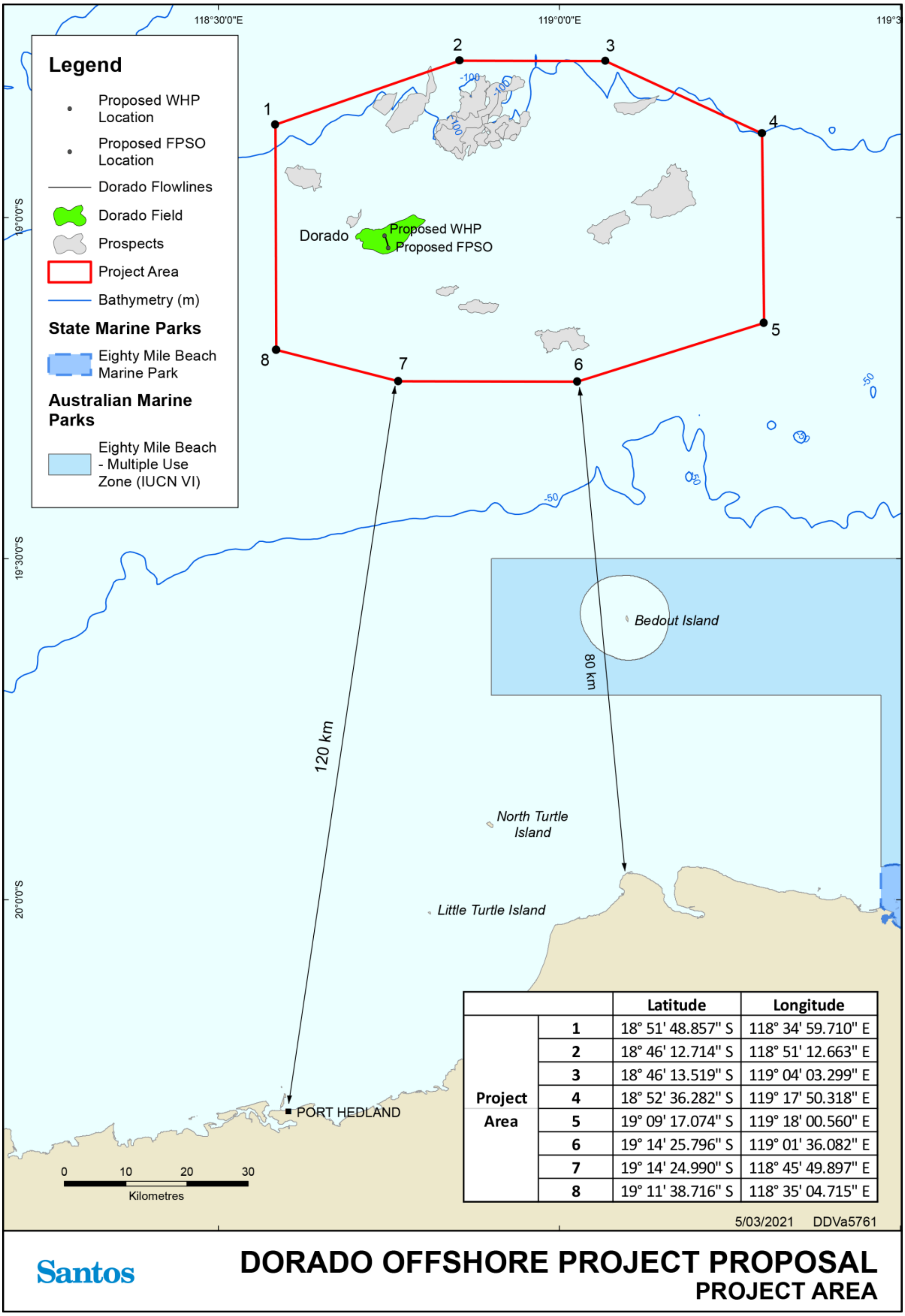
Figure 6-3: Identified prospects within the Dorado Development Project Area

6.3.1 Project Area Definition

The Dorado Development Project Area defines the geographic extent where petroleum activities are planned to take place. The extent of the Dorado Development Project Area is considered to comprise the area outlined in **Figure 6-4** and includes allowance for a staged development with the potential for future tiebacks, should future exploration and appraisal of prospects prove commercially viable. The Dorado WHP, FPSO, flowlines, and potential future tiebacks including associated infrastructure (such as wells, potential WHP or subsea infrastructure and flowlines) are all encompassed within the Project Area. The Dorado WHP location has been determined based on optimal access to the Dorado field. The current Project Area is 3,443 km². The Project Area has been designed to avoid potential overlap with any KEFs (such as ancient coastline at 125 m depth contour) and fishing sensitivities (such as pearl oyster). Each of these facilities will result in either short-term or long-term exclusion of some activities by other maritime users, such as shipping and commercial fishing, within the Project Area. This exclusion is necessary to ensure the safety of other marine users and of the vessels and facilities associated with Dorado Phase 1.

The Dorado Development Project Area also covers the operation and movement of project vessels that will be undertaking activities directly related to the development activities (such as installation vessels when installing facilities and vessels supporting drilling operations). The general transit of vessels to or from the Project Area is within the jurisdiction of AMSA, and outside the scope of this OPP. Vessel transit will be undertaken in accordance with relevant maritime legislation, such as the Commonwealth *Navigation Act 2012* and Marine Orders. Helicopter activities outside of the Project Area are not defined as petroleum activities, and therefore such activities are only considered in the OPP while occurring inside the Project Area for the purposes of Dorado Phase 1.

The operation of onshore facilities required to support the offshore development is outside the scope of this OPP. Onshore support facilities required (likely to be those already used by Santos through other projects) during construction, commissioning, operation and decommissioning will be located in existing ports and associated industrial areas, and subject to separate regulatory approvals processes specific to each jurisdiction e.g. State offshore waters, State onshore. Dorado Phase 1 is not expected to significantly increase the demand on these existing facilities/ services.



		Latitude	Longitude
Project Area	1	18° 51' 48.857" S	118° 34' 59.710" E
	2	18° 46' 12.714" S	118° 51' 12.663" E
	3	18° 46' 13.519" S	119° 04' 03.299" E
	4	18° 52' 36.282" S	119° 17' 50.318" E
	5	19° 09' 17.074" S	119° 18' 00.560" E
	6	19° 14' 25.796" S	119° 01' 36.082" E
	7	19° 14' 24.990" S	118° 45' 49.897" E
	8	19° 11' 38.716" S	118° 35' 04.715" E

Figure 6-4: Dorado Development Project Area extent (latitude and longitude)

6.4 Description of the Dorado Field and Hydrocarbon

The produced light oil and condensate from Dorado Phase 1 would have a density of 773 kg/m^3 (American Petroleum Institute (API) gravity of 51.4), a low pour point (-1.5°C), and low viscosity (1.45 cP). The produced hydrocarbons would be in a liquid form and would quickly evaporate at atmospheric conditions, with a low likelihood of forming solids.

For context, in **Figure 6-5**, the hydrocarbons produced from Dorado Phase 1 are presented against other hydrocarbons produced in the region (the greater the API gravity, the lighter the product and the more likely it will evaporate at atmospheric conditions).

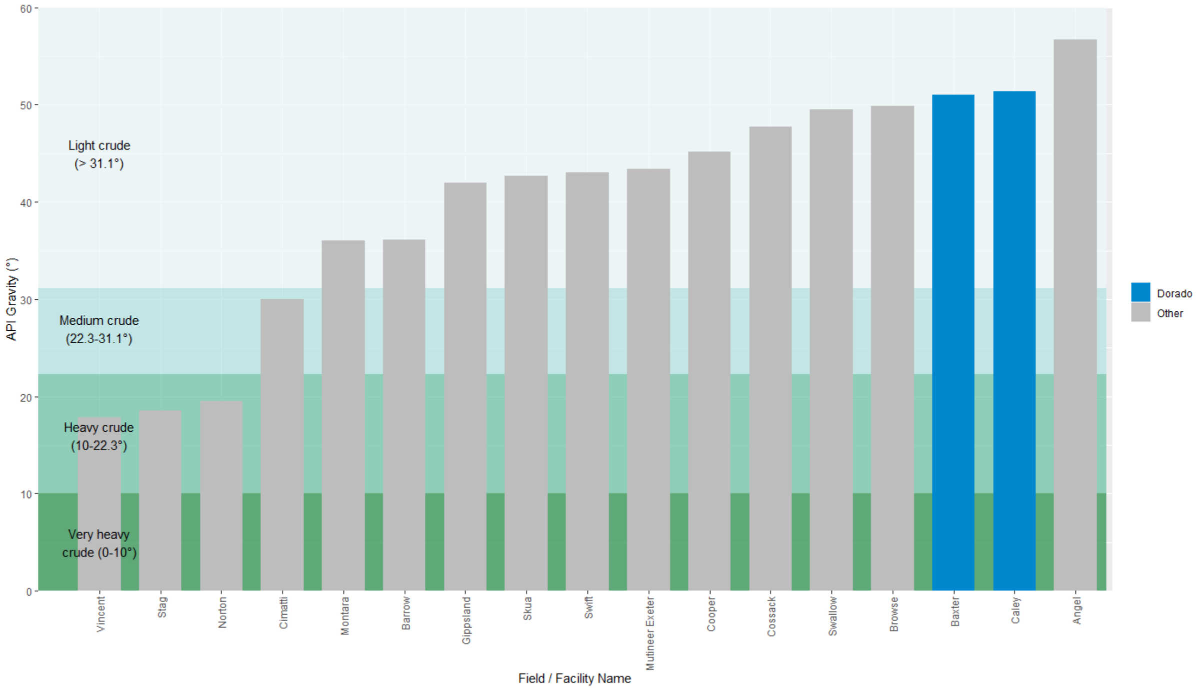


Figure 6-5: Dorado field light oil and condensate API gravity

6.5 Schedule

The indicative timeframes and development schedule of key activities are presented in **Table 6-2**.

Table 6-3: Indicative Dorado Development schedule

Activity	Approximate Commencement Timing	Approximate Duration
Dorado WHP installation and FPSO mooring installation (including piling)	Approximately 18 to 24 months post FID, 2024	3 to 6 months
Dorado field wells drilling (production and reinjection wells; up to 16 total)	Approximately 18 to 24 months post FID following Dorado WHP installation, 2024	24 months
FPSO arrival and commissioning (ready for start-up)	Approximately 4 years post-FID	3 months prior to the ready for start-up date
Production Operations commence	2027 (pending FID timing)	20 years

Activity	Approximate Commencement Timing	Approximate Duration
Future tiebacks well drilling (production and reinjection; up to 22)	Within the 20-year operating life of Dorado Phase 1	
Decommissioning	At the end of the commercial life of the Dorado Development, which would be 2047 at the earliest.	

6.6 Dorado Phase 1 Facilities Description

Dorado Phase 1, inclusive of any potential future tiebacks, will comprise:

+ Dorado WHP, positioned over the Dorado field;
+ Production and gas reinjection wells with dry trees located on the Dorado WHP;
+ Flowlines, risers and umbilicals connecting the WHO to the FPSO;
+ FPSO, approximately 2.2 km from the Dorado WHP; and
+ Potential future tieback facilities: WHP and/or subsea facilities (e.g. subsea well heads, flowlines), flowlines and umbilicals.

Figure 6-6 illustrates the concept layout for the Dorado WHP, FPSO and moorings and subsea flowlines.

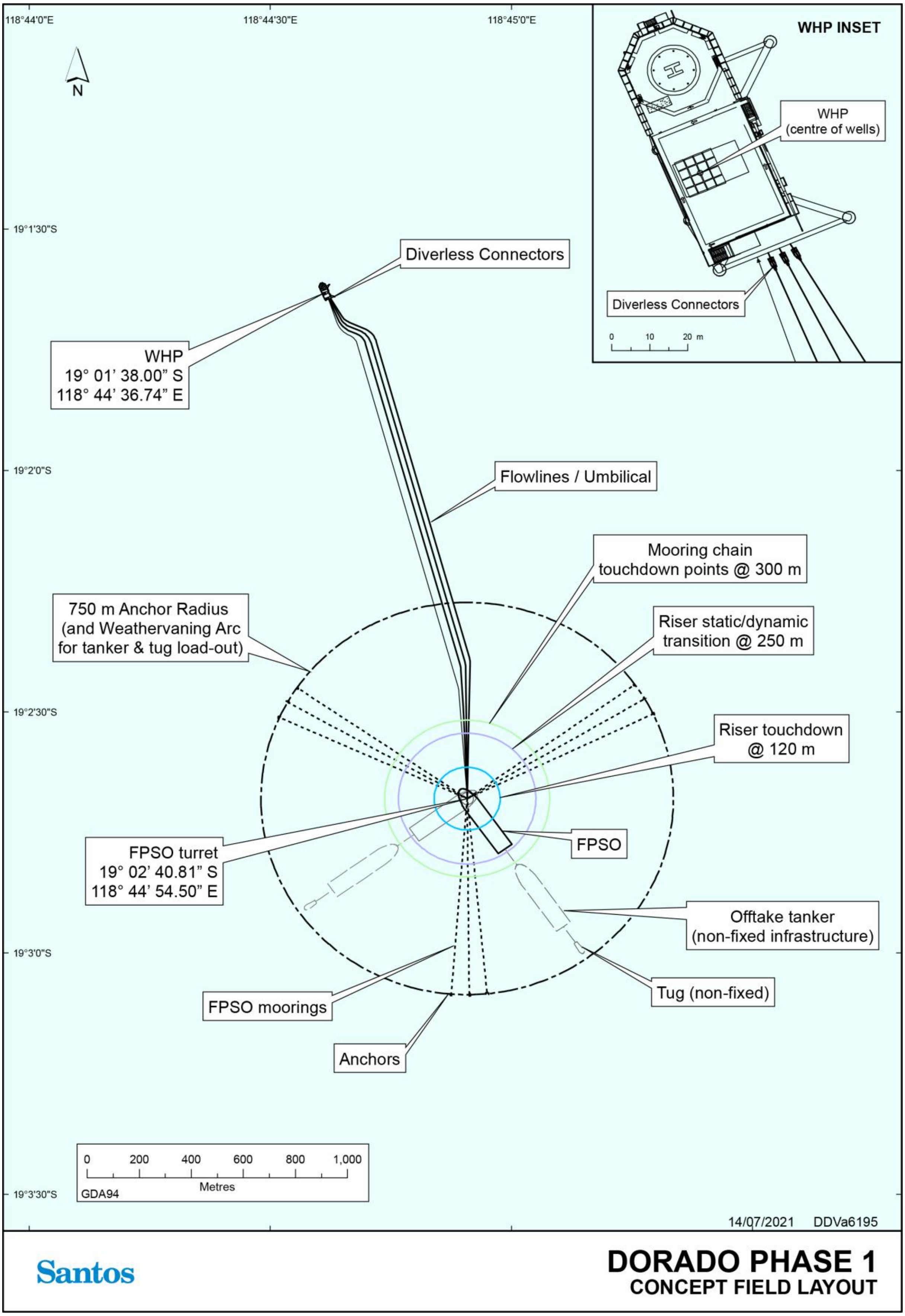


Figure 6-6: Conceptual field layout – Dorado Phase 1

6.6.1 Dorado Wellhead Platform

The Dorado WHP will be a steel substructure that will accommodate 16 slots for production and reinjection wells with associated instrumentation, gathering manifolds and metering of production fluids. There will not be any processing of production fluids on the Dorado WHP. There will be chemical injection facilities (with the chemicals either stored on the Dorado WHP or pumped from the FPSO via the umbilical) and a non-hazardous and hazardous drainage system. The collected fluids from the non-hazardous drains will be discharged overboard while the hazardous fluids will be redirected for processing and treatment on the FPSO.

Initially, 10 wells will be drilled and completed, with capacity for six future infill wells from the same drill centre. The design life for the WHP and the wells is 20 years. An illustration of the above-water section of the Dorado WHP is presented in **Figure 6-7**.

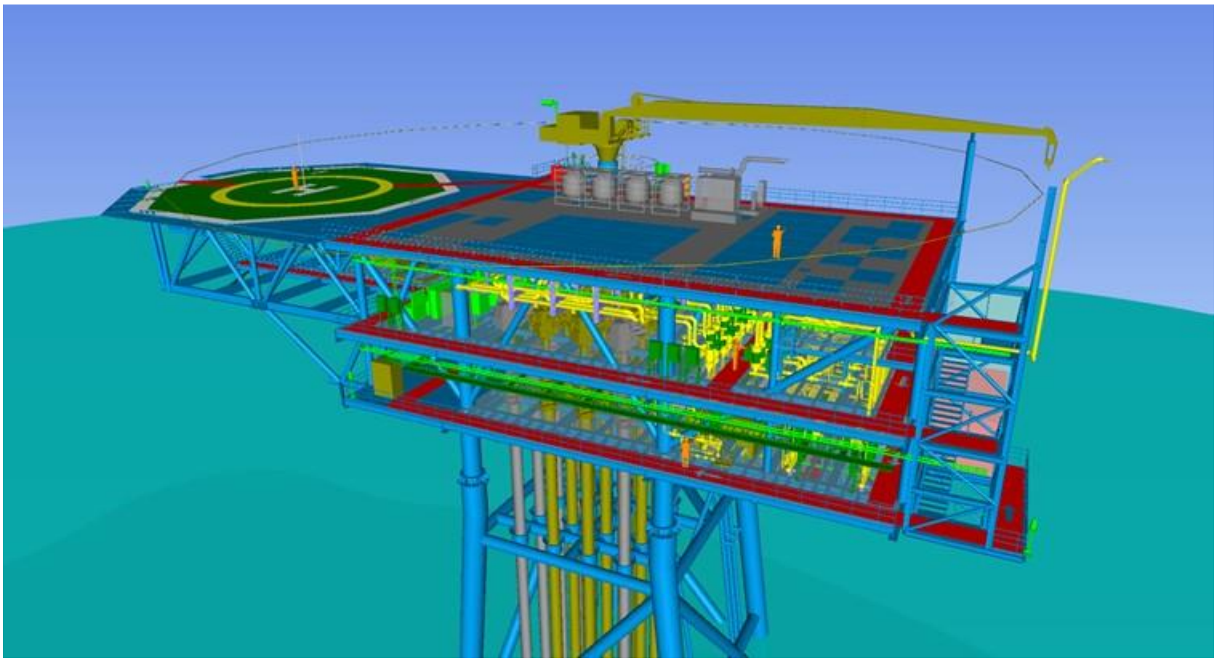


Figure 6-7: Illustration of the above-water section of the proposed Dorado WHP

The production and gas reinjection wells' dry trees will be located on the Dorado WHP topsides. The Dorado WHP topsides will include production well flow control or choke valves and production emergency shutdown valves and may also include a pig launching manifold. All piping on the WHP is fully rated to 392 barg which negates the requirement for a flare system on the WHP. During emergency shutdown events, WHP depressurisation would be to the FPSO flare via the flowlines.

The Dorado WHP (and potential WHPs for future tiebacks) will be designed to be a not normally manned platform remotely powered and operated from the FPSO, including monitoring capability. Where FPSO supplied power will be insufficient for Dorado WHP activities such as well intervention campaigns, power will be supplied through temporary diesel generators. Use of battery storage to reduce reliance on temporary diesel generators is subject to further engineering assessment. As the Dorado WHP will not normally be manned, a bird deterrent system will be required to ensure safe helideck opeations, and to prevent the build-up of seabird excreta (guano) over time which presents a workplace hazard to the workforce when attending the platform for maintenance/campaign activities.

The geotechnical conditions at the WHP location will require that the Dorado WHP be secured in position to the seabed by a steel gravity-based structure (GBS) onto which the "topsides" will be mounted.

The jacket of the Dorado WHP will include a J-tube, to house the umbilical from seabed to the topsides, and rigid risers that will transport hydrocarbons between the topsides and the flowlines on the seabed.

The Dorado WHP will be connected to the FPSO facility via flowlines and umbilical. Up to two additional WHPs may be installed for future tiebacks pending exploration success (further information presented in **Section 6.6.6**) and the design basis to extract hydrocarbons from tieback reservoirs.

6.6.2 Production Wells

The foundation Dorado Development production wells (oil and gas) will target all hydrocarbon zones within the Dorado field (Archer Formation). The initial development wells will be drilled from a single drill centre, within the Dorado WHP footprint, most likely in a single drilling campaign, using a jack-up MODU. The wells will be tied back to the Dorado WHP and completed through dry production trees. The deviated wells will be located to effectively access all hydrocarbon zones and maximise drainage across the target reservoirs.

Production wells for future tiebacks within the Dorado Development Project Area (**Figure 6-3**) would be either via subsea wells with subsea trees tied-back to the Dorado WHP through a subsea system or via a new WHP and tied back to the Dorado WHP or directly to the FPSO. These wells may be drilled with either a semi-submersible or jack-up MODU, depending on water depth.

It is proposed to drill a maximum of 38 development wells for Dorado Phase 1. Of the 16 Dorado field wells, 6 will be oil production wells, 2 will be gas production wells and 2 will be gas reinjection wells (see **Section 6.6.3**). The remaining six platform wells will be a combination of production and injection wells, with the exact breakdown dependent on Dorado field performance. Of the 22 wells associated with potential future tiebacks (refer **Section 6.6.6)** the breakdown of production and reinjection wells will be determined by tieback reservoir characteristics.

6.6.3 Reinjection Wells

The gas reinjection wells will receive treated fluids from the FPSO via one or more subsea flowlines and will reinject gas into multiple reservoir zones – Caley and underlying gas reservoirs. Gas is reinjected for the purpose of reservoir management, specifically:

+ maintaining pressure of the Caley reservoir; and
+ optimising liquids recovery by allowing condensate production from deeper gas-bearing reservoirs.

The reinjection wells will be drilled during the same drilling campaign as the production wells and will use the same techniques (i.e. the same drill centre and wells within the footprint of the Dorado WHP).

Well design will provide the required functionality to effectively manage the miscible flood, maintain reservoir pressure and optimise production. Where possible, the wells will be designed with flexibility to allow for future production of gas.

Of the 16 Dorado field wells, 2 of the initial 10 wells will be gas reinjection wells. The remaining six platform wells will be a combination of production and injection wells, with the exact breakdown dependent on Dorado field performance. Depending on the reservoir characteristics for future tiebacks, there may also be a requirement for reinjection wells for the future tiebacks (refer to **Section 6.6.6**).

6.6.4 Subsea System

For the Dorado WHP and FPSO, the subsea system will consist of flowlines (initially two hydrocarbon production flowlines and one gas reinjection flowline), risers and an umbilical between the Dorado WHP and FPSO.

Flowlines will transport production fluids from the Dorado WHP to the FPSO and will transport reinjection gas from the FPSO to the Dorado WHP.

The umbilical will transfer electrical signals, hydraulic fluids, chemicals (such as hydrate inhibitor scale, corrosion or wax inhibitor), and communication signals to the wellheads and other equipment requiring remote control from the FPSO.

The flowlines will not be trenched and may be either rigid or flexible. Pigging of in-field flowlines may be required (subject to further flow assurance studies to be undertaken during detailed design).

The subsea system layout in relation to the FPSO will allow simultaneous operations to be undertaken on the wells by a workboat or MODU and simultaneous tandem offtakes to be conducted (i.e. outside of the swing radius of the DTM system) (refer to **Figure 6-6**).

6.6.5 Floating, Production, Storage and Offloading Facility

The FPSO will receive production fluids via the flowlines from the Dorado WHP and enable the fluids to be processed and exported periodically from within the Dorado Development Project Area. The processing facilities will stabilise the light oil and condensate to meet storage and export specifications, while the gas will be recompressed and reinjected to the reservoir via the Dorado WHP. The export of the product from the FPSO is expected to occur up to once a week during the initial stages of production, before transitioning to a less frequent schedule. PW will be treated on the facility and discharged to the marine environment. An indicative illustration of the FPSO, with a support vessel and helicopters present for scale, is presented in **Figure 6-8**.

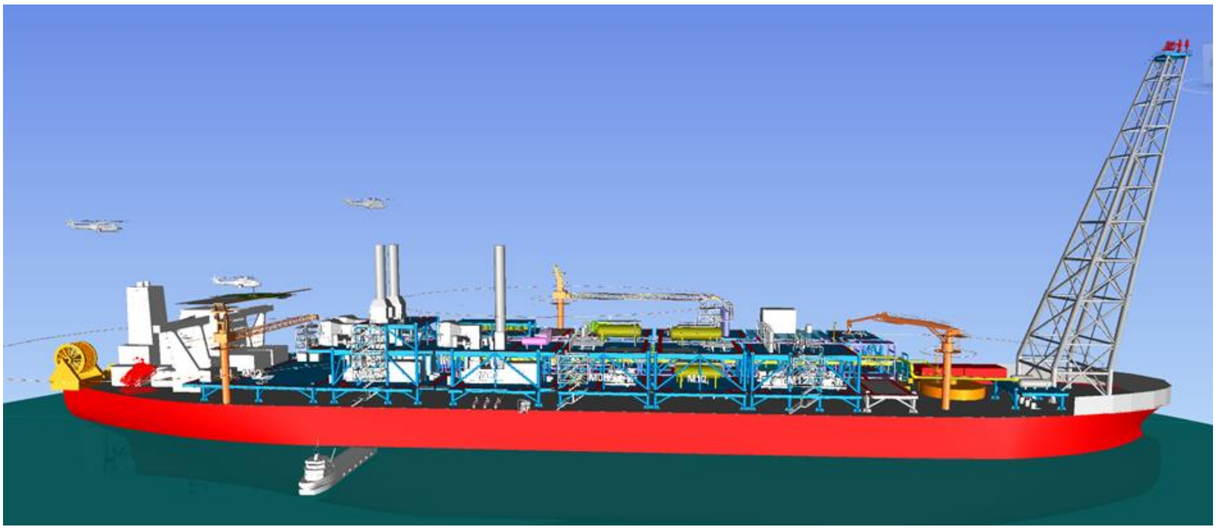


Figure 6-8: Illustration of the proposed FPSO

The FPSO will be double hulled and have a DTM system (further information presented in **Section 6.6.5.1**) to allow the FPSO to move away from the field under its own power if required (such as during adverse weather conditions and planned and unplanned maintenance requirements). The FPSO will have thrusters for positioning under offloading conditions. The FPSO will have double-sided cargo tanks providing two physical barriers between oil inventories and the marine environment.

The key design elements of the FPSO facility are likely to include:

- production fluids separation system to remove the oil and condensate from the reservoir gas, separate the light oil and condensate from the PW, and process the hydrocarbons to meet offloading export market specifications. Oil production is expected to peak at around 100,000 barrels per day (bpd), and the gas handling facilities, which include gas reinjection, at about 220 million standard cubic feet per day (MMscfd);
- gas dehydration (via a triethylene glycol system) and gas compression facilities to enable gas reinjection into the reservoir;
- flash gas compression facilities;
- vapour recovery system for control of emissions during vessel or tank venting;
- flare or blowdown facilities to maintain safe operations;
- fuel gas system for power generation and supply of electrical power;
- PW treatment (to 30 gm/L OIW concentration) and overboarding at an expected maximum rate of 4,350 m^3/day. Discharge volumes are expected to be negligible at start-up but will increase gradually over time as the reservoirs are depleted;
- storage tank suitable for receipt of PW when it does not meet discharge specification (in which case the PW will be redirected for re-treatment on the FPSO);
- cooling water systems to allow seawater to be used as a heat-exchange medium for the cooling of facilities, particularly the processing and compression facilities (up to a maximum rate of 12,879 m^3/hour);
- remote control system to manage operations of the Dorado WHP and subsea system (for example, the control of the dry production trees and subsea manifolds to enable the receipt of production fluids from the production wells in a controlled manner);
- chemical injection system to provide dosing chemicals such as hydrate inhibitor, scale, corrosion or wax inhibitors and hydraulic fluids. These chemicals ensure flow assurance and

integrity of the processing equipment can be managed and maintained. The use of scale inhibitor, demulsifier, wax suppressant and asphaltenes dispersant may be required;
+ heating medium system for any oil and condensate stabilisation requirements;
+ storage facilities for fuel and production support chemicals, such as hydrate inhibitor and scale, corrosion or wax inhibitors;
+ oil storage of up to 1 million barrels (MMbbl), with an offloading parcel size of 650,000 barrels (bbl) to an offtake tanker;
+ reeled offtake hose for connection to the offtake tanker during offloading operations;
+ potable water treatment plant to provide potable water for both process and personnel needs;
+ sewage and greywater treatment systems to manage wastes generated from domestic processes, such as toilets, dishwashing, laundry and showers;
+ drainage systems to separate deck drainage (consisting of mainly washdown water or rainwater) from areas that contain hazardous and non-hazardous materials. The non-hazardous drains will be discharged overboard. The hazardous open drains fluids will either be routed to a dedicated treatment system or be comingled with the bilge system and treated to reduce the hydrocarbon content prior to being discharged overboard. The hazardous closed drains fluids will be circulated through the processing systems for treatment;
+ bilge system to treat and remove bilge water that has collected in any watertight compartments at the base of the FPSO facility hull. The treatment will reduce the OIW content to 15 parts per million or less by volume as required by MARPOL 73/78;
+ ballast water system to manage stability of the facility;
+ the ability to use diesel as a temporary fuel when the FPSO is no longer producing (i.e. when disconnected from the DTM, when production is stopped during events such as shutdown and to operate safety-critical equipment such as fire pumps);
+ fire water and foam system;
+ sands and solids recovery (the recovered sands and solids are expected to settle in the processing equipment);
+ accommodation facilities – the FPSO will normally be manned with the standard operating crew of approximately 40 persons on board. However, the FPSO will be designed to accommodate approximately 100 persons on board during peak periods, such as campaign maintenance;
+ supply vessel; and
+ helicopter deck to enable transfer of personnel.

6.6.5.1 Disconnectable Turret Mooring System

The FPSO has a disconnectable internal turret, referred to as the disconnectable turret mooring (DTM) system, which allows the FPSO to weathervane around the mooring in response to the prevailing weather conditions. The system provides support for the riser and umbilical system and the mooring lines, as well as fluid and electrical swivels and pipework. The mooring system will have multiple legs anchored to the seabed (up to 12 piled anchors expected).

When not connected to the FPSO (i.e. when the FPSO is not on station), the DTM will be lowered into the water column to approximately 30 m BSL.

6.6.5.2 Processing and Treatment Systems

The processing and treatment systems on the FPSO may include the following:

- liquids processing system for the recovered liquids, including stabilisation, dehydration, and storage, with fuel gas blanketing and vapour recovery during normal operations and inert gas blanketing for tank entry activities;
- gas treatment system, including dehydration and compression for gas reinjection; and
- PW treatment for the reduction of hydrocarbon content prior to the PW being discharged overboard.

6.6.6 Future Tiebacks

The extended life of the facilities beyond the Dorado field is subject to future exploration and investment decisions for potential tiebacks. Santos will continue to explore for other similar commercially viable reservoirs in the Bedout Sub-basin, within the Project Area. The future tiebacks will augment oil production and export throughout the life of the Dorado facilities. As outlined in **Section 6.2**, Dorado Phase 1 includes provision for future tiebacks within the Project Area. A number of prospects have been identified by Santos for future exploration (refer to **Figure 6–3**). Following exploration success, if commercially viable, the reservoirs may be developed via tiebacks to the existing facilities to support continued production and operation.

Future tiebacks may be developed via subsea production wells or dedicated WHPs, tied back to the Dorado WHP or FPSO. Key components of future tiebacks may include:

- production and reinjection wells;
- WHP or subsea facilities, such as a subsea gathering system containing manifolds allowing the production fluids to be co-mingled and directed via flowlines to the FPSO; and
- subsea infrastructure, such as flowlines and umbilicals.

It is expected that the reservoir properties, geochemistry, temperature and pressure of the potential tiebacks will be similar to that of the Dorado field. The design of the processing equipment on the FPSO will limit the range of fluids that can be accepted and processed. Dorado Phase 1 is expected to produce 350 MMbbl of oil over the 20-year development life from the Dorado field and future tiebacks, assuming exploration success and commerciality of the tiebacks.

The reservoir properties, geochemistry and pressures of the surrounding fields that may be tied-back to the Dorado WHP and FPSO in future are expected to be comparable to the Dorado field. This includes properties related to PW and hydrocarbon characteristics (refer to **Section 7.2.2** and **Section 7.3.1** for further information). The operating range of the Dorado WHP and FPSO facilities is considered wide enough to safely produce the hydrocarbons and water expected from these surrounding potential fields. This operating range incorporates such considerations as operating pressures, compatible metallurgy and resulting PW composition.

The hydrocarbons received by the Dorado FPSO will have to meet the required specifications to be processed on the facility. For each future tieback, Santos will undertake assurance studies to assess whether the future tieback hydrocarbons can be received and processed by the Dorado WHP and FPSO. The maximum footprint for each potential future tieback (subsea infrastructure or WHP) will depend on the type of development, i.e. either a subsea development or a WHP; however, it is expected to be similar to the Dorado facilities. Additional WHPs, if required for future tiebacks, may be gravity based similar to the Dorado WHP or may have piled foundations at each of the platform peripheral legs (dependent on subsurface conditions). Depending on the final WHP design, there could be one or two piles at each leg. The WHP foundation design, whether gravity based or piled, must ensure the WHP is held in position during all weather and sea conditions. If required, the piles will be driven and/or drilled into the seabed.

The interconnecting flowlines or pipelines will have a similar width corridor to that of the foundation development, i.e. 250 m wide, and will connect back to the Dorado WHP or FPSO. As the hydrocarbons from future tiebacks will be processed on the Dorado FPSO, there will be no additional types of emissions or discharges associated with hydrocarbon processing. Produced gas will continue to be used to supply fuel gas for the FPSO power generation system and flare pilot; otherwise excess gas will be dehydrated, compressed and reinjected into the reservoir via existing reinjection wells (or additional reinjection wells if needed).

6.6.7 Climate Resilience

In alignment with the *National Climate Resilience and Adaptation Strategy 2021-2025,* Santos recognises that effective adaptation to the potential impacts of climate change must be informed by the best available science and information. Santos has considered the potential impacts of climate change as they relate to the Dorado Development design and operations and how they are most appropriately addressed through the Project design phase.

The climate change impact assessment detailed in **Table 6-4** below is informed by the Regional Projections for Western Australia (CSIRO, 2021) which considers the future impacts of climate change for the whole of Western Australia. The regional projections collate available science and literature to predict the climate and weather events out to the year 2040. Dorado Phase 1 development facilities are designed to operate for a life of 20 years through to 2046 (inclusive of potential tiebacks) therefore the timeframe for these predictions are considered broadly suitable for the life of Dorado Phase 1. The regional predictions do however represent a coarse assessment over a large geographical area, and as such should only be considered general indicators for predicted impacts specific to the Dorado Development project area.

The West Australian regional predictions indicate that ambient temperatures will increase; ocean temperatures will rise; rainfall patterns will change significantly; and extreme events, such as droughts, floods, wildfires, and cyclones will become more common. These changes are likely to impact individual species, ecosystems and ecosystem services, such as food and water availability. Within decades, environments across Australia may be substantially different (CSIRO and Bureau of Meteorology 2015).

Table 6-4 summarises the climate resilience impact assessment prepared for the Dorado Development based on regional predictions for Western Australia (CSIRO, 2021). Aspects such as future increases in ambient temperature will require ongoing application of existing Santos heat stress management procedural controls. Other potential impacts related to increase in ocean temperature, sea level rise and frequency/intensity of storm events have been adequately accounted for in the Project basis of design for the Dorado WHP and FPSO, and are considered adequate to mitigate potential future impacts from climate change to an acceptable level.

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Table 6-4: Climate resilience impact assessment for Dorado Phase 1 based on CSIRO projections for Western Australia.

Environmental Indicator	Predicted changes by 2040	Project impact	Comments
Ocean Temperature	0.5 – 1.0 C increase in average ocean temperature by 2040 Marine Heatwaves = >200-day increase. The increase in temperature, currently seen in marine heatwaves will likely extend throughout most of the year (>300 days).	+ WHP and FPSO basis of design, and design/operating temperature philosophy is sufficiently conservative to allow for up to a 1 degree Celsius in ambient ocean temperature and increase in occurrence of marine heatwaves	+ No impact to construction or Operation of the Dorado Project infrastructure. + Equipment design and selection as per engineering specifications. + The design temperature limits for all associated equipment for the Dorado WHP and FPSO were identified in the Design Temperature & Pressure Philosophy This document details the minimum and maximum temperatures under a range of potential conditions (e.g. marine heatwaves). Key elements of the Temperature philosophy include: - Normal operating temperature for equipment plus at least 25°C - Maximum operating temperature plus at least 15°C. - 80°C for equipment that can be exposed to direct solar radiation - 45°C for equipment that cannot be exposed to direct solar radiation + The FPSO basis of design includes cooling water system design parameters, indicating there is sufficient conservatism to accommodate a 1°C increase in ambient water temperature associated with marine heatwaves. + The operating temperature philosophy allows for the increased temperatures associated with increased marine temperatures and heatwave.
Ambient Temperature	Increase in Max temp by 1.4 to 2.1C by 2040	+ Existing controls for heat stress management adequate for potential impacts to workforce. + Given the offshore location of this activity, large bodies of water such as oceans, create a moderate climate with smaller temperature range, when compared to terrestrial environments. Temperature change will have negligible project	+ Santos has an existing Heat Stress Management procedure for managing work in hot environments. A number of key controls from the exposure management procedure will continue to be relevant to managing increases in max temperatures and the number of hot days, including: - Schedule work outside of the summer period - Keep non-essential people out of the field during summer - Conduct work in cooler environment - Work different shift patterns to avoid the heat of the day - Technology alternate work practices to minimise daytime work - Adjust summer work schedules to reduce workloads - Rotate workers to avoid consecutive days in the heat - Use portable cooling, cool suits, erect shade - Establish work/rest cycles with cool refuges for regular relief - Plenty of water, ice, low sugar electrolytes available

Environmental Indicator	Predicted changes by 2040	Project impact	Comments
		impact relative to existing conditions and controls, with predicted temperature changes within equipment design specifications therefore no further assessment is required.	- Light weight breathable clothing, cooling vests/neck bands - Monitor fluid intake, urine, frequency/colour, body temp + The design temperature limits for equipment for the Dorado WHP and FPSO were identified in the Design Temperature & Pressure Philosophy. This document details the minimum and maximum operating temperatures under a range of potential conditions. Key outcomes of the Temperature philosophy include: - Normal operating temperature plus at least 25°C - Maximum operating temperature plus at least 15°C. - 80°C for equipment that can be exposed to direct solar radiation - 45°C for equipment that cannot be exposed to direct solar radiation
Sea Levels	100 – 200 mm sea level rise within the life of the project.	Structural design of the FPSO and WHP anticipates significant storm surge associated with changes in sea level.	**WHP** + As per the WHP Foundation Design for Extreme and Abnormal Environment Conditions, specific requirements to mitigate against sea level rise include: - Alignment with foundation design guidance in "Petroleum and natural gas industries — Specific requirements for offshore structures (ISO 19901)" which contains an environment impact study including erosion from sea level rise and routine and maintenance activities during the life of the structure. - WHP design to account for sea level rise of up to 300 mm. **FPSO Mooring** + Fatigue analysis of the mooring system was carried out, including as a minimum the assessment of the following: - Dynamic loads due to FPSO motions during sea level rise. - Motion at the touchdown point. - Fatigue and wear at all connection points. - Fatigue of fairlead chain due to in-plane and out-of-plane bending of chain links, and tension fatigue during sea level rise. - Risk of fatigue acceleration by small pitting, preferential groove, etc. - Higher corrosion rates at water surface level
Extreme weather events	More intense, longer, unpredictable, and	+ WHP design basis is sufficiently conservative through adherence to	+ The WHP and FPSO (including moorings) structural design is engineered to accommodate extreme weather conditions, including more intense storm events and cyclone activity. Further considerations include:

Environmental Indicator	Predicted changes by 2040	Project impact	Comments
	increased frequency.	conservative design factors up to and including structural resistance to 1000yr storm events. + The FPSO is designed with a disconnectable turret mooring enabling the vessel to move away during storm events. Although there may be some impacts to production if there are more storm events over time, this has been offset by optimisations to the disconnection timeframe.	**WHP:** + Partial load and resistance factors consistent with ISO 19901 recommendations, as summarised in the table below, with the following exceptions for Ultimate Limit State conditions. These design factors ensure the structure is sufficiently robust to account for abnormal storm events: - A partial environmental load factor of 1.35 shall be adopted. - A partial permanent load factor of 1.0 shall be adopted. + The WHP design limit states for ultimate/extreme and abnormal cyclonic events will be 100 Year and 1000 Year return periods respectively, ensuring the structure is strong enough to account for even an abnormal 1 in a 1000 year storm event.

Event	Resistance	Permanent Load	Environment Load
Extreme Level Storm (100 yrp)	1.25	1.0	1.35
Abnormal Level Storm (1000 yrp)	1.0	1.0	1.0

+ The highest risk associated with extreme storm events was determined as the wave crest reaching the main deck of the WHP, which could result in significant increase in overall loads on the structure. Rather than increase the storm return period from 1 in a 1000 year storm event, the decision was taken to design the platform for the maximum omni directional loads using inputs from metocean data reports. This is conservative as it applies the maximum wind, wave and ocean current loads in a single direction, noting that the probability of this actually occurring is unlikely.
+ Additionally, the main deck level was set to include allowances for the following events to occur simultaneously:
  - Storm Surge for a 1000 year cyclonic storm
  - Sea level rise of up to 300 mm
  - Wave crest for a 1000 year cyclonic storm
  - Maximum settlement from a 1000 year cyclonic storm

Environmental Indicator	Predicted changes by 2040	Project impact	Comments
			+ The basis for the WHP design is considered sufficiently conservative by assessing the robustness of the WHP design to withstand simultaneous wind, wave and ocean current loads in a single direction, without needing to increase return periods for storm events. **FPSO:** + The FPSO will be double hulled and have a Disconnectable Turret Mooring (DTM) system to allow the FPSO to disconnect and move away from the field under its own power if required (such as during adverse weather conditions or cyclone). - The DTM has been optimised to minimise the disconnection timeframe to reduce the loss of production during disconnection. + When the FPSO is disconnected (via the DTM system), the top of the DTM Buoy sits at 30m below sea level which allows protection of the DTM system and mooring infrastructure from extreme event conditions while the FPSO is off station. A load case screening study to assess the integrity of the DTM buoy system to various Load and extreme Environment cases (100 yrp) is presented in Feed Riser Design Basis (7806-110-DBM-0002). This study considers an analysis on the integrity of the DTM Buoy in both a connected and disconnected state, confirming the DTM Buoy has been designed to ensure the structure is sufficiently robust to account for abnormal storm events.
Ocean Acidification	25-30% increase in ocean acidification.	+ Ocean acidification has the potential to accelerate corrosion. Structural design of the Dorado WHP and FPSO protects against corrosive processes, and is sufficiently conservative to accommodate increases in ocean acidification.	+ The nature of the environment surrounding the dorado project is highly susceptible to corrosion and marine growth. + All reasonable engineering solutions have been adopted to ensure impacts from corrosion is prevented, including (but not limited to): - Cathodic protection (anode design) - Selection materials (steel, insulated rubber piping for SURF) - Corrosion resistant paint (copper paint), - Impressed currents and cathodic protection + Additionally, integrity corrosion control is part of planned integrity management and IMMR activities. This is further described in Section 6.7.5. + Dorado facilities design has adopted very conservative marine growth density values, in the order of 2-3 times higher than marine growth assumptions adopted for the majority of similar oil and gas developments in the North West Shelf region. This
Ocean acidification and	Cumulative impacts of ocean acidification +	+ The combination of ocean acidification and increased marine temperatures has	

Environmental Indicator	Predicted changes by 2040	Project impact	Comments
temperature increase	temperature increase (referenced above)	potential to accelerate corrosion and marine growth. Structural design of the Dorado WHP and FPSO protects against corrosive processes, and is sufficiently conservative to accommodate the combination of increases in ocean acidification and temperature.	conservatism ensures more vulnerable structures such as the mid-water arch (MWA), the DTM buoy, riser/umbilical and mooring systems are designed to tolerate increases in marine growth densities associated with future increases in ocean temperature. It should be noted that structures such as the DTM buoy and the riser/umbilical system tend to attract a smaller amount of marine growth due to a washing effect as a result of severe weather conditions which are also expected to increase with future climate change. + Marine growth preventative measures will include specifying an anti-fouling polymer coating for the MWA to minimise marine growth accumulation. + In the event a higher marine growth density is observed during routine subsea asset integrity inspections, an in-place marine growth cleaning campaign can be undertaken during production operations.

6.7 Project Stages and Key Activities

6.7.1 Overview

As presented in **Table 6-2**, Dorado Phase 1 will be undertaken in a number of key stages, being:

+ installation of the Dorado WHP;
+ development drilling (this term is used to collectively refer to oil and gas production and gas reinjection well drilling);
+ installation of the FPSO and subsea equipment and connections between infrastructure;
+ commissioning;
+ operations and maintenance, including any future tiebacks to existing facilities within the Dorado Development Project Area; and
+ decommissioning.

The key activities within these project stages are summarised in **Table 6-5**. Future tiebacks are expected to involve components of the same key stages and activities as those of the initial development. The Dorado WHP and FPSO locations will remain unchanged for Dorado Phase 1.

Table 6-5: Project stages and key activities

Project Stage	Key Activities
Installation of the Dorado WHP & FPSO mooring piles	+ Transport and installation of Dorado WHP substructure + Transport and installation of Dorado WHP topsides + Transport, installation and piling of FPSO mooring piles
Development drilling	+ Drilling of oil and gas production and gas reinjection wells + Well testing
Installation of subsea equipment and connections between infrastructure	+ Installation of subsea system, including flowlines, risers, manifolds and umbilicals + Transport, installation and mooring of the DTM + Transport, installation and piling of FPSO mooring piles (if not completed at time of WHP installation activities)
Hook-up of FPSO	+ Sail away and connection of the FPSO to the DTM
Commissioning	+ Commissioning, testing and monitoring of systems and equipment on the Dorado WHP and FPSO topsides + Commissioning of the flowlines and umbilicals (e.g. hydrotesting and dewatering)
Operations and maintenance	+ Dorado WHP and FPSO operations + Planned maintenance and shutdown campaigns + Periodic product offtake by offloading tankers temporarily connected to the FPSO for transport to market + Well interventions campaigns + Drilling of infill wells (up to 6) at the Dorado WHP
Future tiebacks	+ Development of reservoirs (currently identified as prospects) within the Dorado Development Project Area. Key activities associated with these future developments may include: - Survey activities such as side-scan sonar, multibeam echo sounders etc

Project Stage	Key Activities
	- Drilling of additional wells (with the potential installation of subsea production trees) - Installation and commissioning of subsea flowlines or pipelines, WHP or manifolds (if subsea development) and umbilicals from the additional wells to the Dorado WHP or FPSO
Decommissioning	+ Flush flowlines between the WHP and the FPSO + Disconnect the FPSO and sail away for remote offsite decommissioning or reuse + Plug and abandon the production and gas reinjection wells + Disconnect and decommission the Dorado WHP + Decommission the subsea system

6.7.2 Installation

While the specific details of Dorado Phase 1 installation have not been finalised, as detailed design has not been completed, this section provides information based on the most likely installation method. The description of key activities and aspects are considered sufficiently representative to incorporate potential future design changes and provide a conservative estimate of the maximum extent and nature of the activities.

The Dorado WHP and FPSO will be constructed off-site. The Dorado WHP substructure and topsides will be transported to the Dorado Phase 1 location either on a barge or possibly by a heavy-lift vessel. The topsides will be a lifted installation placed onto the substructure. Installation activities will take approximately three months.

The FPSO will travel to the Dorado field on its own power. Up to 12 FPSO anchor piles may be drilled and/or driven into position (via a subsea hydraulic impact hammer). If drilled, a large-diameter pile-top reverse-circulation drilling rig or a conventional drilling rig will be used, aided by seawater and if necessary prehydrated gel sweeps. Conservatively, as the worst case, approximately 8,000 m^3 of drill cuttings may be discharged, assuming the anchor piles are all drilled. The cuttings generated during the pile drilling activities may be discharged either at seabed or above the sea surface. This piling operation is expected to last approximately 30 to 40 days. As part of each anchor pile, up to 200 m of chain and wire may lay on the seabed until connected to the DTM mooring lines. Support vessels and derrick barges will be required to support the FPSO mooring installation.

6.7.2.1 Dorado Wellhead Platform

The Dorado WHP will be installed in two phases: first the gravity-base substructure, then the topsides. The Dorado WHP gravity-base substructure will be transported, positioned and installed by an installation spread (potentially including heavy lift and support vessels). It will be ballasted and directed into position on the seabed. Once lowered onto the seabed, grout will be injected between the base and the seabed to fill any voids under the mudmat foundation of the gravity-base substructure. Once the substructure is in place, the Dorado WHP topsides will be lifted and secured on top of the substructure by a derrick barge (i.e. the topsides will be raised above the substructure and lowered into position).

6.7.2.2 Subsea System

Three 8 to 12-inch diameter and 2.2km long flexible or rigid flowlines will be installed between the Dorado WHP rigid riser and the FPSO flexibles risers.

For either flowline type, the flowlines will be connected to the Dorado WHP subsea connectors and the FPSO flexibles risers. The Dorado WHP subsea connectors will provide the connection between the WHP rigid riser's stress joint and the flowlines. The flowlines (for the flexible option) and umbilical will be laid on the seabed from reels located on the installation vessel. It is expected that multiple umbilical and flowline reels will be required during the laying operations, and therefore transfer of umbilical reels from a support or heavy-lift vessel to the pipelaying vessel will be required. For rigid flowlines, lengths of steel pipe (joints) will be continuously welded, inspected and coated (with anti-corrosion and concrete coating) in a horizontal working plane (called a firing line) on board the pipelay vessel. As the pipelay vessel moves forward along the flowline route, the pipe gradually exits the firing line, curving downward through the water until it reaches the seabed. For both laying methods, an anchor point (which could be a temporary pile or a deadman anchor) from which to initiate the laying of the flowlines may be required.

The flowlines will be connected to the Dorado WHP via the rigid riser and to the FPSO via the DTM through the flexible risers. Similarly, the umbilical will be connected to the Dorado WHP via the J-tube and to the FPSO via the DTM. To support the flexible risers and umbilical, a mid-water arch will be installed to secure the risers and umbilical to the seabed near the FPSO. During the connection of the Dorado WHP J-tube and the rigid risers, it is anticipated that preservation chemicals (such as biocide and corrosion inhibitor) dosed into the J-tube and the rigid risers will be discharged to the marine environment. Anchoring (aside from flowline initiations) is not expected with either pipelaying method. It is expected that it would take between 20 and 30 days to lay the flowlines and umbilical.

While the flowlines will not be trenched, some secondary stabilisation may be required at discrete locations to ensure their stability and long-term integrity. It is expected that either gravel, grout bags, or concrete mattresses will be used for this purpose.

Following completion of the flowline laying activities, a leak test will be performed. The leak test will involve pressuring up the subsea system, using either treated seawater (likely dosed with biocide, corrosion inhibitor, and a dye) or freshwater, and monitoring the pressure to ensure it is maintained for up to a 24-hour period to verify there are no leaks. Upon completion of the test, depending on flowline integrity requirements and the expected ecotoxicity of the fluids, the treated seawater or freshwater will be either left in the flowlines for treatment and disposal on the FPSO during commissioning (treated seawater) or discharged overboard (fresh water). It has been estimated that up to 2,500 m^3 of treated seawater or freshwater could be discharged.

6.7.2.3 Floating Production, Storage and Offloading Facility

Similar to the Dorado WHP, the FPSO will be installed in two stages: first the DTM, then the FPSO. The DTM will either be transported directly to the site via a barge or heavy-lift vessel or transported to a Western Australian port before being towed to site depending on the installation methodology determined during detailed engineering and/ or availability of vessels. Prior to the DTM arriving on site, some or all of the anchor piles may be pre-laid using support vessels. Pre-laid anchors will be connected to the DTM mooring lines on arrival. The tension of the mooring lines will then be adjusted to place the DTM in the required position.

Following the completion of development drilling, the self-propelled FPSO (sails down from shipyard as a vessel) will then be connected to the DTM. As outlined in **Section 6.6.5.1**, the DTM will be lowered into the water column (to approximately 30 m BSL) when not connected to the FPSO.

6.7.3 Development Drilling

A jack-up MODU is proposed to be used for undertaking drilling of the Dorado reservoir, accessing and constructing wells over and through the Dorado WHP.

Future wells (i.e. future tiebacks) could be drilled with either a jack-up MODU or from a semi-submersible MODU dependent on the water depths: jack-up MODUs are typically used in water depths of less than 100 m, while semi-submersible MODUs are used in deeper water. The Project Area water depths range from approximately 70 m to 120 m water depth.

The jack-up MODU will be in direct contact with the seabed, while the semi-submersible MODU will hold station via a temporary mooring system with anchors. Anchor handling vessels will assist with semi-submersible MODU anchoring by deploying an expected eight to 12 anchors laid out approximately 3 km from the MODU (depending on water depth). Prior to a semi-submersible MODU arriving, some or all of the anchors may be pre-laid using support vessels. Pre-laid anchors will be connected to the MODU's existing mooring lines on arrival at the site. Anchors will be retrieved upon completion of the activity, and pre-laid anchors may be retrieved after the MODU has departed.

The future tieback wells are expected to yield similar drilling discharges as the foundation development wells, given that the prospects are targeting the Archer Formation.

For Dorado Phase 1, three broad well types will be drilled:

+ oil producers;
+ gas or condensate producers; and
+ gas injectors.

The Dorado field wells will be drilled from a single drill centre that lies within the footprint of the Dorado WHP jacket footprint. It is expected that initial drilling activities will be continuous over approximately two-year period and that it will take about 60 to 70 days to complete each development well (includes drilling, well construction, well testing and clean-up activities). Future tieback wells may have a central drill centre or may be spread further apart depending on the reservoir characteristics.

All the development wells will be drilled in sections that will decrease in diameter at increasing depths until the target reservoir is reached. Protective steel casing will be inserted into the wells and cemented in place to isolate each section from the subsequent sections and provide structural support and stability to the well. In the process of drilling, drilling muds (drilling fluids) will be used to lubricate and cool the drill bit, maintain well bore stability, and remove drill cuttings (i.e. rock fragments) from the well sections as they are drilled. It is envisaged that water-based muds (WBMs) will be appropriate to drill and complete the wells and that up 8,000 m^3 of WBMs per well will be discharged to the marine environment.

Non-aqueous fluid (NAF) or synthetic-based mud (SBM) were assessed to provide little to no benefit to drilling for the lower sections. Nevertheless, they have been included as contingency should unexpected conditions (for example, increased lubrication or heat resistance needed) be encountered during the drilling operations. It is estimated that up to 100 m^3 of NAF/SBM could be discharged to the marine environment per well. **Table 6-6** presents the types of drilling fluids and their typical components proposed to be used for the different well sections.

Table 6-6: Drilling fluid types and typical components

Well Section Diameter (inches)	Drilling Fluid Type and Typical Main Components
36	WBM – seawater and prehydrated gel sweeps (i.e. seawater to which high-viscosity prehydrated bentonite has been added).
26	
17-½	WBM – drilling fluids in which seawater is the major component of the liquid phase and to which bentonite clay, barite, brine and/or gellants (such as guar gum or xanthum gum) have been added
12-¼	
8-½	
Contingency (for the 17-½ to the 8-½ sections)	NAF/SBM – drilling fluids in which synthetic oil is the base fluid with bentonite clay, barite, fluid-loss control agents, lime, aqueous chloride, bridging agents and emulsifiers added

Drilling fluids and cuttings will be discharged at the seabed during drilling of the tophole (36-inch) sections as a riser connecting the MODU to the wellhead will not yet be installed. The drilling fluids and cuttings from deeper well sections will be circulated to the MODU and discharged overboard. If required, cuttings from the sections drilled with NAF/SBM will be passed through a treatment system onboard the MODU prior to discharge overboard to reduce the volume of NAF/SBM coating the cuttings. Residual NAF/SBM base fluid on cuttings content will be reduce to ALARP levels prior to discharge overboard. It is expected that approximately 1,000 m^3 of drill cuttings per well will be discharged.

A blowout preventer (a valve assemblage or mechanical device used to seal, control and monitor wells) will be installed prior to drilling the lower well sections for well control purposes during drilling. The blowout preventer is removed once drilling is complete. Function and pressure tests of the blowout preventer will be conducted regularly throughout drilling to ensure the system reliability is maintained.

Following completion (drilled, cased and cemented) of each well, well testing and clean-up will be undertaken to ascertain the pressure, flow and composition of the reservoir products. Base oil (NAF) may be used for well integrity testing and to provide underbalance during the completion phase; this fluid will be captured and separated on board the MODU for re-use, or safely flared during well clean-up. All production and reservoir parameters will be recorded. Well clean-up will remove debris, such as drill cuttings not circulated to the MODU with the drilling mud, and residual drilling muds from the well. Well testing involves the production of reservoir fluids back to the MODU via a temporary processing and handling facility installed on the MODU. The resulting hydrocarbons (oil and/or gas) will be flared (combusted) using burners to alleviate the need to store produced hydrocarbons on board the MODU or support vessels, and PW (mainly residual WBM fluids) will be discharged overboard following treatment. For the purpose of this OPP, it has been conservatively assumed that flaring will happen periodically throughout the drilling campaign for each well clean up at completion, typically 1-2 days flaring per well. Once the wells are completed, they will be secured at the tree (barriers tested and verified) and handed over to operations.

It is expected that two permanent support vessels (usually offshore multiple-purpose or anchor-handling vessels) will be required to assist the MODU for the duration of the drilling activities, with a third vessel required on an ad hoc basis for approximately six months. The support vessels will assist with towing operations (where even a fourth vessel might be required), equipment and material transfers, standby operations and emergency response. Anchoring of these vessels in the Dorado Development Project Area is not planned.

Equipment and material transfers will be required and may include, but are not limited to, crew supplies, hydrocarbons (diesel, engine oil, hydraulic fluids, grease, etc.), bulk drilling products, MODU drilling equipment and parts, and waste. Bulk products will be transferred via hose from the support vessels and the MODU. Bulk products include drilling fluids and solids, brine, drilling water, cement and fuel oil (diesel).

6.7.3.1 Drilling Vertical Seismic Profiling

Drilling vertical seismic profiling may be acquired during well installation operations. This involves measurements using geophones, placed inside the vertical wellbore, and a surface seismic source, commonly a small air gun array. During drilling vertical seismic profiling operations, the airgun array is discharged approximately for a few seconds at intervals, which generates sound pulses that reflect through the seabed and are recorded by the geophones to generate a profile of the wellbore. This process is repeated as required at different depths in the wellbore and may take up to 24 hours (per well) to complete, depending on the wellbore's depth and the number of profiles required.

6.7.4 Commissioning

Precommissioning activities for the Dorado WHP and FPSO will occur at the onshore construction yard and are therefore excluded from the scope of the OPP.

Commissioning activities (i.e. preparing and bringing hydrocarbons onto the facilities) of the subsea system, the Dorado WHP, and the FPSO will occur within the Dorado Development Project Area. The commissioning of these system or facilities is concurrent but for ease of presentation, they have been split into subsea system commissioning and Dorado WHP and FPSO commissioning.

The key steps in the Dorado WHP and FPSO commissioning process are expected to include:

+ FPSO processing equipment commissioning, including:
  - stabilisation; and
  - gas compression and gas dehydration.
+ once the dry production trees and tie-in spools are installed, they will be tested on the Dorado WHP prior to introducing hydrocarbons. The fluids used during these tests will be either captured (i.e. not discharged to the marine environment) or sent to the FPSO for disposal via the processing systems;
+ leak testing of the swivel, flowlines, and umbilical;
+ commissioning and testing of the DTM to FPSO connection/disconnection system; and
+ testing the cause and effect system for emergency shutdowns.

Leak testing activities will be similar to the testing activities undertaken during the installation stage of the subsea system where treated seawater (likely dosed with biocide, corrosion inhibitor, and a dye) or freshwater will be pressurised. The ability of swivel, flowlines and umbilical to maintain pressure will be monitored. Upon completion of the test, test fluids, depending on their expected ecotoxicity, will either be recovered or treated and disposed of on the FPSO or discharged overboard. It has been estimated that up to approximately 2,500 m^3 could be discharged.

It is also possible that leak testing will be undertaken with nitrogen, in which case the nitrogen will be vented (inert gas) upon testing completion. Similarly, nitrogen will be vented upon completion of gas compression and gas dehydration commissioning.

Prior to introducing reservoir hydrocarbons, the flowlines will be dried by flushing with hydrate inhibitor and/or diesel. If diesel is used it will be recovered on the FPSO for future use or disposed of onshore. Depending on the quality of the recovered hydrate inhibitor, it will be collected for reuse or disposed overboard.

The initial steps in the field start-up are expected to include:

+ initial start-up and performance testing of each well (the wells will be started up sequentially on a predetermined schedule); and
+ interwell reservoir connectivity testing.

During these activities, the produced gas will be flared, but production rates will be within the safe gas flaring limit. Note that flaring will be intermittent throughout the duration of commissioning.

The following activities will then be undertaken:

+ production ramp-up to nameplate capacity; and
+ gas tracers injection for the reinjection system (once steady-state production has been achieved).

The above activities are expected to last approximately 40 to 60 days.

Throughout the commissioning activities, heightened flaring is expected due to testing and ramping-up of the processing equipment, as well as emergency shutdown testing. It is also expected that preservation fluids, which will have been injected into the Dorado WHP and FPSO systems during onshore precommissioning, will be, depending on the expected ecotoxicity of the fluids, treated before discharge overboard or directly discharged overboard. Preservation fluids might include treated seawater, corrosion inhibitors, oxygen scavengers, biocide, hydrate inhibitor, and fluorescein dye. These fluids are essential to maintaining systems integrity by preventing metal corrosion, bacterial growth, and accumulation of scale on internal surfaces.

Commissioning activities could also take place concurrently with operations and maintenance activities, especially for future tiebacks. It is expected that, to prepare for and during the commissioning of the tieback, the following activities will be undertaken:

+ ROV operations on subsea infrastructure;
+ flushing and priming activities on subsea infrastructure;
+ cleaning subsea infrastructure;
+ pressure testing; and
+ dewatering and start-up.

6.7.5 Operations and Maintenance

Once a steady flow of production fluids has been established along with the stabilisation of the Dorado WHP and FPSO processing systems, Dorado Phase 1 will be regarded as entering the operations and maintenance stages. The following operational and maintenance activities are anticipated to occur throughout the life of the facility:

- extraction of production fluids;
- processing of the production fluids;
- reinjection of reservoir gas;
- storage and offtake of the light oil and condensate;
- planned maintenance and shutdown campaigns;
- ongoing planned integrity testing to ensure operations are safe at all times;
- well intervention and well testing; and
- well suspension and/or abandonment.

Once production fluids have been extracted from the reservoirs, they will be sent from the Dorado WHP to the FPSO where they will be processed. The main aim of the processing system is to separate the light oil and condensate from the reservoirs' gas and the PW. Once separated, the light oil and condensate will be stored on the FPSO for offloading. A fraction of the reservoirs' gas will be used to keep the pilot flare ignited and as fuel gas for facilities power generation. The remaining gas will be dehydrated prior to being compressed and reinjected into the reservoirs. The PW will be treated (i.e. hydrocarbons removed) and discharged overboard. The entire extraction, processing, offtake, and reinjection activities will be monitored and managed from the FPSO.

The frequency of the offtake operations will depend on the production rates, but it is expected to occur approximately weekly initially. The maximum offloading parcel size is 650,000 bbl, which is expected to take around 48 hours to offtake (excluding mooring and disconnection time of the offtake tanker). It is too early at this stage to know which tankers will be used, but it has been assumed (conservatively) that they will be fuelled with heavy fuel oil (HFO).

Topside and subsea IMMR activities are expected to be undertaken using dedicated crew, ROVs, autonomous underwater vehicles or diving contractors. IMMR activities will include:

- general inspections;
- topside cleaning of facilities;
- integrity corrosion control;
- facilities and subsea infrastructure installation, cleaning, repair and modifications;
- flowlines and seafloor imaging surveys;
- marine growth removal;
- installation of replacement equipment or parts;
- installation of subsea structures' additional secondary stabilisation;
- flowlines stabilisation; and
- rigless well servicing or intervention.

It is expected that planned maintenance campaigns, for minor work when the facilities are still producing, will take place regularly on the FPSO (through an estimated six-week cycle) and WHP (under an estimated 12-week cycle). During maintenance activities on the Dorado WHP, it might be necessary to mobilise on the facility a dedicated temporary generator. Both the WHP and FPSO may be shut down annually simultaneously (approximately for two weeks) to undertake annual maintenance.

As part of the IMMR, it is also anticipated that the FPSO external hull in-field inspection will be undertaken as per Class requirements (verification of the structural strength and integrity of essential parts of the FPSO's hull and its appendages, the reliability and function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the FPSO in order to maintain essential services on board) with ROV or any other suitable Class-approved automated systems. Similarly, to meet Class requirements, the vessel mooring system will be inspected and maintained via ROV or any other suitable Class-approved automated systems. Additionally, unmanned aerial vehicles may be used to survey and inspect the submerged exterior of the FPSO and Dorado WHP. Unmanned aerial vehicles may also be used to conduct aerial surveys within the Dorado Development Project Area.

Throughout the operations and maintenance stages, it might be necessary to undertake well interventions or workovers. Well interventions may be required to service a well and undertake chemical treatments (such as lubricating bleed, topping up annulus fluids, applying corrosion and/or scale treatment), to improve production (by installing bridge plugs to isolate water zones and perforating new zones in the well), or to monitor bottom-hole pressure and determine hydrocarbons and water content. Interventions could also occur when tools, fluids, and/or equipment are deployed in pressurised or dead completed wells. Interventions may also be required to temporarily suspend or plug a well or to suspend a well in preparation for re-entry and drilling of a side-track, or for permanent abandonment. This will involve the placing of cement plugs in the casing of the well at various intervals and flooding the casing with fluids containing corrosion inhibitor and/or biocide. Well workovers may be carried out when major maintenance or remedial treatments are required.

To support the operations and maintenance activities within the Project Area, support vessels will be used. Such vessels will typically undertake:

- transportation of materials, fuel (marine diesel oil (MDO) for refuelling of the FPSO) and chemicals;
- backload of equipment, waste, and materials;
- support offtake operations; and
- support FPSO DTM reconnection activities.

It is expected that a support vessel will be present at the FPSO/WHP Petroleum Safety Zone (PSZ) approximately 75% of the time. IMMR activities may require project-specific vessels, which will be chosen specifically for the technical requirements of the project.

Helicopters will also be used for crew changes. During operations, it is expected that, on average, three round trips a week will be required (depending on operational requirements). Support vessels and helicopters will also be used to transfer personnel from the FPSO and/or shore to the Dorado WHP.

6.7.5.1 3-D Vertical Seismic Profiling

During production, there is potential for additional vertical seismic profiling acquisition over the Dorado field (and within the Project Area) and future developed reservoirs. This would be to assess reservoir properties and subterranean oil movement to optimise oil recovery.

To facilitate vertical seismic profiling, fibre optics (which act as seismic receivers) would be installed in the development wells during well construction. The VSP acquisition survey would involve a source vessel and a seismic source that sails a planned circular course covering approximately 100 km^2 over the Dorado field. Note the vessel does not tow streamers as the fibre optics in the well act as the seismic receivers.

A baseline three-dimensional (3-D) vertical seismic profiling survey would be undertaken ahead of field start-up, with periodic vertical seismic profiling surveys acquired approximately every two to three years during field production, if the technology proves successful. The approximate duration of each survey would be approximately 25 days. Assessment to understand the feasibility and logistics of acquiring fibre optic vertical seismic profiling surveys over the Dorado field is ongoing.

6.7.6 Future Tiebacks

The future tiebacks may either be developed subsea or via a WHP.

Future tiebacks may require surveys to be undertaken to assess the suitability of the seabed for infrastructure or surveys may be needed along the length of proposed flowlines routes. These geotechnical surveys may include techniques that involve using high-frequency sonar to provide high-resolution bathymetry and geophysical data, such as side-scan sonar, sub bottom profiler or multibeam echo sounder. Sonar generates high-frequency acoustic emissions that attenuate rapidly in the underwater environment. These geophysical surveys would be expected to take up to seven days to complete, depending on the length of the flowline route.

Any additional WHP (if required) may be fixed to the seabed either by piles or by a gravity base, dependent on the nature of the subsurface conditions at the relevant locations. Up to eight foundation piles (two at each leg) may be drilled and/or driven into position.

If a piled foundation is suitable, it would be installed via a two-stage piling system, consisting of a primary driven pile and a drilled and grouted insert pile. The driven piles would be relatively shallow in depth and are expected to be driven by a subsea hydraulic-impact hammer. For the drilled and grouted piles, a large-diameter pile-top reverse-circulation drilling rig or a conventional drilling rig may be used to drill a hole into which the insert pile will be grouted into place. The hole may be drilled with seawater and, if necessary, prehydrated gel sweeps as used for drilling the development wells. Depending on the drilling rig selected, the generated drill cuttings may be discharged either at seabed or above the sea surface. Conservatively, as the worst case, approximately 8,000 m^3 of drill cuttings may be discharged, assuming the piles are all drilled. The piling operation is expected to last approximately one day per driven pile and three days per drilled and grouted pile. Fluorescein dye may be used in the grouting operations. Support vessels and derrick barges will be required to support the piling installation. If a gravity-based substructure is required, then the installation method will be similar to that described in **Section 6.7.2.1** for the Dorado WHP.

It is not anticipated that the associated flowlines or pipelines and risers will require to be trenched, but secondary stabilisation may be needed in some areas to ensure the stability and long-term integrity of the subsea facilities.

Drilling activities for the future tiebacks are described in **Section 6.7.3.**

As the hydrocarbons from future tiebacks will be processed on the Dorado FPSO, there will be no additional types of emissions or discharges associated with hydrocarbon processing. Produced gas will continue to be used to supply fuel gas for the FPSO power generation system and flare pilot; otherwise excess gas will be dehydrated, compressed and reinjected into the reservoir via existing reinjection wells (or additional reinjection wells if needed).

6.7.7 Decommissioning

Dorado Phase 1 will be decommissioned at the end of its operating life when production from the reservoirs ceases to be economically viable, and will be decommissioned in accordance with the prevailing legislation at that time. Decommissioning of petroleum facilities requires approval under the OPGGS Act, including acceptance of appropriate EPs under the OPGGS Environment Regulations prior to decommissioning activities commencing.

As part of the asset life cycle management requirements, Dorado Phase 1 will be required to have a decommissioning strategy and plan. Santos' current decommissioning strategy is based on removing property at the end-of-field-life (EOFL) unless infrastructure/equipment is no longer being used, in which case property will be managed in compliance with Section 572 of the OPGGS Act.

Santos commits to achieving full compliance with decommissioning requirements under Section 572 the OPGGS Act. These requirements will be subject to other provisions of the OPGGS Act and regulations, directions given by NOPSEMA or the responsible Commonwealth Minister, and other applicable laws such as the *Environmental Protection (Sea Dumping) Act 1981*. The policy of the Department of Industry, Science, Energy and Resources (2020) and NOPSEMA's draft policy *Section 572 Maintenance and removal of property* (NOPSEMA 2020b) may permit Santos to make alternative arrangements for decommissioning, provided that the alternative arrangements (e.g. decommissioning of infrastructure in situ) are demonstrated to result in equal or better environmental outcomes when compared to the removal of property. NOPSEMA's acceptance of an EP proposing alternative arrangements would mean that Santos' obligations under Section 572 of the OPPGS Act are met with respect to the property covered under the EP.

During front end engineering and design for Dorado Phase 1, Santos will incorporate decommissioning considerations into project equipment and infrastructure design, and plan for the removal of property (as defined in Section 572 of the OPPGS Act).

In-field decommissioning activities are expected to take several years to complete. Prior to decommissioning, an EP will be submitted to NOPSEMA for acceptance after considering a range of decommissioning options.

After the successful completion of decommissioning activities, Santos will apply to surrender the relevant production and infrastructure licences. Once satisfied that Santos has complied with all requirements for the surrender of these licences, the Joint Authority can give consent to the surrender of the licences.

Key environmental risks associated with decommissioning have been broadly addressed through the evaluation of project impacts and risks in **Section 7**. Further detailed information on the nature and scale of the activity, potential environmental impacts and risks, and the control measures that will be implemented will be provided in future activity-specific decommissioning EP(s). This OPP only outlines broad EPOs relating to decommissioning activities, as aligned with the intent for this to be an 'early stage, whole-of-project' assessment.

7 Evaluation of Environmental Impacts and Risks

7.1 Impact and Risk Assessment Methodology

Santos operates under an overarching Risk Management Policy, which is underpinned by Santos' health, safety and environment management processes. The Santos Risk Procedure (SMS-MS1-ST01) underpins the Risk Policy and is consistent with the requirements of AS/NZS ISO 31000:2018, Risk Management – Guidelines (International Organization for Standardization, 2018). The key steps of Santos' process for assessing environmental impacts and risks for this OPP are shown in **Figure 7-1**. This process is aligned to the risk management process outlined in **Table 7-2** and the Risk Management Policy. Each element of **Figure 7-1** is described in further detail below. Common terms applied during the impact and risk assessment process are defined in **Table 7-1**.

The process outlined in **Figure 7-1** was implemented during a series of environmental impact and risk assessment workshops in which hazards, impacts and risks were identified and assessed using the Santos risk matrix (**Table 7-2**). Participants in the workshops included Santos' environmental, drilling and completions, engineering, operations and geology disciplines, with facilitation support from external consultants. The workshop participants were suitably skilled and experienced to identify and understand environmental impacts and risks that may credibly arise from the Dorado Development. All stages of Dorado Phase 1 were considered.

Table 7-1: Impact and Risk Assessment Terms

Name	Definition
Acceptability	An 'acceptable level' is the specified amount of environmental impact and risk that an activity may have that is tolerable, is consistent with all relevant principles, and does not compromise the EPOs. A definition of receptor-specific acceptable levels adopted in this OPP is provided in **Section 4**.
EMBA	Environment that may be affected by planned or unplanned events.
Consequence	The severity of an impact in terms of its adverse effects on the environment.
Impact	Any change to the environment, whether adverse or beneficial, wholly or partly resulting from the planned activity.
Risk	Applies to unplanned events. Risk is a function of the likelihood of the unplanned event occurring and the severity (consequence) of the environmental impact that arises from that event.
Hazard	Something with the potential to cause harm.
Likelihood	Probability of an unplanned event occurring.
Planned activity	The activity to be undertaken, including the services, equipment, products, assets, personnel, timing, duration and location.
Receptor	A feature of the environment that may have environmental, social and/or economic values.
Unplanned event	An event that results in some level of environmental impact and may occur despite preventive safeguards in place. An unplanned event is not intended to occur during the activity.

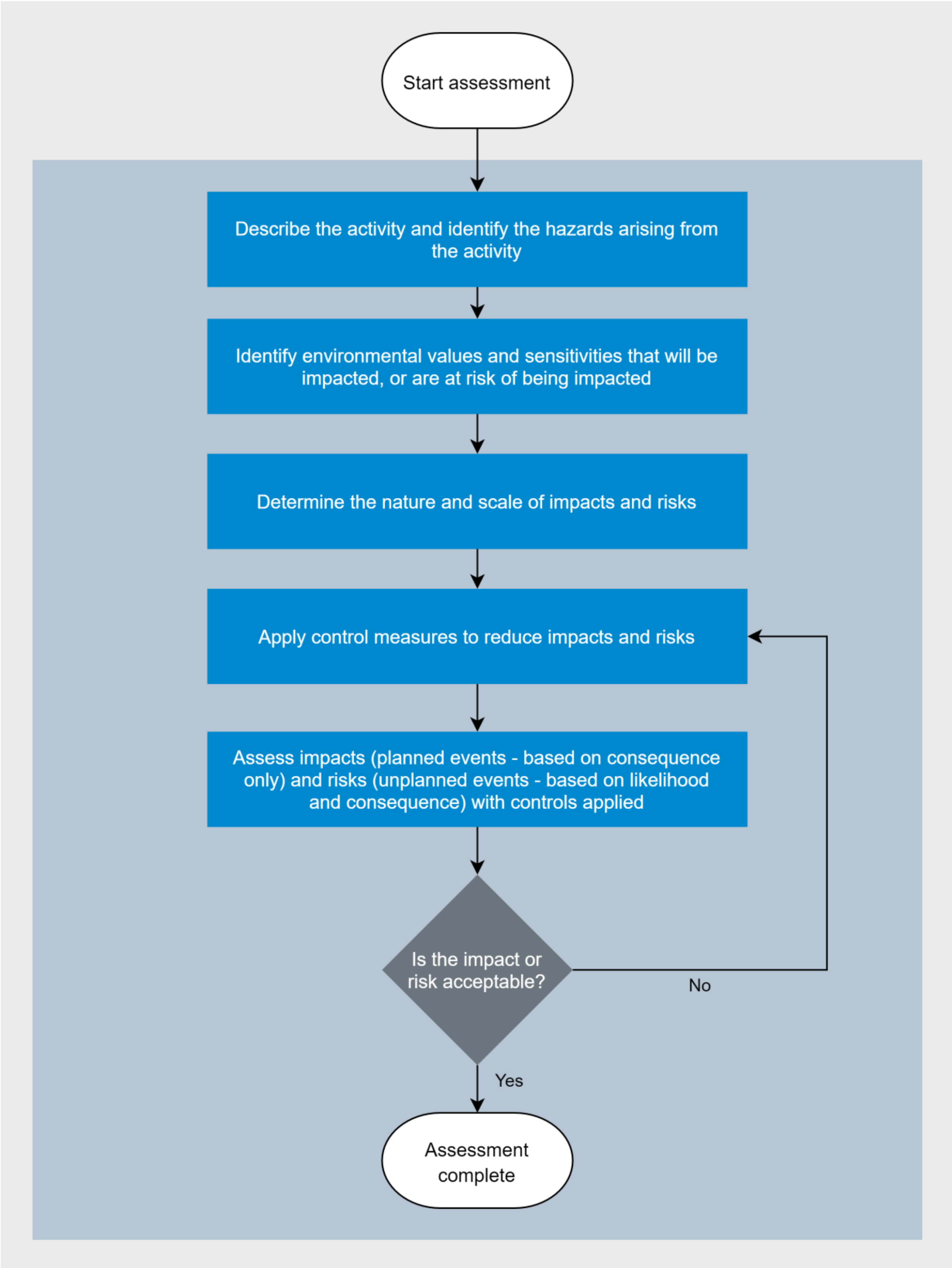


Figure 7-1: Environmental impact and risk assessment process

Table 7-2: Santos risk matrix

Consequence	I	II	III	IV	V	VI
Safety	**Negligible Harm** + No bodily damage or minimal harm or impairment (hours to days)	**Minor Harm** + Short term impairment (days to weeks)	**Moderate Harm** + Temporary disablement or medium term impairment (weeks to months)	**Severe Harm** Long term/life altering disablement or impairment	**Single fatality OR critical life threatening injuries**	**Multiple Fatalities**
Environment	+ No impact to Environmental Value(s)	+ Small-scale impact to Environmental Value(s) of conservation significance + Potential surface or groundwater impact	+ Moderate scale impact to Environmental Value(s) of conservation significance + Localised surface or groundwater impact	+ Large-scale impact to Environmental Value(s) of conservation significance + Moderate scale surface water impact + Localised impact to groundwater with potential or known beneficial use	+ Extensive population or community scale impacts to Environmental Value(s) of conservation significance + Extensive impact to other EV(s)	+ Irreversible impact to Environmental Value(s)
Community & Reputation	+ No actual or potential community criticism + Details remain within Santos sites and/or offices	+ Minor level local community criticism (less than week) + No reputation impact	+ Local community criticism (more than week) or one-day community protest + Local company reputation impacted	+ State-level community criticism or protect over multiple days/locations + State-based company reputation impacted + Very short-term share price impact (less than week)	+ National community criticism or large scale protest + Company reputation and approvals impacted + Shareholder intervention or short-term share price impact (less than month)	+ Sustained national community criticism or widespread protest + Industry reputation and approvals impacted + Changes at executive/board level or long-term share price impact (more than month)
Financial (A$)	less than $30K	$30K to $300K	$300K to $3m	$3m to $30m	$30m to $300m	more than $300m
Workforce	+ Will request some staff attention over several days + No actual or potential impact to culture	+ Will require several days local management time + Minor impact to employee engagement and limited staff turnover	+ Will require several weeks of senior management time + Moderate impact to employee engagement and staff turnover above industry average with some key roles	+ Will require several weeks of senior management time + Impact to employee engagement (less than 6 months), moderate turnover of key roles and no succession	+ Will require several months of senior management time + Impact to employee engagement (less than 18 months), high staff turnover and attraction issues	+ Will require more than a year of senior management involvement and operations severely disrupted + Impact to employee engagement (more than 18 months), significant key role turnover and attraction issues
Compliance	+ Non-conformance with legislation, instruments (e.g. tenure licence) or contract + No regulatory or punitive action	+ Minor breach of legislation, instruments or contract + Notification/report to, request for information by, and/or administrative / warning notice from the regulator	+ Limited number of minor breaches of legislation, instruments or contract + Statutory notice from the regulator	+ Systemic minor breaches (or one moderate breach) of legislation, instruments or contract + Company charged with an offence with minor penalty/fine	+ Systemic moderate breaches (OR single material breach) of legislation, instruments or contract + Company charged with an offence with moderate penalty/fine	+ Material breaches of legislation, instruments or contract + Company or officers charged with an offence with material penalty/fine or loss of tenure/operatorship

Likelihood		I	II	III	IV	V	VI
Almost Certain (less than 4 months) Occurs in almost all circumstances OR could occur within days to weeks	f	Low	Medium	High	Very High	Very High	Very High
Likely (4 monthly to 1 yearly) Occurs in most circumstances OR could occur within weeks to months	e	Low	Medium	High	High	Very High	Very High
Occasional (1 to 3 yearly) Has occurred before in Santos OR could occur within months to years	d	Low	Low	Medium	High	High	Very High
Possible (3 to 10 yearly) Has occurred before in the industry OR could occur within the next few years	c	Very Low	Low	Low	Medium	High	Very High
Unlikely (10 to 30 yearly) Has occurred elsewhere OR could occur within decades	b	Very Low	Very Low	Low	Low	Medium	High
Remote (30 to 100 yearly) Requires exceptional circumstances and is unlikely, even in the long term OR only occurs as a "one in 100 year event"	a	Very Low	Very Low	Very Low	Low	Medium	Medium

Santos

7.1.1 Describe the Aspect and Identify Hazards

An assessment of Dorado Phase 1 activities described in **Section 6** was undertaken to identify the aspects of activities that may interact with the environment. Each of these aspects was assessed to determine what environmental hazards could credibly arise from the aspect. Hazards were characterised by their:

+ duration – how long in the hazard present;
+ spatial extent – how far could the hazard extent in the environment; and
+ magnitude – how great is the potential for the hazard to cause impacts.

Additional studies were undertaken where there was uncertainty in the characteristics of a hazard. These studies include the numerical modelling studies provided in **Attachment 2** to **Attachment 12** and additional early engineering design.

The aspects of Dorado Phase 1 that may result in environmental impacts and risks, along with the environmental values and sensitivities these aspects may interact with, are summarised in **Table 7-3**.

Table 7-3: Interactions between aspects of Dorado Phase 1 and environmental values and sensitivities

Aspect		Physical							Biological					Socio-economic						
		Bathymetry	Climate	Oceanography	Water Quality	Sediment Quality	Air Quality	Acoustic Environment	Communities and Habitats	Fishes	Marine Mammals	Reptiles	Birds	Regional Centres	Protected Areas	Fisheries	Heritage	Tourism	Maritime Industry	Defence
Planned Activities	Drill Cuttings and Fluids				✓	✓			✓	✓	✓	✓								
	PW Discharges				✓	✓				✓										
	Wastewater Discharges				✓	✓				✓										
	Light Emissions								✓	✓	✓	✓	✓							
	Acoustic Emissions							✓	✓	✓	✓	✓				✓				
	GHG Emissions		✓																	
	Atmospheric Emission						✓													
	Interactions with Other Users															✓			✓	
	Seabed Disturbance				✓	✓			✓	✓										
	Waste Management						✓		✓							✓				
Unplanned Events	Hydrocarbon and Chemical Spills				✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
	Loss of Solid Material								✓	✓	✓	✓	✓							
	Introduction of IMS								✓											
	Fauna Collision									✓	✓	✓								

7.1.2 Identify Environmental Values and Sensitivities

Environmental values and sensitivities were identified based on the nature and scale of the environmental aspects of Dorado Phase 1. The spatial and temporal extent of each aspect and any associated hazards were considered when identifying environmental values and sensitivities. These environmental values and sensitivities are presented in **Section 3**.

Santos estimated the spatial and temporal extents of environmental aspects using a range of methods, such as:

+ calculations of direct seabed footprints (**Section 7.2.9**);
+ scheduling and duration of project activities (**Section 6**);
+ characteristics of project components (e.g. vessels) (**Section 6**);
+ modelling studies to predict the extent of emissions and discharges, such as:
+ PW discharge modelling (**Attachment 7**);
+ drill cuttings and fluids discharge modelling (**Attachment 6**);
+ acoustic emissions modelling (**Attachment 10, Attachment 14**);
+ atmospheric emissions inventory (**Attachment 12**);
+ artificial light emissions modelling (**Attachment 9**); and
+ hydrocarbon spill modelling (**Attachment 8**).

Santos has also undertaken a range of environmental investigations to provide information on environmental values and sensitivities, including:

+ sediment quality surveys (**Attachment 4**);
+ water quality surveys (**Attachment 5**);
+ benthic habitat surveys (**Attachment 2**);
+ benthic habitat modelling (**Attachment 3**); and
+ stakeholder engagement (**Section 9**).

7.1.3 Determine the Nature and Scale of Impacts

The nature and scale of impacts to environmental values and sensitivities was assessed for each aspect. This assessment was undertaken qualitatively by environmental impact and risk assessment workshops participants. The assessment considered a range of factors, such as:

+ the potential pathways between the hazards and the environmental values and sensitivities;
+ the vulnerability of the environmental values and sensitivities to hazards;
+ the value of the environmental values and sensitivities (**Section 4**);
+ the potential for the environmental values and sensitivities to recover after being exposed to the aspect; and
+ sources of uncertainty in the characteristics of the hazard or the environmental values and sensitivities.

The nature and scale of impacts and risks was used to determine the consequence when assessing impacts and risk (**Section 7.1.5**).

7.1.4 Apply Control Measures

Control measures to reduce environmental impacts and risks were applied to each aspect after determining the nature and scale of environmental impacts and risk. Controls that reduce the consequence of a planned activity or an unplanned event, as well as controls that reduce the likelihood of an unplanned event, were considered.

Controls were identified from a range of sources, such as:

+ Santos' environmental management systems and practices;
+ Santos' operational experience;
+ industry standards and good practice;
+ relevant requirements;
+ material published under the EPBC Act, such as recovery plans and conservation advice; and
+ feedback received from stakeholders.

The effectiveness of each control was considered when applying control measures. This included considerations such as:

+ Does the control deliver the intended benefit?
+ Is the control available when it is needed?
+ Does Santos have a history of successfully implementing the control?
+ Is the control resilient?

Controls having a relatively high effectiveness were prioritised for implementation. Multiple iterations of the application of control measures were carried out as required until the impacts or risks were reduced to an acceptable level (**Section 7.1.5**).

7.1.5 Assess Impacts and Risks

The impact or risk for each aspect and associated hazards was assessed following the application of controls. The consequence level of the impact is determined for each planned and unplanned event using the Corporate Santos Risk Matrix (**Table 7-2**) and the more detailed environmental consequence descriptors provided as guidance in Table 7-4 and Table 7-5.

For planned impacts, only the consequence of the impact was assessed (refer Table 7-4). Likelihood was not assessed, as the occurrence of planned events is effectively certain. The consequence for planned activities was based on all controls functioning effectively. During the workshops it was identified that all planned activities could result in a potential impact to environmental value, even if the impact is not measurable, quantifiable, or identifiable. The minimum consequence of a potential environmental impact was therefore regarded as "Minor – II" in the Santos risk matrix.

Table 7-4: Summary of Environmental Consequence Descriptors

Consequence Level	Consequence Level Description
I	**Negligible** - No impact or negligible impact.
II	**Minor** - Detectable but insignificant change to local population, industry or ecosystem factors.
III	**Moderate** - Significant impact to local population, industry or ecosystem factors.
IV	**Major** - Major long-term effect on local population, industry or ecosystem factors.
V	**Severe** - Complete loss of local population, industry or ecosystem factors AND/ OR extensive regional impacts with slow recovery.

VI	**Critical** - Irreversible impact to regional population, industry or ecosystem factors.

For unplanned events, the environmental residual risk of the event was determined based on the likelihood and consequence of the events. The likelihood of an event occurring was based on all controls functioning effectively. The consequence was based on a worst-case event occurring with all controls having failed. This provides a conservative approach to assessing consequence, as the likelihood of a worst-case event with the failure of all controls is remote. This approach is expected to over-estimate the environment consequence of an event, which is consistent with the precautionary principle and the principles of ESD.

The resulting consequence (planned activities) or residual risk (unplanned events) was then compared to Santos' acceptable levels of impact and risk, including receptor-specific acceptable levels of impact described in **Section 4**. If the impact or residual risks was determined to not be acceptable, additional controls were applied and the impact or risk assessed again. This process was repeated until each impact or residual risk was reduced to an acceptable level.

Table 7-5: Detailed Environmental Consequence Descriptor

Consequence Level		I	II	III	IV	V	VI
Acceptability		Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Severity Description		**Negligible** No impact or negligible impact.	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect	**Moderate** Significant impact to local population, industry or ecosystem factors.	**Major** Major long-term effect on local population, industry or ecosystem factors.	**Severe** *Complete loss of local population, industry or ecosystem factors AND/ OR extensive regional impacts with slow recovery.*	**Critical** *Irreversible impact to regional population, industry or ecosystem factors.*
Environmental Receptors	**Fauna** In particular, EPBC Act listed threatened/migratory fauna or WA Biodiversity Conservation Act 2016 specially protected fauna	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity; No decrease in local population size; No reduction in area of occupancy of species; No loss/disruption of habitat critical to survival of a species; No disruption to the breeding cycle of any individual; No introduction of disease likely to cause a detectable population decline.	Detectable but insignificant decrease in local population size; Insignificant reduction in area of occupancy of species; Insignificant loss/disruption of habitat critical to survival of a species; Insignificant disruption to the breeding cycle of local population.	Significant decrease in local population size but no threat to overall population viability; Significant behavioural disruption to local population; Significant disruption to the breeding cycle of a local population; Significant reduction in area of occupancy of species; Significant loss of habitat critical to survival of a species; Modify, destroy, remove, isolate or decrease availability of quality of habitat to the extent that a significant decline in local population is likely; Introduce disease likely to cause a significant population decline.	Long term decrease in local population size and threat to local population viability; Major disruption to the breeding cycle of local population; Major reduction in area of occupancy of species; Fragmentation of existing population; Major loss of habitat critical to survival of a species; Modify, destroy, remove, isolate or decrease availability of quality of habitat to the extent that a long term decline in local population is likely; Introduce disease likely to cause a long term population decline.	Complete loss of local population; Complete loss of habitat critical to survival of local population; Wide spread (regional) decline in population size or habitat critical to regional population.	Complete loss of regional population; Complete loss of habitat critical to survival of regional population.
	Physical Environment / Habitat Includes: air quality; water quality; benthic habitat (biotic/abiotic), particularly habitats that are rare or unique; habitat that represents a Key Ecological Feature[15]; habitat within a protected area; habitats that include benthic primary producers[16] and/ or epi-fauna[17]	No or negligible reduction in physical environment / habitat area/function.	Detectable but localised and insignificant loss of area/function of physical environment / habitat. Rapid recovery evident within about 2 years (two season recovery)	Significant loss of area and/or function of local physical environment / habitat. Recovery over medium term (2 to 10 years)	Major, large-scale loss of area and/or function of physical environment / local habitat. Slow recovery over decades.	Extensive destruction of local physical environment / habitat with no recovery; Long term (decades) and wide spread loss of area or function of primary producers on a regional scale.	Complete destruction of regional physical environment / habitat with no recovery. Complete loss of area or function of primary producers on a regional scale.

[15] As defined by DaWE.

[16] Benthic photosynthetic organisms such as seagrass, algae, hard corals and mangroves.

[17] Fauna attached to the substrate including sponges, soft corals and crinoids.

Consequence Level		I	II	III	IV	V	VI
Acceptability		Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Severity Description		**Negligible** No impact or negligible impact.	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect	**Moderate** Significant impact to local population, industry or ecosystem factors.	**Major** Major long-term effect on local population, industry or ecosystem factors.	**Severe** *Complete loss of local population, industry or ecosystem factors AND/ OR extensive regional impacts with slow recovery.*	**Critical** *Irreversible impact to regional population, industry or ecosystem factors.*
	Threatened ecological communities (EPBC Act listed ecological communities)	No decline in threatened ecological community population size, diversity or function; No reduction in area of threatened ecological community; No introduction of disease likely to cause decline in threatened ecological community population size, diversity or function.	Detectable but insignificant decline in threatened ecological community population size, diversity or function; Insignificant reduction in area of threatened ecological community.	Significant decline in threatened ecological community population size, diversity or function; Significant reduction in area of threatened ecological community; Introduction of disease likely to cause significant decline in threatened ecological community population size, diversity or function.	Major, long term decline in threatened ecological community population size, diversity or function; Major reduction in area of threatened ecological community; Fragmentation of threatened ecological community; Introduce disease likely to cause long term decline in threatened ecological community population size, diversity or function.	Extensive, long term decline in threatened ecological community population size, diversity or function; Complete loss of threatened ecological community.	Complete loss of threatened ecological community with no recovery.
	Protected Areas Includes: World Heritage Properties; Ramsar wetlands; Commonwealth/ National Heritage Areas; Land/ Marine Conservation Reserves.	No or negligible impact on protected area values; No decline in species population within protected area; No or negligible alteration, modification, obscuring or diminishing of protected area values.	Detectable but insignificant impact on one of more of protected area's values. Detectable but insignificant decline in species population within protected area. Detectable but insignificant alteration, modification, obscuring or diminishing of protected area values	Significant impact on one of more of protected area's values; Significant decrease in population within protected area; Significant alteration, modification, obscuring or diminishing of protected area values.	Major long term effect on one of more of protected area's values Long term decrease in species population contained within protected area and threat to that population's viability Major alteration, modification, obscuring or diminishing of protected area values	Extensive loss of one or more of protected area's values; Extensive loss of species population contained within protected area.	Complete loss of one or more of protected area's values with no recovery; Complete loss of species population contained within protected area with no recovery.
	Socio-economic receptors Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping.	No or negligible loss of value of the local industry; No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry; Significant medium term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry; Extensive loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry; Permanent loss of key natural features or populations supporting the local or regional industry.

7.1.5.1 Cumulative Impacts

In addition to assessing each aspect and its associated hazards independently, Santos has also undertaken a cumulative impact assessment. This cumulative impact assessment considered potential synergistic impacts on environmental values and sensitivities from all aspects of Dorado Phase 1 and third-party activities. The cumulative impact assessment was only undertaken for planned activities. No consideration of cumulative impacts from unplanned events was made, as these events are not expected to occur during Dorado Phase 1. Refer to **Section 7.3.3** for additional information on the assessment of cumulative impacts, including the methods used and the assessment outcomes.

7.2 Impact Assessment of Planned Activities

7.2.1 Discharges – Drilling Fluids and Cuttings Discharges

7.2.1.1 Description of the Event

Activities for Dorado Phase 1 that will generate drilling discharges include the drilling of the FPSO anchor and future tieback WHP piles, drilling of the Dorado reservoir development wells, drilling of future tieback wells, well intervention and well abandonment activities. The Dorado WHP does not require piling as its foundation will be gravity based.

Routine discharges from these activities will include drilling fluids, drill cuttings, subsea control fluids, cement and completion fluids (such as well clean up and suspension fluids).

7.2.1.1.1 Dorado Drilling Operations

Development Wells

The drilling of development wells will generate drill cuttings, broken formation solids removed from the borehole, and fluids. Drilling fluids are used to cool and lubricate the drill bit, maintain overbalance, and remove cuttings from the well. Cuttings and drilling fluids from the top-hole sections will be discharged directly to the seabed. Cuttings and drilling fluids from the bottom-hole sections will be circulated to the MODU via a riser (lower sections), processed onboard the MODU to recover drilling mud, and then discharged into the marine environment. Some residual drilling fluids will adhere to the drill cuttings.

It is anticipated that a total of 10 wells (oil and gas production and gas injection wells) will be batch drilled at the WHP location during the initial development drilling stage of Dorado Phase 1, with a further 6 infill wells planned for the Dorado WHP to be drilled during the operational stage. These will be drilled using a jack-up MODU in a similar fashion to the initial production and gas injection wells.

The development drilling of potential additional wells for future tiebacks (up to 22 wells may be drilled) within the Project Area is expected to require the same drilling activities as those presented above. Moored semi-submersible or jack-up MODUs may be used to drill tieback wells; the selection of MODU type will largely depend on the water depth at the future tieback location.

The development wells for Dorado Phase 1 will be a conventional monobore design, and will be drilled using a jack-up MODU. The well design is expected to contain five sections:

+ Conductor (36” bore diameter);

+ Surface hole (26”);
+ Intermediate hole (17 ½”);
+ Production hole (12 ¼”); and
+ Production hole (8 ½”).

It is proposed that the drilling activities will be undertaken in batches with the top-hole sections (36” and 26”) of all wells being drilled first, followed by a second drilling stage where all downhole sections (17 ½” to 8 ½”) will be drilled sequentially.

The top-hole sections will be drilled using seawater and prehydrated gel sweeps. The extracted drill cuttings and drilling muds will be discharged directly to the seabed for the conductor section, while the cuttings and drilling muds generated within the surface section will be returned up to the surface (a diverter may be used for this section).

Following completion of the surface section, a riser will be installed for the remainder of the drilling activity to circulate the cuttings and muds to the MODU. Cuttings will then be separated before being discharged along with unrecoverable or spent muds into the marine environment above the sea surface. With the riser in place, WBM will be used in the drilling of the intermediate and production sections (17 ½” to 8 ½”). While not planned, it might be required to drill these sections with NAF / SBM should unexpected conditions be encountered (e.g. required for increased lubrication or heat resistance). In this instance, cuttings from sections drilled with NAF / SBM will be passed through a treatment system onboard the MODU prior to discharge overboard to reduce the volume of NAF coating the cuttings. Residual NAF / SBM base fluid on cuttings content will be reduced to ALARP levels prior to discharge overboard.

All discharges associated with the initial drilling operations will occur at the WHP location. The expected drill cutting and mud volumes to be discharged and activities duration are presented in **Table 7-6**.

During drilling operations, a casing will be cemented in place within each well (the casing is a hollow pipe within the wellbore which protects and supports the well stream). There will be minor planned cement discharges at seabed during cementing of surface casings. Likewise, a small cement discharge (up to 5 m^3) is expected to be discharged at sea surface when flushing tanks and lines. However, as a contingency, it might be required to discharge up to 150 m^3 at seabed and up to 45 m^3 at sea surface of cement slurry should a cement job not meet technical and safety standards. Following completion of the cementing activity, any surplus mixed concrete will also be discharged overboard.

During drilling completions activities brine (mostly saturated sodium chloride), up to 2,500 m^3 per well, might be discharged to the marine environment. During well construction, wells will be suspended at a number of stages to facilitate access, install different pieces of equipment and optimise the well construction sequence. Details of how this process will be managed (within Company Standards, Industry Standards and consistent with Regulations) will be included in the well operations management plan. Following completion of the drilling, the wells will be secured at the tree (barriers tested and verified) ready for commissioning activities.

Pressure-control equipment such as blow out preventers use hydraulics for operation. Subsea control fluids are water-based hydraulic control fluids used in control systems on the blowout preventers.

Subsea control fluids will be discharged during function testing of the blowout preventer control system. The maximum volume of control fluid that will be released to the marine environment per well is 1,320 to 2,250 L of water-based fluid containing about 3% active ingredient (40 to 68 L of control fluid additive).

Completion fluids are used to run well completions, and during wellbore clean-up and flowback during drilling. Wellbore and casing clean-up are required at various stages of the drilling operations to ensure the contents of the well are free of contaminants before the next stage of drilling. A chemical wellbore cleanout fluid train may be used to remove residual fluids from the wellbore. The wellbore cleanout fluid is usually brine (similar to completion fluid) that can include several chemicals, such as biocide and surfactant. Completion fluids are usually brines (i.e. a mixture of seawater or formation water) with additives that can include, chlorides (often sodium, potassium or calcium), bromides, hydrate inhibitor (MEG), biocide, oxygen scavenger. They are designed to have the proper density and flow characteristics to be compatible with the reservoir formation. During the clean-up process, fluids are circulated back to the MODU, and, if required, analysed before they are discharged overboard. Discharge volume would be about 400 m^3 (based on the designs of the proposed production wells). Kill-weight brine may also be used during well suspension or well abandonment, which is a brine (e.g. sodium chloride) of adequate density to control formation pressure.

Pile Drilling

Pile installation will be required for the FPSO anchor piles, and potentially contingent for the Dorado WHP GBS, as well as potentially required for future tieback WHP. The piles may be installed by pile driving and/ or drilling dependant on the subsurface conditions.

The FPSO is proposed to have 12 anchor piles and future tieback WHP (if required) may be piled and have up to 8 piles each, depending on the subsurface conditions. All the piles are planned to be driven; however, drilling may be required as a contingency if the required pile depth cannot be achieved by driving. The Dorado WHP GBS substructure may also require up to 4 piles.

It is conservatively estimated that up to 8,000 m^3 of cuttings for the FPSO anchor piling activities and 16,000 m^3 of cuttings for the pilling activities associated with future tieback WHP (allowing for 8 drilled piles for a WHP) will be discharged to the environment, if the piles are fully drilled.

It is anticipated that seawater will be used as the drilling fluid. Prehydrated gel sweeps (i.e. seawater to which high-viscosity prehydrated bentonite has been added) may be used. To assist in removing cuttings from the pile borehole. Bentonite is a naturally occurring clay mineral with minimal ecotoxicity potential. The discharge volumes of drill cuttings and fluids required for potential future tiebacks would be expected to be less than this volume, as each tieback could consist of a WHP which requires jacket foundation piles and wells to be drilled. If pile grouting is required fluorescein dye will be added assist with detection of grout at surface of piles.

Drilling of the piles will be from a barge using reverse circulation, with the cuttings and fluids returned to the surface, and discharged overboard.

Well Intervention and Workovers

Well intervention activities to maintain, repair or replace well components may be required during the life of the development wells. These activities generally occur within the wellbore and could include well logging, well testing and flowback and well workovers. Typical discharges from intervention activity includes subsea control fluid, completions and well annular fluids. Well annular fluids refer to the fluids that remain in the wellbore or annular space between the casing (typically consists of weighted drilling fluid, cement contaminated mud, sweater, barite, cement polymer and may include small amounts of hydrocarbon).

Well Abandonment

Well abandonment activities include installing and pressure testing the blowout preventer, cutting/ perforation of casing or production tubing and installing permanent reservoir and surface barrier (cementing). Typical discharges include subsea control fluid, completions and well annular fluids. Drilling fluids used during riserless drilling will be released to the environment when the well head is removed during abandonment. Upon wellhead removal, small volumes (approximately $1m^3$) of this fluid may be exchanged to the marine environment. The exchange is not instantaneous as the fluids are typically heavier than seawater.

Table 7-6: Expected drill cutting and mud volumes and activities duration for a typical Dorado Phase 1 well (including future tiebacks)

Well Section	Hole Diameter (inch)	Discharge Methodology	Discharged Cutting per Well (m^3)	Drilling Fluid	Drilling Fluid Discharges per Well[1] (m^3)	Discharge Duration for a Well (days)	Drilling Operations Duration (days) – 10 Wells
Conductor	36	Returned directly to the seafloor	82	WBM (seawater & prehydrated gel sweeps)	10,000	1 day of cuttings discharge every 2 days	24
Surface	26	Cuttings brought to surface (diverter expected to be used)	385	WBM (seawater & prehydrated gel sweeps)	6,000	2 days of cuttings discharge every 4 days	48
Intermediate	17 ½	Cuttings brought to drilling rig, then discharged to surface	330	WBM		5 days of cuttings discharge, then no discharge for 5 days	120
Production 12¼”	12 ¼	Cuttings brought to drilling rig, then discharged to surface	214	WBM		7 days of cuttings discharge, then no discharge for 6 days	156
Production 8½”	8 ½	Cuttings brought to drilling rig, then discharged to surface	46	WBM		3 days of cuttings discharge, then no discharge for 6 days	252
Contingency	17 ½ to 8 ½	Cuttings brought to drilling rig and treated prior to being discharged to surface	NA*	NAF /SBM	200	NA*	NA*
Total			**1,057**	**-**	**16,000**	**18**	**600**

[1] To account for the level of uncertainty associated with the specific wells conditions to be encountered during the drilling of each well and the possibility of having to side-track or redrilled section(s) of the well, the volumes presented include 100% contingency (i.e. the expected WBM volumes discharged, under normal conditions, per well are 8,000 m^3)

* It is not expected that NAF / SBM will be required, but it has been included as contingency should unexpected conditions be encountered during the drilling operations of the 17 ½, 12 ¼, or 8 ½ sections. The use of NAF / SBM will have no impact on the maximum amount of drill cuttings discharged or the duration of the activity.

7.2.1.1.2 Development Well Drill Cutting Dispersion Modelling

A numerical modelling study was undertaken to inform the assessment of the potential environmental impacts and risks from the discharge of drill cuttings and muds into the marine environment (**Attachment 6**). The study focused on:

- establishing a sediment dispersion model to simulate all stages of the development drilling program; and
- mapping the distribution and sediment thicknesses from discharged drill cuttings and drilling fluids on the seabed based on the hydrodynamic regime of the Project Area.

Plume Model

MUDMAP, a 3-D plume model, was used. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near-field (i.e. the immediate area of the discharge) and the far-field (the wider region). **Figure 7-2** shows a conceptual diagram of the dispersion and fates of drill cuttings and fluids discharge to the ocean and an idealised representation of the three discharge phases (**Attachment 6**).

Larger particles (such as rocks, gravel to sand) tend to settle quickly, forming a pile that aligns with the predominant current axis. Smaller particles (especially silts and clays) tend to remain suspended for exponentially longer time periods and will therefore be dispersed more widely by local currents. Dispersion of the finer discharged material will tend to be enhanced with increased current speeds and water depth, and with greater variation in current direction over time and depth (**Attachment 6**).

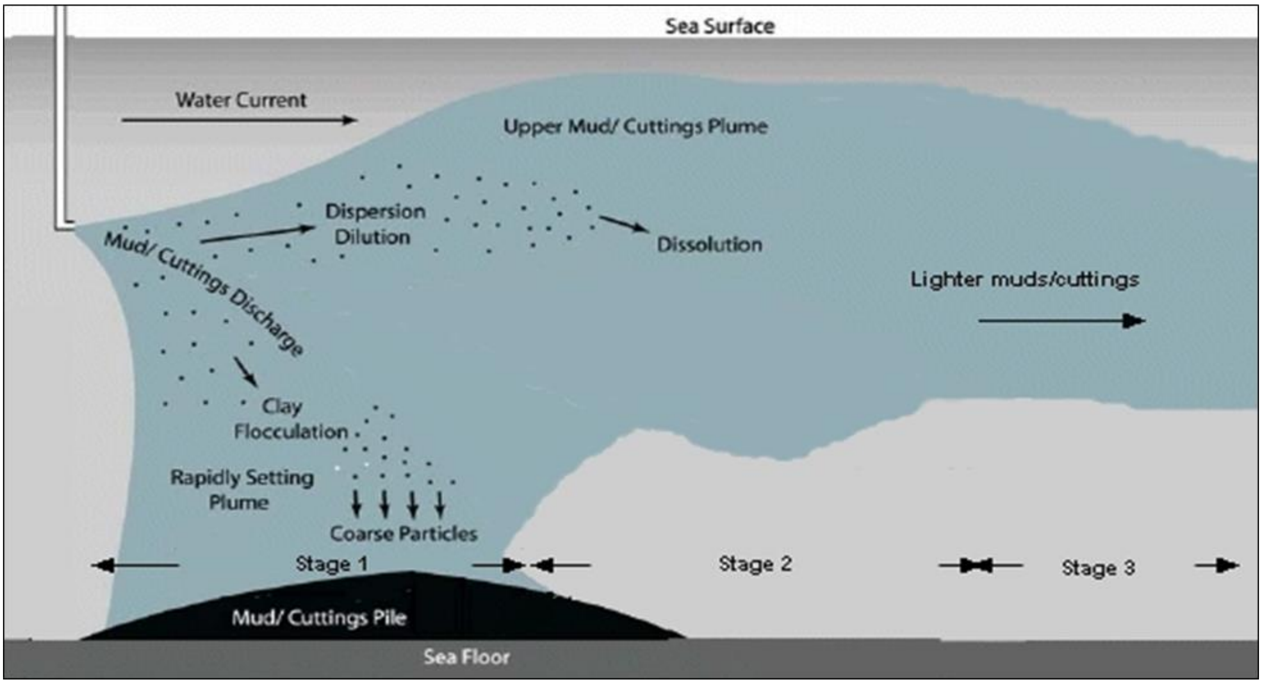


Figure 7-2: Conceptual diagram showing the general behaviour of cuttings and muds discharged to the ocean and the idealised representation of the three discharge phases (Neff 2005).

Key inputs into the MUDMAP model simulations included:

- estimated cuttings volumes;
- discharge sequence and durations;
- the particle size distributions (measured during previous drilling campaign in the Bedout Basin) and associated settling velocities;
- the bulk density of the released material;
- the temperature and salinity profiles of the receiving waters;
- the height of the discharge points relative to mean sea level; and
- the current data representing local physical forcing.

A uniformly sized rectangular grid covering a 20 km (longitude, x-direction) by 20 km (latitude, y-direction) region around the WHP location was used to calculate the concentration of drill cuttings and muds in the water column and on the seafloor. The resolution of each grid cell was approximately 20 m (x) x 20 m (y) x 5 m (z).

Hydrodynamic Model

Water movement and characteristics, along with characteristics of cuttings, are the principle determinants of the distribution of discharged drilling fluids and cuttings. A hydrodynamic model of the currents within the cuttings model domain was developed to predict the effect of currents on the distribution of discharged drilling cuttings and fluids. The model comprised two components:

- a mesoscale current model (HYCOM); and
- a regional tidal current model (HYDROMAP).

The hydrodynamic model was used to model a 10-year hindcast period between 2009 and 2018. The model was validated and found to agree well with metocean observations made over the same period (**Attachment 6**). This provides confidence that the hydrodynamic model is representative of the currents that may occur in the Project Area.

Metocean Conditions

El Niño-Southern Oscillation (ENSO) refers to irregular periodic variations in winds and sea surface temperatures over the tropical eastern Pacific Ocean. ENSO phases in the eastern Pacific Ocean consist of a warming phase (El Niño), a cooling phase (La Niña) and a transitional phase between the El Niño and La Niña phases. ENSO phases affect the large-scale currents in the western Indian Ocean. To examine the potential range of seasonal variability from ENSO events, the Southern Oscillation Index was used to identify interannual trends in metocean conditions (e.g. water temperature and currents) over the same 10 years as the current data set (2009 to 2018 (inclusive)). The index broadly defines transitional, El Niño and La Niña conditions based on differences in the surface air-pressure between Tahiti on the eastern side of the Pacific Ocean and Darwin (Australia), on the western side (Philander 1989; Rasmusson and Wallace 1983). Based on the index's assessment, 2010 was selected as a representative El Niño year, 2012 was selected as a representative neutral year, and 2015 was selected as a La Niña year (**Attachment 6**).

Thresholds

Sedimentation exposure thresholds for the interpretation of modelling results were set based on natural sedimentation rates in the region and studies of biological impacts from deposition. A study by Glenn (2004) found that the maximum natural sedimentation rate for northwest Australia is

223.21 cm/thousand years (or 0.0061 mm/day). Trannum et al. (2010) found a significant decrease in species count, abundance of individuals, and biomass of marine animals with deposited cuttings of 3 to 24 mm. Furthermore, a study by Kjeilen-Eilertsen et al. (2004) reports that depositional thicknesses greater than 9.6 mm are likely to cause smothering impacts on benthic ecosystems, including corals. It is also worth noting that a study by Smit et al. (2008) established that a thickness threshold of greater than 6.5 mm would be needed before potential harm to benthic macrofauna occur. Based on this information 0.1 mm, 1 mm, and 10 mm have been used as natural, low and high exposure thresholds respectively (**Attachment 6**). While considering and interpreting the modelling results, it is important to note that observations of the seabed in the Project Area indicate sediments are mobile (e.g. bedforms consistent with water movement) (**Section 3.2.5**). The processes that transport sediments and generate bedforms on natural sediments are also expected to act upon any drill cuttings deposited on the seabed.

Results

For a single well modelling simulation, the results showed that deposition of cuttings was concentrated in the vicinity of the well (**Table 7-5**). The maximum thickness (or height of mound) was predicted to be 126 mm adjacent to the well location during El Niño conditions. The maximum distance from the well to the natural threshold (0.1 to 1 mm) was 1,115 m, occurring during neutral conditions and the corresponding area of coverage was 0.65 km^2 (***Table 7-8***). The maximum distances to the low (1 to 10 mm) and high (equal to or greater than 10 mm) exposure thresholds was 837 m (neutral conditions) and 251 m (El Nino conditions), respectively. The greatest areas of coverage on the seabed at the low and high exposure thresholds, was recorded as 0.29 km^2 and 0.02 km^2, respectively.

When combining the results for 12 wells (representing consecutive drilling of these wells) and the three ENSO events, the modelling results showed that the settlement of drill cuttings and fluids were generally spread along the northwest–southeast axis, coinciding with the dominant tidal current directions (**Figure 7-3**). The maximum thickness was predicted to be 1,315 mm adjacent to the well location (within 20 m). The natural threshold was predicted to extend up to 2,871 m from the well location and cover an area of 9.81 km^2. The maximum distances from the release site to the low and high exposure thresholds were 954 m and 447 m, respectively (**Table 7-8**).

Modelling of the distribution of TSS within the water column indicates that the greatest spatial extent of TSS is expected to occur near the sea surface, with TSS concentrations through the water column expected to be elevated only directly under the cuttings and fluids discharge point on the MODU (**Figure 7-4**).

Given that future tieback wells are targeting the same formation, likely to have the same drilling methodology and well design, located within 50 km of the Dorado drill centre and the Project Area experiences similar metocean conditions across the area, it is expected that the development wells associated with the tiebacks, if drilled, will deposit drill cuttings in a similar manner to that modelled for the Dorado reservoir.

Table 7-7: Predicted maximum sediment thickness, area of coverage and maximum distance for 1 well

ENSO event	Maximum sediment thickness (mm)	Total area of coverage (km²) above threshold			Maximum distance from well to thresholds (m)		
		0.1 to 1 mm (natural threshold)	1 to 10 mm (low exposure)	Equal to or more than 10 mm (high exposure)	0.1 to 1 mm (natural threshold)	1 to 10 mm (low exposure)	Equal to or more than 10 mm (high exposure)
La Niña	91	0.66	0.21	0.02	771	451	190
Neutral	112	0.65	0.29	0.00	1,115	837	40
El Niño	126	0.58	0.16	0.01	863	398	251

Table 7-8: Predicted maximum sediment thickness, area of coverage and maximum distance for all 12 wells and the three ENSO conditions

ENSO event	Maximum sediment thickness (mm)	Total area of coverage (km²) above threshold			Maximum distance from well to thresholds (m)		
		0.1 to 1 mm (natural threshold)	1 to 10 mm (low exposure)	Equal to or more than 10 mm (high exposure)	0.1 to 1 mm (natural threshold)	1 to 10 mm (low exposure)	Equal to or more than 10 mm (high exposure)
La Niña	1,205	7.69	0.78	0.27	2,501	736	426
Neutral	1,315	8.93	0.73	0.25	2,813	954	447
El Niño	1,224	8.39	0.73	0.23	2,871	758	391

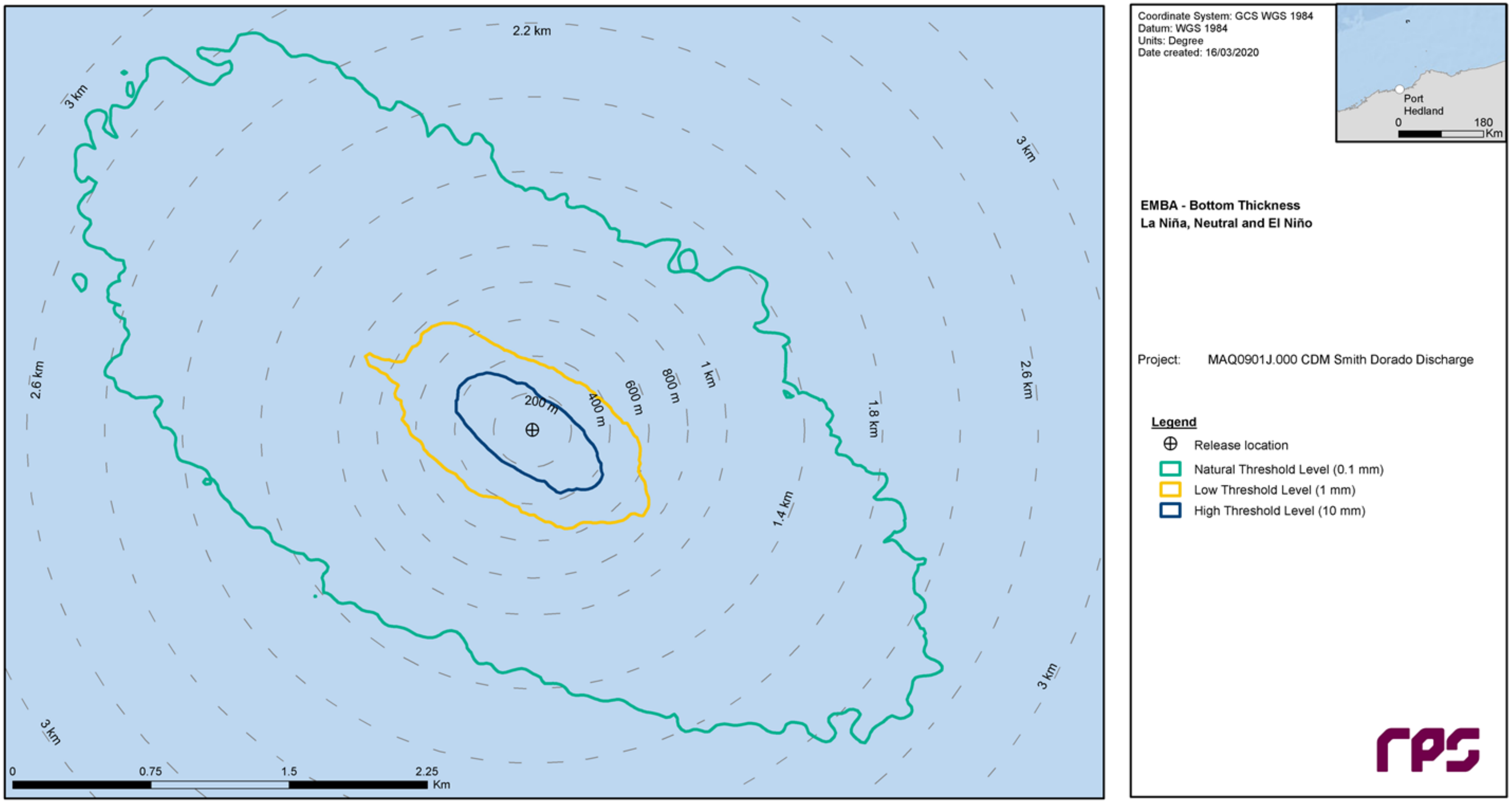


Figure 7-3: Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for combined results of all 12 wells and all three ENSO conditions

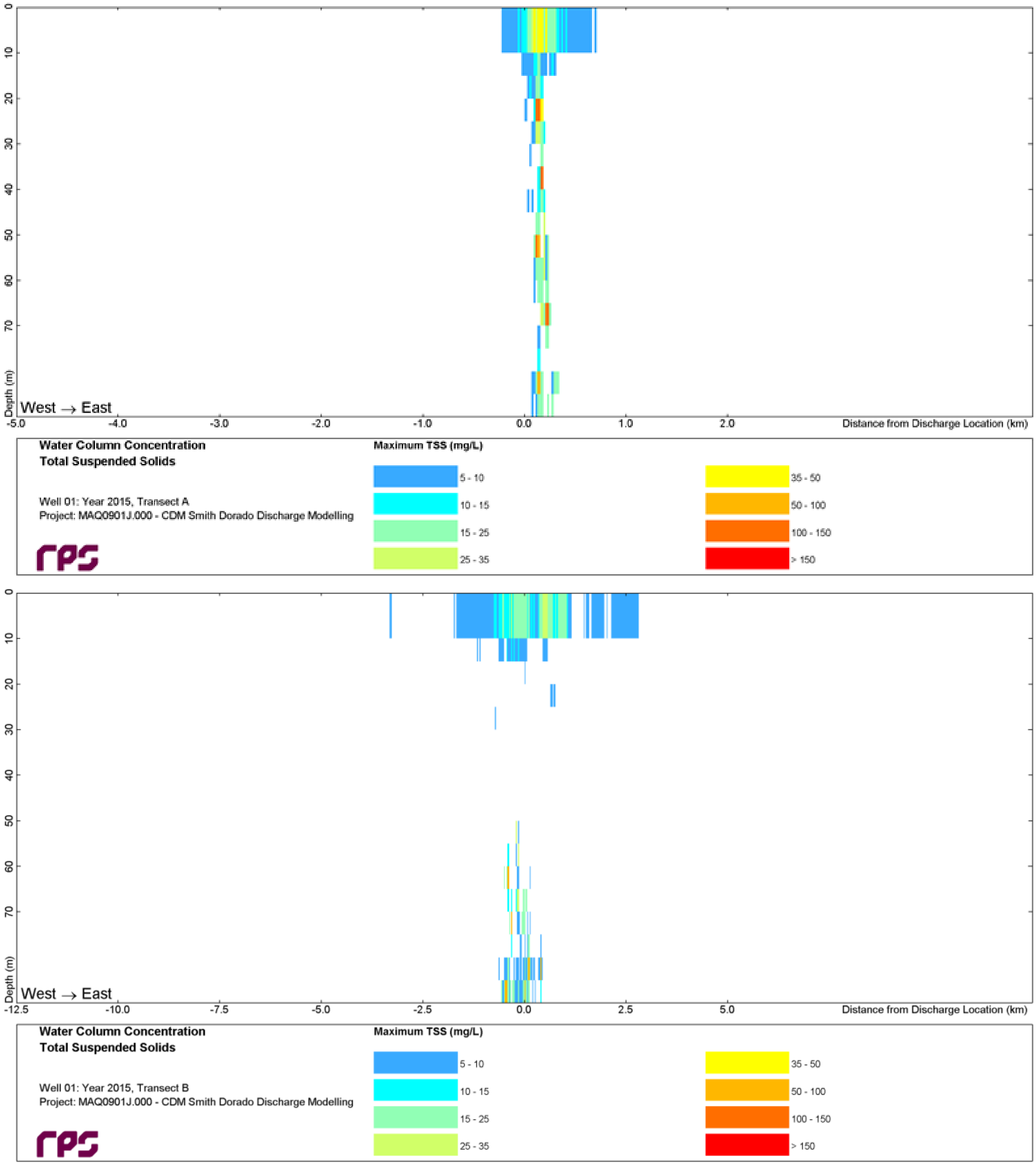


Figure 7-4: Cross-section (a) east–west and (b) north–south of the predicted maximum suspended sediment concentrations within the water column resulting from the drill cuttings and muds discharges for Well 1 over 18 days commencing in El Niño conditions (Attachment 6)

7.2.1.2 Details of Environmental Impacts and Risks

A summary of the analysis of the environmental impact of the discharge of drill cuttings and fluids to the marine environment as a result of Dorado Phase 1 is provided in this section. **Table 7-9** identifies the potentially impacted receptors as a result of the discharge of drill cuttings and fluids within the Project Area.

Table 7-9: Receptors potentially impacted by the discharge of drilling fluids and cuttings

Description of the Impact	Receptor Categories

Localised decrease in water and seabed quality during the drilling activities Deposition of drill cuttings on the seabed Change in fauna behaviour	Water Quality – **Section 7.2.1.2.1** Sediment Quality – Section **7.2.1.2.2** Benthic Habitats – Section **7.2.1.2.3** Marine Fauna – Section **7.2.1.2.4**

7.2.1.2.1 Water Quality

The discharge of drill cuttings from the Dorado WHP location, or potential future tieback locations, will temporarily increase the turbidity and toxicity in the receiving marine environment within the Project Area. The natural turbidity of the water across the Project Area is typically low in the upper 75m of the water column (water depth across the Project Area ranges from more than 70m up to 115m) with increased turbidity generally recorded near the seabed due to resuspension of benthic sediments by seabed currents (**Attachment 5**). The discharge of drill cuttings to the seabed will result in a temporary increase in turbidity and total suspended solids. As presented in **Section 7.2.1.1.2** larger particles (such as rocks, gravel to sand) tend to settle quickly and therefore have little potential to impact water quality (International Association of Oil and Gas Producers 2016).

As cuttings particle size decreases, the settling velocity will typically decrease, and the ratio of residual drilling fluids to cutting size increases. Cuttings may also entrain in the water column and reach neutral buoyancy. This will result in a turbidity plume that will decrease as the plume is diluted and the suspended particles are deposited on the seabed. The increase in total suspended solids from the discharge of drill cuttings will be concentrated in surface waters, and will extend through the water column at the discharge location (**Figure 7-4**). A study undertaken by Hinwood (1994) indicates that a drilling cuttings and fluids plume will have diluted by a factor of at least 10,000 within 100 m of the discharge point. Neff (2005) indicates that within well-mixed ocean waters (similar to that of the Project Area), drilling cuttings and fluids will have diluted by over 100-fold within 10 m of the discharge point. The dilution factor determined by Neff (2005) of 10,000 is widely accepted within industry. Using this dilution factor, it has been predicted that discharges of cuttings and adhered fluids will reach 100 ppm within 100 m of the MODPU within about 16 minutes, assuming a conservative 0.1 m/s current speed (noting the average current speed for the Project Area approximately 0.3 m/s – refer **Attachment 6**). Therefore, changes in water quality associated with increased turbidity are restricted to close to the discharge source. Discharges from the surface are expected to impact a larger area than that of subsea discharges, however, volumes are much lower and drilling cuttings and adhered fluids will disperse rapidly within the offshore marine environment, resulting in a relatively small footprint of water quality change. Neff (2005), states that although total drilling cuttings discharge volumes associated with drilling a well are large, environmental impacts within the water column are low due to the intermittent nature of such discharges.

Dissolved components of the plume, particularly the salts and water-soluble drilling fluid organic additives, dilute rapidly by mixing in the water column. Most of the organic additives in WBM are strongly adsorbed to inorganic cuttings particles and are deposited to the sediments rather than being available in the water column.

There are no known bathymetric features, such as reefs, shoals or banks, within the Project Area. Due to the relatively short duration of the discharge (i.e. only during drilling activities) the potential for decreased water quality to impact upon receptors such as plankton or benthic communities is limited.

Impacts to water quality from the discharge of drill cuttings and fluids typically occur within close proximity of the discharge point, and likely in a northwest and southeast direction, the dominant water movement across the Project Area, driven by the large tidal range (refer **Section 3.2.3**). Very fine cuttings form a very small portion of the total amount of drill cuttings and fluids as they tend to clump together to form larger particles that sink relatively quickly. The potential increase in turbidity levels is therefore expected to be very low. This reduction in light availability is typically intermittent and brief (International Association of Oil and Gas Producers 2016). Increased turbidity from natural events (e.g. cyclones) occurs in the Project Area, and the biotas of the area are adapted to short duration increases in turbidity and therefore no significant adverse impacts are expected.

7.2.1.2.2 Sediment Quality

Following drilling of the conductor section of the wells (where drill cuttings and drilling muds will be discharged directly to the seafloor), the drill cuttings will be discharged into the marine environment from the MODU after being treated by solids control equipment to reduce the concentration of residual drilling fluids. The majority of drill cuttings and residual fluids will be deposited in the area around the discharge location and will form a cuttings pile. The accumulation of cuttings will physically modify the sediments by modifying the particle size distribution. Modelling results indicate the cuttings pile may reach a thickness of up to 126 mm for a single well (**Attachment 6**), which will be largely comprised of coarse cuttings directly under the discharge location. Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with surface discharges are not expected to reach marine sediments at concentrations that will result in notable changes to sediment quality.

The initial development drilling campaign for the Dorado reservoir (10 wells) will result in deposition of drill cuttings at the base of the WHP. Sediments at this location will be considerably modified by the discharges of drill cuttings and fluids, however modelling studies indicate impacts to sediment will decline with increasing distance away from the wells. Modelling for the cumulative deposition of drill cuttings and fluids indicated the maximum thickness would be up to 1,315 mm at the base of the platform, with cumulative cuttings from 10 wells reaching the 1 mm thickness 'no-effects' threshold at a maximum distance of 954 m from the discharge location (**Attachment 6**) and cover a potential worst case area of 2.86 km^2 (assuming deposition in a 954 m radius from the drill centre). It is important to note that the soft sediment and biota at the WHP location is well represented in the area (**Attachment 2**). Similar level of impacts are expected from the discharge of pile drilling cuttings associated with the FPSO anchor moorings, and if required for stabilisation of the WHP GBS.

Cuttings from potential individual future tieback wells are expected to become progressively finer with increasing distance from the well location, with the thickness of deposited cuttings expected to be ≤ 1 mm (considered to represent a low ecological threshold) within a maximum distance of 837 m of the discharge location (single well) (**Attachment 6**). Deposition ≥ 10 mm thickness (representative of a high ecological threshold) for a single tieback well was predicted to extend up to a maximum distance of 251 m from the release location and cover an area of approximately 0.2 km^2. The silty sand/ hard reef substrate to predominantly silty sand, coarse sand with rubble sediment found at each of the tieback prospect locations is also well represented across the area (refer **Figure 3-9, Attachment 2)**.

The coarser sediments deposited directly under the discharge location are unlikely to be resuspended by currents and will gradually be buried by naturally deposited sediments over time.

Finer sediments deposited further will likely be reworked by currents and transported via saltation or as suspended sediments.

The deposition of the drill cuttings and fluids may lead to a decrease in sediment quality in the area within which cuttings will be deposited, noting that benthic habitats in the Project Area are broadly homogeneous (**Attachment 2**). The modelling indicates that for the initial 10 wells drilled from a single location, deposition was expected to be ≤ 1 mm (low ecological impact threshold) within a maximum of 954 m of the discharge location and more than 10 mm (high ecological impact threshold) within a maximum 447 m (**Table 7-8**). However, for a single well (i.e. for future subsea tie backs), deposition thicknesses of ≤ 1 mm and more than 10 mm were predicted to be within a maximum 837 m and 251 m, respectively (**Table 7-7**). Modelling results also indicate that the natural threshold is expected to be reached within 1,115 m from the drilling location for one well, and within 2,871 m for 12 wells (**Table 7-7** and **Table 7-8**). The sandy sediments within this deposition footprint, and the associated benthic communities, are very widely represented in the region (refer **Figure 3-9, Attachment 2** and **Attachment 3**) and are not considered to be particularly sensitive or of high conservation value. Prospects identified for future tiebacks are located within silty sand/ hard reef substrate to predominantly silty sand, coarse sand with rubble, and silty sand to rubble similar to conditions at the Dorado WHP location (**Figure 3-9**). These ecotypes are widely represented in the region.

WBM will constitute most of the drilling fluids discharged to the marine environment. The residual WBM may contain metals (predominantly barium, a component of the commonly used weighting agent barium sulphate), as well as residual organic matter. Microbial degradation of residual organic matter can lead to depletion of oxygen in sediments within the cuttings pile, although this is unlikely to impact upon biota. Upon completion of a well, excess WBM may be discharged to the ocean from the drilling rig but pose little environmental risk or impact beyond a localised, temporary sediment plume.

As mentioned, Barite is one of the main constituents in WBM, which results in elevated levels of barium (Ba) in drill cuttings. Published literature has concluded that barium sulfate associated with the deposition of drill cuttings and fluids does not pose a significant toxicity risk to finfish due to the insolubility of barium sulphate (Payne, 2011). Other chemicals of concern in drill cuttings, either because of their potential toxicity and/or abundance in WBM include arsenic (As), chromium (Cr), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn) (Breuer et al., 2004).

Acidic conditions in anoxic cuttings piles may lead to barium and other heavy metal contaminants present in the barite becoming more soluble, and slowly leaching out(Neff. et al., 2005). Breuer et al. (2008) has also observed that metals in cuttings, migrate either upward into the water column (Ba, Mn, and Fe), or diffuse downward (Cr, Cu and Pb) where they become incorporated into Fe monosulfides as part of seabed sediment. The exposure of these Fe monosulfides to oxygen via bioturbation or advection and/or cuttings resuspension may then lead to the release of the associated metals into the water column (Saulnier and Mucci, 2000; Huerta-Diaz et al., 1998), noting that the release would be gradual over time limiting the release and concentration of metals at any one time.. In a stable cuttings pile with minimal physical disturbance or bioturbation, the fraction of metals in the total cuttings pile that is dissolved and bioavailable remains low. Cuttings piles are expected to mostly remain in a stable condition, with only intermittent disturbance or bioturbation. If used, it is expected that cuttings with NAF/ SBM will clump together in large particles that settle rapidly to the seabed (Neff et al. 2000) and will be more likely to be concentrated around the release location , in contrast to cuttings with residual WBM. NAF/SBM may contain a range of synthetic hydrocarbons such as paraffins and olefins, which have low potential for toxicity and bioaccumulation, but may persist in the environment. Cuttings with residual NAF/SBM are expected to have a higher concentration of residual organic matter compared to WBM. The seabed affected by cuttings with residual SBM have greater potential for oxygen reduction via microbial degradation and associated changes to sediment chemistry (e.g. modified reduction/oxidation (redox) potential). Due to the expected aggregating behaviour of the NAF/ SBM cuttings, it is expected to result in a smaller impacted area than that drilled with WBM. Excess NAF/ SBM will not be discharged to the marine environment and may either be reused or disposed of onshore.

For cement discharges, the potential for toxicity is associated with the chemical additives that are added to cement mixtures; therefore, toxicity associated with the discharge of cement is limited to the subsurface release of cement (not discharge of dry cement). Terrens et al. (1998) suggest that once the cement has hardened, the chemical constituents are locked into the hardened cement. Consequently, the extent of this hazard is limited to the waters directly adjacent to the displaced subsea cement (expected to be 10 to 50 m from the well) or pelagic waters within 150 m of the well (BP Azerbaijan, 2013). Overspill of cement will alter physical sediment properties in the long-term, immediately adjacent to the well (within less than 50 m).

7.2.1.2.3 Benthic Habitats

The discharge of drill cuttings and residual fluids has the potential to impact benthic communities due to the potential physical and chemical changes to sediments (refer to the above section). As presented earlier the deposition of cuttings has the potential to smother sessile benthic organisms, with effects predicted to occur at a deposition thickness more than 6.5 mm (International Association of Oil and Gas Producers 2016).

The Project Area is characterised as soft bottom substrate of fine sediments (typically more than 90% cover) with discrete areas of filter-feeder communities, and the seabed is relatively flat in topography throughout. The soft sediment (silt/sand sediment) and hard substrate (low relief hard substrate) habitats identified in the habitat survey (RPS 2020d) within the Project Area were well represented across the survey area.

The majority of the Project Area comprises habitats composed largely by fine sediments (typically more than 90% cover) but it also contains areas of hard pavement reef, which represents habitat for forming filter feeder communities, especially whip corals, gorgonians and sponges, typical of the NWS (**Figure 3-9**, **Attachment 2**). Benthic habitat surveys revealed predominantly soft sediment habitats, with low sand waves (ripples) and scattered rocky reef over the Project Area (**Attachment 2**). The sediment habitats support low abundance of infauna and epifauna, and the rocky substrates support low to medium density filter-feeder communities and other fauna including fish at low densities (**Attachment 2**). These are widely represented in the region and are considered to be of low sensitivity. There are no high conservation features or fish habitat identified within the Project Area (RPS 2020d). Mobile fauna associated with benthic habitats, such as fish and crustaceans, are expected to temporarily move away from areas subject to relatively high levels of deposition and are unlikely to experience injury or mortality as a result of the discharge of drill cuttings and fluids.

Benthic communities subject to deposition at or above the high threshold are predicted to be restricted to within 251 m and 457 m from the drilling location for a single and twelve consecutive wells respectively (**Table 7-7** and **Table 7-8**). Sessile benthic fauna within this deposition footprint may experience smothering that may result in mortality. The recovery of the area subject to deposition ≥ 10 mm thickness will potentially take many years, depending on natural sedimentary processes. Recovery may be linked to the deposition of relatively fine natural sediments on the coarse sediments in the cuttings pile to create suitable habitat. Studies of the recovery of benthic communities on visible cuttings piles (consistent with the area subject to drill cuttings and fluids deposition ≥ 10 mm) indicated considerable recovery within three years (particularly where deposition was thinner), however the benthic communities had not yet recovered to be similar to predischarge conditions or the surrounding unaffected seabed (Gates and Jones 2012).

Benthic communities subject to deposition between 1 mm and 10 mm thickness are less likely to experience mortality but may experience sub-lethal impacts (International Association of Oil and Gas Producers 2016), such as impaired feeding due to clogging of filter feeding organs and increased energy expenditure from removing sediment from burrows. Modelling results indicate these impacts will be restricted to within 837 m (**Table 7-7**) and 954 m (**Table 7-8**) from the drilling location for a single well and twelve consecutive wells respectively. Recognising that sediment deposition from drill cuttings and fluids is in addition to natural processes, benthic communities subject to deposition of drill cuttings and fluids of less than 1 mm thickness are unlikely to experience impacts from physical deposition of cuttings, as this thickness is consistent with natural sedimentary deposition rates.

Changes in sediment chemistry may impact upon benthic communities, particularly changes in oxygen demand from biodegradation of organic compounds in residual drilling fluids. Trannum *et al.* (2010) examined the effects of cuttings with residual WBM and found a significant reduction in abundance and diversity of benthic infauna with increasing cuttings thickness compared to natural sediment and suggested that changes in sediment chemistry were a significant factor. Increased oxygen demand resulting from aerobic degradation of organic compounds in the WBM were suggested as a cause, along with fluxes in silicon and phosphorous (Trannum et al. 2010). The effects at low sediment thickness (less than 10 mm) were much less apparent than relatively high rates of burial. These results are consistent with findings from other investigations of potential impacts of WBM (Smit et al. 2006). The increased oxygen demand will diminish over time as organic material is consumed and natural conditions return.

Given the nearest KEF, the Ancient Coastline and 125 m Depth Contour, lies approximately 23 km from the WHP, no impacts to the environmental values of any KEFs from the deposition of drill cuttings or fluids will occur. The nearest prospect that may be tied back to the FPSO is approximately 3.2 km from the Ancient Coastline and 125 m Depth Contour, which is a greater distance than the modelled furthest extent of drill cuttings (cumulative 10 wells from a single drill centre and considered worst case for a future tieback) of 2.8km. Applying the same reasoning, no impacts to KEFs from the discharge of drilling fluids and cuttings for tieback wells will occur based on the modelling results presented in **Table 7-7**and **Table 7-8.**

7.2.1.2.4 Plankton

Studies by Smit et al. (2008) indicated that phytoplankton and filter-feeding zooplankton typically exhibit greater effects from suspended solids from drilling fluids and cuttings and suggest that these biotas are less well-adapted to relatively high concentrations of suspended sediments than benthic biota. Smit et al. (2008) suggested that impacts to zooplankton were primarily the result of physical effects to filter-feeding and respiration organs, while impacts to phytoplankton were the result of reduced light levels. It is expected that drilling cuttings and fluids discharges will have a negligible effect on plankton populations at a measurable level. Jenkins and McKinnon (2006) identified suspended sediment concentrations greater than 500 ppm will likely result in a measurable impact to larvae species of most fish species, with concentrations of 100 ppm effecting larvae species of most fish if exposed to for longer than 96 hours. Changes in water quality associated with increased turbidity are likely to be restricted to close to the discharge source.

Assuming the drilling fluids dilute 100-fold within 10 m of the discharge source (Vik et al. 1996), the drilling fluid concentrations are likely to fall below acute toxicity thresholds (10,000 ppm) within 100 m of the discharge source, assuming that 100% fluids concentrations and adopting a conservative current speed of 0.1 m/s.

Studies of zooplankton indicate effects of drilling fluids and cuttings at concentrations greater than 100 ppm are unlikely, based on 96 hours exposure duration experiments. Concentrations greater than 100 ppm for more than 96 hours during the drilling activities would only occur in the immediate vicinity of the discharge location.

7.2.1.2.5 Marine Fauna

The toxicity of widely used NAFs/SBMs is generally considered low, with WBMs inherently less toxic. Neff (2005) states that in well-mixed ocean waters (as is likely to be the case within the drilling area), drilling mud is diluted by more than 100-fold within 10 m of the discharge point, indicating that, following dilution, concentrations would be well below acute impact levels. This is further demonstrated by Melton et al. (2000), who used modelling to demonstrate that WBM and synthetic based fluids cuttings and solids within the water column fall below the United States Environment Protection Agency (USEPA) minimum 96-hour LC50 for drilling fluids within the first few metres of a surface discharge point. Various other studies support the understanding that only organisms very close to the discharge point will be exposed to chemical concentrations above toxicity thresholds (Boehm et al., 2001; Kinhill, 1998; IRCE, 2003; SKM, 1996; Melton, 2000).

The transfer and accumulation of contaminants (heavy metals, hydrocarbons) through trophic levels (known as biomagnification) resulting from marine organisms feeding in proximity to drilling locations is one potential pathway that could lead to accumulation of contaminants in higher order marine fauna (e.g. fish, marine reptiles, marine mammals). However the area impacted by drill cuttings deposition represents a fraction of the total foraging area for mobile marine fauna, greatly reducing the potential for biomagnification in mobile marine fauna. Also, given the limited bioavailability of contaminants within drill cuttings, combined with marine species natural avoidance of turbid stretches of water, risk of biomagnification to mobile marine fauna is further reduced. This is supported by Hartley et al.(2003) finding that marine fauna, specifically fish, starfish and crabs; that are exposed to drill cuttings in sediments do not bioaccumulate significant quantities of metals (Hartley et al., 2003).

There is some evidence of potential for bioavailability for some metals, such as Pb and Zn, which are present in cuttings piles. However, the estimated concentrations are likely insufficient to cause harmful effects in marine fauna (fish, crabs) living on or near cuttings piles (OSPAR, 2019), with potential impact limited to species living within the cuttings and sediment matrix (benthic infauna).

There is no evidence to support the risk of bioaccumulation of contaminants to fish exposed to drill fluids and cuttings. Published literature indicates that the relative insolubility of barium sulfate in drilling fluids and cuttings does not pose a significant toxicity risk to finfish (Payne, 2011). Furthermore, there is no indication that the levels of trace metals in fish and shellfish collected in close proximity to existing offshore installations are significantly different from natural background concentrations (Bakke et al., 2013). Neff et al. (2000) also found that drilling cuttings are of little risk to water column biota due to WBMs having low toxicity levels and are considered by OSPAR to pose little or no risk to the environment (PLONOR). If contingency NAFs/SBMs are used, returns will be treated to reduce oil on cuttings (OOC) to 10%, which is aligned with Santos and industry standards. As the discharges of drill fluids and cuttings will be localised and subject to rapid dilution, and considering the transitory nature of fish movements, impacts to fish populations and commercial fisheries are unlikely.

There is no known significant benthic habitat or benthic features within the Project Area that would result in the aggregation of marine fauna (fish, marine mammals, marine reptiles) within the Project area. Mobile marine fauna, such as fish, marine mammals and marine reptiles, are expected to actively avoid discharge plumes and associated turbidity and toxicity within the water column.

Refer to **Section 3.3** for the full list of Marine species listed under the EPBC Act within the Project Area. The Project Area intersects with a foraging BIA for the whale shark. Within the North West Shelf, Whale Sharks are primarily found in seasonal aggregations around Ningaloo Reef, between March and June. However, they have also been reported from oceanic and coastal waters across the region (Wilson et al. 2006). Based on the foraging habitat preferences of whale sharks and the results of tagging studies, the foraging BIA overlap with the Project Area is unlikely to represent critical foraging habitat. The BIA may be used by migrating whale sharks moving to and from Ningaloo Reef, however tagging studies indicate most tagged whale sharks to not use the majority of the BIA when moving away from Ningaloo Reef (**Figure 3-17**). The approved Conservation Advice for Whale Sharks (Threatened Species Scientific Committee 2015d) states that the main threat to the species occurs outside Australian waters. Whale Sharks are highly mobile, therefore they are not expected to be affected by negligible increases in toxicity and short-term turbidity increases.

The Project Area overlaps the Humpback Whale migration BIA. Humpback Whales migrate between May and November each year; with peak northern migration occurring during June and July, and no noted peak for the southern migration (Threatened Species Scientific Committee 2015a).

The EPBC PMST also shows that five species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) are known or are likely to occur within the Project Area. The Project Area overlaps with the flatback turtle internesting BIA centred around North Turtle Island, approximately 39km from the Project Area. The Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) identifies chemical and terrestrial discharge as a threat; however, this is mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources.

Drill fluids and cuttings discharges within the Project Area are localised and rapidly dilute, and given that fish, marine mammals and marine reptile species are highly mobile and transitory in nature, the impacts of these discharges are expected to be negligible. The expected volumes of discharges would not be significant enough to cause any notable impact to marine fauna, in the well-mixed marine environment. The discharge of drill fluids and cuttings will impact upon seabed habitat below the cuttings pile, particularly where the thickness of the cuttings deposition is ≥ 10 mm. This may result in a highly localised, temporary behavioural impact to marine fauna such as turtles and fishes (e.g. avoidance). Drill cuttings accumulation on seafloor sediments can cause changes in the physical properties and chemical composition of the seabed sediments. However, impact is limited to species living within the cuttings-sediment matrix (benthic infauna), and there is no evidence to support the bioaccumulation of contaminants to fish, starfish and crabs and higher order species (marine reptiles and cetaceans) due to the limited bioavailability of contaminants within drill cuttings and mobile marine species avoidance of turbid stretches of water from metals.

As impacts to fish are not expected from drilling fluids and cuttings discharges, indirect impacts to fish populations and commercial fisheries are not expected.

7.2.1.3 Summary of Impact Evaluation

The controls outlined in **Table 7-10** will be implemented by Santos to manage the potential impacts of the discharge of drilling fluids and cuttings during Dorado Phase 1.

Table 7-10: Summary of impacts, EPOs, controls and consequence evaluation of drill cuttings and fluid discharges during Dorado Phase 1

EPOs	
EPO1A: Impacts to sediment quality and water quality as a result of Dorado Phase 1 drilling fluids and cuttings discharges restricted to a 1 km radius from Dorado facilities. **EPO2A**: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area. **EPO3A**: No mortality or significant[18] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of drilling fluids and cuttings.	
Receptor	**Impact**
Water Quality	Localised decrease in water quality during drilling operations.
Sediment Quality	Deposition of drill cuttings during drilling operations.
Benthic habitats	Localised smothering and loss of habitat.
Marine Fauna (benthic infauna)	Oxygen degradation and bioaccumulation of contaminants in benthic infauna.
Control Measures (CM)	
CM1: All wells to be drilled using WBM, with NAF/SBM only to be used where technical requirements preclude the use of WBM. **CM2**: Santos chemical selection process will be implemented to select drilling chemicals, muds and fluids with low environmental risk, while meeting technical requirements. **CM3**: Drilling fluids inventory will be developed and tracked to reduce discharge of excess powders, brines, and drilling fluids. **CM4**: Drill cuttings will be processed on the MODU to recover drilling fluids and reduce residual fluids content prior to overboard discharge. **CM5**: An assessment of drill cuttings and fluids discharges will be undertaken prior to drilling future tieback wells to ensure impacts to environmental values and sensitivities are within acceptable levels. **CM6**: Benthic habitat surveys will be undertaken prior to drilling at tieback locations to identify and avoid sensitive benthic habitat.	
Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

[18] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013)

7.2.1.4 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by the discharge of drilling fluids and cuttings during Dorado Phase 1 compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-11** and **Table 7-12.** The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case consequence for the discharge of drilling fluids and cuttings was evaluated as minor (**Table 7-10**). This consequence is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from discharge of drilling fluids and cuttings are acceptable.

Table 7-11: Demonstration of acceptability for the discharge of drilling fluids and cuttings

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	The risks and impacts from discharge of drilling fluids and cuttings are consistent with the principles of ESD based on: + the environmental values and sensitivities within the Project Area are not expected to be substantially impacted (refer **Section 7.2.1.2**), and + the precautionary principle has been applied through habitat surveys of the existing environment (**Attachment 2**) and modelling studies of the discharge of drilling fluids and cuttings studies (**Attachment 6**) where knowledge gaps were identified.
Internal Context	The management of drilling fluids and cuttings discharges is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of potential impacts and risks.
MNES	**Threatened Migratory Species** The evaluation of impacts and risks indicates or significant impacts[19] to marine species listed under the EPBC Act including threatened and migratory species will not credibly result from the discharge of drilling fluids and cuttings from Dorado Phase 1. Alignment of Dorado Phase 1 with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided below. Commonwealth Marine Environment - Conservation Advice The below conservation advice and recovery plans identify habitat degradation as a threat to threatened species. Impacts to benthic habitats from the discharge of drilling fluids and cuttings will be highly localised. The benthic habitats that may be affected are very widely distributed throughout the Project Area and beyond. As such,

[19] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Acceptability Criteria	Demonstration of Acceptability
	Santos considers the impacts of drilling fluids and cuttings to not be inconsistent with applicable conservation advice: + Approved conservation advice for *Pristis clavata* (dwarf sawfish) (Threatened Species Scientific Committee 2009), + Approved conservation advice for *Pristis pristis* (largetooth sawfish) (Threatened Species Scientific Committee 2014b), and + Approved conservation advice for *green sawfish* (Threatened Species Scientific Committee 2008a). + Conservation advice for *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b) + Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee 2015c) **Commonwealth Marine Environment – Recovery Plans** Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b) - This recovery plan identifies habitat degradation as a threat to sawfish. Impacts to benthic habitats from the discharge of drilling fluids and cuttings will be highly localised within the Project Area. The benthic habitats that may be affected are very widely distributed throughout the Project Area and beyond. The closest Sawfish BIA (for pupping, nursing and foraging) is approximately 87 km from the southern extent of the Project Area. Santos considers the impacts of drill cuttings and fluids discharges to not be inconsistent with the recovery plan. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) - This recovery plan identifies chemical discharges as a threat to marine turtles. Impacts from chemical discharges (e.g. drilling fluids) may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of drill cuttings and fluids discharges to be consistent with the recovery plan. Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPac, 2013b) – This recovery plan identifies habitat modification as a potential threat to White Sharks. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges (e.g. drilling fluids) may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of drill cuttings and fluids discharges to not be inconsistent with the recovery plan. Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a) – this recovery plan identifies acute and chronic chemical discharge as a threat to Blue Whales. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges (e.g. drilling fluids) may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of drill cuttings and fluids discharges to not be inconsistent with the recovery plan.

Acceptability Criteria	Demonstration of Acceptability
	Recovery Plans / Conservation Advices for other species that may occur in the Project Area do not identify habitat degradation as a key threat; or have any explicit relevant objectives or management actions related to habitat degradation.
Other Relevant Requirements	Management of the impacts and risks from the discharges of drilling fluids and cuttings associated with Dorado Phase 1 are consistent with relevant legislative requirements, including the management of emissions and releases of mercury and mercury compounds as per the obligations under the Minamata Convention on Mercury. At present there are no specific guidelines in the Minamata convention regarding acceptable levels of mercury in drilling fluid releases. The ANZG 2018 provide for guidance and levels of protection for both water and sediment associated with Mercury. Santos' management of the discharge of drilling fluids and cuttings is consistent with industry practice in Australia, for example **CM2** chemical selection process and **CM**4 reducing residual fluid volumes discharged overboard The chemical selection process adopts relevant changes in legislation and ANZG.

Table 7-12: Demonstration of acceptability of the discharge of drilling cuttings and fluids against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels (RSAL)	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[20] are acceptable. **RSAL4**: Substantial[21] impacts to water quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	The discharge of drilling fluids and cuttings will result in a temporary reduction in water quality at the discharge location, primary due to increased total suspended solids and turbidity. Modelling and operational experience indicates these impacts will be limited to a small area around and directly below the discharge location. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity will be maintained outside the immediate vicinity of the discharge location, and that no substantial impacts to water quality will be observed within 1 km of the discharge point. It is also anticipated that water quality will recovery rapidly once the discharge ceases.
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity[17] are acceptable.	The discharge of drilling fluids and cuttings will result in a decrease in sediment quality at drilling locations. Modelling studies indicate that the potential for substantial impacts to sediment quality are highly localised around the discharge location. The controls will reduce the amount of potential sediment contaminants that are discharged with

[20] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[21] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

Receptor-specific Acceptable Levels (RSAL)	Demonstration of Acceptability
RSAL6: Substantial[18] impacts to sediment quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	the drilling fluids and cuttings. The impacts to sediment quality will not result in changes to the environment beyond a highly localised environment around the drilling location. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity will be maintained outside the vicinity of the discharge location, and that no substantial impacts to sediment quality will be observed within 1 km of the discharge location.
RSAL8: No significant[22] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities	The benthic communities within the Project Area that may be impacted by drilling fluids and cuttings discharges are broadly represented in the region and are not considered to be particularly sensitive. Prior to undertaking future tieback activities, a habitat survey will be completed to identify and avoid potentially sensitive benthic habitat. The discharge of drilling fluids and cuttings will not result in substantial impacts to these benthic habitats.
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1. **RSAL19**: No negative impacts to the economic viability of the commercial fish resources.	Impacts from drill cuttings and fluid discharges within the Project Area are localised (less than 0.1% of the project area), and given that fish, marine mammals and marine reptile species are transitory in nature, the impacts of these discharges will not result in significant impacts to listed threatened, migratory or cetacean species under the EPBC Act. Drill cuttings accumulation on seafloor sediments can cause changes in the physical properties and chemical composition of the seabed sediments. Chemical selection process will be implemented to select chemicals for the drilling campaign with low environmental risk, reducing the likelihood of any impacts. Due to low toxicity of drilling fluids and limited bioavailability of contaminants within drill cuttings, bioaccumulation is not expected. In addition, mobile marine species are expected to either avoid turbid stretches of water or pass through, limiting their exposure to contaminants in drilling fluids and cutting discharges and the potential for bioaccumulation. Potential bioaccumulation impacts are limited to species living within the cuttings-seabed matrix (benthic infauna) due to prolonged exposure to contaminants. However, the potential transfer and bioaccumulation of contaminants through trophic levels from feeding by marine organisms in proximity to drilling locations is not anticipated, due to the drill cuttings piles representing only 0.1% of the project area. Accordingly, no impact at a population level is expected for higher order marine species (fish, cetaceans and marine reptiles). As no impacts to fish populations are expected from drilling fluids and cuttings discharges (discharges will be localised, are expected to dilute

[22] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

Receptor-specific Acceptable Levels (RSAL)	Demonstration of Acceptability
	rapidly and fish are transitory in nature) indirect impacts to fish populations and commercial fisheries are not expected. The negligible impacts associated with drilling fluids and cuttings discharges are not inconsistent with relevant recovery plans.

7.2.2 Discharges – Produced Water Discharge

7.2.2.1 Description of the Event

PW is the amalgamation of the formation water (water that is naturally present in the reservoir) and condensed water (water that is condensed out of the reservoir hydrocarbons due to temperature and pressure changes during extraction and processing). The elevated salinity of the formation water drives the overall salinity of the PW.

PW is returned to the FPSO via the subsea wells and flowlines during extraction of hydrocarbons (e.g. oil and natural gas). The composition of PW is a complex mixture of dissolved and particulate organic and inorganic chemicals (Neff et al. 2011). The composition of PW will vary depending on several variables, including the attributes of the reservoir geology and when the reservoir and production characteristics change (International Association of Oil and Gas Producers 2005; Neff et al. 1992; OSPAR Commission 2014). PW generated at offshore petroleum facilities is generally warmer and more saline than seawater.

The characteristics of the PW discharge will change during the life of Dorado Phase 1. During the initial period of operations, it is not expected that formation water will be extracted from the reservoir. The PW volume will therefore be small and mostly made up of condensed water with intermittent discharges of treated PW to the marine environment. As the formation water breaks through, the amount of PW generated and requiring treatment prior to disposal will gradually increase over time. The maximum rate of water production per facility design is 4,350 m^3/day, although in practice is expected to be much lower than this as the facilities and well operations teams manage production across the reservoir to minimise water production. Notwithstanding, the impact assessment has assumed continuous discharge of PW to the marine environment at a maximum design rate of 4,350 m^3/day.

PW will be discharged to the marine environment from the FPSO during hydrocarbon processing throughout the operational life of Dorado Phase 1 (**Section 5**). The discharge will be via a single discharge point that is planned to be approximately 10 m below the sea surface. This discharge scenario has been computationally modelled to inform the nature and scale of the PW discharge in the environment. The modelling studies are summarised in **Section 7.2.2.1.2** and provided as **Attachment 7**.

The PW stream is expected to include potential contaminants from the reservoir, such as hydrocarbons and metals, as well as residual amounts of production chemicals. As Dorado Phase 1 is not yet producing, it is not possible to undertake chemical characterisation or ecotoxicological tests on the PW stream to define its characteristics. A description of expected and representative potential contaminants that are likely to be present in the PW are provided in **Section 7.2.2.1.1**. For the purpose of impact assessment, the actual discharge concentrations for OIW for the PW will be reduced to ALARP and are likely to be less than 30 mg/L (but the actual concentrations will be determined during FEED). The PW treatment system onboard the FPSO will be designed to reduce the residual OIW to less than 30 mg/L prior to marine discharge.

7.2.2.1.1 Characteristics of Produced Water

PW often contains small amounts of naturally occurring contaminants, including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons (organic compounds that are made out of only carbon and hydrogen atoms), organic acids, and phenols), and inorganic compounds (e.g. soluble inorganic chemicals and dissolved metals).

Hydrocarbons

Hydrocarbons in the PW will consist of both relatively low and high molecular-weight compounds. Hydrocarbon solubility generally decreases with increasing molecular weight, and aromatic hydrocarbons also tend to have increased water solubility and have the greatest potential for toxicity compared to non-aromatic hydrocarbons of equivalent molecular weight (Neff et al. 2011). These compounds include benzene, toluene, ethylbenzene and xylene (BTEX) and polycyclic aromatic hydrocarbons (PAHs). Higher molecular weight compounds typically pose less environmental risk and are largely recovered during the production process and the PW treatment system onboard the FPSO. Residual high molecular-weight hydrocarbons will occur as very fine entrained oil droplets.

BTEX compounds are the most common hydrocarbon component of PW. BTEX are highly volatile and do not persist in the environment; upon release, evaporation and dilution rapidly reduce the concentration of BTEX in the receiving environment (Ekins et al. 2005; International Association of Oil and Gas Producers 2005; Neff et al. 2011). BTEX is known to be toxic to marine organisms and has been shown to result in developmental defects (Fucik et al. 1995) but does not significantly bioaccumulate (Neff 2002).

PAHs are less volatile and soluble than BTEX and have greater potential to accumulate in the marine environment (Neff et al. 2011). PAHs can be broadly divided into two types: low molecular weight and high molecular weight. PAHs dissolved in PW are predominantly low molecular weight; and, while toxic, they are neither mutagenic nor carcinogenic (although their metabolic by-products may be) (International Association of Oil and Gas Producers 2005). Higher molecular-weight PAHs are rarely detected in treated PW due to their low aqueous solubility. These compounds are primarily associated with dispersed oil droplets, which are removed by the production process and PW treatment system (Neff et al. 2011; Schmeichel 2017). PAHs are generally removed from the water column through volatilisation to the atmosphere upon reaching the sea surface, particularly the lower molecular-weight fractions (Schmeichel 2017). PAHs can also degrade in the water column, with half-lives ranging from less than a day to several months, with the more abundant and lower molecular-weight compounds being more degradable (International Association of Oil and Gas Producers 2002).

Dissolved Solids

PW typically contains a range of dissolved solids. The most abundant inorganic ions in high-salinity PW are, in order of relative abundance, sodium, chloride, calcium, magnesium, potassium, sulphate, bromide, bicarbonate, and iodide (Neff et al. 2011). Heavier metals most frequently present in PW include barium, iron, manganese, mercury, and zinc (Neff 1987).

The heavier metals are potentially toxic. With the exception of iron, heavy-metal guideline values for marine water quality are provided in the *Australian and New Zealand Guidelines for Fresh and*

Marine Water Quality (Commonwealth of Australia and New Zealand Government 2018). Dissolved heavy metal concentrations in PW are typically low. Metals such as iron and manganese may precipitate out of solution once the PW is exposed to oxygen (PW is typically anoxic in the reservoir), with other metals potentially also being co-precipitated (Neff et al. 2011). Any precipitated solids discharged to the marine environment will be present as very fine particles. These particles will remain suspended in the water for long periods of time and consequently will be dispersed over a wide area.

Salinity

PW discharge salinity for Dorado Phase 1 is estimated to range between 20 ppt and 30 ppt and most likely will be around 25.5 ppt. The salinity of seawater ranges between 32 and 36 ppt.

Nutrients

The presence of elevated ammonia concentrations in some PW streams have been shown to elicit toxicity and/or eutrophication within receiving waters (Neff et al. 2011). Other plant nutrients, such as nitrate and phosphate, are usually found in low concentrations in PW.

Temperature

PW usually has a naturally high temperature due to exposure to geothermal heat in the reservoir. The temperature of PW discharged from the FPSO is expected to vary between 45°C and 60°C. Once discharged into the marine environment, PW cools through mixing with the receiving waters.

Process Chemicals

Chemicals may be used in the wells and production system to aid in the recovery and pumping of hydrocarbons; protect the production system from corrosion; and facilitate separation of oil, gas, and water. Examples include reverse emulsion breakers, scale and corrosion inhibitors, and oxygen scavengers. These are used sparingly to reduce operating costs; however, residual chemicals may be discharged in small quantities in the PW. The PW therefore may contain traces of added process chemicals, such as biocides, corrosion inhibitors, scale inhibitors, emulsion breakers, coagulants or flocculants, and oxygen scavengers, which are required for the production operations (Johnsen et al. 2004; Neff 2002). All these chemicals may be used during Dorado Phase 1 operations.

7.2.2.1.2 Produced Water Discharge Modelling

Numerical modelling studies were commissioned to inform the environmental impact assessment regarding the discharge of PW. PW discharges were modelled to predict the likely extent of the discharge plume and the dilution of PW in the marine environment. The modelling studies included near- and far-field modelling of dilution for summer, winter, and transitional conditions. The model was based on the characteristics in **Table 7-13**. Note alternatives for the discharge height were modelled as part of the options analysis in **Section 5** and 10 m BSL selected as the preferred option based on better environmental outcome. The model outputs for the seasonal results per case were combined and presented on an annualised basis. The modelling report is provided in **Attachment 7**.

Table 7-13: Summary of PW discharge modelling characteristics

Parameter	Description / Value
Outlet characteristics	
Location	FPSO
Number of ports	1
Outlet pipe orientation	Vertical (downwards)
Outlet pipe internal diameter (m) [in]	0.35 [13.78]
Flow velocity on exit (m/s)	0.52
Discharge port height/depth	10 m below sea surface
Discharge characteristics	
Flow rate (m^3/day) – maximum flow rate	4,350
Duration	Continuous
Discharge salinity (ppt)	25.5
Discharge temperature (°C)	45 to 60

A custom composite regional hydrodynamic model for the Project Area, comprising both tidal (HYDROMAP) and mesoscale (HYCOM) models, was used to inform the produced water modelling studies. The tidal, mesoscale, and composite models were validated against oceanographic observations, including data collected within the Project Area, and showed strong agreement with oceanographic observations (**Attachment 7**).

Two environmental criteria were used for the PW modelling study, as follows:

+ The World Bank Group's *Environmental Health and Safety Guidelines for Offshore Oil and Gas Development* (International Finance Corporation 2015) cooling water discharge guideline of '*no more than 3°C at edge of the zone where initial mixing and dilution take place*' was used as a guide due to the absence of any formally recognized PW discharge criterion; and
+ Maximum plume extent with far-field modelling results are presented as a range of dilution contour maps. This approach permits interpretation of the modelling results based on dilutions required to achieve particular environmental outcomes (e.g. reducing the concentration of potential contaminants below the predicted no-effect concentration derived from the species protection levels for water quality presented in the *Australian and New Zealand guidelines for fresh and marine water quality* (Commonwealth of Australia and New Zealand Government 2018) or – for contaminants not included in the guidelines – from published concentrations using methods aligned with the guidelines).

Target dilution thresholds for PW are typically based on chemical characterisation and ecotoxicity testing of the PW. This information is used to determine the number of dilutions after which the PW will no longer pose an environmental risk to the receiving environment. This information can only be collected once the FPSO commences operation and hence is unavailable to inform this impact assessment. A predicted no-effect concentration of 70.5 µg/L has been established for dispersed OIW (OSPAR Commission 2014). This predicted no-effect concentration was developed from toxicity data from marine species from five taxonomic groups (OSPAR 2014; Smit et al. 2009). The predicted no-effect concentration values for naturally occurring substances in PW were compiled in support of OSPAR Recommendation 2012/5 and Guidelines 2012/7 (OSPAR 2012a; OSPAR 2012b). Given OIW is a notable potential contaminant and that concept design for the PW treatment system will reduce OIW to less than 30 mg/L as the detailed engineering has not yet been undertaken, a target dilution of 1:425 is required to assign a zone beyond which there are no predicted impacts to the marine environment from OIW.

This target dilution of 1:425 is considered conservative and is expected to overestimate potential impacts based on Santos' operational experience:

+ Once stabilised, the PW treatment system is expected to consistently reduce OIW to less than 30 mg/L whereas the dilution factor is based on 30 mg/L; and
+ Target dilutions based on predicted no-effect concentrations derived from PW chemical characterisation and ecotoxicity testing at other facilities on the NWS are generally well below a 1:425 target dilution.

Near-field Modelling Results

The near-field mixing and dispersion of the PW discharge was simulated using the 3-D flow model, CORMIX (**Attachment 7**). CORMIX is a mixing-zone model and decision-support system for environmental impact assessment of mixing zones. The near-field model was used to predict the movement and dilution of the PW plume where the plume's inertial forces and buoyancy are the main processes forcing the dilution of the plume.

The near-field modelling of the PW discharge predicted the following:

+ Discharge height and current speed have a strong effect on PW discharge. The lowest dilutions predicted were identified under weak currents with high dilutions predicted under increasing current speeds;
+ Temperature of the PW plume was predicted to be within 3°C of the ambient (background) temperature within 100 m from the FPSO discharge location. The PW plume temperature was generally predicted to return to ambient water temperature within 15 m (i.e. horizontally) from the release location;
+ Depth of the plume was between approximately 10 and 12 m below the sea surface. This provides a greater vertical distance for the plume to rise under buoyancy and entrain with the ambient waters;
+ A maximum near-field horizontal distance of 129.7 m under higher current speeds with plume diameter predicted to be approximately 4 m (**Figure 7-5**); and
+ Average dilution factors ranged from 1:85 to 1:981 at the end of the near-field zone; hence, the 1:425 target dilution may be met within the near-field zone under some conditions.

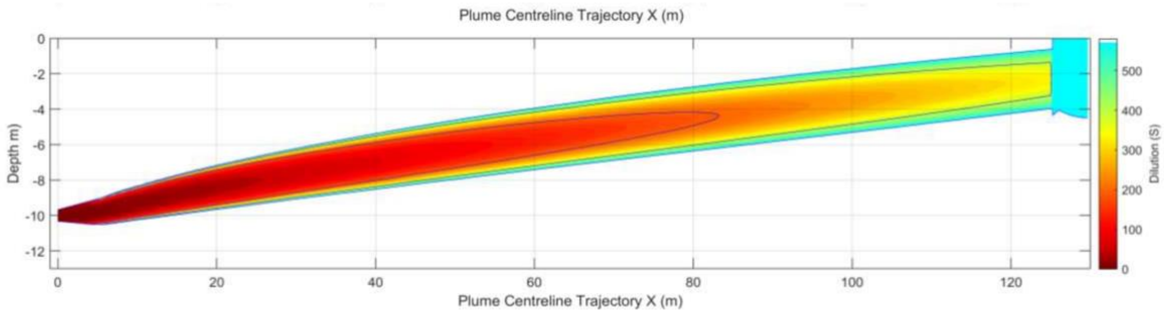


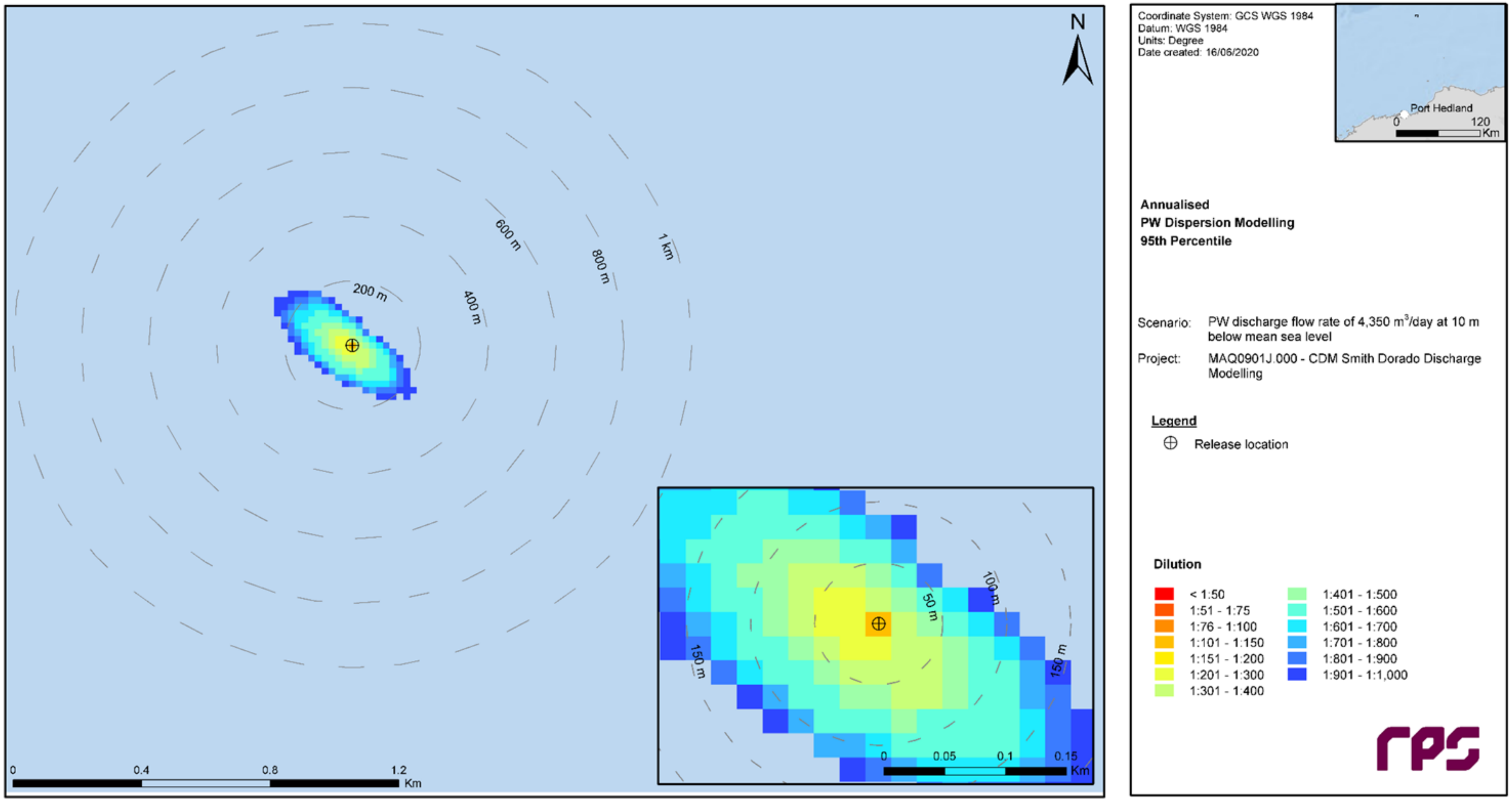
Figure 7-5: PW discharge cross-section at 10 m below sea surface for a 4,350 m^3/day discharge rate under strong current conditions (annualised results)

Far-field Modelling Results

The far-field modelling dilution of the PW discharges was predicted using the 3-D discharge and plume behaviour model, MUDMAP (**Attachment 7**). The far-field modelling simulated the processes once the transition from the near-field dilution has occurred (i.e. inertia and buoyancy no longer account for most of the mixing of the plume). Dilution of the PW plume in far-field modelling is driven by water currents. The far-field model simulated processes such as the potential for localised build-up when current speeds are low (e.g. at the turning of the tide) and recirculation of the plume back to the discharge location.

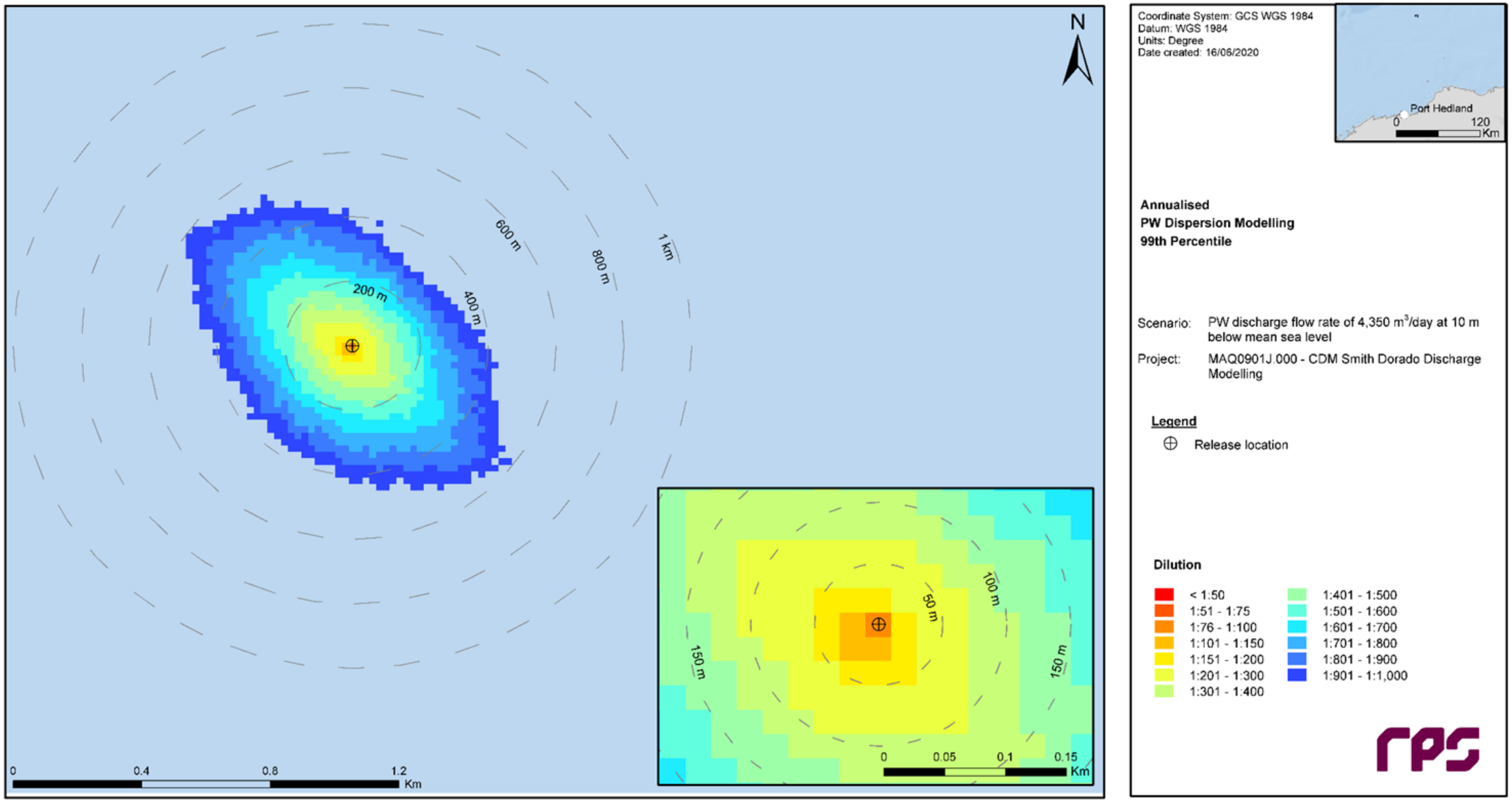
A stochastic procedure was applied for the far-field modelling, running 50 simulations per season over three seasons – summer, winter, and a transitional season (i.e. 150 simulations in total), with each simulation representing discharge for 10 days. **Figure 7-6** and **Figure 7-7** illustrate the predicted spatial extent of the PW discharge plume for the 95th and 99th percentile dilutions respectively. The far-field modelling of the PW discharge predicted the following:

+ the 1:425 target dilution for OIW would be met within 200 m of the discharge based on the 99th percentile dilutions;
+ PW discharges would rapidly disperse within the receiving marine environment and were expected to achieve 1:1,000 dilution within 591 m of the discharge based on the 99th percentile dilutions;
+ the maximum areas to have less than 1:1,000 dilution from the PW discharge location would be 0.072 km^2 and 0.550 km^2 at the 95th and 99th percentile dilutions, respectively; and
+ the maximum depth below the discharge location to achieve the 1:1,000 PW dilution level would be 4 m, approximately 14 m below the sea surface, depending on the volume of oil the FPSO is carrying.



Source: **Attachment 7**.

Figure 7-6: Predicted 95th percentile dilutions for PW discharge at 10 m below sea surface to achieve 1:1,000 dilutions (annualised results)



Source: **Attachment 7**.

Figure 7-7: Predicted 99th percentile dilutions for PW discharge at 10 m below sea surface to achieve 1:1,000 dilutions (annualised results)

7.2.2.2 Details of Environmental Impacts and Risks

A summary of the analysis of the environmental impact of the FPSO PW discharges as a result of Dorado Phase 1 is provided in this section. **Table 7-14** describes the impacts and identifies the potentially impacted receptors as a result of the discharge of PW within the Project Area.

Table 7-14: Receptors potentially impacted by the discharge of PW

Description of the Impact	Receptor Categories
Localised decrease in water quality during the operational stage of Dorado Phase 1. Localised decrease in sediment quality from the deposition of very small quantities of precipitated solids during the operational stage of Dorado Phase 1 Potential bioaccumulation of contaminants in marine fauna.	Water Quality – **Section 7.2.2.2.1** Sediment Quality – **Section 7.2.2.2.2** Plankton – **Section 7.2.2.2.3** Marine Fauna and Flora – **Section 7.2.2.2.4**

7.2.2.2.1 Water Quality

Water quality will change as a result of the chemical and physical properties of PW discharges (described in Section 7.2.2.1.1). Based on a conservative 1:1,000 dilution threshold, modelling results show these impacts will be localised to within approximately 600 m from the discharge location (**Figure 7-7**) given that the target dilution of 1:425 is achieved within 200 m of the discharge location. Impacts are expected to be much more localised during the early operational stage, where the PW discharge rate is expected to be much lower than 4,350 m^3/day, which has been assumed as the worst-case discharge rate expected in later field life. Dispersed OIW is buoyant and may float to the sea surface, potentially resulting in a very thin layer of oil that may be visible as a sheen. Given the volatile nature of the oils that will be produced by Dorado Phase 1, any surface sheen is expected to evaporate and weather rapidly in the tropical conditions experienced in the Project Area.

As BTEX is highly volatile, it will evaporate and dilute such that there will only be a localised zone of increased concentrations. PAHs within PW discharge have a greater potential to accumulate within the marine environment than BTEX due to their solubility, toxicity and persistence. It is expected that PAHs will be mostly removed from the water column through volatilisation to the atmosphere upon reaching the sea surface, particularly the lower molecular-weight fractions (Schmeichel 2017). Therefore, only localised increased concentrations are anticipated.

Dissolved metals may be present in low concentrations in the PW stream. Azetsu-Scott et al. (2007) indicated three different pathways for these inorganic elements once they enter the marine environment with the PW:

+ elements that stayed in solution would rapidly dilute along with the PW plume;
+ elements that oxidize or precipitate to form insoluble inorganic compounds would either form precipitates, which will be transported away from the discharge location while suspended in the water column, or would sink; and
+ elements that associate with oil droplets that are lighter than seawater and would rise to the surface.

While concentrations of dissolved metals in PW can be greater than those in the marine environment, they are rapidly reduced through dilution and mixing processes and other physico-chemical reactions to levels that pose a low risk to the receiving environment (International Association of Oil and Gas Producers 2005). Elevated dissolved metals concentrations are therefore only expected within close vicinity of the discharge point.

The PW discharge is expected to be warmer (45 to 60°C) than the receiving environment (which is typically less than 30°C), with the discharge predicted to be less dense (i.e. positively buoyant) than the receiving seawater. Turbulent mixing from the inertia and buoyancy of the plume will mix the PW discharge rapidly, resulting in the temperature of the PW discharge dropping rapidly. Temperature is predicted to be within 3°C of ambient seawater temperatures well within 100 m of the discharge location in most circumstances. Given that the predicted “impact” zone is less than the 500-m exclusion that will be in place around the FPSO (and therefore around the discharge location), there will be no fishing or other commercial activity taking place (other than that associated with Dorado Phase 1); therefore, the localised, poorer water quality within the immediate vicinity is of no consequence to socio-economic activity.

7.2.2.2.2 Sediment Quality

Very little solid material (e.g. produced sand) will be discharged with the PW, as the majority of solids are removed by the production and PW treatment systems. Solids in the PW discharge are expected to be limited to a very small mass of precipitates formed from dissolved ions in the anoxic PW after being exposed to atmospheric oxygen.

Discharge modelling suggests that PW is unlikely to reach the seabed due to the buoyant nature of the plume and the rapid mixing with the receiving waters upon discharge. Direct contact of the PW with the sediments is not expected to occur, given the water depth (approximately 90 m) at the FPSO location.

While the PW plumes are expected to disperse mainly within surface waters, there is the potential for particles within the plume, which may comprise metal oxides and low solubility hydrocarbon droplets (such as higher molecular weight PAHs), to drop out of the plume in the far-field mixing zone (Neff et al., 2011). These components of the PW therefore have the potential to accumulate in sediments.

Dissolved elements (particularly metals) in the PW may also form precipitates once released into the environment due to changes in pH and availability of reactants (e.g. oxygen and sulphide). While the exact composition of the PW cannot reasonably be characterised prior to commencing production (and may change character as reservoirs become depleted), metals commonly encountered at elevated levels in PW include barium, iron, manganese, mercury and zinc (Neff et al. 2011). Solids formed by precipitation will initially be very small and will have low settling velocities. As with solid particles in the PW discharge plume, precipitates are unlikely to be deposited near the discharge location and will disperse widely. Sediment quality in the Commonwealth Marine area is therefore not expected to be significantly impacted in the vicinity of the discharge.

The low natural suspended sediment load indicates the potential for adsorption of potential contaminants is limited (RPS 2020a). Due to the small particle size, the potential for adsorbed contaminants to be deposited at the discharge location is low; particles with adsorbed contaminants are expected to be diluted and widely dispersed, resulting in no measurable impact to sediment quality in the region.

The potential for contaminants in the PW to interact with sediment in the Commonwealth Marine area, either directly or through deposition of precipitates or natural suspended sediment with adsorbed contaminants, is very low. It is possible that contaminants from the discharge of PW may accumulate through sedimentation on the seabed, however this is highly unlikely due the following:

- Elevated currents, leading to higher dispersion prior to settling,
- Natural sediment resuspension,
- Only the fine sand fraction would settle to the seabed with the silts dispersing over a wide area at very low concentrations levels,
- High degradation rates of both biogenic (carbon) and hydrocarbons at the sediment interface (Burns et al 2003).

Given that PW contaminants are unlikely to be detectable in sediments in the vicinity of the FPSO discharge point, potential impacts to sediments from the discharge of PW are expected to be minimal.

7.2.2.2.3 Plankton

As presented in **Section 7.2.2.2.1**, water quality may be impacted by PW discharges, which could in turn have an impact on plankton.

Phytoplankton can accumulate hydrocarbons at a rapid rate but are generally not sensitive to hydrocarbons. Exposure to hydrocarbons has the potential to affect their photosynthetic ability, which may result in cascading effects into higher trophic levels (Hook et al. 2016). At low concentrations of hydrocarbons in the water column (10 to 30 ppb), photosynthesis may be stimulated, although inhibiting effects have been shown to occur at concentrations above 50 ppb (Volkman et al. 1994). Other studies have indicated that phytoplankton have been shown to be less affected by weathered oil (Bretherton et al. 2018; Özhan et al. 2014). Potential impacts to phytoplankton are therefore expected to be localised and transient, with phytoplankton replenishing rapidly.

Exposure of zooplankton to hydrocarbons in the water column has the potential to cause mortality or a decline in egg production and hatching rates along with a decline in swimming speeds (Hook et al. 2016). Low molecular-weight hydrocarbons have been shown to cause acute toxic effects in zooplankton (Almeda et al. 2013; Jiang et al. 2010). PAHs within PW discharge have a greater potential to accumulate within the marine environment than BTEX due to their solubility, toxicity and persistence. Based on 1:1000 dilution of PW, these impacts will be restricted to within a few hundred metres of the discharge location.

Plankton is generally abundant in the upper layers of the water column and is the basis of the marine food web; therefore, the discharge of PW is unlikely to have impacts on plankton populations at a regional level. Larval plankton stages are known to be more susceptible to impacts of increased salinity than are most other marine life (Neuparth et al. 2002) and are therefore expected to be the most affected by the increase in salinity in the PW discharge plume. Early life stages of fish (embryos and larvae) and other plankton would also be most susceptible to toxic exposure from residual chemicals in the PW discharges, as they have limited mobility and are therefore likely to be exposed at the discharge location, if present. However, these types of organisms are expected to rapidly recover once background water quality is re-established (International Tanker Owners Pollution Federation 2011) as they are known to have high levels of natural mortality and a rapid replacement rate (United Nations Environment Program 1985). Rapid recovery is also expected due to the fast growth rates of zooplankton and the dispersal and mixing of zooplankton (CSIRO 2017) from both inside and outside of the PW plume. A change in water quality may cause injury or mortality to plankton species through increased toxicity levels and increased water temperatures. The potential impacts of PW discharges on plankton are expected to be localised and are considered to be minor.

7.2.2.2.4 Marine Fauna

As presented in **Section 7.2.2.2.1**, water quality may be impacted by PW discharges, and this could in turn have an impact on marine fauna such as fish, marine mammals and marine reptiles. Given PW discharges occur near the sea surface and will mix rapidly following discharge, pelagic fauna that are at or near the sea surface are most likely to be exposed to the PW plume.

Uptake of dissolved hydrocarbons is less likely for marine mammals and reptiles than for fish and invertebrates, since marine mammals and reptiles are air breathing and do not possess gill structures that promote cellular uptake of dissolved constituents. Fish may be more vulnerable as their gills form an area through which potential PW contaminants may be trapped. Pelagic fish are transient marine fauna that are unlikely to remain within the discharge location and associated plume, which will move around depending on the metocean conditions. Chemicals present in the PW have the potential to cause harm and/or be lethal to fish. Production chemicals are managed via the chemical selection process, which prioritises the use of chemicals that meet technical requirements but have a low environmental risk. There are only expected to be minor traces of production chemicals within the PW discharge from residual production chemicals that aren't fully consumed in the topsides process, significantly reducing the potential toxicity of such chemicals.

The transfer and accumulation of contaminants through trophic levels (known as bioaccumulation) is one potential pathway that could lead to adverse impacts from extended feeding around the activities. Given the transient nature of marine mammals and reptiles, combined with the absence of gill structures to promote cellular uptake, bioaccumulation is not expected in these species.

Presence of pelagic fish is commonly associated with offshore structures, which could increase exposure of these species to the PW discharge for longer periods. However, due to the relatively low concentrations of residual chemicals within the PW discharge, the high level of dilution and mixing within the receiving offshore environment, and the ability of pelagic species to avoid discharge plumes, impacts to pelagic fish populations are not expected. Laboratory and field studies of PW have also concluded that significant biological effects on pelagic organisms will be limited to a distance of less than one km due to rapid effluent dilution, with no expected impact at the population level (Bakke et al,. 2013). This finding is consistent with PW modelling performed for the Dorado Development, with anticipated impacts limited to within 1 km of the PW discharge from the FPSO.

Elevated water temperatures have the potential to induce minor physical stress in marine fauna and may result in potential mortality after prolonged exposure. Wolanski (1994) demonstrated that elevated seawater temperatures have the potential to alter the physiological processes of exposed biota. These alterations may cause a variety of effects, ranging from behavioural responses (including attraction and avoidance behaviour), minor stress, and potential mortality after prolonged exposure (Walkuska and Wilczek 2010).

The potential area of impact from PW discharge is conservatively estimated at up to 0.550 km^2 which equates to 0.02% of the Project Area (3, 443 km^2). Although the Pilbara trap and trawl fishery overlaps 15% of the total Project Area, the extent of the fishery potentially impacted by the PW discharge is negligible. The risk to fish populations is further reduced as discussed above, given the constituents of the PW and the overall risk from PW discharge to pelagic fish is not anticipated.

7.2.2.3 Summary of Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-15**

Table 7-15: Summary of impacts, environmental performance outcomes, controls and consequence evaluation of PW discharge during Dorado Phase 1

<table>
<tr><th colspan="2">Environmental Performance Outcomes (EPOs)</th></tr>
<tr><td colspan="2">EPO3B: No mortality or significant[23] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of produced water (PW).
EPO4A: Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring a 99 % species protection level (based on ANZG 2018) for water quality is achieved outside of the PW mixing zone boundary[24].
EPO5A Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring ANZG 2018 sediment quality guideline values are not exceeded outside the PW mixing zone[21].
EPO6A: Dorado Phase 1 is managed so that seafood caught within the project area remains safe for human consumption.</td></tr>
<tr><th>Receptor</th><th>Impact</th></tr>
<tr><td>Water Quality</td><td>Localised decrease in water quality during the operational stage of Dorado Phase 1.</td></tr>
<tr><td>Sediment Quality</td><td>Localised decrease in sediment quality from the deposition of very small quantities of precipitated solids during the operational stage of Dorado Phase 1.</td></tr>
<tr><td>Plankton</td><td>Localised injury or mortality to plankton species through increased toxicity levels and increased water temperatures during the operational stage of Dorado Phase 1.</td></tr>
<tr><td>Marine Fauna</td><td>Potential bioaccumulation of contaminants in marine fauna.</td></tr>
<tr><th colspan="2">Control Measures (CMs)</th></tr>
<tr><td colspan="2">CM7: PW treatment system to meet OIW discharge standards:
+ Less than 30 mg/L OIW during steady state operations averaged over 24 h
+ between 30 mg/L and 100 mg/L OIW averaged over 24 h during the initial start-up period and for commissioning of future tieback (up to 6 months after first oil)
CM8: Adaptive PW management plan including:
+ PW modelling,</td></tr>
</table>

[23] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

[24] Produced water mixing zone determined to be 1000 m from the FPSO during a <30 mg/L PW discharge.

+ in-field environmental monitoring to verify predicted mixing zone modelling, + in-field environmental monitoring to assess potential impacts against ANZG 2018 water quality and sediment quality guidelines, + PW chemical characterisation, + PW ecotoxicity testing, + tiered management system in response to off-specification water (e.g. storage onboard and retreatment prior to discharge), + studies to verify whether bioaccumulation of toxicants in biota attributable to the discharge of PW, + adaptive management triggers and mitigative measures in response to results of bioaccumulation studies, + adopt changes in relevant legislative requirements and updates to ANZG to PW discharges. **CM9**: Santos chemical selection process will be implemented to select process chemicals with low environmental risk, while meeting technical requirements.	
Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.2.4 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by discharge of PW as a result of Dorado Phase 1 compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-16** and **Table 7-17**. The method by which these acceptable levels were determined and a justification as to why these are acceptable are discussed in **Section 4**.

The worst-case consequence for the discharge of PW was evaluated as minor (**Table 7-15**). This consequence is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from the discharge of PW are acceptable.

Table 7-16: Demonstration of acceptability for the discharge of PW

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	Management of the discharge of PW from Dorado Phase 1 is consistent with the principles of ESD because: + there is no threat of serious or irreversible environmental damage; + the environmental resources within the Project Area are not expected to be significantly impacted; and + the precautionary principle has been applied by setting a trigger zone that is within the modelled discharge plume to meet a conservative 1:1000 dilution, and studies have been undertaken where knowledge gaps were identified (**Attachment 7**). + Adaptive management will also be implemented to compensate for current uncertainties such as actual composition of PW, mixing/dilution processes and bioaccumulation.

Acceptability Criteria	Demonstration of Acceptability
Internal context	The management of PW is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPOs and the controls that will be implemented are consistent with Santos' internal requirements.
External context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	The below conservation advice and recovery plans identify water quality, sediment quality and therefore habitat degradation as an impact to threatened species. **Conservation Advice** + Approved conservation advice for *Pristis clavata* (dwarf sawfish) (Threatened Species Scientific Committee 2009), + Approved conservation advice for *Pristis pristis* (largetooth sawfish) (Threatened Species Scientific Committee 2014b), and + Approved conservation advice for green sawfish (Threatened Species Scientific Committee 2008a). + Conservation advice for *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b) + Conservation Advice Balaenoptera *physalus fin* whale (Threatened Species Scientific Committee 2015c) **Recovery Plans** Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b) - This recovery plan identifies habitat degradation as a threat to sawfish. Impacts to benthic habitats from the discharge of PW will be highly localised within the Project Area. The closest Sawfish BIA (for pupping, nursing and foraging) is approximately 87 km from the southern extent of the Project Area outside the PW modelled impact, therefore,. Santos considers the impacts of produced water discharges to not be inconsistent with the recovery plan. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) - This recovery plan identifies chemical discharges (including PW) as a threat to marine turtles. Impacts from chemical discharges may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of produced water discharges to not be inconsistent with the recovery plan. Recovery Plan for the White Shark (Carcharodon carcharias) (DSEWPac, 2013b) – This recovery plan identifies habitat modification as a potential threat to White Sharks. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges (including PW) may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of PW discharges to not be inconsistent with the recovery plan. Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth

Acceptability Criteria	Demonstration of Acceptability
	of Australia 2015a) – This recovery plan identifies acute and chronic chemical discharge (including PW) as a threat to Blue Whales. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of produced water discharges to not be inconsistent with the recovery plan. Recovery Plans / Conservation Advice for other species that may occur in the Project Area do not identify PW or chemical discharge as a key threat; or have any explicit relevant objectives or management actions related to PW discharge **Commonwealth Marine Areas** Given that the precise composition of the PW is not possible until production is underway, the adaptive management framework provides certainty that the impacts from the discharge of PW in the Commonwealth Marine Area, including the potential for bioaccumulation, will remain within acceptable levels.
Other relevant requirements	Management of the impacts and risks from the discharge of PW associated with Dorado Phase 1 are consistent with relevant legislative requirements, including the management of emissions and releases of mercury and mercury compounds as per the obligations under the Minamata Convention on Mercury. At present there are no specific guidelines in the Minamata convention regarding acceptable levels of mercury in PW releases. The ANZG 2018 provide for guidance and levels of protection for both water and sediment associated with Mercury. Receptor-specific acceptable levels for the management of the discharge of PW have been derived from the species protection levels for water quality presented in the *Australian and New Zealand guidelines for fresh and marine water quality* (Commonwealth of Australia and New Zealand Government 2018). Santos' management of PW is consistent with industry best practice in Australia, for example **CM2** chemical selection process and **CM8** PW adaptive management plan. The adaptive management plan provides for adopting relevant changes in legislation and ANZG 2018 during the Dorado Development.

Table 7-17: Demonstration of acceptability of the discharge of PW against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[25] are acceptable.	The evaluation of impacts from the discharge of PW show that potential impacts will be localised around the discharge location. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity (within the ANZG 2018 water quality guidelines) will be maintained

[25] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

RSAL4: Substantial[26] impacts to water quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable.	beyond 1 km of the discharge location. Given the widespread nature of the open water environment in the region, the discharge of PW from the FPSO will not result in significant impacts to water quality that results in a loss of ecological integrity.
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity[20] are acceptable. **RSAL6**: Substantial[23] impacts to sediment quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable.	The evaluation of impacts from the discharge of PW show that the potential for contaminants in the PW discharge to interact with sediment is very low, given the water depths and resulting dispersion from ocean currents. Although unlikely, it is expected that any potential impacts will be localised to the sediments within the vicinity of the FPSO discharge point. It is also expected that a high level of ecological integrity (within the ANZG 2018 sediment guidelines), will be maintained beyond 1 km of the discharge location. Given the widespread nature of the open water environment in the region, the discharge of PW from the FPSO will not result in significant impacts to sediment quality that result in a loss of ecological integrity.
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1. **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to species listed as threatened or migratory under the EPBC Act as a result of Dorado Phase 1. **RSAL19**: No negative impacts to the economic viability of the commercial fish resources.	The expected potential impacts on marine fauna from PW discharges are limited to fishes. While there is the potential for residual traces of production chemicals in PW discharge, these will be at concentrations that do not pose a significant risk to fish. The risk to fish from production chemicals in the PW discharge, will be further reduced by implementation of Santos' chemical selection process to select chemicals with low environmental risk, reducing the likelihood of any impacts. The transfer and accumulation of contaminants through trophic levels (known as bioaccumulation) is one potential pathway that could lead to adverse impacts if fish congregate and feed in the vicinity of the Dorado facilities for extended periods. However, due to the relatively low concentrations of residual chemical within the PW discharge, the high level of dilution and mixing within the receiving offshore environment, and the ability of pelagic species to avoid discharge plumes, impacts to pelagic fish populations are not expected. To address the uncertainty for potential of bioaccumulation, the adaptive management for produced water discharges includes bioaccumulation studies. The potential area of impact from PW discharge covers a small portion of the Project area (0.02%), posing negligible impact to managed fisheries. The risk to fish populations is further reduced given the constituents of the PW and the overall risk from PW discharge to pelagic fish is not anticipated. As such, impacts on the abundance and quality of commercially targeted fishes are not anticipated.

[26] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

	The assessment of impacts from PW discharges shows that mortality of or significant impacts to threatened or migratory species will not occur. PW has not been identified as a threat in any recovery plans or conservation advice for threatened and migratory species.

7.2.3 Discharges – Wastewater Discharges

7.2.3.1 Description of the Event

A range of wastewater streams will be generated throughout all stages of Dorado Phase 1 and discharged into the marine environment including:

- cooling water;
- grey water;
- sewage;
- reverse osmosis (RO) brine;
- bilge water;
- deck wash;
- drainage water; and
- pipeline hydrotest water.

Each of these discharge streams is described below. Other wastewater streams including PW (**Section 7.2.2**), ballast water (**Section 7.2.3**) and drill cuttings and fluids (**Section 7.2.1**) have been assessed separately, as the nature and scale of these discharges warrants specific assessments.

It should be noted that the actual discharge rates, temperatures and concentrations discussed in this section may vary, however these values have been selected as conservative indications for the purpose of describing and assessing the potential impacts.

7.2.3.1.1 Utility and Cooling Water

The FPSO is expected to generate the highest volumes of utility and cooling water discharges from Dorado Phase 1. The main FPSO systems requiring seawater are the engine room/ bilge ballast and general services; freshwater generator; inert gas system scrubber; ballast and firewater; utility cooling; anchor wash; and process seawater cooling. The FPSO may discharge between 5,100 m^3 to 13,000 m^3 per hour through several discharge ports situated around the FPSO hull during the operational stage.

Utility and cooling water is seawater drawn from sea chest in the FPSO hull, which is treated with a biocide (such as chlorine or copper base biocide) to reduce biofouling risks. The dosing of biocides within the cooling water system will be sufficient to meet technical requirements while making efficient use of biocides (e.g. not over-dosing). Most of the biocide is expected to be consumed within the cooling water system, and the concentration of residual biocide that will be discharged into the marine environment is expected to be relatively low. The biocides typically used in the industry are highly reactive and degrade rapidly in the marine environment. Other chemicals, such as scale inhibitors, may also be used to dose cooling water. Scale inhibitors are typically phosphorous compounds that are water soluble. The cooling water is used in a once-through system and following its use it is discharged to the marine environment. Some systems require constant cooling (such as the freshwater generator and process sweater cooling) while others only require temporary cooling or utility water supply (such as the firewater). The expected maximum utility and cooling water discharge rate (i.e. when all the systems are discharging simultaneously) is approximately 13,000 m^3/h. This assumes that all systems requiring utility or cooling water are discharging at the same time. The minimum (i.e. when only the continuously cooled systems are discharging) is 5,100 m^3/h. The temperature of the discharged utility and cooling water is expected to range between the ambient water temperature and 60°C depending on the system the seawater has been pumped through, and may contain residual traces of biocidal treatment.

Cooling water discharges from other sources (i.e. vessels and MODUs) during Dorado Phase 1 will represent a negligible additional volume compared to the volume discharged by the FPSO. For example, vessels may discharge 210 m^3 to 420 m^3 per hour per vessel.

7.2.3.1.2 Domestic Wastewater

A range of domestic wastewater streams will be discharged during Dorado Phase 1, including:

+ grey water;
+ sewage; and
+ putrescible wastes.

Discharge of these wastes into the marine environment is a standard maritime practice. These discharges will all be made in accordance with relevant requirements including Australian legislation giving effect to MARPOL 73/78.

Grey water is represented by the domestic wastewater from the FPSO, MODU and vessels that is not comingled with sewage. Sources of grey water include showers, sinks and washing machines. The level of grey water generated typically depends on the crewing levels onboard each vessel. Grey water will be generated during all stages of Dorado Phase 1 from the FPSO, MODU and project vessels.

Sewage (also referred to as blackwater) is wastewater that is contaminated with human faeces, urine and toilet paper. It is expected that 0.5 m^3 to 1 m^3 per person per day will be released to the marine environment. Like grey water, sewage will be discharged into the marine environment following treatment in accordance with MARPOL 73/78 during all stages of the Dorado Development. The volumes discharged will depend on crewing levels and the capacity of sewage systems onboard the FPSO, MODU and project vessels. The FPSO, MODU and project vessels will have sewage treatment systems that are in compliance with maritime requirements. Vessels typically discharge sewage when underway, while the FPSO and MODU will discharge sewage when on station under normal circumstances.

Putrescible wastes, such as food scraps, may also be discharged into the marine environment following treatment in accordance with MARPOL 73/78.

7.2.3.1.3 Reverse Osmosis Brine

RO systems are routinely used offshore to generate fresh water from seawater. RO units will be used onboard the FPSO and may also be used on other project vessels. Brine produced as reject water from RO systems will be routinely discharged into the marine environment while RO systems are in operation. Brine discharges are expected to be at ambient seawater temperature and will be approximately 20% to 50% more saline than receiving marine waters.

7.2.3.1.4 Bilge Water

Bilge water collects in the lowest parts of the FPSO and project vessels. It is often water that has drained from other parts of the FPSO or vessel, such as machinery spaces. Bilge water may be contaminated with hydrocarbons, such as lubricating oil or fuel. Bilge water discharges are passed through an oily water separator that will reduce OIW content to ≤ 15 ppm prior to discharge.

7.2.3.1.5 Drains

The FPSO, MODU and vessels will have drain systems. The FPSO will have a range of hazardous (i.e. from hydrocarbon processing areas) and non-hazardous drains. The drainage system will be designed to prevent the discharge of hydrocarbons and chemicals into the marine environment. Drains in non-hazardous areas will be open and drain to the marine environment. Drains in hazardous areas (such as hydrocarbon processing areas) will be closed. All water from the closed drains will be directed inboard of the FPSO to the Slops tank, and treated by an oily water separator that will reduce OIW content to less than 30 ppm prior to discharge.

7.2.3.1.6 Hydrotest Water

Pressure testing of the subsea system is required to assess its structural integrity. Pressure testing is undertaken by using treated seawater and internal pressures monitored to detect any leaks. Hydrostatic testing of the subsea system between the Dorado WHP and the FPSO will require approximately 2,500 m^3 of treated seawater, which will contain biocide and corrosion inhibitor. This will be displaced from the subsea system and discharged into the marine environment, most likely from the FPSO. Hydrotest water is also expected to be discharged during the construction of any future tiebacks.

Hydrotesting to ensure structural integrity of the facilities (Dorado WHP and FPSO), is expected to occur overseas at the construction yards. Nonetheless, hydrotesting could take place in the Project Area, resulting in the discharge of treated seawater to the marine environment.

The chemicals that will be used to treat the seawater have not yet been determined, however all chemicals will be subject to Santos' chemical assessment process. This process will ensure chemicals have an acceptable environmental risk as well as addressing technical constraints, readily degrade in the marine environment, and have a low risk of bioaccumulation. The chemical dosages required will be sufficient to achieve the desired technical outcome (i.e. effective preservation of the subsea system).

7.2.3.2 Details of Environmental Impacts and Risks

A summary of the analysis of the environmental impact of the wastewaters discharges as a result of Dorado Phase 1 is provided in this section. **Table 7-18** identifies the potentially impacted receptors as a result of the discharge of wastewater within the Project Area.

Table 7-18: Receptors potentially impacted by the discharge of wastewaters

Description of the Impact	Receptor Categories
Localised decrease in water quality during the operational stage of Dorado Phase 1.	Water Quality – **Section 7.2.3.2.1** Sediment Quality – **Section 7.2.3.2.2** Marine Fauna – **Section 7.2.3.2.3**

Localised decrease in sediment quality due to the deposition of small quantities of solids during the operational stage of Dorado Phase 1. Potential bioaccumulation of contaminants in marine fauna.	

7.2.3.2.1 Water Quality

A change in water quality will occur following routine and non-routine cooling water discharges due to the addition of biocides and scale inhibitors into the water column. This will result in increased toxicity levels, increased salinity levels and increased water temperature within the vicinity of the discharge points. Water quality within the Project Area, where the discharge would occur, is typical of the offshore marine environment. Surface waters experience high-levels of energy, with wave action and surface currents resulting in rapid dissipation of discharges. Within the immediate area of influence of the discharge, water temperatures will be elevated impacting water quality.

The discharge of wastewater may result in a range of changes in ambient water quality, including:

+ potential toxicity from residual chemicals;
+ increased nutrients;
+ increased temperature; and
+ changes in salinity.

Water quality in the Project Area is considered to be representative of the typical high-water quality found in offshore Western Australian waters.

Residual Chemicals

Several wastewater streams may include residual chemicals which may result in toxic effects, reducing water quality. The wastewater streams with the greatest potential for toxicity are the hydrotest water (due to the presence of biocide and corrosion inhibitor) and the cooling water (due to the presence of residual biocide).

The plume of hydrotest water is expected to mix in the surrounding water once released into the marine environment, either at the FPSO or subsea near the Dorado WHP or FPSO. As the hydrotest water will have similar physical properties to the receiving seawater (e.g. density), there is not expected to be a density interface between the hydrotest water and the surrounding water that would inhibit mixing. The strong tidal currents that occur within the Project Area are expected to rapidly mix the hydrotest water in the receiving marine environment.

The biocide will be the most toxic component of the hydrotest water. As the hydrotest water mixes in the marine environment, the residual biocide will be consumed as it reacts with material in the water column. While the hydrotest water will be anoxic upon release and may have a chemical oxygen demand due to the residual corrosion inhibitor, the surrounding seawater is expected to be well oxygenated as the water column at the release location is well mixed through the majority of the depth profile (**Attachment 5**). The discharge of hydrotest water may result in a localised, short-term decrease in water quality due to the toxic effects of residual chemicals. This decrease is expected to impact primarily upon planktonic communities that cannot avoid the hydrotest water plume. Mobile fauna, such as fish, are expected to detect and move away from the plume. Given the high level of mixing in the receiving waters and high productivity of planktonic communities, any impacts from the discharge are expected to be short term and to recover within days. The planned discharge of hydrotest water is a one-off event and the potential contaminants will degrade within the environment. Hence, the duration of the environmental hazard and associated impacts to water quality will be short-term.

Cooling water discharges may also reduce water quality due to the potential toxic effects of residual biocide. The biocide for use in the cooling water system has not yet been determined but is expected to be either chlorine (e.g. hypochlorite) or copper based. Cooling water containing chemical additives are inherently safe at the low dosages used. The chemical additives are usually consumed in the inhibition process, so there is little or no residual chemical concentration remaining upon discharge.

The proposed biocides are highly reactive and residual traces will be consumed rapidly upon release into the marine environment. Upon release into the marine environment, the cooling water stream will dilute rapidly as the plume becomes mixed in the water column. Studies by Taylor (2006) investigated the effects of chlorination (from biofouling agents used in seawater cooling units) on coastal and estuarine environments which suggested very limited impact of biocide use and the associated chlorination by products on receiving waters, both in terms of plume toxicity or any more widespread ecotoxicological influence. Cooling water will be discharged continuously from the FPSO during the operational stage of Dorado Phase 1. Hence, the impacts from cooling water will be a low intensity but persistent impact to the marine environment. The biocides that may be used will not persist in the environment and impacts from cooling water will cease once the discharge of cooling water ceases.

The concentrations of residual chemicals within the cooling water stream will be relatively low. These chemicals will dilute rapidly upon discharge and will not persist in the environment. The impact to water quality form residual chemicals in cooling water discharges is considered to be minor.

Increased Nutrients

The discharge of sewage and putrescible wastes may result in localised increase in nutrients in the marine environment. Increased nutrients can result in increased productivity, such as blooms of algae, which can result in eutrophication, particularly in waters with little water movement or exchange. The receiving waters in the Project Area are naturally low in nutrients and are very well mixed. The receiving waters are expected to be able to absorb any increases in nutrients with little or no apparent effects. Santos' operational experience indicates nutrients and photosynthetic pigments (an indicator of algal growth) around operating facilities are consistent with reference sites well beyond any potential nutrient sources. As such, impacts to water quality from increased nutrients will be limited to a temporary, very small, localised increase in nutrients and primary productivity around the discharge location following discharge. Eutrophication will not occur as the Project Area is in the open sea and has continuous water exchange driven by tidal currents. The impacts to water quality from increased nutrients are considered to be minor.

Increased Temperature

The cooling water discharge will be warmer than the ambient receiving waters, which will lead to an increase in water temperature in the receiving waters. From industry and Santos' experience operating FPSOs in the NWS, the temperature of the cooling water discharge is expected to rapidly decrease near the discharge location as the cooling water plume mixes with the receiving water. It is expected that the cooling water discharge temperature would be within 3°C of ambient temperature within 100 m of the discharge location.

Water temperatures, particularly in surface waters, vary naturally and planktonic communities are adapted to changes in temperature. Thermal stress of a temperature differential of approximately 5°C has been demonstrated to induce mortality in copepods in a laboratory setting, however the effect could not be detected in response to cooling water discharge in the natural environment (Choi et al. 2012). Choi et al. (2012) suggested this was due to rapid mixing of the cooling water upon release to the receiving waters.

Given the area of potential temperature increases will be highly localised (less than 100 m) around the discharge location, impacts from temperature increases will only occur in a small area. These impacts will be limited to plankton and are expected to not be detectable beyond 100 m from the discharge points. The impacts to water quality from increased temperature are considered to be minor.

Changes in Salinity

The discharge of RO brine will result in an increase in salinity, with the salinity of the brine expected to be up to 50 ppt, compared to a typical salinity of between 32 to 36 5 ppt in the receiving waters. The RO brine will be denser than the receiving water and will sink into the water column. This will encourage turbulent mixing of the brine. Any brine plumes are expected to mix rapidly in surface waters, with any differences in salinity restricted to surface waters. While brine plumes discharged from desalination plants in coastal waters have been shown to result in impacts to benthic communities in coastal waters (Lattemann and Höpner 2008), the volumes discharged by desalination plants are several orders of magnitude greater than the expected brine discharges during Dorado Phase 1. Similar impacts will not occur during Dorado Phase 1 due to the much smaller brine volumes that will be discharged and the water depth of the discharge location (90 m at the FPSO location).

Some of the wastewater discharges, such as domestic waste, may have a lower salinity than the receiving waters. These low salinity discharges are relatively small in volume and are expected to mix rapidly in the receiving environment. The impacts of lower salinity discharges to the marine environment are expected to be similar to natural freshwater inputs, such as rainfall.

Based on the relatively small volumes of discharges that may alter salinity in the receiving waters, along with the well-mixed nature of the environment, impacts from changes in salinity will be limited to very close proximity to the discharge point. The impacts to water quality from changes in salinity are not expected to be of significance.

7.2.3.2.2 Sediment Quality

Wastewater discharges during Dorado Phase 1 will occur at the sea surface (except potentially hydrotest water) and mix rapidly. This will prevent direct interaction between wastewater plumes and the sediments within the Project Area. Some discharge streams are expected to have a high load of suspended solids, such as sewage and putrescible wastes. These solids may be deposited to the seabed, resulting in potential impacts to sediment quality. The FPSO is the most notable source of wastewater with suspended solids due to the sustained crew complement and the long period of time it will be on station within the Project Area. Wastewater discharges from project vessels and MODUs are less like to result in impacts to sediments as they are present in the Project Area for relatively short periods of time.

Studies of suspended solids in sewage indicate the rapid settling of particles achieving settling velocities of up to 25 mm/second (equal to 1.5 m/minute) and most particles had settling velocities much slower than this (Rinas et al. 2019). Assuming this worst-case settling velocity, particles are expected to take approximately one hour to reach the seabed at the FPSO location, where the water depth is approximately 90 m. Given the relatively high levels of water movement in the Project Area, deposition of suspended solids in sewage discharges will be spread over a wide area.

Decomposition of organic matter in wastewater solids is expected to occur upon discharge to the marine environment and continue once deposited on the seabed. This may result in slightly increased concentrations of nutrients and organic carbon in sediments, along with a small increase in biochemical oxygen demand.

Given the expected dilution of wastewater discharges, settling velocity of suspended solids, the water depth in the Project Area and the water movement due to currents, impacts to sediments from wastewater discharges are expected to be limited to a slight increase in nutrients and organic matter, along with a small increase in biochemical oxygen demand. There may be an increase in deposit-feeding benthic biota as a result of these impacts, however any changes in fauna assemblages will not affect ecosystem function. These potential impacts are considered to be minor.

7.2.3.2.3 Marine Fauna

The marine fauna which could be impacted by the discharges of wastewater include plankton, fish, marine mammals and marine reptiles. Given wastewater discharges will primarily occur near the sea surface and will mix rapidly following discharge, pelagic fauna that are at or near the sea surface are most likely to be exposed to wastewater streams. Larval plankton stages are known to be more susceptible to impacts of increased salinity than that of most marine life (Neuparth et al. 2002) and are therefore expected to be the most affected by the increase in salinity in the wastewater discharge plume. Early life stages of fish (embryos and larvae) and other plankton would also be most susceptible to toxic exposure from residual chemicals in the wastewater discharges, as they have limited mobility and are therefore likely to be exposed to at the discharge location, if present. However, these types of organisms are expected to rapidly recover once background water quality is re-established (International Tanker Owners Pollution Federation 2011a), as they are known to have high levels of natural mortality and a rapid replacement rate (Joint Group of Experts on the Scientific Aspects of Marine Pollution 1984). The potential impacts of wastewater discharges on plankton are expected to be localised and are considered to be minor.

Air-breathing marine fauna, such as turtles, cetaceans and seabirds, are generally resistant to potential contaminants in wastewater discharges as their skin forms an impermeable barrier, and thus no noticeable impacts are expected on air-breathing fauna. Fish may be more vulnerable as their gills may form a large area through which potential contaminants may be trapped. Pelagic fish are transient marine fauna that are unlikely to remain within the discharge location and associated plume, which will move around depending on the metocean conditions. Abarnou and Miossec (1992) suggest that mobile organisms such as fish and marine mammals and reptiles may detect and avoid areas with low levels of chlorine (which may be present as residual traces of biofouling treatment in the hydrotest and cooling waters). Chlorine does not persist for extended periods in seawater but is very reactive and its by-products persist longer. It is expected that residual traces of chlorine would rapidly be converted to hypochlorous acid and hydrochloric acid in receiving waters (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management

Council of Australia and New Zealand 2000b). Elevated water temperatures have also the potential to induce minor physical stress in marine fauna and may result in potential mortality for prolonged exposure. Wolanski (1994) demonstrated that elevated seawater temperatures have the potential to alter the physiological processes of exposed biota. These alterations may cause a variety of effects, ranging from behavioural responses (including attraction and avoidance behaviour), minor stress and potential mortality for prolonged exposure (Walkuska and Wilczek 2010).

Due to the relatively inert properties and low concentrations of residual chemical traces within the wastewater discharges, the high level of dilution and mixing within the receiving offshore environment as well as the ability of pelagic species to avoid discharge plumes, impacts to pelagic fish would be limited to species that experienced prolonged exposure close to the source of the discharge. The transfer and accumulation of contaminants through trophic levels (known as biomagnification) is one potential pathway that could lead to higher order vertebrate consumers (e.g. marine reptiles and marine mammals, such as the humpback whale and pygmy blue whale) accumulating contaminants and suffering adverse impacts from extended feeding around the activities. While it is difficult to estimate the number that may be affected, it is expected that this would be limited to individuals and a negligible proportion of the population or a species. There is substantial anecdotal evidence of fishes aggregating around offshore petroleum infrastructure discharging wastewater to the sea with little or no apparent impacts. Mobile marine fauna are expected to move away from any areas affected by wastewater discharges that may result in injury or mortality. The potential impacts of wastewater discharges on plankton, fish, marine mammals and marine reptiles are expected to be localised and are considered to be minor. Potential impacts associated with the discharge of wastewater into the marine environment will typically be restricted to within a few hundred metres of the discharge location, and it is expected that the potential impact on the abundance and quality of commercially targeted fishes will be undetectable.

The potential impacts on marine fauna associated with organic enrichment due to wastewater discharges (such as sewage) is expected to be of an order of magnitude less than those associated with residual chemical discharges and the localised increased water temperature.

7.2.3.3 Summary of Impact Evaluation

A summary of the impact analysis and evaluation, including adopted control measures and EPOs is provided in **Table 7-19**.

Table 7-19: Summary of impacts, EPOs, controls and consequence evaluation discharge of wastewater during Dorado Phase 1

EPOs
EPO3C: No mortality or significant[27] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of wastewater. **EPO7A**: Dorado Phase 1 routine planned wastewater discharges compliant with relevant established industry standard environmental discharge limits

[27] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Receptor	Impact
Water Quality	Localised decrease in water quality around wastewater discharge locations.
Sediment Quality	Minor increase in concentrations of contaminants, nutrients and organic carbon in sediments, along with a small increase in biochemical oxygen nutrients around wastewater discharge locations.
Marine Fauna	Potential behavioural disturbance in close proximity to the discharge and bioaccumulation of contaminants in marine fauna.
Controls	
CM9: Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements. **CM10:** All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification): + Marine Order 91 (Marine Pollution Prevention – Oil), which implements Annex I of MARPOL 73/78, including (as required by vessel class): - Machinery space bilge/oily water shall have IMO-approved oil filtering equipment (oil/water separator) with an on-line monitoring device to measure OIW content to be less than 15 ppm prior to discharge. - A deck drainage system capable of controlling the content of discharges for areas of high risk of fuel/oil/grease or hazardous chemical contamination. - Valid International Oil Pollution Prevention Certificate. + Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including: - Garbage management plan in place. - Garbage record book maintained onboard. + Marine Order 96 (Marine Pollution Prevention – Sewage), which implements Annex IV of MARPOL 73/78, including (as required by vessel class): - a valid International Sewage Pollution Prevention Certificate, - an IMO-approved sewage treatment plant, - a sewage comminuting and disinfecting system, - a sewage holding tank sized appropriately to contain all generated waste (black and grey water), and - discharge of sewage will occur at a moderate rate while vessel is proceeding (more than 4 knots).	
Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.3.4 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by wastewater discharges as a result of Dorado Phase 1 compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-20** and **Table 7-21.** The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case consequence for the discharge of wastewater was evaluated as minor (**Table 7-19**). This consequence is considered to be acceptable when assessed against the Santos risk matrix (**Section 4**).

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from the discharge of wastewater are acceptable.

Table 7-20: Demonstration of acceptability for the discharge of wastewater

Acceptability Criteria	Demonstration of Acceptability
Consistency with the principles of ESD.	Management of wastewater discharges from Dorado Phase 1 is consistent with the principles of ESD because: + there is no threat of serious or irreversible environmental damage, + the environmental resources within the Project Area are not expected to be significantly impacted, and + biological diversity and ecological integrity will be maintained.
Internal Context.	The management of wastewater is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context.	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of potential impacts and risks from wastewater discharges.
MNES	The below conservation advice and recovery plans identify habitat degradation as a threat to threatened species. Impacts to the marine environment from the discharge of wastewater will be highly localised. The marine environment that may be affected is widely distributed throughout the Project Area and beyond. As such, Santos considers the impacts of wastewater discharge to not be inconsistent with these conservation advice and recovery plans: **Conservation Advice** + Approved conservation advice for Pristis clavata (dwarf sawfish) (Threatened Species Scientific Committee 2009), + Approved conservation advice for Pristis pristis (largetooth sawfish) (Threatened Species Scientific Committee 2014b), and + Approved conservation advice for green sawfish (Threatened Species Scientific Committee 2008a). + Conservation advice for Rhincodon typus (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice Balaenoptera borealis sei whale (Threatened Species Scientific Committee 2015b) + Conservation Advice Balaenoptera physalus fin whale (Threatened Species Scientific Committee 2015c) **Recovery Plans** Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b) - This recovery plan identifies habitat degradation as a threat

	to sawfish. Impacts to benthic habitats from the discharge of drilling fluids and cuttings will be highly localised within the Project Area. The benthic habitats that may be affected are very widely distributed throughout the Project Area and beyond. The closest Sawfish BIA (for pupping, nursing and foraging) is approximately 87 km from the southern extent of the Project Area. Santos considers the impacts of wastewater discharge to not be inconsistent with the recovery plan. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) - This recovery plan identifies chemical discharges as a threat to marine turtles. Impacts from chemical discharges may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of wastewater discharge to not be inconsistent with the recovery plan. Recovery Plan for the White Shark (Carcharodon carcharias) (DSEWPac, 2013b) – This recovery plan identifies habitat modification as a potential threat to White Sharks. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of wastewater discharge to not be inconsistent with the recovery plan. Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a) – This recovery plan identifies acute and chronic chemical discharge as a threat to Blue Whales. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from chemical discharges may result in a temporary, localised decrease in water quality, which will recover rapidly. Santos considers the impacts of wastewater discharge to not be inconsistent with the recovery plan. Recovery Plans / Conservation Advices for other species that may occurring the Project Area do not identify habitat degradation as a key threat; or have any explicit relevant objectives or management actions related to habitat degradation.
Other Relevant Requirements.	Management of wastewater discharges will be consistent with MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification).

Table 7-21: Demonstration of acceptability of the discharge of wastewater against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[28] are acceptable. **RSAL4**: Substantial[29] impacts to water quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable.	The evaluation of impacts from the discharge of wastewater show that impacts will be localised around the discharge locations. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity will be maintained beyond 1 km of the of the WHP, FPSO and drilling activities. Given the widespread nature of the open water environment in the region, the discharge of wastewater will not result in impacts to water quality that result in a loss of ecological integrity.
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity[24] are acceptable. **RSAL6**: Substantial[25] impacts to sediment quality within 1 km of the WHP, FPSO, future tiebacks and drilling activities are acceptable.	The evaluation of impacts from the wastewater discharge shows that potential for contaminants in wastewater to interact with sediment is low (limited to a slight increase in nutrients and organic matter, along with a small increase in biochemical oxygen demand). Given the anticipated dilution of wastewater discharges, settling velocity of suspended solids, the water depth in the Project Area and the water movement due to currents, it is expected that potential impacts will be localised to the sediments within the vicinity of the discharge points. It is also expected that a high level of ecological integrity will be maintained beyond 1 km of the Dorado WHP, FPSO and drilling activities. Given the widespread nature of the open water environment in the region, the discharge of wastewater will not result in impacts to sediment quality that result in a loss of ecological integrity.
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat	The expected potential impacts on marine fauna from wastewater discharges are limited to localised impacts on plankton and fishes. While there is the potential for levels of residual chemicals or temperature increases that could injure or kill marine fauna in the event of prolonged exposure, the transient nature of the marine fauna does not suggest that this would occur. Impacts will be limited to any individual that remain within the plume for a prolonged period, and it is not likely that there would be any notable impact to fish populations. These impacts are expected to

[28] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[29] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

abatement plans published by the DAWE. **RSAL16**: No significant[30] impacts to species listed as threatened or migratory under the EPBC Act as a result of Dorado Phase 1. **RSAL19**: No negative impacts to the economic viability of the commercial fish resources.	be minor and localised, with no impact on the abundance and quality of commercially targeted fish populations. The assessment of impacts from wastewater discharges shows that mortality or significant impacts to EPBC Act listed threatened, migratory or cetacean species will not occur. Wastewater discharge has not been identified as a threat in any recovery plans or conservation advice for threatened and migratory species.

7.2.4 Emissions – Artificial Light

7.2.4.1 Description of the Event

The operation of drilling rigs, vessels and facilities associated with the project will generate artificial light emissions. Light emissions from the project will be associated with lighting of drilling rigs, project vessels and facilities for operational and safety requirements within the Project Area. Light sources are summarised in **Table 7-22**.

Table 7-22: Summary of potential light sources for Dorado Phase 1

Project stage	Light source	Lighting Requirement	Lighting Details
Installation	Project vessels (Installation and Support)	Installation activities	Installation of WHP, flowlines, FPSO facility moorings and riser column via project vessels. Lighting will be required temporarily to support installation activities which will be 24 hour operations. Light sources will include navigational and operational light on vessels.
	MODU	Development drilling	Temporary lighting at the WHP location during the development drilling stage (approximately two years). Light sources include continuous navigational and operational lighting on the MODU, and intermittent flaring (1 to 2 days per well, up to 16 wells) associated with wellbore and casing clean-up and flowback (to remove any remaining drilling or completion fluids, debris and solids coming out of the formation and perforations).

[30] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

Project stage	Light source	Lighting Requirement	Lighting Details
Commissioning	FPSO Commissioning	Facility Commissioning	Intermittent high-pressure flaring occurs during commissioning of the FPSO topside systems. Four compressions systems require commissioning individually (reinjection compression, HP compression, LP compression, Vapour recovery unit). Each well will need to be commissioned on a sequential basis, building up to full field flow. During this period the above compression systems will be commissioned as the gas flow rates allow. An allowance for flaring during this period for problems that are encountered during commissioning of the compressors. Short duration of activity approximately up to 3 months, and intermittent flaring (as each system is commissioned).
Operations	Not normally manned WHP	Operations	Light sources include continuous navigational lighting and intermittent operational light during manned periods to support maintenance campaigns, well interventions.
	Manned FPSO	Operations	Continuous lighting (except when the FPSO is disconnected from the mooring). Light sources include continuous navigational and operational light and flaring. FPSO equipped with a low-pressure and a high-pressure flare. The low-pressure flare is a continuous flare required to support safe operations. High-pressure flaring occurs during upset conditions and emergency shutdown. The flare height has been conservatively estimated as 110 m, noting that this will be revised during FPSO design and in accordance with safety requirements.
	Offtake tankers	Operations	Navigational and operational lighting on offtake tankers. Offtakes expected to initially be once per week, with frequency of offtake declining as production declines. Offtake operations may take up to 48 hours.
	Support vessels	Support operations, IMMR activities	Support vessels will be continuously present within the Project Area. Light sources will include navigational and operational light.
Future tiebacks	Project vessels	Future tiebacks	Construction and other vessels will be required to support installation of infrastructure for future tiebacks. The timing and duration of tieback activities has not been determined. Light sources will include navigational and operational light.
Wel l inte rve	MODU	Development Drilling (infill	Periodic MODU lighting associated with well intervention or infill drilling at the WHP or

Project stage	Light source	Lighting Requirement	Lighting Details
		wells and future tiebacks) and well intervention	development drilling associated with future tiebacks. Light sources will include navigational and operational light, and intermittent flaring associated with well clean-up, 1 to 2 days per well, with flaring sequential as each well is completed. The flaring will be limited by the capacity of the rig used to drill the well (less than the FPSO flare). The timing and duration of tieback development and infill activities have not been determined.
Decommissioning	Project vessels	Removal of infrastructure	Lighting requirements on vessels during decommissioning activities. Light sources will include navigational and operational light. The timing and nature of decommissioning activities has not been determined.
	MODU	Plugging and abandonment of wells	Lighting requirements during well abandonment activities. Light sources will include navigational and operational light. No flaring is expected. The timing and nature of well abandonment activities has not been determined.

The characteristics of light emissions associated with sources described in **Table 7-22** will differ depending upon the number, intensity, spectral output and type of light. Historically, vessels and facilities use a combination of high-pressure sodium, fluorescent, metal halide and mercury vapour lights. Recent advances in light emitting diode technology has seen a switch to this more efficient and cost-effective technology. The nature of the emissions will be a result of the final project design and schedule of activities. Operational lights of the FPSO are intended to be light emitting diodes, although the light sources associated with vessels and facilities are currently unknown and could comprise of any or a combination of those mentioned above. As such a conservative approach has been taken where the greatest potential emissions have been modelled and assessed for the purpose of describing potential impacts from light emissions.

There is limited published information regarding light characteristic of flares. Pendoley (2000) showed that the intensity of two flares (a tower flare and a pit flare) at Thevenard Island, Western Australia, peaked at between 650 to 700 nm. This result is similar to three other flares measured in Australia (Pendoley Environmental, unpublished data). Pendoley (2000) found no significant spectral difference between the two flares types, or when varying flow rates.

7.2.4.1.1 Artificial Light Emissions Modelling

The two main sources of light emissions for the Dorado Project are facility lighting and the flare. FPSO operations presents the greatest source of artificial light based on its size, maximum possible intensity (from a full process blowdown flaring event), permanently manned operations, and continuous presence in the Project Area over an estimated 20 year field life (aside from when disconnected and off station). Light sources on the FPSO also include navigation and operational lighting.

The following light emissions sources have been excluded from the modelling to inform the risk assessment:

- Light emissions from support vessels throughout operations or development well drilling (including future tiebacks) due to low intensity and/or temporary and transient nature of support vessel movements;
- Light emissions from the MODU during development well drilling (including future tiebacks) due to low intensity and temporary duration (1 to 2 days per well, with flaring sequential as each well is completed) and limited by the rig flare capacity (less than FPSO); and
- Light emissions during commissioning due to the short duration (approximately up to 3 months) and intermittent flaring over that period (as each system is commissioned sequentially).

Light emissions associated with the FPSO were modelled to represent light emissions associated with Dorado Phase 1 (**Attachment 9**).

Two scenarios were modelled:

- operational lighting with no flaring; and
- operational lighting including flaring.

The facility's lighting design and luminaire specifications were applied to the ILLUMINA artificial light at night model (Aubé et al. 2005). The ILLUMINA model is a 3-D model that predicts both the extent of visible light and radiance (light received in a specific area) (**Attachment 9**). In this assessment light is described in terms of radiance. Radiance describes the light received in a specific area and is provided in the units $W/m^2/sr$, where W = watts, m^2 = meters squared and sr = steradian (unit of solid angle, equal to the angle at the centre of a sphere subtended by a part of the surface equal in area to the square of the radius) (**Attachment 9**).

In the absence of any published or generally accepted units or scale for measuring the impact of ALAN on wildlife, moonlight was selected as a proxy (considered representative of ambient light levels marine fauna are adapted to). The light model output (radiance, units of $W/m^2/sr$) was converted to units of full moon equivalents in an attempt to give the radiance output some biological relevance and to aid interpretation in an environmental impact assessment context. The light emissions are considered to have reduced to ambient when radiance is less than the equivalent of 0.01 ($1/100^{th}$) of one full moon.

In the non-flaring scenario, the model results show that radiance has reduced to ambient (less than 0.01 full moon equivalent) at 17.7 km from the source. In the flaring scenario, the flare is no longer directly visible at 42.4 km, when the flare drops below the horizon (**Figure 7-8** and **Figure 7-9**). At this distance, the radiance is equivalent to 0.25 full moons. As the flare drops below the horizon, radiance declines rapidly and is no longer visible.

The nearest shorelines are Bedout and Turtle Island, at approximately 70 km and 95 km from the FPSO respectively. No light associated with the FPSO will be visible from beaches on these islands, as shown in **Figure 7-8** and **Figure 7-9**.

Figure 7-9 presents the combined critical and important habitat for marine turtles (hawksbill, green and loggerhead turtles). Radiant light sources overlap one important habitat, the flatback turtle internesting BIA centred around North Turtle Island, approximately 39km from the Project Area.

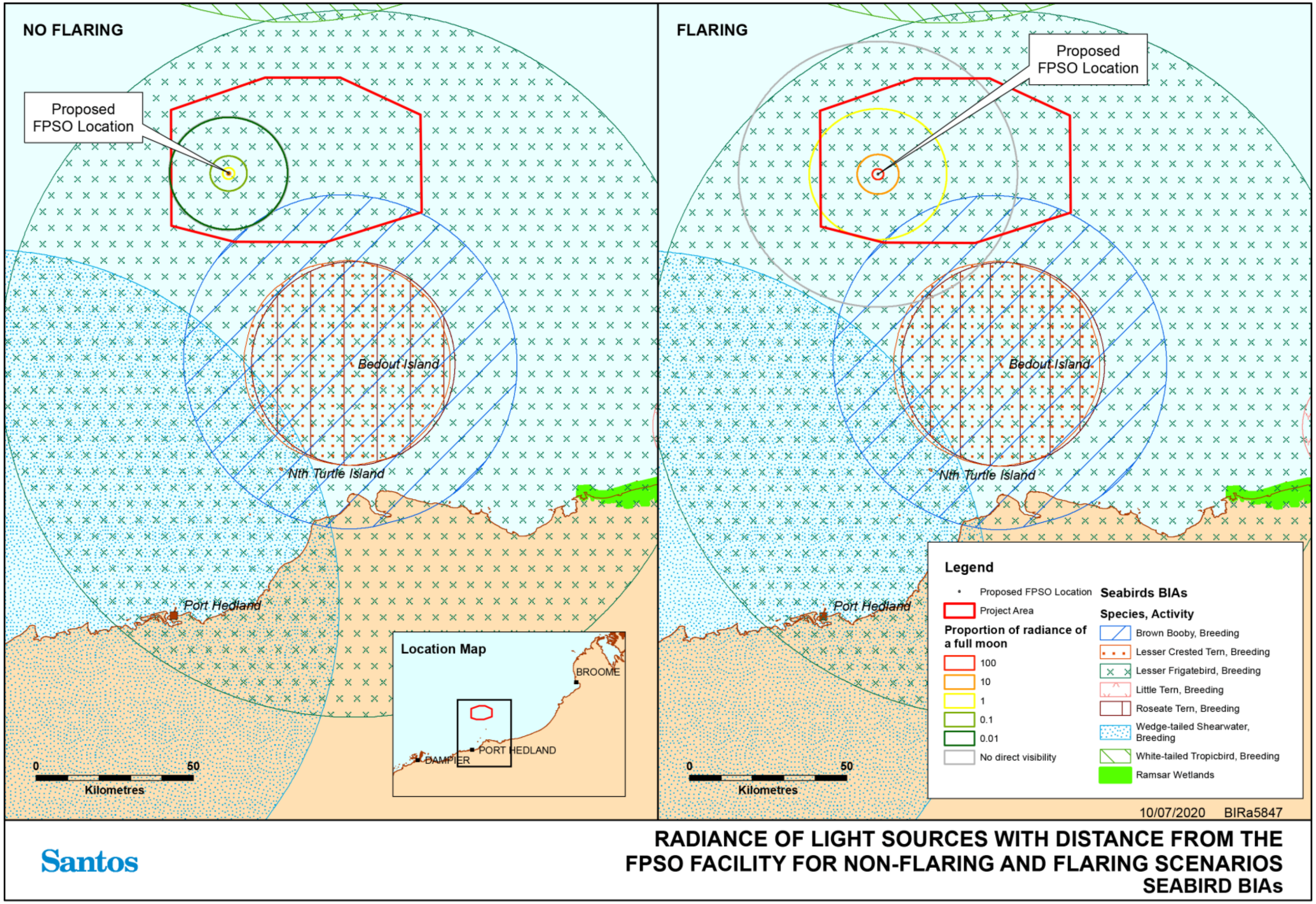


Figure 7-8: Radiance of light sources with distance from the FPSO facility for non-flaring and flaring scenarios in relations to seabird BIAs

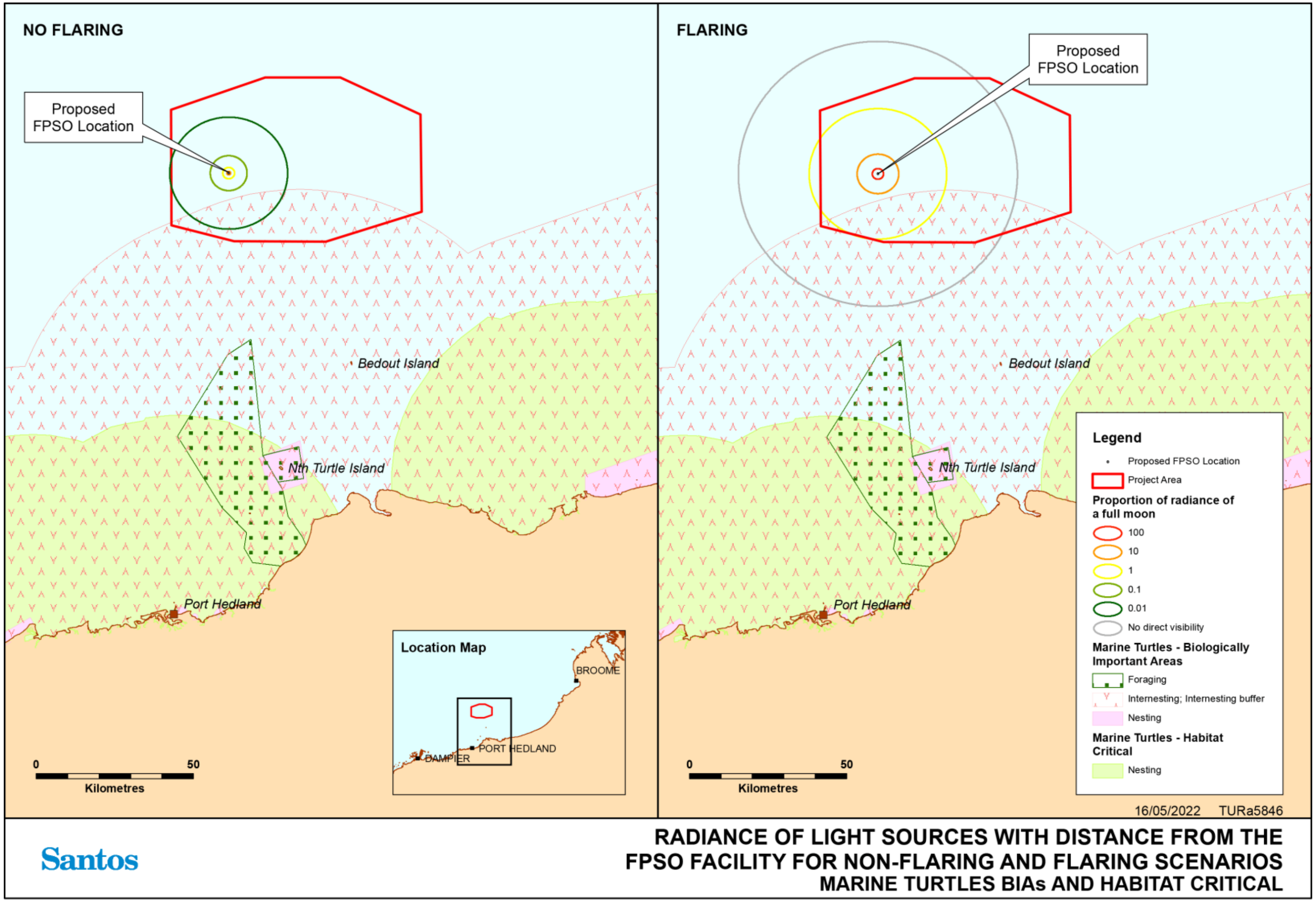


Figure 7-9: Combined BIAs for marine turtles (hawksbill, green and loggerhead turtles), including radiance of light sources with distance from the FPSO facility for non-flaring and flaring scenarios. in relation to turtle critical habitats and BIAs

Given that the future tiebacks may include flaring, light emissions modelling results for the Dorado facilities has been extrapolated for a potential tieback location in the southern extent of the Project Area (**Figure 7-10**) selected as a 'worst-case' location due to its proximity to the turtle and bird sensitivities. It should be noted, as per **Table 7-22** the flaring from future tiebacks would be intermittent, lower intensity and of short duration (1-2 days) from the drilling MODU, therefore the application of modelling is conservative. **Figure 7-10** shows should flaring occur at the southern edge of the operational area (from drilling potential tieback wells), light emissions would not overlap critical habitats for marine turtles. The lack of permanent infrastructure in the area suggests that other artificial light sources will be restricted to the temporary presence of shipping vessels associated with the shipping fairway, and fishing vessels.

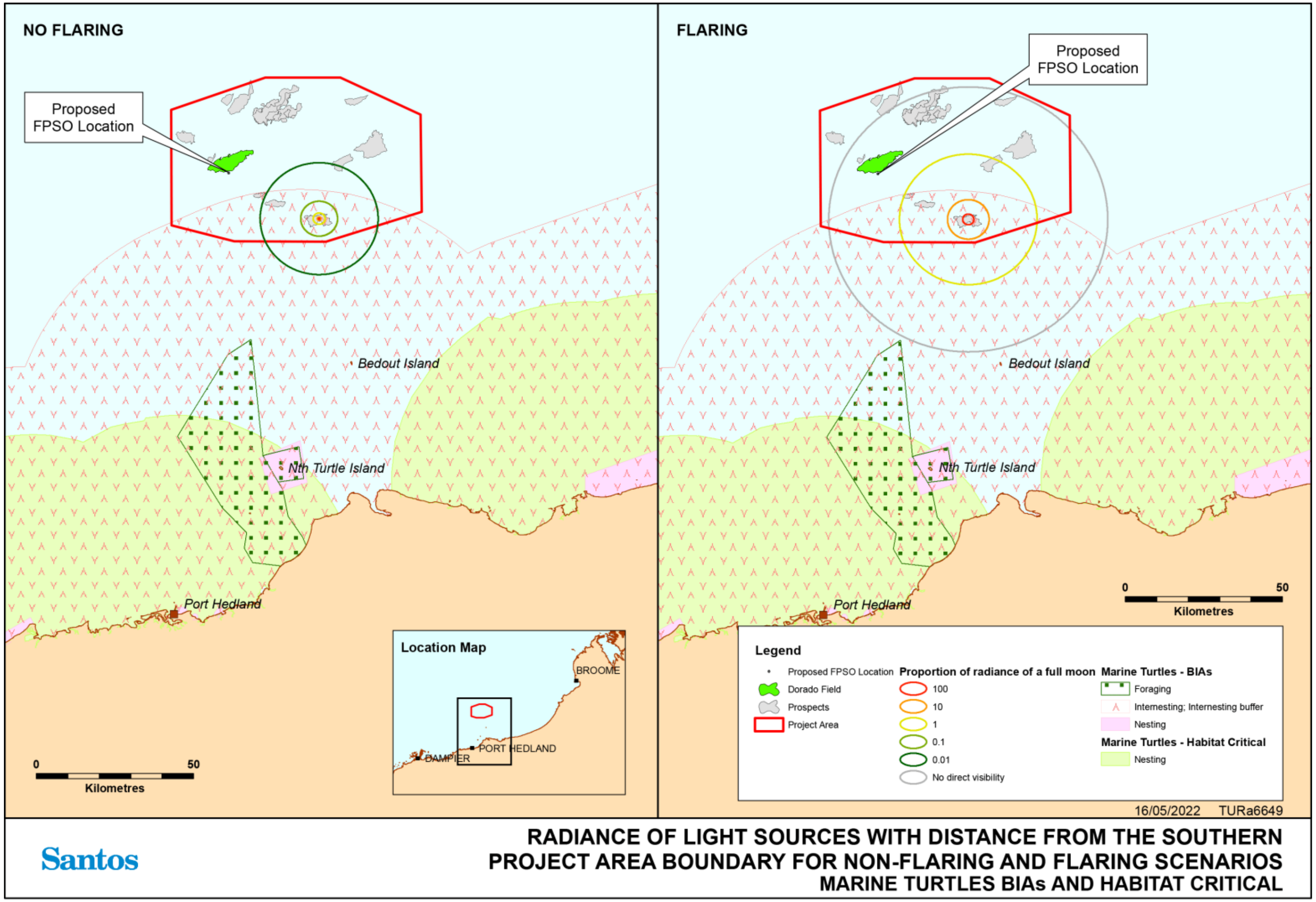


Figure 7-10: Combined BIAs for marine turtles (hawksbill, green and loggerhead turtles), including radiance of light sources from a worst case future tieback location for non-flaring and flaring scenarios.

7.2.4.2 Details of Environmental Impacts and Risks

Light is a form of energy that is emitted over a particular band of frequencies and wavelengths of the electromagnetic spectrum. The visible range (for humans) is typically 400 to 700 nm, with ultraviolet below this wavelength range, and infra-red above it. Fauna perceive light differently to humans, and their visible spectrum can vary between about 300 nm and more than 700 nm depending on the species (Commonwealth of Australia 2020); i.e. it can extend into the ultraviolet and infra-red spectra. Therefore, the potential impact from artificial light emissions can vary depending on the specific characteristics of the source (e.g. light intensity, wavelength) and the sensitivities of the receptor.

Artificial lighting can alter critical behaviours in wildlife. For some species, artificial lighting may extend diurnal or crepuscular behaviours by improving an animal's ability to forage (e.g. Hill 1992). For nocturnal species, artificial light can result in detrimental changes in behaviour.

The severity to which artificial light negatively impacts individuals depends upon the vulnerability, which varies between and within species, depending upon their behaviour, and on the spectral output of the light emissions. The sensitivity of different species to different wavelengths is summarised in **Figure 7-10** which shows that most species are sensitive to short wavelength light (ultraviolet/violet/blue). The potential impact of light emissions associated with Dorado Phase 1 on these receptors are described below.

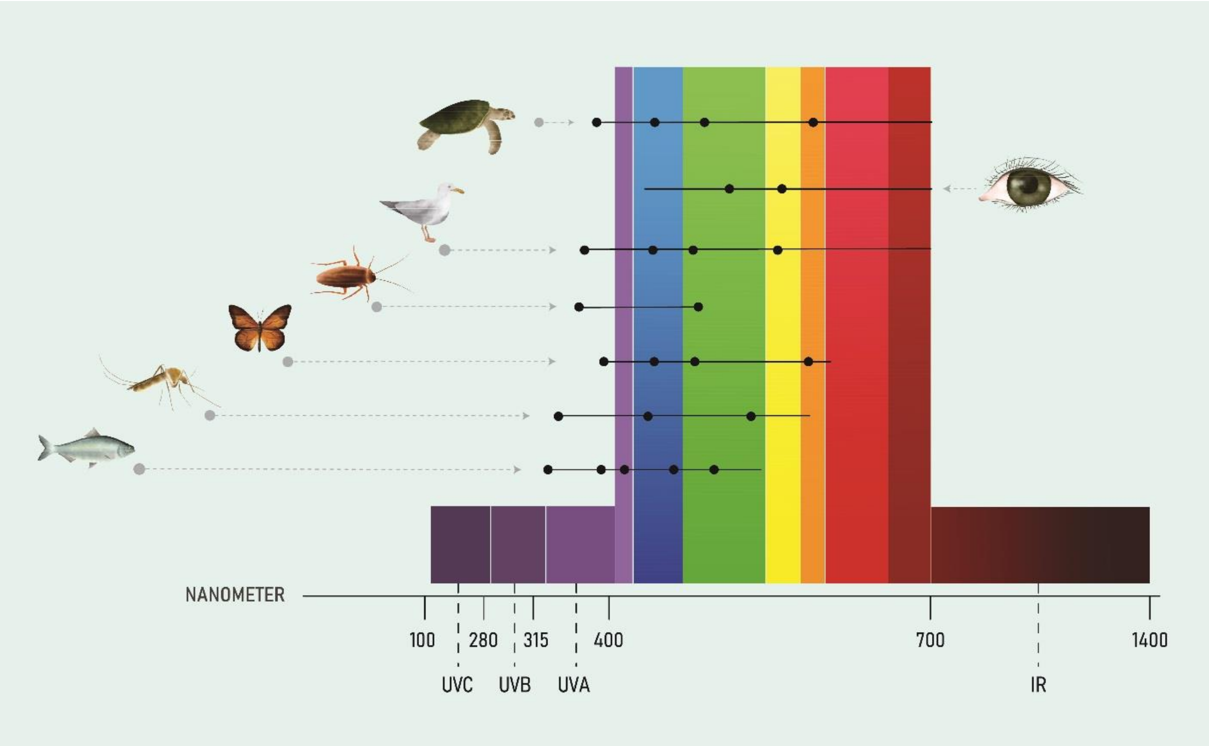


Figure 7-11: Visibility of different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivity (Commonwealth of Australia, (2020a).

Impacts of artificial light emissions are expected to be restricted to within line of sight of Dorado Phase 1 for receptors above the sea (e.g. migratory birds). Impacts of artificial light emissions within the water column will be restricted to the vicinity of Dorado Phase 1 facilities due to the rapid attenuation of light in water compared to air. Considering the water depths of the Project Area (70 to 120 m) light emissions from surface infrastructure and vessels are unlikely to penetrate to the seafloor.

Table 7-23 identifies the potentially impacted receptors as a result of artificial light emissions within the Project Area.

Table 7-23: Receptors potentially impacted by artificial light emissions

Description of the Risk	Receptor Categories
Behavioural impacts to marine fauna as a result of artificial light emissions.	Plankton – **Section 7.2.4.2.1** Fish – **Section 7.2.4.2.2** Marine Mammals – **Section 7.2.4.2.3** Reptiles – **Section 7.2.4.2.4** Birds – **Section 7.2.4.2.5**

No credible impacts to the physical environment as a result of artificial light emissions were identified. Impacts to socio-economic receptors, such as reduced visual amenity, will not credibly occur as artificial light emissions will not be visible from residential areas. The nearest town, Port Hedland, lies approximately 143 km from the proposed FPSO location, which is well beyond the distance at which the flare will be below the horizon.

7.2.4.2.1 Plankton

Diel vertical migration is an omnipresent phenomenon in plankton communities whereby plankton migrate to surface waters at dusk and return to deeper waters at dawn (see Hays 2003 for review). The migration patterns have also been shown to be influenced by the lunar cycle (Ochoa et al. 2013). Although evidence has shown that such migration also occurs in the deep sea where no direct and background sunlight penetrates (van Haren and Compton 2013), light levels in the water column are thought to be strong cues for DVM (Hays 2003). These vertical migrations of zooplankton are integral to structuring pelagic communities since they influence the behaviour of predators (Hays 2003). While not empirically tested, it is possible that artificial light could disrupt Diel vertical migration should the intensity of the light exceed other light cues. Disruption to migration could potentially reduce survival of zooplankton on an individual level.

The reproductive biology of marine invertebrates is influenced by light cues, and may include broadcast spawning, larval phototaxis and recruitment (see Garratt et al. 2019 for review). Micronekton invertebrates (such as krill) may be affected by artificial light via the same pathways described for zooplankton above.

The effects of artificial light on zooplankton would most likely be confined to areas of direct light spill on the ocean surface which would be restricted to areas in close proximity to facilities and vessels, and in the case of impacts to fish spawn, limited to surface waters. Any mortality to zooplankton as a result of artificial light is not expected to be detectable above natural morality rates, which are very high (exceeding 50% per day in some species and commonly exceeding 10% per day) (Tang et al. 2014). Further, ocean currents in the region will continually circulate and replenish zooplankton in Project Area. This will limit potential impacts to localised changes in zooplankton distribution, potentially altering predator distribution at most. Population or ecosystem level effects, both in terms of the regional biomass of zooplankton and of fish or invertebrate populations which may include egg or larval stages, are not considered credible.

7.2.4.2.2 Fish

Behavioural responses of fish to artificial light have been demonstrated in various fish species (Marchesan et al. 2005; Nguyen and Winger 2019). Nguyen and Winger (2019) describe four common movement patterns of fish in response to light; phototaxis (movement towards or away from light), photokinesis (movement or lack of movement in response to light), aggregation and DVM (see **Section 7.2.4.2.1**) and showed that behavioural responses are influenced by both wavelength and intensity. Since many predatory fish rely on visual cues to locate and capture prey, increased light can lead to changes in predator-prey interactions. For example, the proportion of herring *Clupea harengus* feeding increased with prey density in high light intensity experiments, while under dark conditions, increased food availability failed to trigger a similar increased feeding response (Batty et al. 1990).

Light emissions associated with Dorado Phase 1 may influence behaviour of fish resulting in aggregation or increased abundance of fish in the vicinity of facilities. Aggregation around moving vessels is less likely. Whale sharks may forage around the facilities if prey abundance is increased, however, this is unlikely to impede migration. Light has not been identified as a key threat for the whale shark (Commonwealth of Australia, 2005).

The area of impact is likely to be restricted to areas where light is directly visible to fish such as areas of light spill on the ocean surface. The behavioural responses are unlikely to significantly alter critical behaviours such as migration or spawning, reducing the credibility of population level effects.

7.2.4.2.3 Marine Mammals

There is a paucity of research investigating the effects of artificial lighting on marine mammals and direct effects of artificial lighting on cetaceans have not been reported. Many dolphin species are thought to be diurnal, or at least more active during the day, possibly related to prey availability (Sekiguchi and Kohshima 2003). Since fish species may pool in areas of light spill, dolphins may be indirectly attracted to lit structures or illuminated marine environments for foraging purposes.

Since mammals use variations in the length of day to anticipate environmental changes and time their reproduction, light pollution which affects day length perception could lead to changes in biological functions. However, marine mammals occurring within the region will be transient in the Project Area. There is potential for opportunistic foraging should prey abundance be increased; however, individuals are unlikely to be exposed to artificial light for durations sufficient to impact biological functions.

7.2.4.2.4 Reptiles

Marine turtles

Potential impacts of artificial light on marine turtles has been well documented, although the vulnerability of individuals to negative impacts is influenced by life history stage and behaviour.

While the behavioural responses of marine turtles are relatively well understood, there is currently no quantitative impact thresholds for artificial light due to the expansive suite of factors that influence individual vulnerability. In addition to the intensity of the light source, the spectral power distribution (wavelength and colour), atmospheric scattering, cloud reflectance, spatial extent of sky glow, duration of exposure, horizon elevation and lunar phase can all influence behavioural responses to varying degrees.

Wavelength in particular has been shown to significantly affect the vulnerability of individuals to artificial light. In general, artificial light rich in short wavelength blue and green light are most disruptive (Fritsches 2012; Pendoley 2005; Witherington 1992). Green, flatback and loggerhead turtles all show increased sensitivity to wavelengths less than 600 nm (Fritsches 2012; Levenson et al. 2004; Pendoley 2005) with green and flatback turtles showing stronger preference for blue light less than 500 nm (Fritsches 2012; Pendoley 2005). Although longer wavelengths of light are less attractive than shorter wavelengths, long wavelength light can still disrupt sea-finding of hatchlings (Pendoley and Kamrowski 2015, Pendoley 2005, Robertson et al. 2016), and if bright enough can elicit a similar response to shorter wavelength light (Cruz et al. 2018; Mrosovsky 1972; Pendoley and Kamrowski 2015). Hence, the disruptive effect of light on hatchlings is also strongly correlated with intensity. Red light must be almost 600 times more intense than blue light before green turtle hatchlings show an equal preference for the two colours (Mrosovsky 1972).

Pendoley Environmental (**Attachment 9**) outline conservative potential impact criteria at light intensities relative to moon phase. It is considered that at intensities greater than the equivalent of $1/10^{th}$ of a full moon (0.1 full moon equivalents) behavioural impacts are possible, depending on ambient moon phase at the time of exposure, which will influence the visibility of the artificial light sources equivalent to the light output.

Foraging and Migration

Foraging adult turtles have been observed feeding on prey presumed to be attracted by lights of oil production platforms in the Gulf of Mexico (Kebodeaux 1994). However, illumination of fishing gear has been shown to reduce the bycatch of green turtles as it is thought that light sources alert them to the presence of a net (Ortiz et al. 2016). This suggests that marine turtles are most likely attracted to increased prey abundance around offshore facilities, rather than the light sources itself. Foraging marine turtles may be observed around Dorado Phase 1 facilities and vessels in response to increase prey abundance, however, this is not expected to result in negative impact at the individual or population level.

Mating, Internesting and Migration

Marine turtles do not forage during the breeding season and light cues are not thought to guide migration, mating or internesting behaviours. Further, to date, there is no evidence to suggest internesting turtles are attracted to light from offshore vessels. The Flatback Turtle inter-nesting BIA is the only BIA that intersects the Project area or extends to locations where light from flaring (FPSO and/or southern tieback flaring) is visible.

Nesting and Hatchling Emergence

Adult female marine turtles return to land, predominantly at night, to nest on sandy beaches, relying on visual cues to select and orient on nesting beaches and return to the ocean post nesting. Artificial lighting on or near beaches has been shown to disrupt nesting behaviour (see Witherington and Martin 2000 for review). Hatchling turtles emerge from the nest, typically at night, and must rapidly reach the ocean to avoid predation (Salmon 2003). Artificial lights interfere with natural light levels and silhouettes, which disrupts hatchling sea-finding behaviour (Kamrowski et al. 2014; Pendoley and Kamrowski 2015; Witherington and Martin 2000).

Results of the light modelling show that light in either modelled scenario is not visible at the nearest turtle nesting beaches on Bedout and Turtle Islands (**Attachment 9**). Therefore, artificial light associated with the FPSO, including during flaring, is not expected to result in negative impacts to nesting females and emerging hatchlings.

Hatchling Dispersal

Once in nearshore waters, artificial lights on land can also interfere with the dispersal of hatchlings. Presence of artificial light can slow down their in-water dispersal (Wilson et al. 2018; Witherington and Bjorndal 1991) or increase their dispersion path, potentially depleting yolk reserves, or even attract hatchings back to shore (Truscott et al. 2017). In addition to interfering with swimming, artificial light can influence predation rates, with increased predation of hatchlings in areas with significant sky glow (Gyuris 1994; Pilcher et al. 2000). Since the nearshore area tends to be predator-rich, hatchling survival may depend on them exiting this area rapidly (Gyuris 1994). Should this be the case, aggregation of predatory fish occurring in artificially lit areas and under artificial structures (Wilson et al. 2019) may further increase predation of hatchlings.

Results of the light modelling suggest that light levels of the FPSO without flaring may result in a behavioural response within 5.5 km and more likely within 1.8 km (**Attachment 9**). During flaring these distances are increased to 42.4 km and 20.7 km (**Attachment 9**). The spectral output of the flare is expected to be outside the peak sensitivity of marine turtles reducing the vulnerability of individuals to behavioural impacts. However, impacts may still occur if intensity is great enough, especially considering the absence of competing light sources in the vicinity of the Project Area.

While not tested empirically due to the logistical constraints of tracking large numbers of hatchlings concurrently, the density of hatchlings will decrease with distance from the nesting beach as individuals disperse in open ocean. Given the distance between the proposed FPSO location and the nearest turtle nesting beaches (Bedout and Turtle Islands, 70 km and 95 km respectively), the density of hatchlings is expected to be low within 42.4 km of the flare, and lower still within 5.5 km of the FPSO. Due to the strong tidal currents in the region (**Section 3.2**), it is not considered credible that hatchlings would be able to swim towards, and remain in, areas of light spill. However, should hatchlings be carried within a distance of light sources where attraction may occur, an increase in energy expenditure could occur in a small number of hatchlings attempting to remain in the areas of light spill. Given that attraction could only occur during hours of darkness, the potential impact at the individual level is temporary only. At the population level, the consequence of increased energy expenditure in a negligible number of hatchlings is not expected to increase mortality above that of natural levels.

Sea Snakes

Documentation of the effects of artificial lighting on sea snakes is lacking. However, as active and intensive foragers that display prolonged episodes (weeks) of continuous effort in search of prey (Bonnet 2012), sea snakes may be attracted to well-lit areas around marine infrastructure due to the associated attraction of prey species. It is not expected that such a behavioural response would significantly alter behaviour or habitat use to the long-term detriment of sea snake populations.

7.2.4.2.5 Birds

Artificial light can have a variety of effects on seabirds depending upon the species and the life stage or behaviours being undertaken at the time. Negative responses of birds to artificial light may include collision, entrapment, stranding, grounding, disorientation or interference with navigation (being drawn off course from usual migration route), potentially resulting in reduced fitness, injury and/or death (see Commonwealth of Australia 2020 for review).

Species with a nocturnal component of their life history, such as procellariforms (albatrosses, petrels and shearwaters), are at greater risk of negative impacts. The bulk of the literature concerning impacts of lighting upon procellariforms relate to the synchronised mass exodus of fledgling seabirds from their nesting sites (Deppe et al. 2017; Le Corre et al. 2002; Raine et al. 2007; Reed et al. 1985, Rodríguez et al. 2015b, 2015a), with fewer investigating the impacts of light at sea. Reports of interactions between seabirds and artificial light at sea is generally anecdotal following significant interaction events (e.g. Black 2005) or by unsystematic monitoring by oil and gas operators (e.g. Day et al. 2015; Glass and Ryan 2013; Ronconi et al. 2015; Wiese et al. 2001). Deck lights and spotlights on fishing vessels have been recorded attracting numerous seabirds at night, particularly on nights with little moon light or low visibility (Black 2005; Merkel and Johansen 2011; Montevecchi 2006).

While it has been shown that all seabirds are sensitive in the shorter, violet – blue region of the visible spectrum (380 nm to 440 nm (Machovsky-Capuska et al. 2011)), white light poses a potential threat to seabirds as they contain all wavelengths of light (Deppe et al. 2017; Wiltschko et al. 1993). Further, Raine et al. (2007) concluded the intensity of light may be a more important cue than colour; a very bright light will attract seabirds, regardless of the colour.

That procellariforms are shown to be attracted to artificial lights on land, and anecdotally to vessels and oil and gas facilities, in addition to undertaking nocturnal foraging on bioluminescent prey, makes them susceptible to attraction to light sources in the Project Area and negative impacts that could result. The light modelling undertaken assumed the receptor was located at ground level and does not account for a bird in flight. This is most relevant to the result of the flaring scenario where light intensity decreased rapidly once the source dropped below the horizon.

The nearest BIA for procellariform species is approximately 45 km of the Dorado FPSO (a wedge-tailed shearwater breeding BIA) suggesting that any interaction between procellariforms and the facilities would be limited to individuals rather than populations.

Diurnal seabird species, such as terns, noddies and boobies, in contrast to procellariforms, are less vulnerable to impacts resulting from nocturnal behaviours. However, the presence of facilities can alter foraging behaviours and provide artificial roosting sites. Several species of terns and boobies nest in large numbers at Bedout Island, in addition to the lesser frigatebird (Burbidge et al. 1987). Although reports describing the interaction between these species and offshore facilities are lacking, Tasker et al. (1986) reported that a variety of seabird species recorded around oil platforms were observed feeding by the light of the gas flare at night, pecking at small unidentified items in the sea, a behaviour was noted less frequently during the day. Ortego (1978) reported that the only impact of artificial light associated with an oil rig in the Gulf of Mexico on the blue faced booby was increased foraging.

There is a paucity of literature on the sensitivity of diurnal seabirds to different wavelengths. Studies on the eye physiology of gulls and terns found that visual pigments were present in some, but not all, species for vision in the short wavelength ultraviolet region of the spectrum, in addition to the violet (blue) region of the spectrum (Machovsky-Capuska et al. 2011). However, despite being a predatory diving bird, experiments on cormorants suggest that these birds have poor visual resolution in water (Martin et al. 2008).

Presence of light sources in the Project Area may attract diurnal seabird species via increased prey availability and extended foraging activities. The artificial light emissions from offshore facilities may also have the potential to impact seabirds through collisions with infrastructure due to visual disorientation, particularly during periods of low visibility (e.g. cloudy, overcast or foggy conditions) (Wiese et al., 2001). Newly fledged juvenile birds leaving breeding colonies for the first time are the most prone to disorientation by artificial light (Commonwealth of Australia, 2019). Although such attraction increases the risk of collision with facilities, incidents of collision of diurnal species, or similar taxonomic groups, are few (see Ronconi et al. 2015 for review).

As with diurnal seabirds, artificial lighting has been shown to influence the foraging behaviour in shorebirds, with increased foraging success in areas illuminated by artificial light (Santos et al. 2010). Although shorebirds may be attracted to foraging areas with increased illumination, artificial light near nocturnal roosting sites may displace shorebirds if they select darker roost areas where risk of predation is perceived to be lower (Rogers et al. 2006). Given the lack of natural roost sites or intertidal foraging areas in the vicinity of the Project Area, artificial light is unlikely to impact these behaviours.

Artificial light may attract migratory shorebirds in flight (Longcore et al. 2013), influencing stopover selection and impacting successful migration and decrease fitness (McLaren et al. 2018). The FPSO is located approximately 146 km from Eighty Mile Beach, a Ramsar site of international importance for migratory shorebirds in the east Asian-Australasian flyway (Bamford et al. 2008) (**Figure 3-22**). While migration pathways for species occurring at Eighty Mile Beach are poorly defined, birds may migrate through the Project Area. Sage (1979) (cited in Ronconi et al. 2015) reports incidents of migrating waders colliding with offshore platforms, though whether this was due to attraction by artificial light is unknown. The exact mechanism for navigation of migratory birds is not clear, however, it is widely thought they use a mixture of natural cues, including the earth's magnetic field, solar and celestial orientation and polarised light patterns to determine their migratory pathway (Weindler and Liepa, 1999; Wiltschko and Wiltschko, 2001).

There is a risk that artificial light sources along migratory pathways may alter natural patterns, specifically in the absence of terrestrial landmarks (i.e. offshore). Studies have demonstrated that light from offshore facilities has been shown to attract migrating birds, with species that migrate during the night more likely to be affected (Marquenie et al., 2008; Verheijen, 1985). Birds can either be attracted by the light source itself or indirectly as lighted structures in marine environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds. In some cases, sources of artificial light may provide enhanced capability for seabirds to forage at night (Verheijen, 1985). Studies in the North Sea indicate that migratory birds may be attracted to lights on offshore platforms when travelling within a radius of 3 to 5 km from the light source. Outside this area their migratory paths are likely to be unaffected (Marquenie et al., 2008). Artificial lighting may interfere with a bird's internal magnetic compass. It is thought that migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation (Muheim et al., 2002; Wiltschko and Wiltschko, 2001, 1995) whereas red light, the long-wavelength component of light, is more likely to disrupt magnetic compass orientation.

Studies have indicated the potential impact of artificial lighting on the diversion of migratory pathways of seabirds (Verheijen, 1985), particularly those dependent on visual cues. Migratory birds that use the East Asian Australasian Flyway (EAAF) flight paths may include overlap over or near the Dorado Phase 1 (**Figure 3-22**). Light (other than flaring) from the MODU, vessels, WHP and FPSO facilities is unlikely to attract a significant number of seabirds or shorebirds as activities are a considerable distance from known key aggregation areas, such as Bedout Island (70km) Eighty Mile Beach (146 km).

The National Light Pollution Guidelines currently apply to marine turtles, seabirds and migratory shorebirds (CoA 2020a). Given the location of the Project Area, all artificial light sources are offshore and >15 km distance from breeding islands, and therefore are not predicted to adversely impact the nesting of adult birds or emergence of fledglings.

High rates of fallout, or the collision of birds with structures, has been reported in seabirds nesting adjacent to urban or developed areas and at sea where seabirds interact with offshore oil and gas platforms (CoA 2020a). Gas flares can also attract seabirds, potentially due to both the light and noise of the flare, and the birds can become disoriented, grounded or be injured or killed. This potential impact is expected to be spatially restricted to the immediate vicinity of the WHP and FPSO and affect only individuals, if any, rather than populations.

7.2.4.3 Summary of Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-24.**

Table 7-24: Summary of impacts, EPOs, controls and consequence evaluation of artificial light emissions during Dorado Phase 1

EPOs	
EPO3D: No mortality or significant[31] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 artificial light emissions **EPO8A**: Artificial light emissions do not result in the displacement of marine turtles from habitat critical to their survival.	
Receptor	**Impact**
Plankton	Potential changes in behaviour, such as attraction, avoidance and disorientation, of marine fauna.
Fish	
Marine Mammals	
Reptiles	
Birds	

[31] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Controls
CM11: Align lighting design on Dorado Development facilities (e.g. WHP, FPSO) with light design principles described in National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2020), including: + Using minimum number and intensity of lighting to meet operational requirements (e.g. safety, navigation etc.), + Adapting lighting for colour, intensity and timing where practicable, + Use non-reflective, dark coloured surfaces where practicable (i.e. where safety is not compromised). **CM12**: Manage lighting on vessels to reduce light spill to the environment where practicable. **CM13**: Implement adaptive management (e.g. shielding, retrofitting with lower intensity lights etc.) of artificial light emissions if there is a moderate environment incident resulting from light emissions. **CM14**: Flaring limited to operation of the flare pilot during steady state operations.

Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.4.4 Demonstration of Acceptability

The potential impacts of artificial light emissions as a result of Dorado Phase 1 have been compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-25** and **Table 7-26.** The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case consequence for artificial light emissions was evaluated as minor (**Table 7-24**). This consequence is considered to be acceptable when assessed against the Santos risk matrix (**Section 4**).

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from artificial light emissions are acceptable.

Table 7-25: Demonstration of acceptability for artificial light emissions

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	The environmental impacts of artificial light emissions as a result of Dorado Phase 1 are consistent with the principles of ESD based on the following points: + Artificial light emissions from Dorado Phase 1 do not degrade the biological diversity or ecological integrity of the Commonwealth marine area based on the offshore location of the development and the distance from sensitive receptors. + Significant impacts to MNES are not predicted to occur based on the remote offshore location and limited emissions. + The precautionary principle has been applied, and studies undertaken where knowledge gaps were identified (i.e. artificial light emissions modelling). This knowledge has been applied during the evaluation of environmental impacts and risks.
Internal Context	The management of artificial light emissions is aligned with Santos' policies and standards. The consequence is minor, which is acceptable.

Acceptability Criteria	Demonstration of Acceptability
	The EPO and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	The management of artificial light emissions are aligned with the National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2020) through CM11. The design of lighting on the FPSO will consider the Guidelines **Table 7-22**. Santos will implement adaptive management if operational experience indicates a high frequency of light-related interactions with fauna that result in impacts. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a).The plan identifies nesting females and hatchling turtles are at greatest risk of light impacts; the nearest potential turtle nesting habitat is Bedout Island (approximately 70 km from the FPSO). Modelling of light emissions from Dorado Phase 1 indicated light-related impacts to turtles on nesting beaches is not credible. Therefore, actions related to the impacts to turtles on nesting beaches in the Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) relating to the threat of artificial light do not apply. Other actions in the recovery plan include managing anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival of marine turtles, and managing activities in BIAs to ensure that biologically important behaviour can occur. Modelling results indicate light emissions from Dorado Phase 1 do not overlap any known important habitat for marine turtles, hence no impacts from light emissions on habitats critical to the survival of marine turtles are expected to occur. While light emissions from flaring (FPSO and/or southern tieback flaring) are expected to be visible from within a portion of the flatback turtle internesting BIA, light cues are not thought to guide turtle internesting behaviours and there is no evidence to date to suggest internesting turtles are attracted to light from offshore vessels to the extent that it would impact foraging activity. CM's 11-14 address Action Area A8 of the Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a). Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia 2015c). Dorado Phase 1 is aligned to 'Objective 4' of the plan by ensuring that anthropogenic disturbance is considered in development assessment processes. Migratory birds have been considered as an environmental receptor in the evaluation of impacts and risks. Wildlife Conservation Plan for Seabirds (DCCEEW 2022). Dorado Phase 1 is aligned to 'Objective 2' of the plan by ensuring seabirds and their habitats are protected and managed. This is achieved through the implementation of control measures 12-15 where lighting on vessels is managed and minimised to reduce light spill to the environment and seabird habitat. Management of aspects of Dorado Phase 1 must not be inconsistent with conservation advice, recovery plans and threat abatement plans for fishes published under the EPBC Act. + Potential impacts to threatened or migratory fishes (e.g. whale sharks, sawfish) are expected to be limited to minor, temporary behavioural changes (e.g.

Acceptability Criteria	Demonstration of Acceptability
	attraction) that will have no effect on populations of these species - impacts to fish are expected to be restricted to a small area around the FPSO. + Potential impacts to threatened or migratory marine mammals are expected to be limited to minor, temporary behavioural changes (e.g. attraction) that will have no effect on populations of these species - impacts to marine mammals are expected to be restricted to a small area around the artificial light source (e.g. around the FPSO or installation activities). + Potential impacts to threatened or migratory reptiles are expected to be limited to minor, temporary behavioural changes (e.g. attraction) that will have no effect on populations of these species - impacts to reptiles (particularly marine turtles) are expected to be restricted to a small area around the FPSO. Light from the FPSO is not visible from the any turtle nesting beaches. + Potential impacts to threatened or migratory birds are expected to be limited to minor, temporary behavioural changes (e.g. attraction) that will have no effect on populations of these species - impacts to birds are expected to be restricted to the area around the FPSO. Light from the FPSO is not visible from any bird nesting or roosting areas, including Ramsar sites. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify light as a key threat or have explicit relevant objectives or management actions relating to light. The impacts of artificial light emissions from Dorado Phase 1 on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Section 4**.
Other Relevant Requirements	Management of artificial light emissions is aligned with guidelines, conservation advice, and recovery plans for threatened species, including: + the National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2020), and + the Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a). Implementation of recognised industry standard practice, such as: + external lighting on offshore facilities/ infrastructure will be minimised to that required for navigation and safety, except in the case of an emergency.

Table 7-26: Demonstration of acceptability of artificial light emissions against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Justification
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery	The assessment of impacts and risks from artificial light emissions predicts impacts to threatened or migratory species will be limited to minor, temporary behavioural changes (e.g. attraction, avoidance etc.) that will have no effect on populations of these species. Mortality of individual animals as a result of artificial light emissions is not expected to occur. Modelled light emissions from the worst-case flaring scenario, from both FPSO flaring and southern tieback flaring scenarios show no

plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to species listed as threatened or migratory under the EPBC Act as a result of Dorado Phase 1.	overlap with critical habitat for marine turtles. Therefore, the management of artificial light emissions is consistent with conservation advice and recovery plans that identify artificial light emissions as a threat. Significant impacts to EPBC Act listed threatened, migratory or cetacean species under the EPBC Act are not predicted to occur. Areas of importance for species, such as Ramsar sites and turtle nesting beaches, will not credibly be impacted by artificial light emissions from Dorado Phase 1.

7.2.5 Emissions – Acoustic Emissions

Acoustic emissions refer to noise generated during an activity. Activities conducted during Dorado Phase 1 may produce noise and associated vibrations in the air, underwater and beneath the earth's surface.

Sound (or noise generated from human activity) is altered as it propagates away from the source to receptors in the marine environment. Factors influencing propagation include the bathymetry and composition of the seabed and the temperature and salinity of the water column. The physical processes affecting sound along its propagation path are attenuation due to geometric spreading, reflection, scattering at the sea surface and seabed, refraction due to sound speed gradients, and absorption by seawater. A given sound emitted in different locations, or in the same location at different times, may therefore be detectable for varying distances, depending on regional and temporal changes in sound propagation conditions (Richardson et al. 1995).

To assess potential impacts from acoustic emissions it is necessary to understand how underwater sound is measured and referenced. **Attachment 10** provides a detailed account; however, a summary is also provided here. Three metrics are commonly used for analysing and describing the acoustic characteristics of underwater sound and for evaluating underwater sound impacts on marine fauna:

+ peak sound pressure level (PK);
+ sound pressure level (SPL); and
+ sound exposure level (SEL).

The period of accumulation associated with SEL must always be defined and can be per-pulse or accumulated over time, typically 24 hours.

The decibel (dB) is a logarithmic scale that expresses the ratio of two values of a physical quantity and is used to measure the amplitude or 'loudness' of a sound. As the dB scale is a ratio, it is denoted relative to a reference level and in underwater acoustics this is 1 micropascal (µPa).

These metrics and their units are summarised in **Table 7-27,** following the metrics in ISO 18405 Underwater Acoustics – Terminology (International Organization for Standardization 2017).

Table 7-27: Acoustic metrics used in this assessment

Metric	Abbreviation	Symbol	Unit
Sound pressure level	SPL	L_p	dB re 1 µPa
Peak sound pressure level	PK	L_{pk}	dB re 1 µPa
Sound exposure level (per pulse)	Per-pulse SEL	L_E	dB re 1 µPa^2·s

Sound exposure level (accumulated over time)	SEL_{24h}	$L_{E,24h}$	dB re 1 µPa²·s
Source level	SL	$L_{S,pk}$ $L_{S,p}$ $L_{S,E}$	dB re 1 µPa·m (peak source pressure level, SPL source level) or dB 1 µPa²m²s (per-pulse source SEL)

Underwater noise is also divided into two categories, with different metrics used to describe the sound levels in decibels:

+ continuous - continuous noise is a continual non-pulsed sound that can be transient (short duration) but without the rapid rise-time (pulse) (Southall et al. 2007), examples are vessel and drilling operations; and
+ impulsive - impulsive noise is a series of pulsed sound events that are brief, broadband, atonal and transient, examples are acoustic emissions from hammer strikes during pile driving or discharges of air guns during vertical seismic profiling.

7.2.5.1 Description of the Event

7.2.5.1.1 Sources of Acoustic Emissions

Aspects of Dorado Phase 1 will generate noise received underwater throughout all stages of the development. Potential noise emitting activities include:

+ movement of vessels;
+ piling for the Dorado FPSO anchor piles and the WHP jacket piles (if required for future tiebacks);
+ acoustic positioning and survey (e.g. ultra-short baseline, side-scan sonar etc.);
+ drilling;
+ drilling vertical seismic profiling (VSP);
+ 3-D VSP;
+ operation of the WHP and FPSO (including offtake activities);
+ ROV operations; and
+ helicopters.

Each of these noise sources is described further below.

Table 7-28 provides indicative acoustic signatures (frequency and noise levels) for noise sources associated with Dorado Phase 1. Numerical modelling of noise sources that have a relatively high potential for environmental impacts was undertaken (**Attachment 10**).

Table 7-28: Indicative acoustic emissions source characteristics

Source	Operating Frequency	Source Level (@1m or near)	Impulsive or Continuous	References
Impulsive Sources				
Impact piling	less than 1 kHz	210 to 250 dB re 1 µPa (SPL)	Impulsive	**Attachment 10**

Source	Operating Frequency	Source Level (@1m or near)	Impulsive or Continuous	References
Drilling VSP	less than 300 Hz	less than 239 dB re 1 µPa m (SPL)	Impulsive	**Attachment 10**
Survey Ultra-short baseline Side-scan sonar	18 to 36 kHz 70 and 400 kHz	204 dB re 1 µPa m (SPL) 229 dB re 1 µPa RMS @ 1 m	Impulsive Impulsive	Warner and McCrodan (2011) Austin et al. (2013)
3-D VSP	less than 300 Hz	232 to 244.7 dB re 1 µPa m (SPL, PK)	Impulsive	**Attachment 14**
Continuous Sources				
Vessels	10 Hz-10 kHz	less than 175 dB re 1 µPa m (SPL)	Continuous	**Attachment 10**
Drilling operations	less than 2 kHz	120 dB re 1 µPa m (SPL)	Continuous	Todd and White (2012)
WHP operations	100 Hz-2.5 kHz	113 dB re 1 µPa (SPL_{RMS})	Continuous	McCauley (2002)
FPSO Operations – using thruster	10 Hz-10 kHz	less than 175 dB re 1 µPa m (SPL)	Continuous	**Attachment 10**
FPSO Operations – no thruster	10 Hz-10 kHz	less than 175 dB re 1 µPa m (SPL)	Continuous	**Attachment 10**
ROV	3-200	150 to 235 re 1 µPa m (SPL)	Continuous	Jimenez-Arranz et al., (2017)
Helicopter operations	500 Hz	109 dB re 1 µPa	Continuous	Richardson et al. (1995)

Vessels

Vessels will be involved throughout all stages of Dorado Phase 1, with relatively high vessel use during installation, drilling and decommissioning activities. The types of vessels used may range from relatively small supply vessels to large construction vessels. Vessel activity will be concentrated around the foundation Dorado WHP and FPSO location and future tieback locations (refer **Figure 1-2**). Shipping noise generally dominates ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). High-frequency components of the sound source spectrum rapidly dissipate with distance from the sound source, allowing the lower frequency wavelengths to travel further distances.

Sound emitted from vessels differs depending on type and state of propulsion system, vessel installed power, size, transit speed, and load (Vancouver Fraser Port Authority 2018). Vessels generate underwater noise from their propellers and thrusters when moving and may use dynamic positioning where propellers and thrusters are used to hold position rather than anchoring. Propellers and thrusters tend to generate broadband noise due to cavitation, with a noise frequency spectrum ranging from less than 10 Hz to more than 8,000 Hz (McCauley 1998). Thruster noise will typically be the highest intensity noise source generated by the vessels during Dorado Phase 1. Machinery noise may also be transmitted through the vessel hull, although this is expected to be lower intensity than noise from propellers and thrusters.

Acoustic emissions from vessels, particularly thrusters, has the potential to impact upon environmental receptors due to the relatively high source level and potential occurrence throughout all stages of Dorado Phase 1. As such, vessel noise was selected to be modelled as a scenario in the underwater noise modelling studies presented in **Attachment 10**.

Impact Piling

The installation of the FPSO DTM will include mooring anchor piles, and piling may also be required for future tiebacks if developed via a WHP. Impact piling using a hammer to strike each pile is the planned piling method. An alternative lower-noise method such as the adoption of suction piles is not technically feasible due to unsuitable geotechnical conditions in the Dorado Project area. The number of piles required is yet to be finalised, however an indicative number of up to 8 and 16 piles are expected to be installed for the FPSO moorings and the WHPs if required for potential future tiebacks. Driving of individual piles is expected to require less than 24 hours of continuous hammering (impact piling). Hammering of consecutive piles will not occur continuously; there will be a break between the hammering stage for the installation of each pile.

Impact piling has the potential to generate high-intensity noise when the hammer strikes the pile (impact piling). Each hammer strike induces the pile to vibrate briefly, converting some of the energy applied to the pile into a pressure wave in the water column. This pressure wave is perceived as noise and is radiated from the pile into the water column. Piles driven into the seafloor by impact piling are characterised as impulsive sound-radiating sources. This characterisation strongly depends on the rate and extent of pile penetration, pile dimensions, and pile driving equipment.

Piling noise is not continuous, with each strike of the hammer on the pile generating a short, discrete sound impulse. This type of noise contrasts with continuous sources of noise, such as continuous use of vessel thrusters. Piling will not be undertaken concurrently with drilling or vertical seismic profiling.

Given the impulsive nature of impact piling acoustic emissions modelling was undertaken for impact piling (**Attachment 10**).

Surveys and Acoustic Positioning

Geotechnical/ geophysical surveys may be undertaken to assess the suitability of the seabed for infrastructure or surveys along the length of proposed flowlines routes, using high-frequency sonar to provide high-resolution bathymetry and geophysical data, such as side-scan sonar, subbottom profiler or multibeam echo sounders. Sonar generates high-frequency acoustic emissions that attenuate rapidly in the underwater environment.

Santos

Side-scan sonar towfish can use a range of operating frequencies, but typically they are between 70 and 400 kHz. Representative systems could include those from Edgetech, such as the 4200 range which output signals at 120 and 410 kHz. Measurements of an EdgeTech 4200 were reported in Austin et al. (2013), focusing on the 120 kHz impulses. The authors reported a PK of less than 175 dB re 1 µPa and an SPL of less than 170 dB re 1 µPa at 39 m, with the distance from in-beam pulses to an SPL of 160 dB re 1 µPa calculated to be 130 m. The sonar is highly directional, with distances to sound levels outside the beam significantly less than those in the beam. Side-scan sonar towfish are towed close to the seafloor, typically 10 to 20 m above the seabed; thus the beam will be restricted to a swath close to the seabed. Additionally, this type of sonar generates only high frequency signals, and as such will only be relevant for fauna with sensitivity to signals of approximately 110 kHz or higher, as shown in Austin et al. (2013), which excludes low-frequency cetaceans, fish, and turtles.

Acoustic positioning systems will likely be used during the installation, operations and decommissioning stages of the development, with operational frequency and ping rates depending upon different activities. For acoustic positioning systems such as ultra-short baseline, an acoustic pulse is transmitted by the transceiver and detected by the subsea transponder, which replies with its own acoustic pulse. This return pulse is detected by the shipboard transceiver.

Specific noise modelling from acoustic positioning systems was not carried out as there is sufficient information available in peer-reviewed literature to estimate the potential sound levels and inform the risk assessment. The acoustic emissions will decrease rapidly due to the relatively high frequency of the acoustic emissions, with received sound levels estimated to be reduced to 160 dB re 1 µPa within tens of metres.

Drilling

MODUs are expected to produce low-intensity continuous sound during drilling operations. Drilling sound usually exhibits tones below 2 kHz, with harmonics present to 10 kHz and can vary substantially between operations. Underwater noise levels from jack-up and semi-submersible MODUs during routine drilling operations (i.e. excluding vertical seismic profiling) are generally less than 130 dB re 1 µPa, and noted as being considerably lower than noise emissions from support vessels (McCauley 1998; Todd and White 2012). As such, underwater noise from drilling operations excluding VSP have not been modelled have been extrapolated from underwater noise from a semi-submersible drilling rig by McCauley (1998) indicates noise source levels for non-drilling and drilling noise from a rig range from 160 to 164 dB re 1 µPa at 1 m.

Drilling Vertical Seismic Profiling

Drilling VSP will be undertaken during drilling activities and operations to provide detail on the geological formations. It will be done by installing, or lowering, a series of receivers within the well bore. A seismic source will then be suspended below the MODU, or below a vessel if walkaway vertical seismic profiling is undertaken. The seismic source will be discharged repeatedly, and the receivers will record the resulting seismic energy reflected from geological formations. The data will then be processed to characterise the geological formations. Drilling VSP is critical to effectively managing the Dorado field for the efficient recovery of the petroleum resources.

Drilling VSP operations will generate relatively high levels of low frequency underwater noise, which may propagate for long distances. The frequency of underwater noise generated by vertical seismic profiling overlaps the functional hearing range of cetaceans, and hence has the potential to result in impacts to these species. Thus, drilling VSP was modelled as a scenario in the underwater noise modelling studies presented in **Attachment 10**.

3-D VSP

As described in Section 6.7.5.1, 3-D VSP will be undertaken prior to field start-up and may be repeated at two or three yearly intervals throughout the production phase.

The 3-D VSP acquisition survey involves a source vessel with a seismic source secured 5 m below the sea surface sailing a planned circular course covering approximately 110 km^2 over the Dorado field and taking up to 25 days. As with drilling VSP, 3-D VSP will also generate relatively high levels of low frequency underwater noise, which may propagate long distances. 3-D VSP was modelled using a 1,200 cubic inch air gun array towed by a vessel travelling at 2.5 knots, with an overall inter-pulse-interval of 25 m and a total of 4448 seismic pulses (Koessler and McPherson, 2022).

FPSO Operation

Machinery onboard the FPSO, such as topside processing equipment and the flare, may generate noise emissions., however this is unlikely to contribute significantly to underwater noise levels as most noise will be reflected by the sea surface. Topside equipment and other machinery may contribute to hull vibrations, which may then be transmitted into the sea through the FPSO hull. However, this source of noise is expected to be low as most equipment is topside and the FPSO is double hulled which will insulate the environment from FPSO noise (Erbe et al. 2013).

The FPSO may use its engines and thruster when manoeuvring on, or disconnected from, the DTM, which will generate underwater noise from propeller cavitation. The FPSO may also use its thruster to hold a given heading during offtake operations, which may last for up to 48 hrs. Offtake operations may be as frequent as weekly during the early operational stage of the development, with the interval between offtake operations becoming progressively longer as production declines over time. The use of thrusters may generate relatively high levels of broadband underwater noise.

Underwater noise emissions from the FPSO were modelled, as they represent a long-term source of noise emissions throughout the operational stage of Dorado Phase 1. The underwater noise modelling studies are presented in **Attachment 10**.

ROV Operations

An ROV is a tethered underwater vehicle equipped with at least a video camera and lights. Additional equipment that the ROV may have installed could include sonars, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, water temperature, water density, sound velocity, light penetration and temperature. ROVs may be used during all stages of Dorado Phase 1. The ROVs may be fitted with measurement devices such as sonar, that emit a pulse of sound (often called a ‘ping’) and then listens for reflections (echo) of that pulse. ROVs may be used during construction, operation and decommissioning stages of the Project. Typical frequency and sound source levels for ROV mounted sonar is (Jimenez-Arranz et al., 2017):

+ frequency range between 3k Hz to 200 kHz; and
+ source level 150 to 235 dB re 1 uPa SPL @ 1 m.

Helicopters

Sound traveling from a source in the air (e.g. a helicopter) to a receiver underwater is affected by both in-air and underwater propagation processes, which are further complicated by processes occurring at the air-seawater surface interface (e.g., wind and waves). The level of noise received underwater depends on source altitude and lateral distance, receiver depth, water depth, and other variables.

Helicopter engine noise is emitted at various frequencies; however, the dominant tones are generally of a low frequency below 500 Hertz (Hz) (Richardson et al. 1995). Sound pressure in the water directly below a helicopter is greatest at the surface and diminishes with increasing receiver depth. Noise also reduces with increasing helicopter altitude, but the duration of audibility often increases with increasing altitude, with sound penetrating water at angles less than 13°. The noise from the flyover of a Bell 214 helicopter (stated to be a noisy model) has been recorded underwater (Richardson et al. 1995). The recorded broadband sound level was 109 dB re 1 µPa (SPL) when the helicopter was 152 m from the surface, with dominant frequencies below 500 .

7.2.5.1.2 Noise Effect Criteria

Elevated underwater noise can result in changes to marine fauna behaviour by masking or interfering with other biologically important sounds, including vocal communication, echolocation, signals and sounds produced by predators or prey, and through disturbance leading to behavioural changes or displacement from important areas (Richardson et al. 1995). The sensitivity of fauna behaviour to elevated noise levels vary both inter- and intraspecifically, with individual responses often being influenced by the present behaviour, such as reproductive behaviours, foraging or migration. Thresholds, where appropriate, for behavioural response of different species to noise are discussed in the sections that follow.

Exposure to sufficiently intense sound may lead to an increased hearing threshold. If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift (TTS). Southall et al., 2007 defined TTS as a threshold shift of 6 dB above the normal hearing threshold. If the threshold shift does not return to normal, permanent threshold shift (PTS) has occurred. Threshold shifts can be caused by acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser et al.,2017).

Where the functions, interests or activities of other marine users involve marine fauna, any effect to fauna presence or abundance may indirectly impact these users. The potential impact may occur for the duration of the noise emission; however, following cessation of the activity, long term changes in fauna abundance or distribution are not expected. Given the location, short-term nature of the more significant noise generating activities, and that the impacts to fish populations will be negligible, changes to the functions, interests or activities of other users, such as commercial fisheries, from acoustic emissions are not notable. A change in noise can potentially impact on the functions, interests or activities of other marine users that are dependent on underwater communications (e.g. Defence).

A summary of the criteria used in the impact assessment is provided below, with **Attachment 10** providing details.

Plankton

There are few studies that have reported negative impacts of impulsive noise on zooplankton (including meroplankton or temporary members of the plankton such as fish eggs and larvae, and invertebrate and coral larvae), and none from more than 10 m away from an airgun. This suggests the range of chronic effects on fish eggs and larvae due to seismic discharges is likely to be restricted to less than 10 m (**Table 7-31** and **Table 7-32**). Popper et al., (2014) presented a threshold of more than 210 dB re 1 µPa2.s (SEL) or 207 dB re 1 µPa (PK) for mortality and potential mortal injury, which is lower (and therefore more conservative) than the observed effects provided in **Table 7-31** and **Table 7-32**.

Marine Mammals

Thresholds for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals (low-frequency, high-frequency, and very-high-frequency cetaceans) were derived from Southall et al. (2019) and considered two metrics: peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated SEL ($L_{E,24h}$). Thresholds for marine mammal behaviour were based on the current Section 7 ESA Consultation Tools for Marine Animals on the West Coast (National Oceanic and Atmospheric Administration 2019). These thresholds are summarised in **Table 7-29** for impulsive noise and **Table 7-30** for continuous (non-impulsive) noise.

Applying the auditory frequency weighting functions developed for low-, mid- and high-frequency cetaceans to the derived SEL ($L_{E,24h}$) in the ambient noise monitoring in the Dorado Project Area (**Section 3.2.7**), indicated that all functional hearing groups received at least an SEL of approximately 150 dB re 1 µPa^2·s (Lucke et al, 2022).

Table 7-29: Criteria for impulsive noise effects on marine mammals: SPL, weighted SEL$_{24h}$ and unweighted PK thresholds.

Hearing Group	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (Lpk; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
High-frequency cetaceans		185	230	170	224
Very-high-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak SPL thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes SPL period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative SEL over a 24-hour period.

Table 7-30: Criteria for continuous noise effects on marine mammals: SPL and weighted SEL_{24h} thresholds.

Hearing Group	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
Low-frequency cetaceans	120	199	179
High-frequency cetaceans		198	178
Very-high-frequency cetaceans		173	153

L_p denotes SPL period.
L_E denotes cumulative SEL over a 24-hour period.

Fishes

Sound is perceived by fish through the ears and the lateral line which are sensitive to vibration. Potential impacts on fish, fish eggs, and larvae were assessed using the guidelines developed by the Popper et al. (2014). The guidelines define quantitative thresholds for three types of immediate effects:

+ Mortality, including injury leading to death;
+ Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma; and
+ TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds.

Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Fish eggs and fish larvae are considered separately.

The criteria listed in **Table 7-31** were used to assess the effects from impulsive noise (piling and vertical seismic profiling). The criteria listed in **Table 7-32** were used to assess the effects from continuous, or non-impulsive sound sources.

Table 7-31: Criteria for impulsive noise exposure for fish

Fish Group	Mortality / Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	more than 219 dB SEL_{24h} or more than 213 dB PK	more than 216 dB SEL_{24h} or more than 213 dB PK	More than 186 dB SEL_{24h}	Pile driving: + (N) Moderate, (I, F) Low Seismic: + (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or more than 207 dB PK	203 dB SEL_{24h} or more than 207 dB PK	More than 186 dB SEL_{24h}	Pile driving: + (N) Moderate, (I, F) Low Seismic: + (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or more than 207 dB PK	203 dB SEL_{24h} or more than 207 dB PK	186 dB SEL_{24h}	Pile driving: + (N, I) High, (F) Moderate Seismic: + (N, I) Low, (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	more than 210 dB SEL_{24h} or more than 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: + (N) Moderate, (I, F) Low Seismic: + (N, I, F) Low	(N) Moderate (I, F) Low

Source: Adapted from Popper et al. (2014)
Peak SPL dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N – tens of metres), intermediate (I – hundreds of metres), and far (F – thousands of metres).

Table 7-32: Criteria for continuous noise exposure for fish, adapted from Popper et al. (2014)

Type of animal	Mortality and Potential mortal injury	Impairment			Behavior
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N – tens of metres), intermediate (I – hundreds of metres), and far (F – thousands of metres).

Reptiles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles).

Sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Ketten and Bartol 2006). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014). Finneran et al. (2017) presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). The Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) acknowledges the sound levels reported in McCauley et al. (2000) as levels associated with behavioural responses in sea turtles. There are no thresholds available to apply to the assessment of potential impacts to sea snakes.

The recommended criteria for sea turtle PTS, TTS and behavioural response/disturbance for impulsive noise is presented in **Table 7-33**, while that for vessel and non-impulsive noise is presented in **Table 7-34.**

Table 7-33: Criteria for assessing acoustic effects of impulsive noise on sea turtles: SPL, weighted SEL_{24h}, and unweighted PK thresholds.

Effect type	Source	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behavioural response	NSF (2011)	166	NA	
Behavioural disturbance	McCauley et al. (2000b)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak SPL thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes SPL period and has a reference value of 1 µPa.
L_{pk}, flat denotes peak sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative SEL over a 24-hour period and has a reference value of 1 µPa²s.

Table 7-34: Criteria for assessing acoustic effects of non-impulsive noise on sea turtles: Relative risk and SEL_{24h} thresholds.

Effect type	Criterion	Relative risk	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
Behaviour	Popper et al. (2014)	(N) High (I) Moderate (F) Low	NA
PTS onset thresholds (received level)	Finneran et al. (2017)	NA	220
TTS onset thresholds (received level)			200

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).
L_E denotes cumulative SEL over a 24-hour period and has a reference value of 1 µPa²s.

Birds

Seabirds and migratory shorebirds may be affected by atmospheric noise emissions from helicopters transiting between the Port Hedland (most likely location for heliport) and the Project Area. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a).

The generation of underwater noise from helicopters will be brief, typically during take off and landing, with peak received levels diminishing with increased altitude. Given the high visibility and noise levels associated with helicopter movements, bird species are expected to actively avoid interaction. Any disturbance from helicopters in transit will be of limited duration as they pass by. Impacts to bird species in the area surrounding Port Hedland are expected to be negligible as helicopters passing by bird aggregation areas (eg Bedout Island) will be at significant altitude, impacts are not considered credible. The impacts to birds from atmospheric noise emissions resulting from Dorado Phase 1 were not assessed further.

Other Receptors

To assess impacts to plankton, there are only a few studies to base threshold criteria on. Popper et al. (2014) cites many of the references and studies on potential impacts of noise emissions on fish eggs and larvae prior to 2014. Literature primarily relates to impulsive noise. Results presented in Day et al. (2016) for embryonic lobsters and Fields et al. (2019) for copepods align with those presented in Popper et al. (2014), which is that mortality and sub-lethal injury are limited to within tens of metres of seismic sources. Research by McCauley et al. (2017) has indicated the potential for effects at longer range; however, Fields et al. (2019) noted that it was difficult to reconcile the high mortality reported by McCauley et al. (2017) with the low mortalities reported in the greater previous body of earlier research and their experiment.

While there are reputable published studies indicating the potential for underwater noise to impact upon invertebrates, no suitable published guidelines were identified. Invertebrates have been considered in the assessment of risks and impacts from underwater noise, although no threshold values have been applied.

7.2.5.1.3 Summary of Underwater Noise Modelling Results

Ambient noise levels in the Project Area may be elevated during all stages of the project. Underwater noise surveys in the region detected marine fauna vocalisations and anthropogenic sources including vessel noise; seismic survey signals; mooring noise artefacts (McCauley 2011). Ambient noise levels in the Project Area are expected to be elevated given the presence of shipping fairways and associated high vessel traffic that cross over the Project Area. Underwater noise modelling was undertaken for activities/ scenarios that were considered to have the greatest source levels, and therefore the greater potential impact. The modelling study s are provided as **Attachment 10 and Attachment 14**. The noise sources that were modelled comprised:

+ pile driving – underwater noise from piling is expected to have a high source level and is impulsive in nature;
+ Drilling VSP and 3-D VSP– impulsive underwater noise from vertical seismic profiling is expected to have a high source level with noise energy concentrated at relatively low frequencies, which is expected to result in the potential for long sound transmission distances;
+ support vessels – support vessels using dynamic positioning to hold position are expected to emit broadband noise at a high source level; and
+ FPSO operations (including offtakes).

Modelling results for each of the modelled scenarios are provided in **Table 7-35**. These results have been compared to the noise effect criteria outlined in **Section 7.2.5.1.2** and used to inform the assessment of environmental impacts and risks.

Figures showing the predicted maximum radius at which noise effect criteria in **Table 7-35** are reached are provided for as follows:

+ WHP piling:
  - SPL (**Figure 7-11**); and
  - SEL_{24h} (**Figure 7-12**).
+ FPSO mooring piling:
  - SPL (**Figure 7-13**); and
  - SEL_{24h} (**Figure 7-14**).
+ Drilling VSP:
  - SPL (**Figure 7-15**); and
  - SEL_{24h} (**Figure 7-16**).
+ 3-D VSP:
  - SPL (**Figure 7-20**); and
  - SEL_{24h} (**Figure 7-21**)
+ FPSO offtake operations:
  - SPL (**Figure 7-17**); and
  - SEL_{24h} (**Figure 7-18**).

These figures are based on the maximum-over-depth modelled received noise levels and hence represent the worst-case output from the modelling results.

Table 7-35: Maximum-over-depth distances (in km) from noise modelling derived by applying noise effect criteria (Refer to Attachment 10 for further information)

Receptor Category	Impact Type	WHP Jacket Pile	FPSO Anchor Pile	Drilling VSP	3-D VSP	FPSO not using Thrusters	FPSO using Thrusters	FPSO Offtake Operations	Vessel
	Marine Mammals								
Very-high-frequency Cetaceans	PTS	0.55	1.04	0.02	-	-	0.21	0.21	0.05
	TTS	2.78	4.27	0.13	1.95	0.16	4.14	4.51	0.93
	Behavioural	5.4	4.59	2.42	3.78	1.49	10.4	11.0	4.57
High-frequency Cetaceans	PTS	-	0.03	-	-	-	-	-	-
	TTS	0.029	0.36	-	-	-	0.16	0.16	0.03
	Behavioural	5.4	4.59	2.42	3.78	1.49	10.4	11.0	4.57
Low-frequency Cetaceans	PTS	5.29	5.84	0.47	3.4	-	0.07	0.08	0.03
	TTS	22.6	28.2	3.1	15	0.1	2.13	2.62	0.79
	Behavioural	5.4	4.59	2.42	3.78	1.49	10.4	11.0	4.57
	Fish								
No Swim Bladder	Mortality/Potential Mortal Injury	0.13	0.113	-	0.03	Low risk at all distances			
	Recoverable Injury	0.27	0.23	-	0.03	Low risk at all distances			
	TTS	5.59	5.88	0.84	4.65	Moderate risk at tens of metres, else low risk			
Swim Bladder not involved in Hearing	Mortality/Potential Mortal Injury	0.47	0.39	0.037	0.07	Low risk at all distances			
	Recoverable Injury	1	0.96	0.05	0.07	Low risk at all distances			
	TTS	5.59	5.88	0.84	4.65	Moderate risk at tens of metres, else low risk			
Swim Bladder involved in Hearing	Mortality/Potential Mortal Injury	0.56	0.52	0.037	0.07	Low risk at all distances			
	Recoverable Injury	1	0.96	0.05	0.07	20 m for 48 hours	21 m for 48 hours	22 m for 48 hours	23 m for 48 hours
	TTS	5.59	5.88	0.84	4.65	30 m for 12 hours	31 m for 12 hours	32 m for 12 hours	33 m for 12 hours
	Reptiles								
Turtles	PTS	0.72	0.68	0.03	0.03	-	-	-	-
	TTS	4.11	3.98	0.38	2.92	-	0.05	-	-
	Behavioural Disturbance	1.39	1.07	0.38	0.72	-	-	-	-
	Behavioural Response	3.51	2.91	1.22	1.99	-	-	-	-
	Plankton								
Fish eggs and larvae	Mortality/Potential Mortal Injury	0.47	0.39	0.037	-	Low risk at all distances			
	Recoverable Injury	1	0.96	0.05	0.07	Low risk at all distances			
	TTS	5.59	5.88	0.84	4.5	Low risk at all distances			

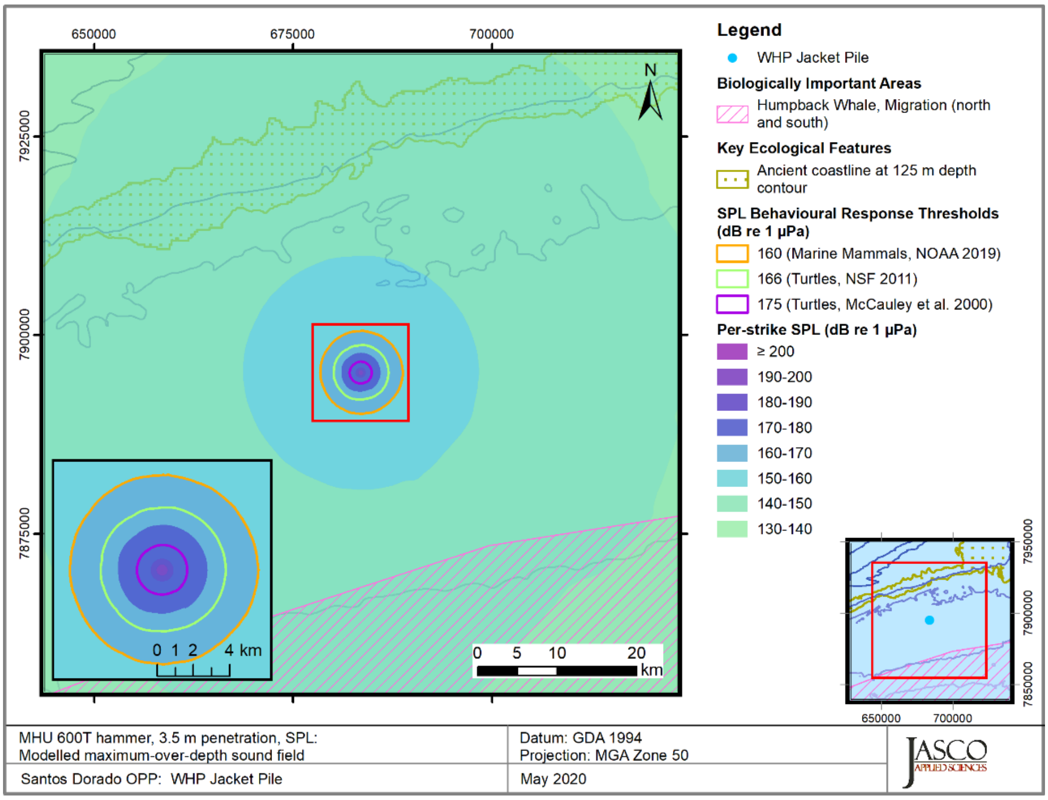


Figure 7-12: WHP piling, SPL, 3.5 m penetration depth: Sound level contour map, showing maximum-over-depth results.

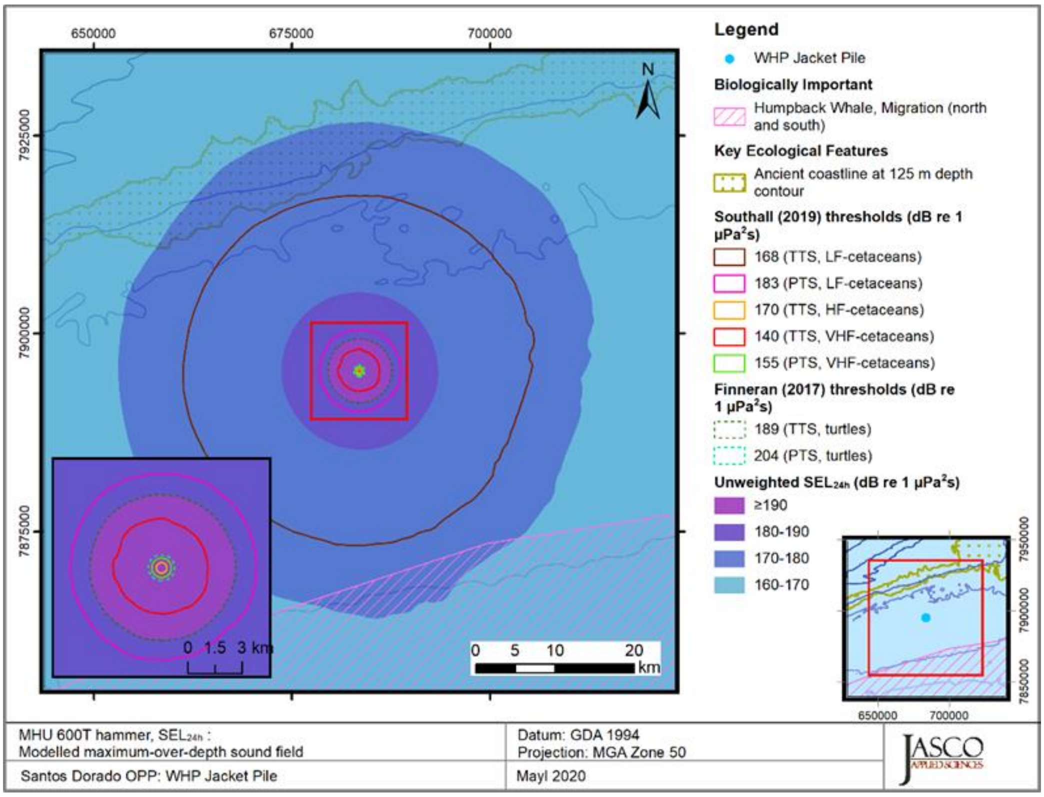


Figure 7-13: WHP piling, SEL_{24h}: Sound level contour map showing weighted maximum-over-depth SEL_{24h} results.

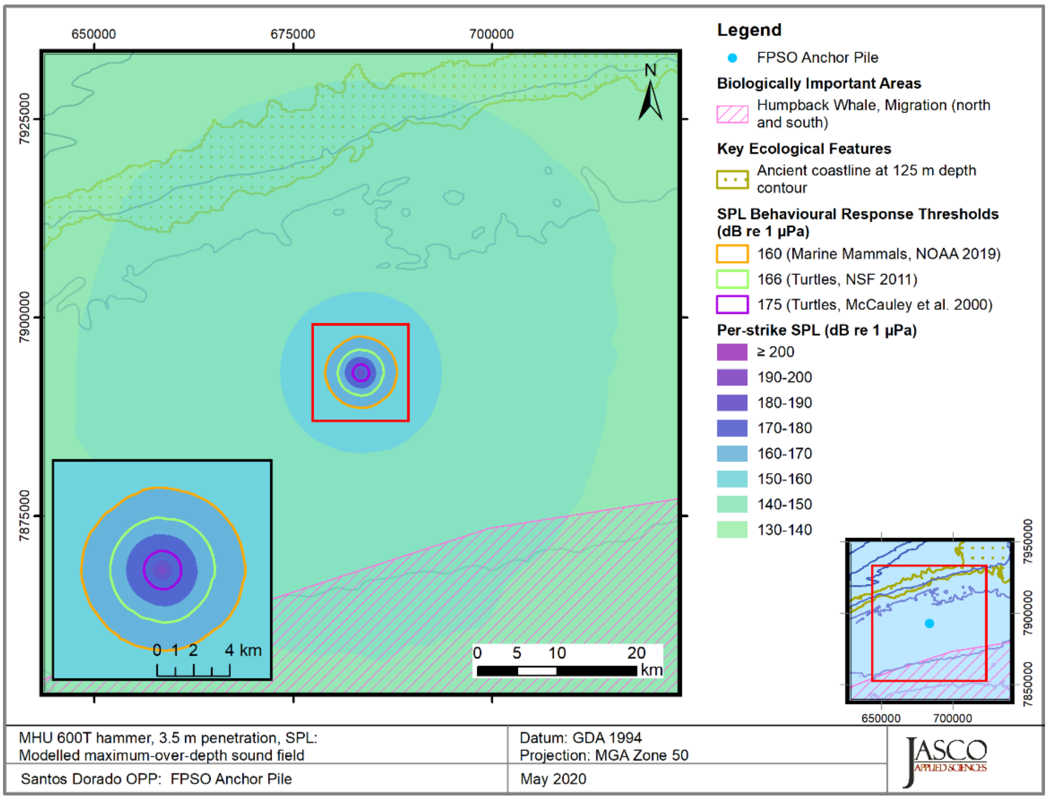


Figure 7-14: FPSO piling, SPL, 3.5 m penetration depth: Sound level contour map, showing maximum-over-depth results.

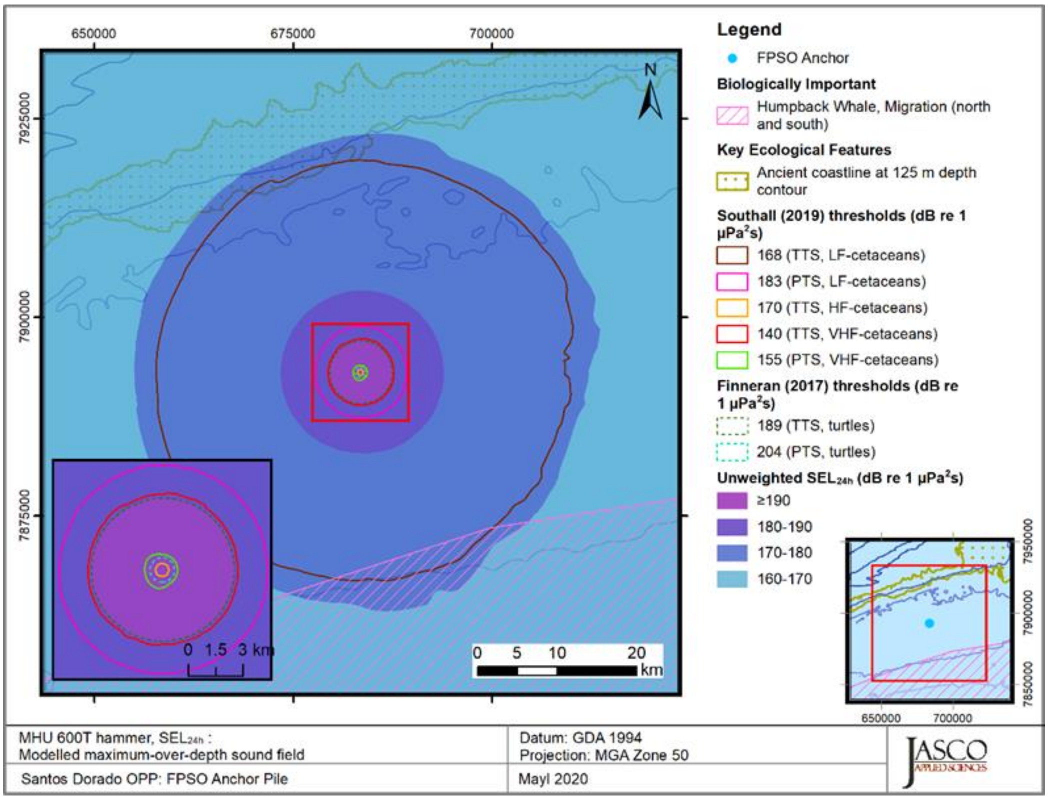


Figure 7-15: FPSO piling, SEL_{24h}: Sound level contour map showing weighted maximum-over-depth SEL_{24h} results.

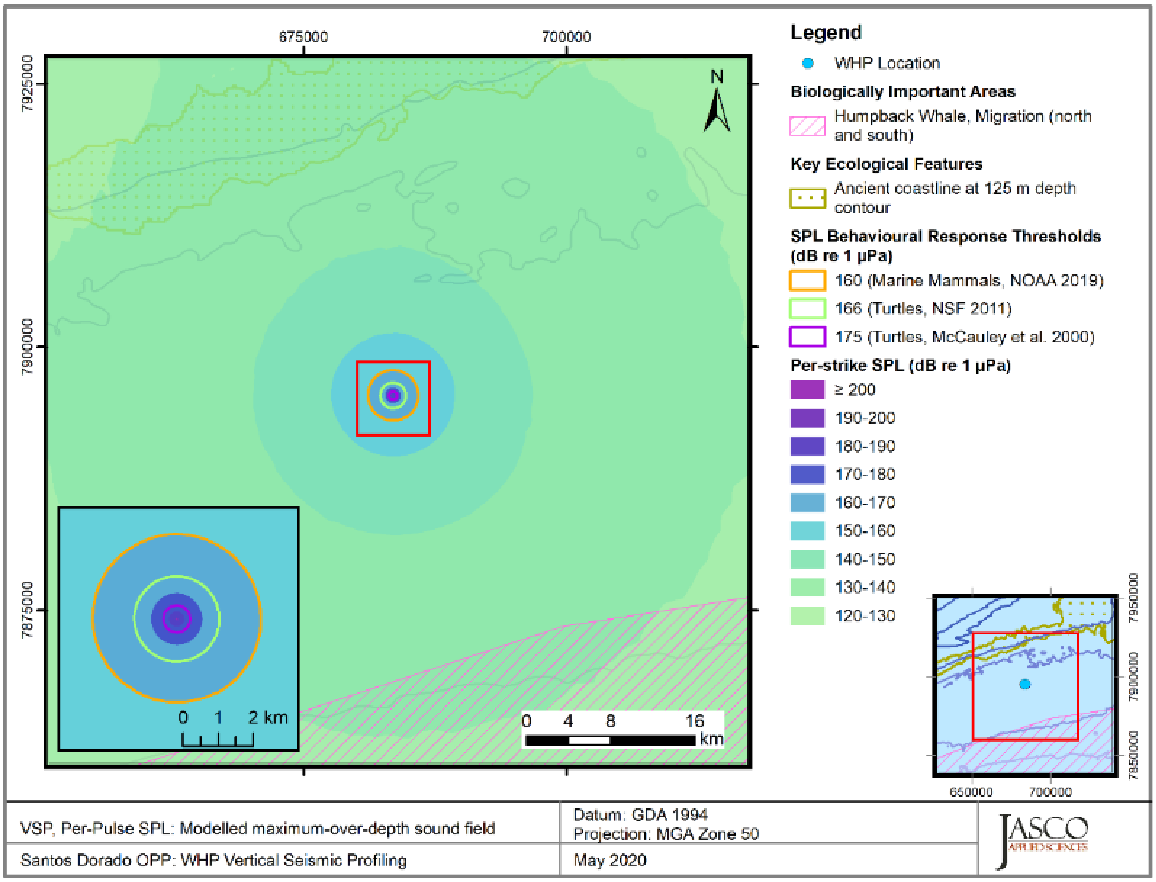


Figure 7-16: Drilling VSP SPL: Sound level contour map showing unweighted maximum-over-depth results.

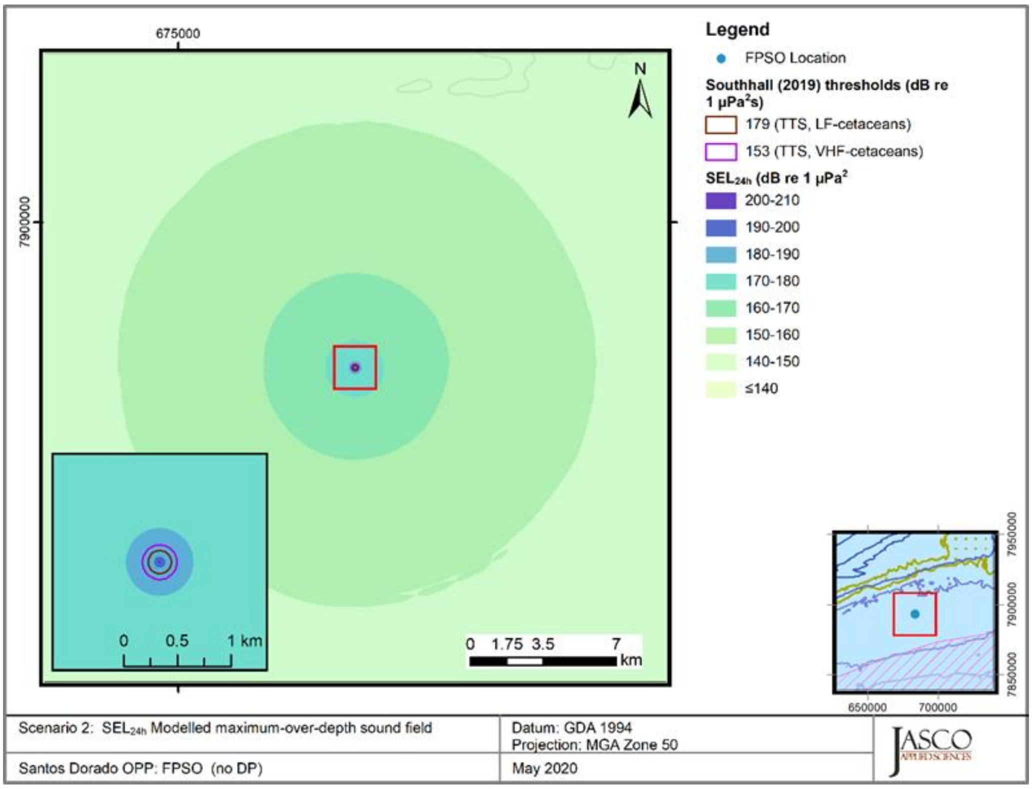


Figure 7-17: Drilling VSP, multiple-pulse SEL: Sound level contour map showing weighted maximum-over-depth SEL_{24h} results for 300 vertical seismic profiling impulses.

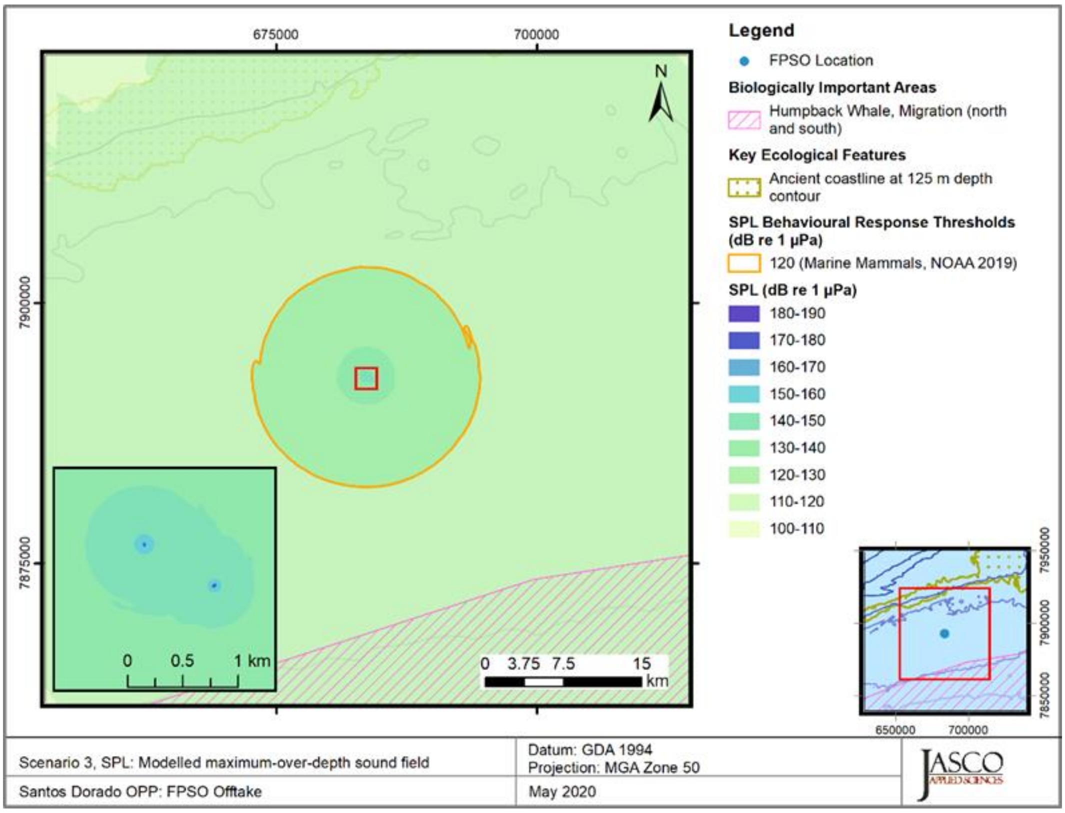


Figure 7-18: FPSO offtake operations SPL: Sound level contour map showing maximum-over-depth results.

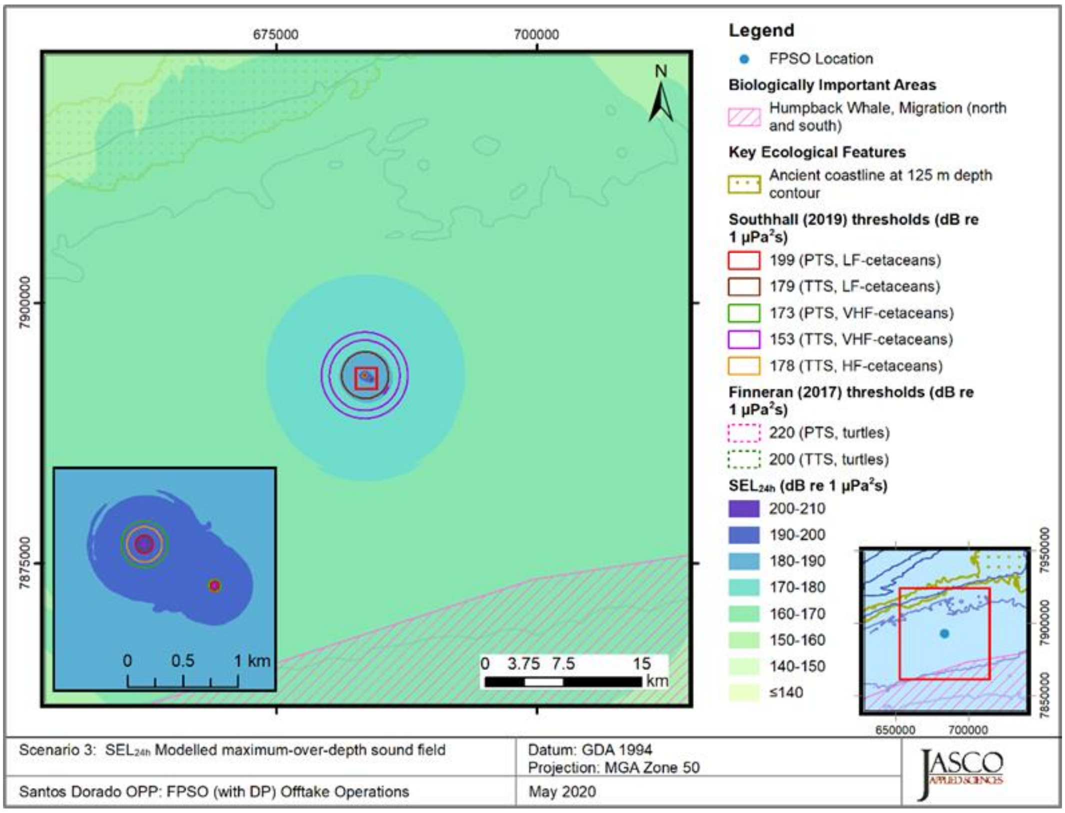


Figure 7-19: FPSO offtake operations SEL_{24h}: Sound level contour map showing weighted maximum-over-depth SEL_{24h} results.

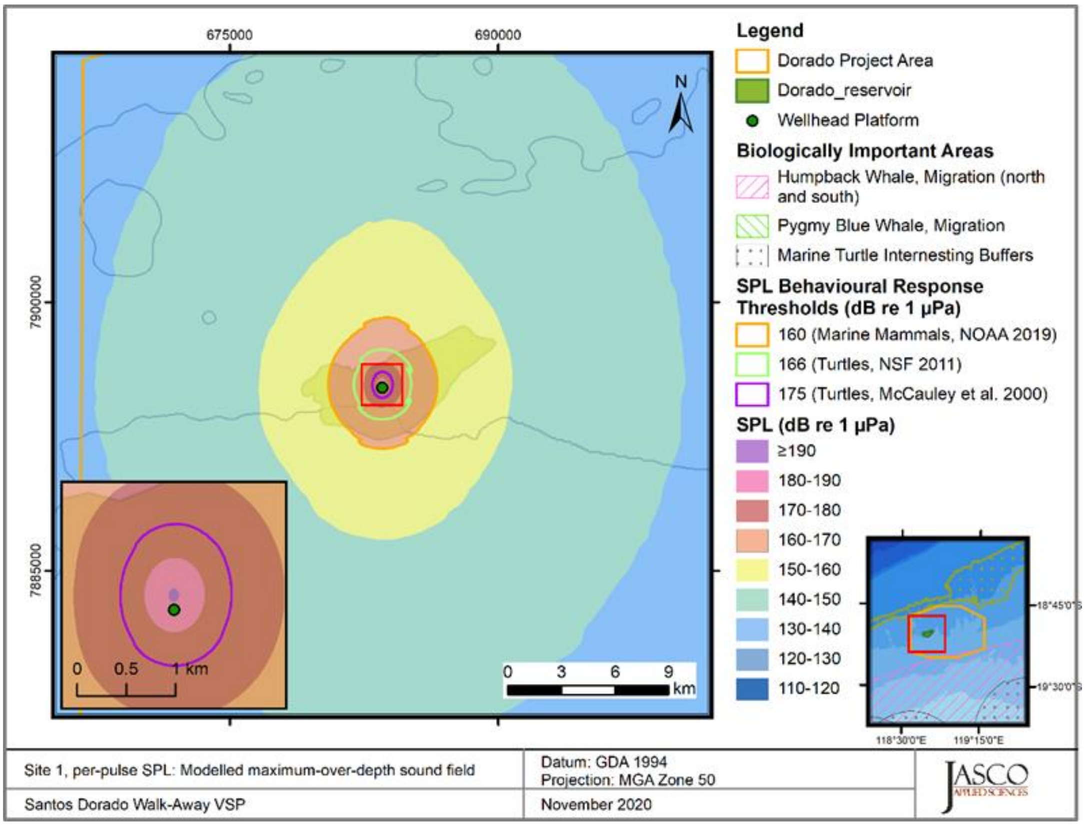


Figure 7-20: 3-D VSP SPL: Sound level contour map showing maximum-over-depth results.

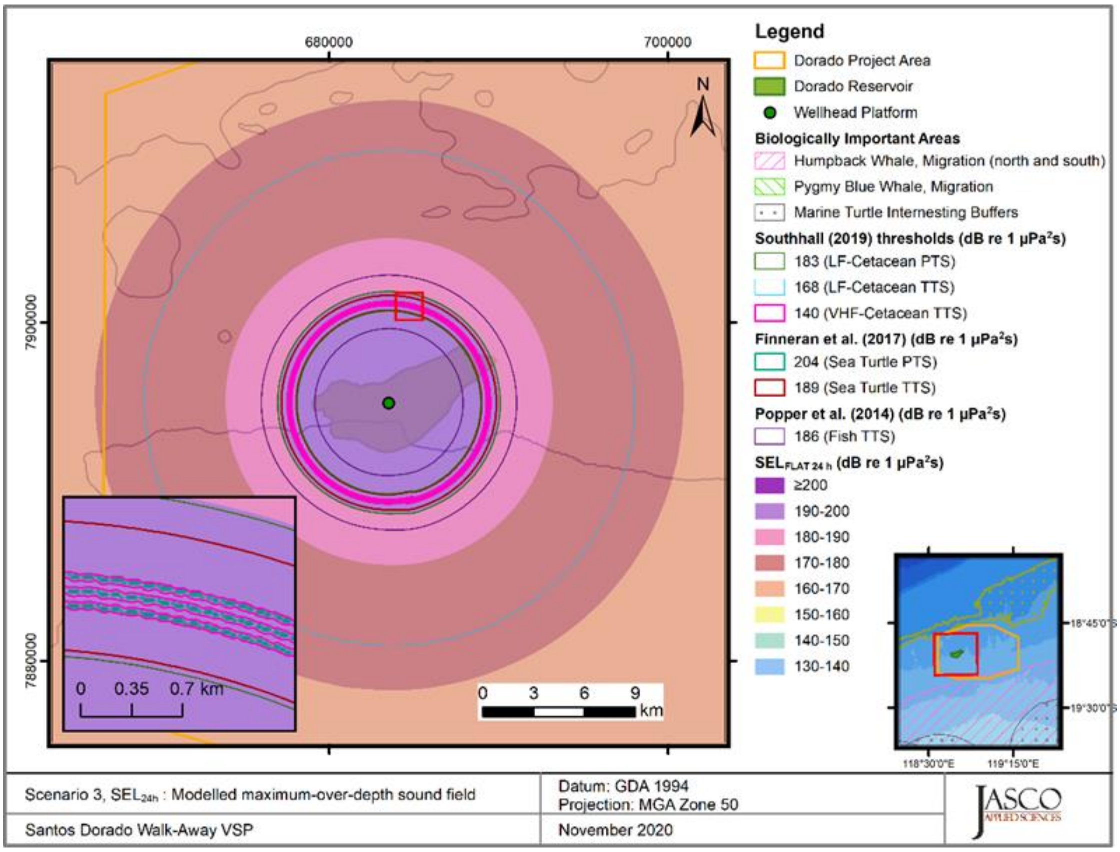


Figure 7-21: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results.

7.2.5.2 Details of Environmental Impacts and Risks

Marine fauna use sound in a variety of functions, including social interactions, foraging, orientation, and responding to predators. Underwater noise can impact upon marine fauna in six main ways:

- Inducing stress;
- Masking or interfering with other biologically important sounds such as vocal communication echolocation, signals and sounds produced by predators or prey;
- Disturbance leading to behavioural changes or displacement of fauna;
- Injury or fatigue to hearing or other organs;
- Mortality and mortal injury resulting in immediate or delayed death either due to injury or substantially reduced fitness; and
- Cumulative or chronic effects from repeated or long-term exposure to noise leading to additive severity of noise-induced effects.

Detailed descriptions of these impacts are provided in **Attachment 11**.

Table 7-36 identifies the potentially impacted receptors as a result of acoustic emissions from Dorado Phase 1.

Table 7-36: Receptors potentially impacted by Acoustic Emissions

Description of the Risk	Receptor Categories
Potential impacts to marine fauna including PTS, TTS, behavioural disturbance and masking	Plankton – **Section 7.2.5.2.1** Benthic Communities and Habitats – **Section 7.2.5.2.1** Marine Mammals – **Section 7.2.5.2.1** Fishes – **Section 7.2.5.2.3** Reptiles – **Section 7.2.5.2.4**

7.2.5.2.1 Plankton

Applying sound exposure guidelines for eggs and larvae (SEL_{24h} more than 210 dB re 1 µPa2.s) (Popper et al. 2014) indicates that mortality or potential permanent injury may occur within 5.59 km of the largest acoustic source. A study by McCauley (1994) calculated the impact in seismic survey area assuming plankton mortality of 100% within 10 m of an airgun. It argued that the total mortality due to seismic testing would be less than 1% of plankton in the surveyed area.

A more recent study undertaken by McCauley et al. (2017) showed potential for noise impulses discharged from a single 150 cui airgun resulted in zooplankton mortality and reduction in abundance out to more extended ranges (1.2 km), at levels up to 178 dB re 1 µPa PK-PK Pressure. Furthermore, Richardson et al. (2017) modelled the effect proposed by McCauley et al. (2017) in the context of ocean ecosystem dynamic and zooplankton population dynamic. The report concluded that even if the full effect reported by McCauley et al. (2017) did exist, plankton abundance would not be adversely affected, due to extensive movement of water masses carrying plankton through survey areas, and the rapid reproductive cycle and high reproductive potential characteristics of planktonic organisms.

Acoustic modelling results suggest that the worst-case maximum distance for impacts to plankton may occur within 88 m of the acoustic source, representing a small proportion of the plankton stock across the northwest shelf. Rapid recovery and repopulation are expected and the overall impact to plankton abundance is likely to be negligible, and not evaluated further.

7.2.5.2.2 Benthic Communities and Habitats

There is some evidence to suggest components of benthic communities may be vulnerable to underwater noise-related impacts, while other components are not. Studies have indicated scallops exposed to seismic survey noise show increased potential for mortality (Day et al. 2016; Harrington et al. 2010), whereas other studies have shown no evidence of mass mortality in the short-term post exposure or other negative impacts of seismic airgun arrays on scallops (Przeslawski et al. 2016). Preliminary studies on the effects of underwater noise on sponges did not observe any effects attributable to noise exposure (Wilmut et al. 2006).

Underwater noise generated by operational platforms does not appear to have any detrimental effect on benthic communities. Inspection of fixed platforms worldwide shows these structures serve as artificial reefs and develop relatively diverse benthic communities.

Benthic habitat surveys of the Project Area did not indicate the presence of particularly diverse or sensitive benthic communities (**Attachment 2**). Potentially vulnerable taxa, such as bivalve molluscs, were not observed. Given the duration, frequency spectrum and intensity of potential noise generated during Dorado Phase 1, no impacts to benthic communities as a consequence of underwater noise are expected to occur.

7.2.5.2.3 Marine Mammals

As described in **Section 3**, a number of species of marine mammals may occur in the Project Area. Acoustic signals of Omura's whales, killer whales, and dolphins and possibly a sperm whale were detected during ambient noise monitoring in the Dorado Project Area (Section 3.2.7). Note that the absence of acoustic signals from other marine mammals does not necessarily mean that they were not present. Omura's whales are not currently listed under the EPBC Act. The Project Area does not overlap any known resting, nursing, breeding or foraging BIA's for any marine mammal species; however, sensitivities for consideration include the following:

+ Humpback whale migration BIA, which occurs in nearshore waters and is 26 km southeast of the WHP at the closest point and slightly overlaps the Project Area (**Figure 3-13**);
+ Pygmy blue whale migration BIA, which passes approximately 110 km northwest of the WHP location at the closest point and 87 km northwest of the Project Area (**Figure 3-13**); and.
+ Pygmy blue whale distribution range, which overlaps the Project Area (see **Section 3.3.3** for context).

A number of other cetacean species may also occur in the Project Area (refer to **Section 3**), but the Project Area and surrounding waters are not identified as significant habitat for these species.

Most cetacean species use sound to communicate (e.g. humpback whale calls) or perceive their environment (e.g. echolocation of prey). This reliance on underwater noise, and their high conservation value, makes cetaceans of concern when assessing potential impacts from underwater noise.

The type and scale of the effect of sound on marine mammals will depend on a number of factors including the level of exposure, the physical environment, the location of the animal in relation to the sound source, how long the animal is exposed to the sound, the exposure history, how often the sound repeats (repetition period) and the animal sensitivity within the soundscape. The behavioural context of the exposure plays a critical and complex role in the way an animal might respond (Ellison et al. 2012; Gomez et al. 2016).

Direct mortality of marine mammals due to tissue damage from acoustic emissions are not considered credible. Direct tissue damage from sound in laboratory animals have been reported to require SPL in the order of 240 dB re 1 µPa (Carstensen 1997, cited in Cato et al. 2004). Piling, drilling VSP and 3-D VSP sources approach this source level at a maximum, and a marine mammal would need to be very close to the source to be subjected to this SPL. This scenario is not considered to be credible given marine mammals would move away from the noise source at levels well below these.

Permanent Threshold Shift – WHP and FPSO Piling and 3-D VSP

The activity with the highest potential to result in PTS is driving of the WHP jacket piles and the FPSO anchor piles. Considering the Southall et al. (2019) SEL_{24h} threshold criterion, there is potential that low-frequency cetaceans (such as humpback and pygmy blue whales) could experience PTS at a maximum distance of 5.84 km from piling and 3.4 km from the 3-D VSP noise sources (**Table 7-35**). Ranges at which high-frequency and very-high-frequency cetaceans PTS effect criteria are met is approximately less than 1 km from the source.

For low frequency cetaceans, acoustic emissions from piling at the Dorado facilities locations potentially resulting in PTS, are approximately 20 km clear of the northern boundary of the humpback whale migration BIA (**Table 7-35)** and 104 km clear of the southern boundary of the pygmy blue whale migration BIA. Distances for acoustic emissions from 3-D VSP to the BIAs potentially resulting in PTS will be approximately 2.5 km further away than piling noise sources. These distances are sufficient to ensure that humpback whales and pygmy blue whales within their respective migration BIAs will not be exposed to acoustic emissions at levels that would induce PTS.

As shown in **Figure 7-22**, satellite tracking data for humpback whales indicates a more south-easterly route within the migration BIA and away from the Dorado Project Area.

The SEL_{24h} is a cumulative metric that reflects the measured dose impact of noise levels over 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. Driving of individual piles is expected to require less than 24 hours of continuous hammering and installation of consecutive piles will not occur continuously; there will be a break between the hammering stage for the installation of each pile. Whilst 3-D VSP may occur continuously over 25 days, whales would not stay in the same location or at the same range when exposed to underwater noise levels sufficient to induce PTS, as animals would move away from painful noise stimuli. This would particularly be the case for an animal migrating through the Project Area. A humpback whale passing the Project Area within the migration BIA or at a distance of 50 km (as per Australian Antarctic Division tagging data) in less than a day is unlikely to remain within a fixed range of the piling or 3-D VSP. Migrating humpback whales in the region have been recorded travelling between 40 and 60 km per day (Double et al. 2012a). This speed is sufficient to allow humpback whales to avoid the area that may be exposed to noise levels that may induce PTS. Improved modelling techniques which more accurately simulate aquatic species' behaviour, movement and densities will be utilised in future acoustic modelling to reduce conservatism and improve confidence in predictions to inform activity specific environment plan impact assessments.

Noise from the FPSO and vessels would only result in PTS if a whale remained relatively close (less than 1 km) to the source. This is not considered a credible scenario, as whales typically move away from vessels and noise sources (Dunlop et al. 2017, 2015).

On this basis, PTS in marine mammals as a result of underwater noise emissions from Dorado Phase 1 are not considered to be credible.

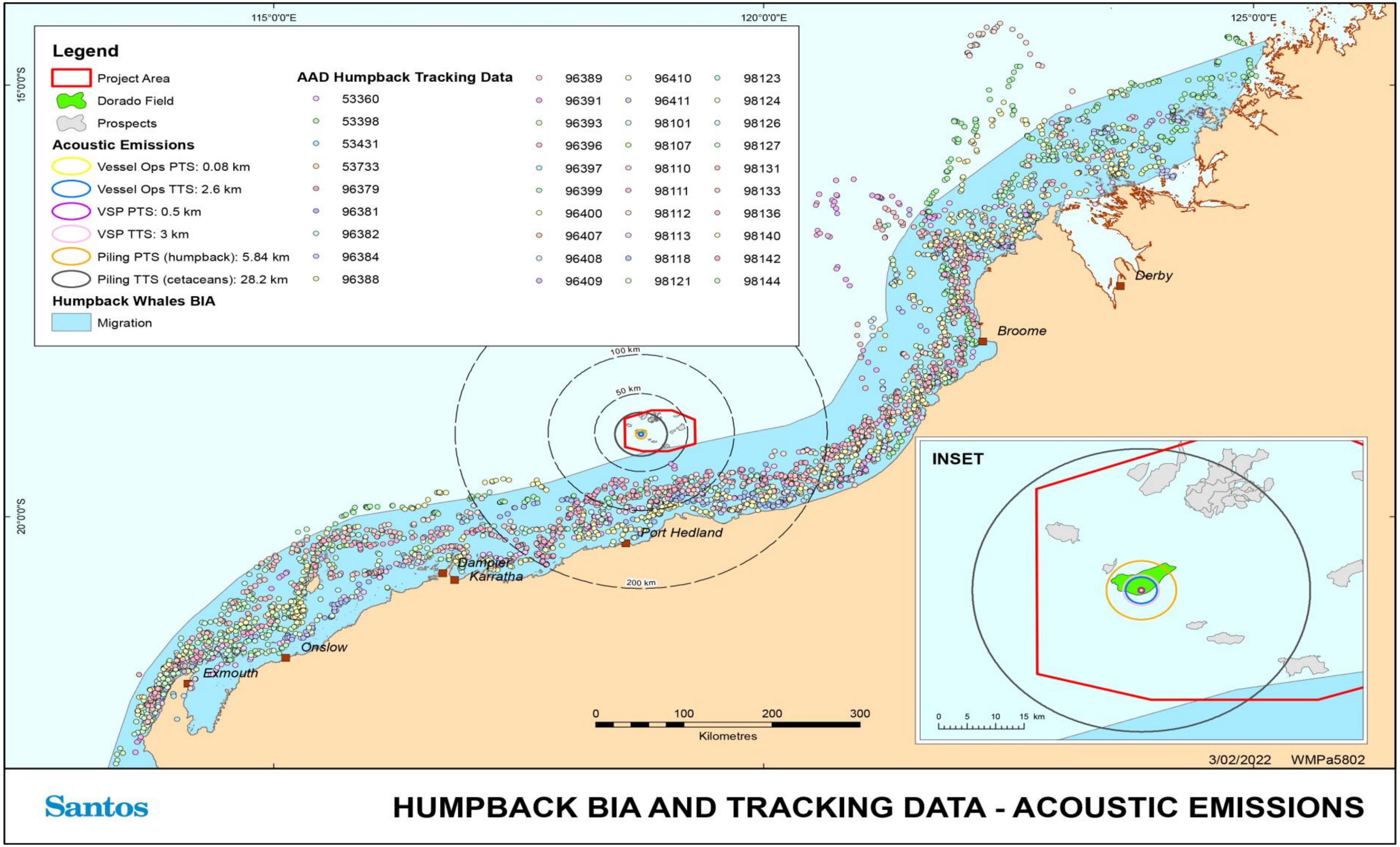


Figure 7-22: Extent of acoustic emissions related to humpback whales, showing the migration BIA and satellite tracking data.

Given that the future tiebacks may include piling (depending on geotechnical conditions) and 3-D VSP, acoustic modelling results for the Dorado facilities has been extrapolated for a potential tieback locations in the southern and northern extent of the Project Area (**Figure 7-23**) selected as a 'worst-case' location due the proximity to the humpback and pygmy blue whale migration BIAs. The threshold for PTS for piling activity at the southern-most prospect overlaps the western margin of the humpback whale migration BIA but does not overlap any humpback whale migration tracking data. The Northern prospect does not overlap any pygmy blue whale BIAs.

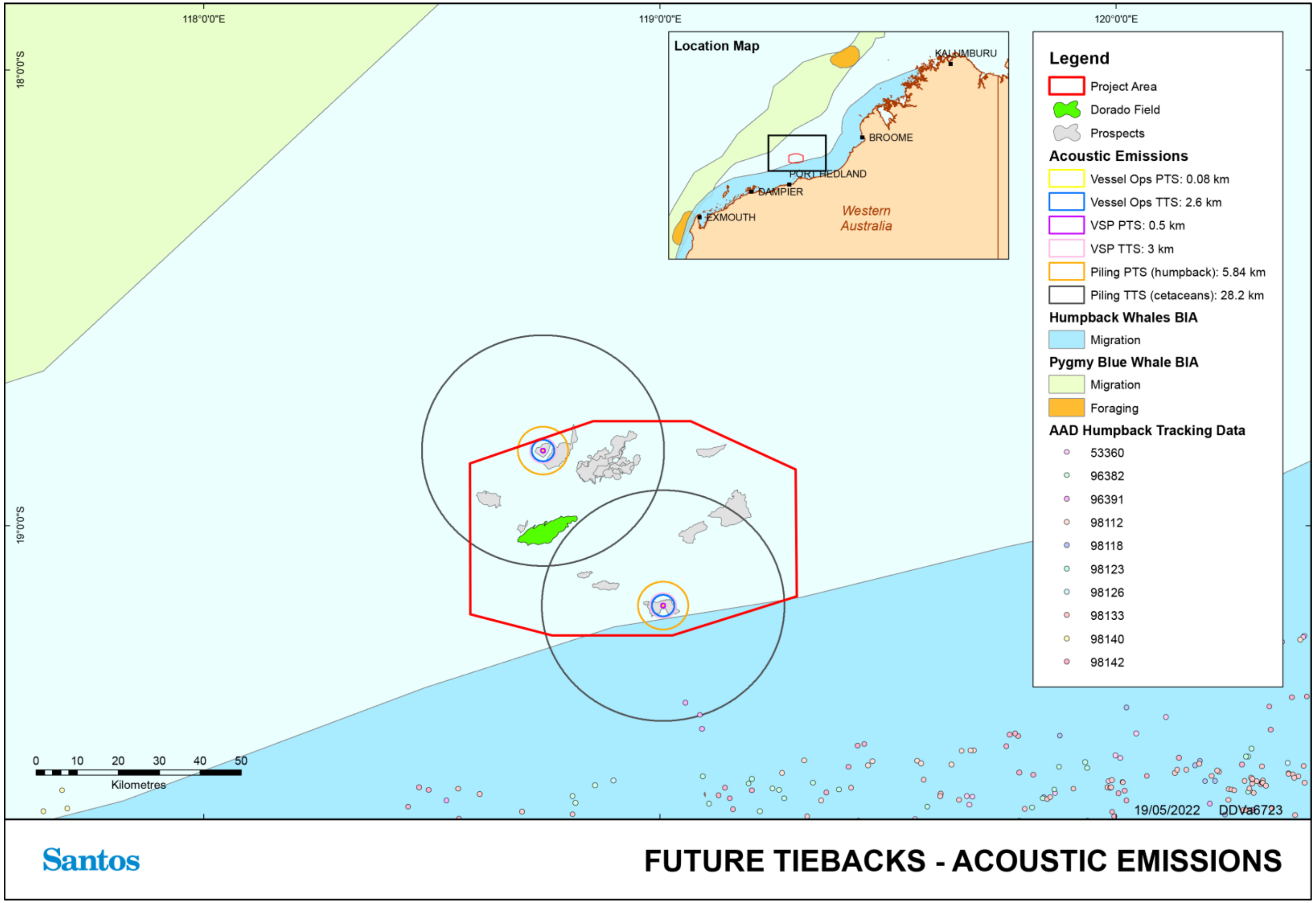


Figure 7-23: Extent of acoustic emissions related to Humpback Whales from a potential future tieback location in the southern extent of the Project area showing the humpback whale migration BIA and satellite tracking data.

Temporary Threshold Shift – WHP and FPSO Piling and 3-D VSP

Like PTS, the activity with the highest potential to result in TTS is Dorado facility piling, followed by 3-D VSP. Considering the Southall et al. (2019) SEL_{24h} threshold criterion, low-frequency cetaceans (such as humpback and pygmy blue whales) are predicted to experience TTS at a maximum distance of 28.2 km from FPSO anchor piling operations and 15 km from 3-D VSP. The TTS envelope for FPSO anchor piling overlaps by approximately 4km with the humpback whale migration BIA south of the Project Area, but does not overlap with any of the satellite tracking with humpback whales migrating to the south and further inshore (**Figure 7-22**).

At the closest possible point within the Project Area, the TTS modelled exposure range for piling is at least 59 km from the pygmy blue whale migration BIA and 72 km for 3-D VSP. Recent clarification of terms in the Conservation Management Plan for the Blue Whale (DAWE, 2021)defines 'injury' as impacts from PTS or TTS. Given the distance between the Project Area and the pygmy blue whale migration BIA, any pile driving and 3-D VSP activity within the Project Area would not cause injury to a migrating pygmy blue whale and would not be inconsistent with the relevant action of the Conservation Management Plan for the Blue Whale (DAWE, 2021).

TheSEL_{24h} criteria for TTS is considered to be a very conservative noise effect criterion, as cetaceans are unlikely to remain stationary within the sound field for 24 consecutive hours. Additionally, the duration of piling for individual piles is expected to be shorter than 24 hrs, hence accumulation of a 24 hr dose of impulsive noise is very unlikely to occur. Improved modelling techniques which more accurately simulate aquatic species' behaviour, movement and densities will be utilised in future acoustic modelling to reduce conservatism and improve confidence in predictions to inform activity specific environment plan impact assessments.

The range at which TTS as a result of acoustic emissions from Drilling-VSP source may occur is much shorter, at 3.1 km for low-frequency cetaceans and 0.24 km for very-high-frequency cetaceans (**Table 7-33**). The noise effect criteria for TTS in high-frequency cetaceans was not predicted to be exceeded by this VSP.

Noise from the FPSO and vessels exceeded the TTS threshold for very-high-frequency cetaceans up to 4.51 km from the source. Very-high-frequency cetaceans, such as orcas and dolphins, are highly mobile and not expected to occur in the Project Area in high numbers.

Marine mammals are expected to move away from noise sources before being exposed to sufficient noise to induce TTS. In the event that any whales do experience TTS, it is likely that there will be full recovery after sound exposure ceases (National Marine Fisheries Service 2018).

Given that the future tiebacks may include piling (depending on geotechnical conditions) and may include 3-D VSP, acoustic modelling results for the Dorado facilities have been extrapolated for a potential tieback location in the southern and northern extent of the Project Area (**Figure 7-23**) selected as a 'worst-case' location due to the proximity to the humpback and pygmy blue whale migration BIAs . It is recognised that the threshold for TTS for piling activity at the southern-most prospect overlaps the western margin of the humpback whale migration BIA and several humpback whales from the tracking data. The Northern prospect does not overlap any pygmy blue whale BIAs.

Behavioural

Behavioural impacts may be variable, with individual whales of the same species reacting differently when exposed to the same sound (Southall et al. 2019). The Behavioural Response of Australian

Humpback Whales to Seismic Surveys study provides one of the most comprehensive assessments of behavioural responses of whales to underwater noise. Key results from the study included (Dunlop et al. 2017, 2015):

- The likelihood of a behavioural response (avoidance of the survey vessel) typically increased when:
  - the vessel was within 3 km of the whale, and
  - received SEL_{24h} exceeding 140 dB re 1 µPa^2s.
- The typical behavioural response consisted of a deviation from their expected swimming patterns in the order of hundreds of metres and a decrease in dive time. These responses were much smaller than the avoidance responses the species is capable of;
- The behavioural responses observed were within the normal suite of behaviours exhibited by humpback whales. No behaviours considered abnormal were observed; and
- The exposure to acoustic emissions did not appear to inhibit the southward migratory movement of the whales.

Behavioural impacts (e.g. avoidance, displacement from a foraging area, disruption to resting), may occur if marine mammals pass close to the noise source. The noise source with the greatest predicted distance to illicit a marine mammal behavioural response (120 dB re 1 µPa SPL) is for FPSO offtake operations at a distance of 11 km, followed by the FPSO using thrusters (10.4 km), WHP jacket piling (5.4 km), FPSO anchor piling (4.6 km), support vessel operations (4.5 km), 3-D VSP (3.78 km), drilling VSP at (2.4 km) and FPSO not using thrusters (1.49 km) (**Table 7-35**). FPSO offtake operations may occur as frequently as weekly during the early operational stage of Dorado Phase 1, and will decline over time as production diminishes. At these distances, potential behavioural response impacts associated with any of the sources are restricted to an area close to the source which does not overlap the migration BIAs for humpback whales and pygmy blue whales.

Recent clarification of terms in the Conservation Management Plan for the Blue Whale (DAWE, 2021) advise that activities proposed to occur outside designated foraging areas must adopt best practice adaptive management approaches in the event that indicators of whale foraging are evident to ensure impacts to whales are not unacceptable. No such measures are required for the Dorado Project as the activity is not inconsistent with the Conservation Management Plan for the Blue Whale given: i) designated foraging areas are a minimum of 527 km away, ii) the Dorado Project Area is not an area of upwelling or known for high primary productivity, iii) any foraging activity that may take place whilst migrating is at least 87 km away based on location of the migration BIA and iv) it is highly unlikely that pygmy whales would be present in the Dorado Project Area given historic whale catch data, satellite tracking and passive acoustic records (Figure 1, CMP; Double et al., 2014; Thums et al., 2022) corroborated by the absence of their acoustic signals during ambient underwater noise monitoring in the Dorado Project Area overlapping with migration timing (**Section 3.2.7**).There are relatively few studies of the effects of helicopter noise on marine mammals. Observations of bowhead whales exposed to helicopter noise indicate that most individuals are unlikely to react significantly to occasional single helicopter passes by low-flying helicopters ferrying personnel and equipment to offshore operations at altitudes above 150 m (Richardson et al. 1995). Given the typical altitude of helicopter flights to the FPSO are only below 150 m when taking off or landing at the FPSO, no behavioural impacts to marine mammals are expected to occur in response to helicopter flights.

Masking

Given the relatively short duration and intermittent nature of piling, 3-D VSP and drilling VSP and the distance to noise sources from Dorado to the migration BIAs, these activities are unlikely to result in any significant period of masking of whale calls, although may cause whales to cease or alter their vocalisations at times, as outlined in Erbe et al. (2016).

Operational noise from the FPSO and vessels will occur throughout much of Dorado Phase 1, and hence represents a relatively long-term source of noise that may result in masking. While the frequency range of these noise sources is broadband and may overlap the functional hearing ranges of most marine mammals, the source levels are relatively low. Noise from these sources is not expected to result in masking beyond the range at which behavioural impacts were predicted to occur (up to 11 km from the FPSO). Humpback whales are often sighted very close to other FPSOs located on the northwest shelf, including Santos' Ningaloo Vison. In terms of pygmy blue whale impacts, the same reasoning detailed above for behavioural impacts applies to masking.

Positioning equipment could cause masking of vocalisations of high-frequency and very-high-frequency cetaceans due to the overlap in frequency range between signals and vocalisations. However, due to the rapid attenuation of the relevant frequencies, the range at which the impact could occur will be small (within hundreds of meters). Hence, positioning equipment acoustic emissions are not expected to result in masking.

7.2.5.2.4 Fishes

The presence or absence of a swim bladder and ancillary structures determines the level of susceptibility of fishes to injurious effects from exposure to intense sound. Accordingly, different exposure guidelines were developed for fishes without a swim bladder, fishes with a swim bladder not involved in perception of acoustic signals and fishes that use their swim bladders for hearing.

Most fish species detect sounds from below 50 Hz up to 500 to 1,500 Hz. A smaller number of species can detect sounds to over 3 kHz, while a very few species can detect sounds to well over 100 kHz. The critical issue for understanding whether an anthropogenic sound affects hearing is whether it is within the hearing frequency range of a fish and loud enough to be detectable above threshold.

The fish receptors identified for this assessment, such as site-attached species (including syngnathids) and demersal fish species, are included in the category of fish having a swim bladder while mackerel, a pelagic fish species, do not have a swim bladder. See **Attachment 10** for a detailed description of typical fish common in Australian waters related to the classifications of Popper et al. (2014) from which the noise effects criteria presented in **Section 7.2.5.1.2** were derived. Individual demersal fish may be impacted in the vicinity of the Project Area, and tuna and billfish and other mobile pelagic species may transverse the Project Area. However, the Project Area is not known to be an important spawning or aggregation habitat for commercially caught targeted species.

The fish groups most likely to be present within the Project Area are pelagic fish, such as Spanish mackerel (*Scomberomorus commerson*), and demersal fish, such as snapper and emperor (family Lutjanidae). These groups are classified by Popper et al. (2014) as fish with no swim bladder (Group I) and fish with a swim bladder which is not involved in hearing (Group II). Fish with swim bladder involved in hearing (Group III), are uncommon in the Project Area. Sharks, such as whale sharks, are considered to be fish with no swim bladder for the purpose of this assessment.

Injury

The activity with the highest potential of risk is subsea impact driving of the WHP jacket piles and the FPSO anchor piles followed by 3-D VSP. The most sensitive fish group in the Project Area, those with a swim bladder not involved in hearing (demersal fish), could experience mortality or potential mortal injury within 470 m of piling operations and recoverable injury within 1 km and for 3-D VSP, mortality/potential mortal injury and recoverable injury within 70 m, based on threshold criteria (**Table 7-33**). The ranges for these effects drilling VSP are considerably shorter: potential mortal injury within 37 m and potential recoverable injury within 50 m. The noise criteria ranges for fish without swim bladders, such as pelagic fishes and sharks, are also shorter (**Table 7-33**).

Meekan et al. (2021) undertook a large-scale experiment that quantified the impacts of exposure of an assemblage of tropical demersal emperors (family Lutjanidae), snappers (family Lethrinidae) and groupers (family Epinephelidae) to a commercial-scale seismic source on the North West Shelf off Western Australia. The effective source level in this experiment was 231 dB re 1 µPa (SPL), that is, within the range of source levels for piling and 3-D VSP (**Table 7-28**). A combination of Baited Remote Underwater Video Systems (BRUVS) and acoustic tagging methods were used to measure the behaviours and movements of fishes at high (directly below source), medium (300 m from source) and low exposure sites (2 km), as well as at vessel control (10 km) and control sites (11 km). The maximum modelled SEL values received at the high, medium and low exposure sites were in the order of 180 – 200 dB re 1 $\mu Pa^2 \cdot s$, 130 – 160 dB re 1 $\mu Pa^2 \cdot s$ and 115 – 125 dB re 1 $\mu Pa^2 \cdot s$ respectively. There were no short-term (days) or long-term (months) effects of exposure detected on the composition, abundance, size structure, behaviour, or movement of fishes at any exposure sites.

The impulses from piling, 3-D VSP and drilling VSP will not occur simultaneously and will occur with time periods in between sufficient for recovery from injury to occur. Given the conservative threshold criteria considered, relevant field experiment findings and intervals between noise emitting activities the potential impacts from piling, 3D VSP and drilling VSP to fish will be localised, restricted to the area immediately around the noise source, and occur only over a short periods of time throughout the Dorado Phase 1.

Noise from vessels and the FPSO is considered to present a low risk of mortal or recoverable injury to fish. Based on the assessment above, injuries to fish as a result of acoustic emissions from Dorado Phase 1 are not expected to occur.

Temporary Threshold Shift

The most sensitive fish group likely to be in the Project Area, those with a swim bladder not involved in hearing (particle motion detection), could experience TTS within 5.59 km of piling noise sources, within 4.65 km of the 3-D VSP and within 840 m of the drilling vertical seismic profiling source (**Table 7-33**). The impulses from piling and vertical seismic profiling are unlikely to occur continuously for 24 hrs, and recovery in the ability to perceive noise is likely to occur within the 24 h period assessed. Fish recover from TTS relatively quickly (**Attachment 10**) and as the longest pile driving activity will take approximately 4.7 hours with breaks between the driving of each pile, the impact period is limited. The 3-D VSP, whilst over a longer duration of 25 days, is a moving noise source such that demersal and pelagic fish are not exposed continuously to noise levels that may induce TTS.

Noise from vessels and the FPSO is considered to present a low risk of TTS to fish at ranges of more than tens of metres.

Masking

Underwater noise sources that overlap the functional hearing range of fishes include piling, vertical seismic profiling (3-D and drilling) and vessel noise. Given piling and vertical seismic profiling activities are of short duration and 3-D VSP is a moving source, masking-related impacts would only credibly occur over a short duration. Operational noises, such as FPSO and vessel-related noise, are relatively low intensity and are only expected to potentially mask biologically important noise in a localised area around the noise source. Given the widespread and homogeneous habitats in the Project Area, these impacts are not expected to result in impacts to fish.

Larval coral reef fish have been shown to use noise cues to locate suitable habitat for settlement (Leis et al. 2002). Given the lack of coral reef habitat within the Project Area, acoustic emissions from Dorado Phase 1 are not expected to result in impacts to recruitment of reef fish.

Behavioural

Behavioural impacts to fish will be limited to responses within metres of the noise source, and fish may be temporarily displaced from the vicinity of the noise emissions. As demonstrated by Meekan et al. (2021), behavioural responses of demersal fishes to a simulated seismic survey in the field in a similar area to Dorado Project Area on the North West Shelf were not detected at high, medium and low exposure sites compared to control sites. The acoustic tags and telemetry found little evidence that fish were displaced by the exposure to the seismic source. Movements of tagged fish occurred over a limited area focused on two or three acoustic receivers, and there was no evidence for the departure of tagged fish after exposure. These multiple lines of evidence suggest that seismic surveys have little impact on the behaviours of demersal fishes in this environment.

7.2.5.2.5 Reptiles

Marine reptiles such as turtles and sea snakes are not known to be particularly sensitive to underwater noise. Research on marine turtles suggests that functional hearing is concentrated at frequencies between 100 and 800 Hz (Ketten and Bartol 2006), which is a subset of the low-frequency cetacean functional hearing range.

Several turtle species were identified as likely to occur within the Project Area, with only one BIA (Flatback Turtle inter-nesting BIA) intersecting the Project Area. The water depth and benthic habitat within the Project Area is typically too deep for turtle foraging for several species (e.g. Hays et al. 2001; Polovina et al. 2003), although species that eat primarily pelagic prey (e.g. leatherback and juvenile green turtles) may forage for pelagic prey. As such, turtles are expected to occur only at low densities within the Project Area and are likely to be transiting the area rather than foraging, breeding or inter-nesting.

Permanent Threshold Shift

The activity with the highest potential of risk is subsea impact driving of piles and vertical seismic profiling. The noise modelling results indicate PTS may occur at ranges of 0.72 km and 0.03 km for piling and 3-D and drilling VSP (**Table 7-33**). These results are based on a SEL_{24h}, and it is not considered credible that such a long noise exposure would occur, as piling and VSP activities will be of shorter duration than 24 hrs and turtles are unlikely to remain within the noise field for this length of time.

The vessel and FPSO noise did not exceed the PTS noise effect criteria for turtles. These noise sources will not credibly result in PTS in turtles.

Temporary Threshold Shift

The TTS noise effect thresholds for marine turtles were reached at ranges of 4.11 km, 2.92 km and 0.38 km for piling, 3-D VSP and drilling VSP respectively **Table 7-33**). These results are based on a SEL_{24h}, and it is not considered credible that such a long noise exposure would occur, as piling and drilling vertical seismic profiling activities will be of shorter duration than 24 hrs, 3-D VSP involves a moving source and turtles are unlikely to remain within the noise field of these sources for this length of time.

The TTS noise effect threshold was only exceeded by vessel and FPSO noise sources at very close ranges. Turtles are not expected to remain in such close proximity to vessels for any length of time; TTS in marine turtles is not considered to be credible as a result.

Behavioural

The behavioural disturbance and response noise effect criteria were exceeded by piling, 3-D VSP and drilling VSP at 3.51 km, 2.91 km and 1.22 km, respectively. These criteria were not exceeded by any vessel or FPSO modelled scenarios. Given the low number of turtles expected to be in the Project Area, along with the relatively short durations and small area ensonified above the behavioural noise effect criteria, any behavioural impacts will be short-term and restricted to a small number of turtles.

7.2.5.2.6 Commercial Fisheries

Management areas for the State and Commonwealth-managed fisheries active in the area are presented in **Section 3.4.3**.

The impact assessment of underwater noise on fish is described in **Section 7.2.5.2.4**. The impacts to fish from underwater noise are limited to localised behavioural changes that will not have any flow on impact to commercial fishing operations**.** As demonstrated by Meekan et al. (2021), behavioural responses of demersal fishes to a simulated seismic survey in the field in a similar area to Dorado Project Area on the North West Shelf were not detected at high, medium and low exposure sites compared to control sites. The experiment was focused on tropical demersal emperors (family Lutjanidae), snappers (family Lethrinidae) and groupers (family Epinephelidae) targeted by commercial fisheries. Dominant species included spangled emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*), and brownstripe snapper (*L. vitta*). There were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure, behaviour, or movement of fishes at any exposure sites. The researchers suggest that the behavioural responses of demersal fishes to the bait cue provided by the Baited Remote Underwater Video Systems are a realistic proxy of the likely response of the same species to baited hooks or traps used by the commercial fisheries that target them. The acoustic tags and telemetry found little evidence that fish were displaced by the exposure to the seismic source. These multiple lines of evidence suggest that seismic surveys have little impact on the behaviours of demersal fishes in this environment. The effective source level in this experiment was 231 dB re 1 µPa (SPL), that is, within the range of source levels for piling and 3-D VSP.

In addition, negligible impacts are expected to plankton (including fish eggs and larvae, Section 7.2.5.2.1) or benthic habitats and communities (Section 7.2.5.2.2) that would have any flow on impact to commercial fishing operations.

7.2.5.3 Summary of Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-37**.

Table 7-37: Summary of impacts, environmental performance outcomes, controls and consequence evaluation of acoustic emissions during Dorado Phase 1

EPOs	
EPO3E: No mortality or significant[32] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 acoustic emissions. **EPO9A** Undertake Dorado phase 1 in such a manner that noise in biologically important areas will be managed to prevent any displacement of threatened species as per EPBC species conservation requirements **EP010A** No impacts from Dorado Phase 1 acoustic emissions to pre-existing commercial fish stocks that occur within the project area that could be subject to existing or future fishing effort. **EPO11A:** No injury to pygmy blue whales within a biologically important area. **EPO12A:** noise generating activities of Dorado Phase 1 are managed in such a manner to prevent PTS and reduce the risk of TTS and biologically important behavioural disturbance to all whales in the Commonwealth marine area.	
Receptor	**Impact**
Marine Mammals	Potential PTS up to 5.84 km from FPSO anchor piling, 3.4 km from 3-D VSP, 0.47 km from drilling VSP sources, and 0.21 km from FPSO operations. Potential TTS up to 28.2 km from FPSO anchor piling, 15 km from 3-D VSP, 3.1 km from VSP drilling source, and 4.51km from FPSO operations. Potential behavioural disturbance up to 5.4 km from FPSO anchor piling, 3.78 km from 3-D VSP, 2.42 km from drilling VSP source, and 11 km from FPSO operations. Only the TTS envelope resulting from Dorado FPSO anchor piling, and future tieback piling (at a worst-case tieback location) overlaps with the humpback whale migration BIA. No noise sources (including future tieback activities) resulting in potential PTS, TTS injury overlap with the pygmy blue migration BIA.
Fishes	Potential mortal injury up to 0.56 km from piling, 0.07 km from 3-D VSP and 0.037 km from VSP sources. Potential recoverable injury up to 1 km from piling, 0.07 km from 3-D VSP and 0.05 km from drilling VSP sources. Potential TTS up to 5.88 km from piling, 4.65 km from 3-D VSP and 0.84 km from drilling VSP sources. Moderate risk (at 10s of metres) to low risk (at all distances) of behavioural disturbance from all other noise sources.
Reptiles	Potential PTS up to 0.72 km from piling, and 0.03 km from VSP (3-D and drilling) sources.

[32] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

	Potential TTS up to 4.11 km from piling, 2.92 km from 3-D VSP, and 0.38 km from drilling VSP source. Behavioural response up to 3.51 km from piling, 1.99 km from 3-D VSP and 1.22 km from drilling VSP sources
Controls	

CM15: Vessels movements and helicopter flights comply with Part 8 of EPBC Regulations for interacting with cetaceans.

CM16: Implement Santos' Protected Marine Fauna Interaction and Sighting Procedure.

CM17: Undertake acoustic modelling for piling, 3-D VSP and drilling VSP activities for potential future tiebacks.

CM18: Implement mitigation measures for drilling VSP and 3-D VSP activities aligned with EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a), including:

- development of low-power and shutdown zones,
- marine fauna observers,
- pre-start visual observations,
- soft-start procedures,
- stop work procedures, and
- night-time and low visibility procedures.

CM19: Implement mitigation measures for piling activities, including:

- marine fauna observers,
- pre-start visual observations,
- soft-start procedures,
- stop work procedures, and
- night-time and low visibility procedures.

CM20: Where future activity specific acoustic emissions modelling results indicate PTS, TTS envelopes overlap with a pygmy blue whale BIA, related impulsive noise generating activities will not occur during corresponding peak migration periods.

Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.5.4 Demonstration of Acceptability

The potential impacts from underwater noise emissions as a result of Dorado Phase 1 have been compared against receptor-specific acceptable levels of impact and other considerations, which are summarised in **Table 7-38** and **Table 7-39**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case consequence for underwater noise emissions was evaluated as minor (**Table 7-37**). This consequence is considered to be acceptable when assessed against the acceptable levels of impacts and risks outlined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from acoustic emissions are acceptable.

Table 7-38: Demonstration of acceptability for acoustic emissions

Acceptability Criteria	Justification
To meet the principles of ESD	The risks and impacts from underwater noise associated with Dorado Phase 1 are consistent with the principles of ESD based on: + the environmental values/sensitivities within the Project Area are not expected to be significantly impacted, and + the precautionary principle has been applied and studies undertaken where knowledge gaps were identified (**Attachment 10** and **Attachment 11, Attachment 14**).
Internal Context	Management of underwater noise is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Underwater noise emissions are not expected to result in impacts to stakeholders, such as commercial fishers. Santos' ongoing consultation program will consider stakeholders' feedback.
MNES	The following material published in relation to threatened and migratory species within and adjacent to the Project Area identify acoustic emissions as a threat: + Conservation advice: Conservation advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b), Approved conservation advice for *Balaenoptera physalus* (fin whale) (Threatened Species Scientific Committee 2015c), + Recovery plans: Conservation management plan for the southern right whale: a recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2011-2021 (DSEWPaC 2012c). This recovery plan identifies noise interference as a threat to Southern Right Whales. Adoption of CMs 15 – 20 satisfies Action Area A.2 from the management plan: Assessing and addressing anthropogenic noise. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a). This recovery plan identifies noise interference as a threat to marine turtles. Adoption of CMs 15 – 20 satisfies Action Area B.3 from the management plan: Assessing and addressing anthropogenic noise., and Conservation Management Plan for the blue whale: A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2015-2025 (Commonwealth of Australia 2015a). This recovery plan identifies noise interference as a threat to Blue Whales. Adoption of CMs 15 – 20 satisfies Action Area A.2 from the management plan: Assessing and addressing anthropogenic noise; and Guidance on key terms within the Blue Whale Conservation Management Plan (DAWE, 2021). The objectives of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The controls outlined in **Table 7-37** are consistent with the objectives of the material listed above

Acceptability Criteria	Justification
	and Santos considers the impacts of acoustic emissions to not be inconsistent with the EPBC management plans. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify noise as a key threat or do not have explicit relevant objectives or management actions related to noise.
Other Relevant Requirements	Management of the impacts of underwater noise emissions are not inconsistent with relevant legislative requirements, including: + alignment with EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a) + The AWS provides for a high level of protection to all cetaceans including whales from all anthropogenic threats.

Table 7-39: Demonstration of acceptability of acoustic emissions against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Justification
RSAL8: No significant[33] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities	Benthic habitat surveys of the Project Area did not indicate the presence of particularly diverse or sensitive benthic communities, and potentially vulnerable taxa, such as bivalve molluscs, were not observed. Given the duration, frequency spectrum and intensity of potential noise generated during Dorado Phase 1, no impacts to benthic habitats and communities as a consequence of underwater noise are expected to occur.
RSA13: No mortality of species listed as threatened, migratory or cetacean under the EPBC Act as a result of Dorado Phase 1. **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL15**: No injury to pygmy blue whales in a pygmy blue whale BIA. **RSAL16**: No significant[31] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	Potential noise-related impacts will be concentrated around the Dorado WHP and FPSO locations during the installation and operations stages, and potential future tieback locations within the Dorado Project rea. This area is not important habitat for threatened or migratory MNES that may be impacted by acoustic emissions, such as cetaceans and marine turtles. As required in the CMP for the Blue Whale, a precautionary approach has been adopted through inclusion of control measures (CM15 to CM20) to manage potential impacts to blue whales, given that the project area is outside of PBW foraging or migration BIAs, but overlaps the distribution range. The CMP for the Blue Whale does not suggest controls for distribution ranges, and as such, overlapping of the PBW distribution range with the Dorado Project Area is not inconsistent with the CMP for the Blue Whale. Recent distribution and movement of pygmy blue whales by Thums et al. (2022) reveals migratory paths in deeper waters of the continental slope to the west of

[33] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

RSAL19: No negative impacts to the economic viability of the commercial fish resources.	the Project Area (**Figure 3-13** and **Section 3.3.3**), which further reduces the risk of anthropogenic noise impacts within the PBW distribution range. Recent clarification of terms in the CMP for the Blue Whale 2021-25 (DAWE, 2015) advise that PTS and TTS do constitute an injury. No Dorado noise sources resulting in potential PTS, TTS or behavioural impacts overlap with the pygmy blue migration BIA and as such Dorado development activities are not inconsistent with the CMP for the Blue Whale (DAWE, 2021). Under the AWS and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) all cetaceans (whales, dolphins and porpoises) are protected in Australian waters, and it is an offence to kill, injure or interfere with a cetacean. EPO12A provides an appropriate level of performance to prevent PTS and reduce the risk of TTS and biologically important behavioural disturbance to all whales in the AWS, attributable to noise generating activities of the Dorado Phase 1 Development. Santos' management of acoustic emissions is aligned to industry practices and relevant requirements. Santos has experience in effectively implementing these controls. This management is aligned to relevant conservation advice and recovery plans for threatened and migratory species. While impacts to individual fish may occur, these are expected to consist of recoverable TTS. These impacts will not result in impacts to commercially exploited fish resources as a whole.

7.2.6 Emissions – Greenhouse Gas

This section details the assessment of direct (Scope 1) greenhouse gas (GHG) emissions from the development, operation and decommissioning stages of Dorado Phase 1 and the indirect (Scope 3) GHG emissions from the transportation, processing and third-party consumption of product. This assessment includes the predicted GHG emissions from Dorado Phase 1 and the potential impacts of climate change on sensitive receptors, including matters of national environmental significance, within Australian jurisdictions.

GHG emissions refers to gases that trap heat within the atmosphere through the absorption of longwave radiation reflected from the Earth's surface. The emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are recognised as GHG emissions.

To quantify potential GHG emissions impact, the emissions of carbon dioxide equivalent ($CO_{2\text{-}e}$) are used as a metric to compare the emissions of GHG on the basis of their global-warming potential by converting amounts of GHG emissions emitted to the equivalent amount of carbon dioxide based on global-warming potential.

The assessment is framed within the national and international legally binding Paris Agreement treaty to limit global warming, and country-specific emissions reduction policies and regulation to reduce their greenhouse gas emissions in line with the long-term temperature goal of the Paris Agreement, of which Australia is a signatory.

7.2.6.1 GHG Emission Sources

GHG emissions will be generated in the Dorado Development Project Area during the following stages:

+ development drilling;
+ installation;
+ commissioning;
+ operations and maintenance; and
+ decommissioning.

The GHG emissions generated during the above stages will be associated with:

+ fuel combustion – emissions from power generation on the support and installation vessels, helicopters, MODU, and FPSO. For instance, the FPSO will be self-sufficient in power generation and will supply power to a range of production operations, such as separation, oil export and gas reinjection, as well as the utilities, support systems and power to the Dorado WHP and potential future tiebacks;
+ flaring – the recovered gas from the reservoir will be reinjected (approximately 235 MMscfd), with the exception of a portion used as fuel gas on the FPSO (approx. 12 MMscfd) and to maintain a pilot flame on the FPSO flare system (0.1 MMscfd), which is required for safety reasons. Flaring of the pilot gas is regarded as planned flaring for safety purposes. planned flaring from the FPSO is expected to be minimal relative to combustion of gas for fuel and will occur continuously to ensure hydrocarbons disposed of in the flare system are combusted prior to discharge. Unplanned flaring may also occur as a result of non-routine plant trips or process upsets, and similar to planned flaring, is also required to ensure safe operations during upset conditions. Examples of non-routine events may include loss of compression, emergency conditions (such as emergency depressurisation and unplanned shutdown and start-up) and pressure relief events. Other non-routine events that may result in flaring, include well testing, commissioning, planned maintenance shutdowns, blowdown and re-start (before and after planned maintenance shutdowns). Flaring associated with well testing is estimated at 890 MMscf (assuming 38 wells). The assessment of episodic unplanned flaring associated with non-routine events considered both the expected frequency of non-routine events and the expected quantity flared during event. Santos conservatively estimates that 4,196 MMscf may be flared for non-routine events over the 20-year life of Dorado Phase 1 inclusive of potential future tiebacks;
+ venting – venting is the atmospheric emission of non-combusted gas resulting from safety devices designed to release emissions to atmosphere to prevent overpressure of process piping/vessels/equipment such as pressure safety valves and is limited to two main sources:
    - WHP maintenance drain drum venting. The maintenance drain drum and associated atmospheric vent are to allow sections of pipework to be isolated and drained/vented for maintenance purposes. This is manually operated vent system for when maintenance operations are being performed by personnel on the WHP. Any depressurisation would be initially to the flowlines to their operating pressure and then the last ~100 bar via the maintenance drum vent to minimise venting to atmosphere; and
    - systems pressure testing (generally nitrogen is used during flowline or equipment pressure testing to identify potential leak pathways prior to introducing hydrocarbons);

+ fugitive emissions – unintentional atmospheric emissions from pressurised piping components and equipment leaks. Fugitive emissions from leaks are typically caused by corrosion or wear of mechanical joints, seals, and rotating surfaces over time and can occur from devices that are not operating properly, such as intermittent pneumatic devices that are malfunctioning and continuously bleeding gas or stuck liquid drain valves on separators.

A breakdown of the expected Dorado Phase 1 Scope 1 GHG emissions sources and the predicted quantity of those emissions as million tonnes of CO2-e (MtCO2-e) by project stage is presented in Table 7-40. The volume of gas to be released, combusted, and reinjected by Dorado Phase 1 is summarised in Table 7-41.

Table 7-40: Scope 1 GHG emissions sources and basis for estimated emissions for Dorado Phase 1 (Attachment 12)

Stage	Emissions Sources	Description	Estimated Emissions ($MtCO_{2-e}$)
Development drilling (Dorado field and future tiebacks) Installation (Dorado and future tieback facilities) Commissioning	MODU Support vessels Installation vessels FPSO	To generate the necessary power onboard the MODU, installation vessels, and support vessels, marine diesel oil (MDO) will be combusted as fuel. **Drilling** As part of the drilling operations, wells will flow back to the MODU during well clean-up and testing, and the recovered hydrocarbons will be flared (both liquids and gas) (allowance for up to 38 wells to be drilled and cleaned up). Drilling support vessels on location to support drilling campaigns (assumed duration for drilling and completing up to 38 wells, with two vessels permanently on location and allowance for a third vessel for periodic support). **Construction and Installation Activities** Construction and installation support vessels (assume five vessels at approximately 12 m^3/day/vessel, for a total period of up to 12 months: four months for the foundation Dorado WHP and FPSO installation and up to a further eight months for associated future tieback construction and installation activities). **Commissioning** On the FPSO, during commissioning activities (when the FPSO first arrives in the field) the produced hydrocarbons will be flared and MDO will be combusted as fuel to generate the necessary power (until an appropriate and sufficient supply of produced gas is established). An allowance of up to four months of support vessel emissions is included (assumes approximately 12 m^3/day/vessel).	0.77
Operations and maintenance (Dorado field and future tiebacks)	FPSO Dorado WHP Future tieback WHP and/or subsea facilities) Support vessels	On the FPSO, during operations and maintenance activities: + a portion of the produced gas will be combusted as fuel gas to generate the necessary power. To include a suitable level of conservatism, given that the maintenance downtime requirements and number of cyclone demobilisations are not known (i.e. when the FPSO will not be operating), it has been assumed that power generation and compression equipment are used at full capacity (i.e.	14.65

Stage	Emissions Sources	Description	Estimated Emissions ($MtCO_{2-e}$)
		100% of the time) during the operations and maintenance stage of Dorado Phase 1 (20 years), inclusive of future tiebacks. + a portion of the produced gas will be used to maintain the flare pilot flame (a safety feature), which is continuously lit (approximately 0.1 MMscf/day). **Non-routine Events** To maintain safe operations there will be a requirement to send gas to the flare during non-routine events such as process upsets/trips, emergency shutdown (ESD), and unplanned shutdowns (i.e. unplanned flaring). A conservative assumption of up to 15 extended unplanned flaring events (12 spurious and three associated with cyclones), each up to 48 hours in duration, at a rate of approximately 125 MMscfd per annum is the basis of unplanned flaring estimates. These events may be associated with process upsets, gas compressor downtime, cyclone avoidance. When the FPSO is not producing or is off station (i.e. when it is disconnected from the DTM or when production is stopped during events such as shutdown), diesel will be combusted as fuel to operate safety-critical equipment such as fire pumps. On the WHP there may be a requirement to vent produced hydrocarbon gas during planned maintenance activities. It is a reasonable expectation that there will be some fugitive emissions from non-point sources (such as valves or flanges) on the Dorado WHP and FPSO. For the purpose of calculations that dictate equipment fugitives as a result of gas throughput, annual gas reinjection is assumed to be constant through the project lifetime, independent of crude production. To generate the necessary power onboard the support vessels, MDO will be combusted as fuel.	
Decommissioning	MODU FPSO Installation vessels Support vessels Future tieback facilities	To generate the necessary power onboard the MODU, FPSO, installation and support vessels for infrastructure removal, MDO will be combusted as fuel. It has been assumed that it would take four weeks to decommission one well; up to 38 wells may require decommissioning for Dorado Phase 1 (inclusive of Dorado reservoir and future tiebacks). Removal of infrastructure has assumed similar timeframe as for installation.	0.16

Table 7-41: Breakdown of total gas flows by project activity and basis for GHG emission estimates

Stage	Activity	Location	Unprocessed Gas (tonnes)	Contribution to Total Gas Flows during the Dorado Phase 1 (%)
Drilling and installation	Flaring	Dorado wells	10,500	0.02%
		Dorado infill wells	3,500	0.01%
		Future tieback wells	14,500	0.03%
FPSO commissioning	Flaring	FPSO	21,400	0.04%
Operations and maintenance	Flare pilot	FPSO Dorado WHP Future tiebacks WHP and/or subsea facilities	20,900	0.04%
	Unplanned flaring		2,140,000	3.97%
	Compressor fuel gas		2,600,000	4.82%
	Gas reinjection		49,100,000	91.07%
	Gas venting		0	0%
	Fugitives		3,650	0.01%

7.2.6.2 GHG Emissions Estimate

A quantification study was undertaken to inform the assessment of the potential impacts and risks from the GHG emissions associated with Dorado Phase 1 (**Attachment 12**). The study focused on quantifying the predicted GHG emissions.

To describe the direct and indirect emission sources, improve transparency, and satisfy the interests of different organisations and different climate policies and business goals, three emissions "scopes" (Scope 1, Scope 2, and Scope 3) are defined for GHG accounting and reporting purposes:

- Scope 1 emissions are direct GHG emissions that occur from sources that are owned or controlled by Santos; this includes fuel combustion, flaring and venting;
- Scope 2 emissions account for GHG emissions from the generation of purchased electricity consumed by Santos. Dorado Phase 1 will not generate Scope 2 emissions; and
- Scope 3 emissions are indirect GHG emissions from sources not owned or controlled by Santos, including the transportation, refining and use of sold products by customers.

The above definitions have widely been accepted globally and throughout the energy industry (for instance, Scope 1 and Scope 2 emissions definitions align with those presented in the *National Greenhouse and Energy Reporting Act 2007* (NGER Act)).

In this section, to put the Dorado Phase 1 lifecycle $CO_{2\text{-}e}$ emissions into context, the estimated total annual average emissions of Dorado Phase 1 are used. The total annual average $CO_{2\text{-}e}$ emissions were established by adding the estimated annual average $CO_{2\text{-}e}$ emissions of each stage of Dorado Phase 1. To better categorise emissions aligned with comparable sources across the five stages of Dorado Phase 1, they have been grouped as follows:

- drilling, installation, and commissioning – including development drilling, installation and commissioning; and
- operations and maintenance (for a duration of 20 years, including future tiebacks); and
- decommissioning.

The average annual emissions for each group was established by estimating the overall $CO_{2\text{-}e}$ emissions associated with the group and dividing this by the number of years for each group. At this early stage of Dorado Phase 1, these values represent the best possible estimate based on the current understanding of Dorado Phase 1 project.

Dorado Phase 1 is expected to produce 350 MMbbl of oil from up to 38 wells (refer to **Section 6.6.6**) over the 20-year project life from the Caley reservoir (approximately 150 MMbbl) and the proposed future tiebacks (approximately 200 MMbbl), assuming exploration success and commerciality of the tiebacks. The future tiebacks will augment oil production and export throughout the life of Dorado Phase 1. For the purpose of this assessment, timing on up to two future tiebacks has been estimated to occur in year 6 and year 10 of the operations and maintenance stage for Dorado Phase 1. For the Caley reservoir and each future tieback, oil export is expected to peak during the first years of production from the reservoir before steadily decreasing as the reservoir is depleted.

7.2.6.2.1 Scope 1 GHG Emissions

The boundary of Scope 1 emissions has been set as operations occurring with the Dorado WHP, FPSO, MODU, support vessels and potential future tiebacks over the key stages presented in **Section 6.7**.

The key activities generating Scope 1 GHG emissions and the phase at which they are expected are summarised in Table 7-42**.**

Table 7-42: Key activities generating Scope 1 emissions

Activity	Drilling, Installation, and Commissioning including Future Tiebacks	Operations and Maintenance including Future Tiebacks	Decommissioning
Fuel gas combustion – power generation and compression		✓	
Diesel combustion – power generation (FPSO during commissioning and when it is no longer connected to the DTM during operations and maintenance)	✓	✓	✓
Diesel combustion – support and installation vessels and the MODU	✓	✓	✓
Flaring (planned and unplanned)	✓ (well clean-up flaring)	✓	
Venting		✓	
Fugitive emissions		✓	

To estimate GHG emissions, the calculation method presented in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* together with the most recent emission factors outlined in the *National greenhouse accounts factors - Australian National Greenhouse Accounts* (Department of Industry, Science, Energy and Resources August 2021) were adopted. This allowed for the establishment of the CO_{2-e} emissions associated with the CO_2, CH_4, and N_2O emissions. It also enabled the direct comparison of the GHG emissions associated with each stage of Dorado Phase 1 on a uniform metric basis. Further information on the emissions methods and the factors used are detailed in Table 9 of **Attachment 12**.

Throughout the life of Dorado Phase 1, approximately 15.6 $MtCO_{2-e}$ of Scope 1 emissions are estimated to be emitted (the expected GHG emissions by activities and stages of Dorado Phase 1 are presented in **Table 7-43)**. The majority (85%) is attributable to CO_2 emissions, 15% to CH_4, and 0% to N_2O.

Table 7-43: Estimate Scope 1 GHG emissions by activities and project stages (Attachment 12)

Activity	Total Scope 1 GHG Emissions ($MtCO_{2-e}$) by Stage		
	Drilling, Installation, and Commissioning, including Future Tiebacks (assumes 38 wells)	Operations and Maintenance including Future Tiebacks	Decommissioning
Fuel gas combustion	0	6.21	0
Diesel combustion	0.42	0.05	0.16
Flaring:			
Flare pilot	0	0.08	0
Unplanned flaring	0.08	8.06	0
Well clean-up flaring	0.27	NA	NA
Fugitive emissions	0	0.25	0

Nearly all of the Scope 1 emissions (94%) are related to activities taking place during the operations and maintenance stage, approximately 5% to drilling, installation, and maintenance, and 1% to decommissioning (**Figure 7-20**). The annual average emissions during the operations and maintenance stage is 0.732 $MtCO_{2-e}$/a based on total emissions (including for assumed unplanned events), and 0.767 $MtCO_{2-e}$/a based on the year of highest production. The majority (52%) of the operations and maintenance stage emissions are due to flaring (planned and unplanned associated with non-routine events) and 40% to combustion of fuel gas. The remaining 8% made up of diesel combustion (4%), well clean-up activities (2%), fugitive emissions (2%) and flare pilot (less than 1%). Due to the early engineering stage of the project, the unplanned flaring component of GHG emissions has been conservatively estimated to account for a number of design and operational outcomes that are yet to be finalised. There are many non routine events that may result in unplanned flaring. The estimate provided includes events and situations such as:

- control and shut down system reliability issues;
- systems redundancy level (which is yet to be confirmed) that may result in flaring due to non-spared equipment, i.e. 2x 50% trains or 1 x 100% train for flash gas compression and reinjection;
- compressor response to unsteady operation and overall control scheme of the compression trains;
- power configuration and time to recover from process trips;
- cyclone disconnect requirements, such as depressurising the plant and/or the flowlines;
- start-up restrictions due to cold temperatures resulting in extended flaring to ensure minimum temperature material constraints are not exceeded;
- design of the fuel gas system and time to bring back on line after a trip;
- well injectivity issues resulting in unsteady operation of reinjection compressors and resultant trips or flaring;
- gas turbine and compressor reliability; and
- process configuration.

As the design is further defined and the equipment selection is agreed on, it is likely that the current assumption for flaring due to faults and/or cyclone preparedness can be optimised. This will both benefit the GHG emissions volume and provide greater liquid production due to the direct link between gas reinjected and liquids recovered from the reservoir. The success of the miscible flood in the reservoir is related to maintaining pressure via gas reinjection. More gas flared, less gas reinjected. Less gas reinjected, less oil produced.

In **Table 7-43** and **Figure 7-20**, the contribution of fugitive emissions did not take into consideration the vapour recovery system, which will further reduce emissions from unplanned flaring and venting.

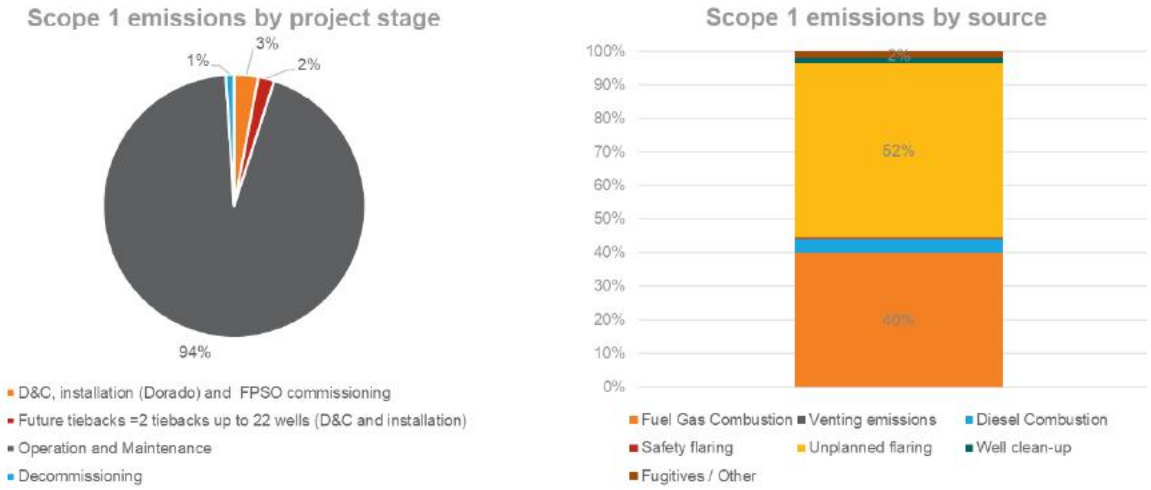


Figure 7-24: Scope 1 emissions overview (refer to Attachment 12)

7.2.6.2.2 Scope 3 GHG Emissions

Australian and international carbon accounting rules mean that each country and each emitter reports their own Scope 1 and Scope 2 emissions. Santos is not required to report Scope 3 emissions under the Australian NGER reporting framework because they are the Scope 1 and 2 emissions of other emitters. Scope 3 emissions are disclosed in Santos' Climate Change Report (Santos 2022), in accordance with the World Resources Institute Greenhouse Gas Protocol Technical Guidance for Scope 3 Emissions.

For the purposes of providing a Scope 3 emissions estimate for the Dorado Development, Scope 3 GHG emissions have been split into 15 subcategories as presented in the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard. **Table 7-44** presents the subcategories that apply to Dorado Phase 1. This selection defines the boundary of Dorado Phase 1 Scope 3 emissions.

Table 7-44: GHG Protocol Corporate Value Chain Accounting and Reporting Standard Scope 3 emissions subcategories

GHG Protocol Subcategory	Included in Scope 3 Emissions	Key Reasons for Inclusion or Exclusion
Purchased goods and services	✓	- Goods (such as production chemicals) will be purchased and transported to the facilities.
Capital goods	✓	- Capital goods (such as the steel required to build the Dorado WHP and FPSO) will be purchased and acquired throughout Dorado Phase 1 lifecycle. The mass of the materials that make up the structure of the WHP and FPSO were used to quantify this category. - Assumes installation of up to 3 WHPs (to account for future potential tiebacks).
Fuel- and energy-related activities (not included in Scope 1 or Scope 2)	✓	- Additional fuel (such as diesel) will be acquired and transported to the facilities (emissions from the use of such fuel are accounted for in Scope 1 emissions).
Upstream transportation and distribution	×	- The transportation and distribution of goods upstream is likely to be immaterial noting that the transport of raw materials like diesel to the FPSO will be covered in the above subcategory (fuel- and energy-related activities) and Scope 1 transport-related emissions. The exclusion of this category is in accordance with the size and influence criteria in Table 6.1 of the GHG Protocol.
Waste generated in operations	×	- Offshore waste treatment and disposal is already accounted for in Scope 1 emissions.
Business travel	✓	- Being an offshore project, business travel will be dominated by flights between Perth and Dampier (via plane) and Dampier and the FPSO (via helicopter).
Employee commuting	×	- Material emissions associated with the movement of people are included in the above subcategory business travel.
Upstream leased assets	×	- It is possible that leased assets may be required at some stage during Dorado Phase 1 lifecycle, but this emission source is unlikely to be material relative to the whole inventory.
Downstream transportation and distribution	✓	- The transportation and distribution of sold products will take place between Dorado Phase 1 area and the refineries. The furthest refinery port, i.e. Kobe, Japan, is assumed and no domestic use. Assume cargo ship travels back empty to be reloaded. The emissions associated with travel back to the FPSO fall within Santos' Scope 3 inventory

GHG Protocol Subcategory	Included in Scope 3 Emissions	Key Reasons for Inclusion or Exclusion
Processing of sold products	✓	- The products sold will have to be refined before being sold on for use. As no estimates for the refining slate (the mix of crude oil grades that a refinery is processing) for Caley or Baxter crude were readily available, public sources of similar light sweet condensates were considered as a proxy. Cossack crude was identified as the closest to these in terms of geographic location and API gravity. Cossack crude is extracted from the North West Shelf and exhibits an API gravity of 48.8, comparable with Caley and Baxter.
Use of sold products	✓	- Limited to the combustion of fuels and excludes any downstream emissions related to the production and use of plastics and chemicals. The products from the refining process will follow the typical slate from the processing of Cossack crude. It is recognised that vacuum residues (residues from the vacuum refining process) are commonly used to produce non-fuel products; however, a conservative approach has been taken, and it is assumed that this fraction will be combusted using the emissions factor for fuel oil based on the categorisation of this heavy residue product as low-sulphur waxy residue.
End-of-life treatment of sold products	×	- Excluded as this category is limited to the combustion of fuels and excludes any downstream emissions related to the production and use of plastics and chemicals. The combustion of fuels is covered in the above category
Downstream leased assets	×	- The downstream leased assets will fall under the company-wide emissions reporting and are not specific and/or significant to Dorado Phase 1
Franchises	×	- The operations of franchises will fall under the company-wide emissions reporting and are not specific and/or significant to Dorado Phase 1
Investments	×	- The operations of investments will fall under the company-wide emissions reporting and are not specific and/or significant to Dorado Phase 1

At this early stage of Dorado Phase 1, it is not possible to know the exact destination/s of the produced oil, how it will be processed, and who the final end user will be. The assumptions presented in the subsections below have been made for the following subcategories:

- downstream transportation and distribution;
- processing of sold products; and
- use of sold products.

Downstream Transportation and Distribution

To present the most conservative case for GHG emissions from the transport and distribution of Dorado Phase 1 products, the Scope 3 emissions calculations have assumed that 100% of Dorado Phase 1 products will be shipped to Asia for refining (with Japan chosen as the furthest expected destination for calculations and assumptions in determining the inventory). To include sufficient conservatism, the return tanker travels (from Kobe, Japan, to the FPSO) were also included.

Processing of Sold Products

Caley light oil has been used as a proxy for Dorado Phase 1 product (this is conservative as the product will contain Caley light oil, as well as condensates from other reservoirs) inclusive of potential future tiebacks. The processing stages required to refine a product depend largely on the market the processed oil is being sold into. 'Light' oils, such as those from the Caley reservoir, have a lower density than heavy oils due to a higher proportion of shorter chain hydrocarbons. Caley oil is expected to require less processing to yield high-value fuel products, such as petrol and diesel (Gordon et al. 2015). Additionally, emissions through the product lifecycle are lower for light sweet crudes than for other oils because the shorter hydrocarbon chains take less energy to convert into end products than do the heavy crudes. The Intergovernmental Panel on Climate Change found that heavy oils can have up to 24% more CO_2 emissions per barrel than light oils (IPCC2018).

Conservatively, the emissions factor established for the refining of Arab medium-crude oil (a conventional crude) was used for assessing emissions in this subcategory. This resulted in a conservative estimation of GHG emissions, given that the Dorado Phase 1 product is a sweet light oil and its processing is expected to be a less energy and emissions-intensive process than the processing of a typical Arab medium-crude oil (**Attachment 12**).

Use of Sold Products

The refined final products are not known definitively; thus, Scope 3 emissions calculations have assumed they will be similar to Cossack crude. Emissions from the combustion of the sold product were conservatively estimated by assuming 100% combustion of 100% of the refined product (this is a conservative approach as it assumes that the carbon in the oil is most rapidly released to the atmosphere as a GHG as these products are combusted in use). This does not take into consideration the vacuum residues, which are expected to be processed into non-fuel products (such as road material or asphalt) (**Attachment 12**). The calculated emissions intensity for Cossack crude (0.38 tCO_{2-e}/bbl) falls within the range of the average emissions intensity for oil combustion identified by the International Energy Agency (2020b). However, the significance of this category to total Scope 3 emissions underscores the importance of understanding the final processing and market placement of the oil from Dorado Phase 1.

To calculate Scope 3 emissions, emission factors from the DISER's compilation of National Greenhouse Account Factors (DISER August 2021) were used as much as possible. When no National Greenhouse Account Factors were available, published sources were used; for example, Ecoinvent Database (v3) (Gregor Wernet et al (2016) was used as the source of lifecycle emissions factors for the "purchased goods and services" subcategory (**Attachment 12**).

Scope 3 CO_{2-e} emissions over the life of Dorado Phase 1 are estimated at 153 $MtCO_{2-e}$. As presented in **Figure 7-21**, most of the Scope 3 emissions (87%) are associated with the combustion of sold products ("use of sold products" subcategory) and 9% with the refining process ("processing of sold products" subcategory). The "downstream transportation and distribution" subcategory represents

3%, and the remaining subcategories less than 1%. **Table 7-45** provides a further breakdown of the Scope 3 emissions categories contributions.

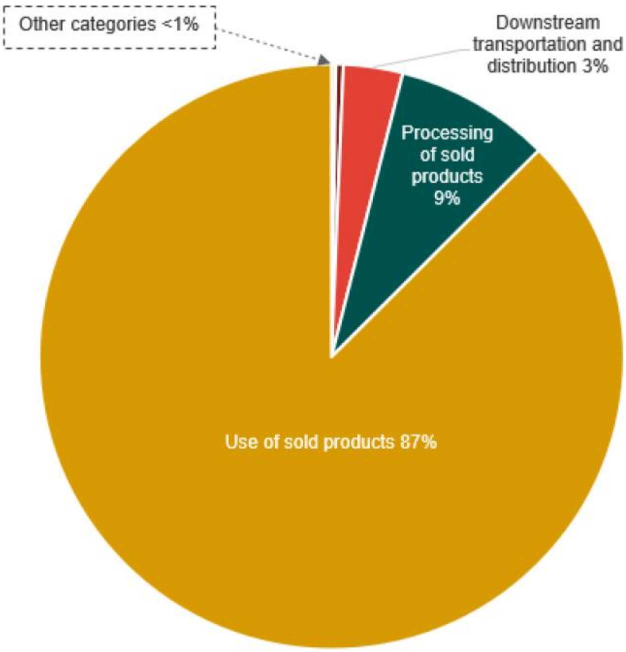


Figure 7-25: Scope 3 emissions overview (Attachment 12)

Table 7-45: Summary of Scope 3 GHG emissions

GHG Protocol Subcategory	Emissions ($ktCO2_e$)	Proportion of Scope 3 Inventory	Boundary
Purchased goods and services	3.75	0.002%	Limited to spend on chemicals and diesel
Capital goods	319	0.21%	Limited to WHP and FPSO
Fuel- and energy-related activities (not included in Scope 1 or Scope 2)	44.3	0.03%	Limited to use of diesel on FPSO
Business travel	617	0.40%	Limited to use of helicopters and support vessels
Downstream transportation and distribution	5,010	3.28%	Limited to sea transport from FPSO to sale port
Processing of sold products	13,200	8.61%	Limited to activities at the refining facility
Use of sold products	134,000	87%	Limited to combustion of fuel products

Hereafter, the "use of sold products", the "processing of sold products" and the "downstream transportation and distribution" subcategories have been grouped and are referred to as "end-user combustion".

7.2.6.3 Paris Agreement

A reduction in net global atmospheric GHG emissions is required to minimise the risk of temperature increases caused by atmospheric GHGs absorbing infrared radiation and trapping energy as heat.

The United Nations Framework Convention on Climate Change came into force in 1994 and has been ratified by 197 countries. The convention established a goal of preventing dangerous anthropogenic interference with the climate system. Subordinate treaties and agreements have been ratified by parties to the convention, including the Paris Agreement, which was agreed under the convention at the 21st Conference of the Parties in 2015 and has been endorsed by 197 countries. The Paris Agreement is currently the world's most comprehensive climate action agreement underpinned by broad international support with 192 countries party to the agreement as at July 2022.

One of the key aspects of the Paris agreement (the agreement) is Article 2 which in seeking to strengthen the global response to climate change, reaffirms the goal of limiting global temperature increase to well below 2 degrees Celsius, while pursuing efforts to limit the increase to 1.5 degrees. Australia is a signatory to the agreement; and in support of meeting the aims of the agreement, the Australian Government has set a target of reducing emissions by 43% below 2005 levels by 2030 and committing to net zero emissions by 2050 (refer to **Section 7.2.6.3.1**).

The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) to reduce greenhouse gas emissions and to strengthen these efforts in the years ahead. The NDCs represent national action for each country individually; and as such, countries will choose to implement their nationally determined contributions in a variety of ways, consistent with their domestic policies and strategies. Countries are required to regularly and transparently report on their climate actions and support, including whether they have met or are on track to meet the goals per their NDCs. As at July 2022, there are 192 parties to the Paris Agreement that have put forward NDCs.

The participating Paris Agreement parties aim to reach global peaking of greenhouse gas emissions as soon as possible, to achieve a climate neutral world by 2050 (recognising that developing country parties' peaking emissions may occur later than developed countries). Following the peak in greenhouse gas emissions, it is expected that there will be rapid reductions in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity and in the context of sustainable development and efforts to eradicate poverty (United Nations Framework Convention on Climate Change 2021).

The convention recognises that to achieve the Paris Agreement's long-term goals, climate action will need to get more ambitious over time. To sustain this rising ambition, the agreement establishes a continuous improvement cycle through which countries plan and communicate their NDCs, then implement their plans, and finally review individual and collective progress to inform future planning and updates to their next NDCs. This process provides the foundation for countries to fully bring the objectives of the Paris Agreement to fruition (World Resources Institute 2021).

Effective interaction between climate science and policy underpins the Paris Agreement. Scientific observations, research and assessment continue to inform the international climate regime, as well as national and regional climate policies. The UN climate change process, under the Paris Agreement, relies on scientific information on climate change.

This continuous improvement cycle supports the agreement's commitment to comprehensively take stock of collective progress every five years (global stocktake – Article 14 of the Paris Agreement), a key element of the process that is sometimes referred to as the agreement's ambition mechanism. The global stocktake process assesses the collective progress towards achieving the purpose of the agreement and its long-term goals, evaluates both the performance of countries in meeting their NDCs and contemporary climate and environmental scientific literature. The Intergovernmental Panel on Climate Change (IPCC) assesses the scientific, technical and socioeconomic information relevant for understanding the risk of human-induced climate change and prepares comprehensive assessment reports and special reports to support the global stocktake process. The IPCC is currently in its Sixth Assessment cycle with reports in preparation for publishing at the end of 2022. The global stocktake will inform countries as they each consider how to strengthen their NDCs in light of their different national circumstances. Each round of NDCs is meant to reflect a country's most ambitious plans and to be stronger than the last.

The Paris Agreement is underpinned by the international environmental legal principle of common but differentiated responsibilities. The principle holds that all states (i.e. countries rather than businesses) are responsible for addressing global environmental degradation yet are not equally responsible. The principle balances, on the one hand, the need for all countries to take responsibility for global environmental problems and, on the other hand, the need to recognize the wide differences in levels of economic development between countries. Australia, for example, has a more ambitious target than developing countries precisely because of this principle.

The enhanced transparency framework (ETF) established within the Paris Agreement (Article 13), requires that, starting in 2024, countries report transparently on actions taken and progress in climate change mitigation, adaptation measures and support provided or received. It also provides for international procedures for review of submitted performance reports and contemporary climate and environmental scientific literature. The information gathered through the ETF is intended to then feed into 5-yearly global stocktakes, which in turn feed into review and updates to NDCs.

To facilitate implementation of the Paris Agreement, the Katowice climate change package (United Nations Framework Convention on Climate Change 2018) sets out the essential procedures and mechanisms that brings the Paris Agreement into operation and contains operational guidance on:

+ the information about domestic mitigation and other climate goals and activities that governments will provide in their nationally determined contributions;
+ how to communicate about efforts to adapt to climate impacts;
+ the rules for functioning of the transparency framework for action and support (referred to in Article 13 of the agreement), which will show what countries are doing about climate change;
+ establishing a committee to facilitate implementation of the Paris Agreement and promote compliance with the obligations undertaken under the agreement;
+ how to conduct the global stocktake (the first stocktake is in 2023) of overall progress towards the aims of the Paris Agreement;
+ how to assess progress on the development and transfer of technology; and
+ how to provide advance information on financial support to developing countries and the process for establishing new targets on finance from 2025 onwards.

The Katowice package provides countries with detailed guidance for carrying out the continuous improvement cycle of the agreement, guidance on how to prepare their nationally determined contributions (clear and transparent information on how GHG emissions are calculated and timeframes for contributions commitments), and what types of information participating countries should share concerning adaptation priorities, plans and actions.

To inform further planning for meeting the global Paris Agreement targets, countries must review their efforts, individually and collectively. The review of individual countries' progress will aim to verify data quality and assess progress against each country's targets, while the global stocktake review will assess the collective progress toward the agreement's long-term goals and identify the remaining gaps, challenges and opportunities for further action. The agreement has also set up an expert committee focused on facilitating implementation and promoting compliance to help countries address barriers to implementation and further climate action.

The countries to which Dorado oil will be exported will report their associated GHG emissions from processing, refining and use of the Dorado oil as their Scope 1 and 2 GHG emissions, within the context of their own NDCs and associated emissions reduction policies and regulation, as parties to the Paris Agreement. These are described and accounted for in this OPP within the Scope 3 emissions estimates (assumed as 100% refined and based on the volumes of oil exported and associated transport of the oil cargo).

7.2.6.3.1 Australia's Nationally Determined Contributions

As a party to the Paris Agreement, the Australian Government most recently updated its Nationally Determined Contributions (NDCs) on 16 June 2022, when the Prime Minister and Minister for Climate Change and Energy wrote to the Executive Secretary of the United Nations (UN) Framework Convention on Climate Change updating Australia's 2030 GHG emissions target confirming the 2030 target to reduce emissions by 43% below 2005 levels and committing to net zero emissions by 2050. In support of meeting its NDC emission reduction targets, the Australian Government establishes appropriate climate and energy policy and regulation (where required).

7.2.6.3.2 Australia's Legislative Frameworks for Regulating and Reporting GHG Emissions

7.2.6.3.2.1 Safeguard Mechanism

One of the key statutory instruments for regulating Australia's emissions in line with Australia's NDCs under the Paris Agreement, is the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (Cth) (the Safeguard Mechanism) made under the NGERS Act and administered by the Clean Energy Regulator. The Safeguard Mechanism was developed to ensure that Australia's largest greenhouse gas emitters keep their net emissions below an emissions limit (a baseline). The Safeguard Mechanism currently applies to facilities that emit more than 0.1 $MtCO_{2\text{-}e}$ per annum and requires annual emissions to be reported against a designated emissions 'baseline'. The Safeguard Mechanism can be considered one element of a whole of economy approach implemented to achieve Australia's NDCs, and is complementary to a range of programs that measure, manage, reduce or offset Australia's GHG emissions. In turn, achievement of Australia's NDCs supports achievement of the Paris Agreement long-term temperature goal, therefore management of Dorado Phase1 emissions in accordance with the Safeguard Mechanism indirectly supports achievement of the Paris Agreement temperature goal to mitigate the impacts of global climate change.

Dorado Phase 1 emissions will be regulated under the Safeguard Mechanism through establishment of a cap (baseline) on Dorado facility emissions. Under this policy, annual emissions are reported under the National Greenhouse & Energy Reporting Scheme (**Section 0**) and compared against the facility baseline, and Santos is required to generate or procure and surrender Australian Carbon

Credit Units for any emissions above the baseline for the compliance period, to ensure that net emissions for the facility remain under the prescribed baseline.

Key elements of the mechanism include:

- safeguard facilities must meet the reporting and record-keeping requirements of the NGER Act, including the Clean Energy Regulator's requirements for audits prior to baseline setting or to check compliance management;
- if a safeguard facility is likely to exceed its baseline, the responsible emitter must act, including by purchasing and/or surrendering Australian carbon credit units, to offset excess emissions; and
- penalties for non-compliance.

Santos transparently reports its GHG emissions, including fugitive emissions pursuant to NGER methodology, as demonstrated in annual climate change reporting consistent with the G20's Taskforce on Climate-related Financial Disclosures.

Subject to any changes resulting from the current federal Government's review of the Safeguard Mechanism (currently underway) new facilities are required to apply to the Clean Energy Regulator for a benchmark baseline. Benchmark baselines are intended to be aligned with 'best-practice' emissions performance as relevant to each industrial sector. The Dorado facility will be subject to baseline requirements for new facilities.

7.2.6.3.2.2 National Greenhouse & Energy Reporting Scheme

The National Greenhouse and Energy Reporting (NGER) Scheme is a single national framework for reporting company information about:

- greenhouse gas emissions;
- energy production; and
- energy consumption.

Key NGER Scheme legislation includes:

- the National Greenhouse and Energy Reporting Act 2007 (the Act);
- the National Greenhouse and Energy Reporting Regulations 2008; and
- the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (the Measurement Determination).

The NGER Act provides a single, national framework for the reporting and distribution of information related to GHG emissions, energy production, and energy consumption to meet the following objectives:

- inform government policy;
- inform the Australian public;
- help meet Australia's international reporting obligations;
- assist Commonwealth, state and territory government programs and activities; and
- avoid duplication of similar reporting requirements in the states and territories.

The reporting of GHG emissions under the NGER Act will apply to reporting of Scope 1 GHG emissions from Dorado Phase 1. Santos is not required to report Scope 3 emissions under the Australian NGER reporting framework because they are the Scope 1 and 2 emissions of other emitters.

7.2.6.3.3 27th Annual Conference of Parties – Egypt

COP27 was the 27th annual meeting of the Conference of Parties held in November 2022, a meeting that primarily focuses on climate change and global efforts involving mitigation. Since the inception of the Paris Agreement in 2015, the main goal of the annual COP meetings is to ensure that the global temperatures stay well below the 2-degree Celsius threshold.

Key outcomes from COP27 were as follows:

- Agreement to establish a loss and damage fund to support developing countries impacted by extreme weather events.
- Reaffirmation of the agreement reached at COP26 at Glasgow to focus on limiting temperature increase to 1.5C, and associated progressive ratcheting of cuts to greenhouse gas emissions at each subsequent COP to stay within the 1.5C limit. A resolution to cause emissions to peak by 2025 did not pass.
- A resolution was passed to boost ‘low-emissions’ energy.
- A resolution to phase down all fossil fuels did not pass. The resolution passed at COP27 to phase down use of coal was retained without change.
- Reforms to World Bank financing and other public funded financing to provide funds to poorer countries to help them cut their greenhouse gas emissions was discussed but no resolution passed.
- Reaffirmation of the COP26 agreement to double the proportion of funding provided by richer countries to fund climate adaptation and resilience initiatives for poorer countries, from $20bn/annum to $40bn/annum.
- The final text included reference to the latest IPCC findings, regarding “tipping points” which refers to potential for the climate to exhibit rapid, escalating changes, rather than gradual, linear changes.
- The final text also included reference to “the right to a clean healthy and sustainable environment" drawing the link between global heating and health.

7.2.6.4 Santos’ Climate Change Strategy

Santos recognises the scientific consensus of climate change assessed by the Intergovernmental Panel on Climate Change and supports the objective of the Paris Agreement to limit global temperature rise to less than 2 degrees Celsius and pursue efforts to limit the temperature rise to 1.5 degrees Celsius. In 2022, Santos released new 2030 emission reduction targets, in addition to its previously announced long-term target of achieving net-zero equity Scope 1 and 2 emissions by 2040:

- Reduce absolute Scope 1 and 2 equity emissions by 30 per cent by 2030 (from the Santos and Oil Search combined 2019-20 equity Scope 1 and 2 baseline of 5.9 $MtCO_{2\text{-}e}$, representing a reduction to 4.1 $MtCO_{2\text{-}e}$ or lower);
- Reduce Scope 1 and 2 equity emissions intensity by 40 per cent by 2030 (from Santos’ 2019-20 equity Scope 1 and 2 baseline of 55 $ktCO_{2\text{-}e}$/mmboe, representing a reduction to 33 ktCO2e/mmboe or lower);
- Use CCS technology to accelerate the economic feasibility of hydrogen and deliver a step change in emissions reduction by 2030; and
- Reduce customers’ emissions by at least 1.5 million tonnes per year of $CO_{2\text{-}e}$ from the supply of clean fuels by 2030.

Santos' purpose is to be a global leader in the transition to cleaner energy and clean fuels, by helping the world decarbonise to achieve net-zero in an affordable and sustainable way. At the same time, Santos' recognises the importance of price stability and supply security to ensure a just transition, especially for the world's most vulnerable communities.

Santos is committed to supplying critical fuels such as oil and gas in a more sustainable way at the same time investing today to deliver cleaner fuels tomorrow. The world continues to rely on hydrocarbon fuels for around 80 per cent of its primary energy (IEA, 2021). These fuels will be in demand for decades and making them progressively cleaner is essential to meet global climate goals.

In support of delivering on its Climate Change Strategy and Targets, Santos has established a Climate Transition Action Plan. The Action Plan focuses efforts in the following areas:

+ Operational Efficiencies - Broad range of initiatives that are designed to reduce the Scope 1 and 2 emissions of Santos operations. Operational efficiency initiatives include fuel, flare and vent reductions, electrification, renewable integration, and fugitive emissions reduction and will be managed under adopted control measures in **Table 7-51;**
+ Carbon Capture and Storage - Step-change technology that will reduce emissions and pave the way for future transition initiatives;
+ Carbon Reduction Solutions - Opportunities to reduce carbon emissions and generate offsets for Santos and customers;
+ Clean Fuel Hubs - Leverage CCS hubs as pathway to generating clean fuels; and
+ Supply Chain Collaboration - Working with customers to cultivate demand for lower carbon fuels.

Santos continually reviews the appropriateness of its climate change strategy, and updates associated emissions reduction targets from time to time. Santos will continue to adapt the Climate Transition Action Plan to take account of the evolving energy transition environment between now and 2040 and apply disciplined economic and commercial criteria to inform investment decisions.

7.2.6.4.1 Carbon Capture and Storage

CCS is a critical technology that will be needed to meet the goals of the Paris agreement. Santos will use CCS technology to accelerate the economic feasibility of clean hydrogen and deliver a step-change in emissions reduction by 2030.

CCS is the process whereby carbon dioxide is captured from a facility, then dehydrated and compressed for transportation via pipeline to a storage site. The carbon dioxide is then injected underground via deep wells into depleted reservoirs that have previously produced natural gas, with proven seals and capacity.

CCS is expected to play a critical role in global decarbonisation efforts by providing the opportunity to achieve low cost and large-scale emissions reductions. Today, there are more than 27 commercial CCS facilities operating around the world, with a storage capacity of over 36 million tonnes of carbon dioxide each year (Global CCS Institute, 2021).

Building on decades of experience injecting and storing gas in oil and gas reservoirs, Santos has developed a strategic hub CCS strategy, with the potential to create more than 30 million tonnes per annum of carbon storage capacity, with line of sight to 10 million tonnes per annum of online carbon storage capacity by 2030.

1. Eastern Australia CCS Hub
   - 100 $MtCO_2$ total storage resource booked in the Cooper Basin;
   - Moomba CCS Phase 1;
     - Carbon capture of 1.7 Mtpa (1.1 $MtCO_2pa$ Santos share);
     - Facilities construction to start in 3Q 2022 and four injector wells to be drilled into depleted gas reservoirs by year-end. First injection expected in 2024; and
     - Estimated Moomba CCS capacity ~20 $MtCO_2pa$.
2. Northern Australia and Timor-Leste Hub
   - CCS services at DLNG enable development of regional resources and clean fuels production; and
   - Estimated Bayu-Undan CCS capacity ~10 MtCO2pa.
3. Western Australia Hub
   - Desktop studies underway to confirm CO_2 injection capacity; and
   - Estimated Western Australia CCS capacity >2 $MtCO_2pa$, with expansion opportunities.

The CCS hubs will give Santos the ability to both store carbon dioxide emitted from our own operations as well as carbon dioxide that is generated from third-party facilities.

7.2.6.5 Global Energy Outlook

To inform and test the robustness of Santos' climate change strategy and action plans, Santos considers four global macro-economic scenarios, against a reference case scenario which is reflective of current market conditions.

- One scenario reflective of today's announced policy intentions and targets: the Stated Policies Scenario (STEPS) from the IEA 2021 World Energy Outlook;
- Three scenarios demonstrating possible paths towards an accelerated energy transition:
  1. The Sustainable Development Scenario (SDS) from the IEA 2021 World Energy Outlook, delivering sustainable development in line with the Paris Agreement while limiting global temperature increase to 1.65 degrees Celsius
  2. The 2021 IEA Net Zero by 2050: A Roadmap for the Global Energy Sector case (NZE), achieving net zero emissions from the global energy sector in 2050 while limiting global temperature increase to 1.5 degrees Celsius
  3. The IHS Markit 2021 Accelerated CCS case (ACCS), achieving net zero emissions in 2050 from the combined global energy and non-energy sectors while limiting global temperature increase to 1.5 degrees Celsius

It is important to note that the scenarios modelled do not reflect a forecast or a definitive outcome. Scenario analysis relies on assumptions that may or may not be, or prove to be, correct and may or may not eventuate, and scenarios may be impacted by additional factors to the assumptions disclosed. As such, while interpretation of modelled scenarios can be a useful aid for strategy and policy development, the scenarios should not be confused with actual government policy or in-force legislative frameworks, nor should they be used as a basis to evaluate Dorado Scope 1 GHG emissions impacts or risks or determine acceptability of future oil and gas developments for the purposes of the OPP.

Notwithstanding the limitations of modelled scenarios, Santos has considered the potential risks and opportunities of each scenario. In all scenarios modelled, Santos achieves its 2030 emission reduction targets and net-zero 2040 target.

7.2.6.5.1 IEA STEPS

Under the IEA STEPS scenario reflecting current policy, the continued growth in global energy demand drives continued growth in demand for hydrocarbon fuels including oil and gas. This growth in demand compared to 2020, combined with the need to replace production from depleting fields, maintains elevated oil and LNG prices in order to promote investment in new supply. Under this scenario, Santos would continue seeking to supply the energy needs of its customers, maximising the value from its base business and growth projects, while maintaining its commitment to decarbonise its operations in line with its net zero strategy. In this way, Santos would continue contributing to the decarbonisation of the global energy sector, while providing affordable and reliable energy to regional economies.

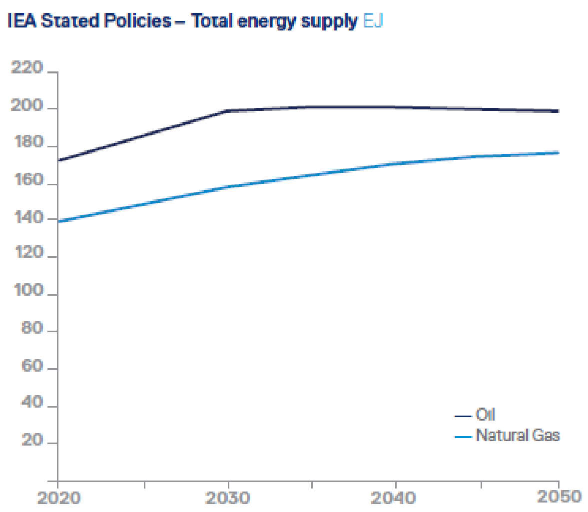


Figure 7-26: Oil and natural gas supply under IEA World Energy Outlook 2021 Stated Policies Scenario (STEPS)

7.2.6.5.2 Accelerated Energy Transition Scenarios

Under accelerated energy transition scenarios such as the IEA SDS, NZE and the IHS ACCS, the demand for oil and natural gas declines after 2030 as transport and heating is electrified and an increasing proportion of electricity is generated from renewables (**Figure 7-27**). The extent and timing of the demand decline depends on specific scenario assumptions relating to policy and technology developments; however, each scenario still requires investment in oil and gas production to maintain sufficient supply through the transition. Natural gas demand is particularly robust with demand increasing through to 2030 under the SDS and ACCS scenarios due to its role as an affordable, lower carbon fuel for the industrial and electricity sectors, particularly for developing countries within Asia Pacific.

Offsetting the decline in oil and natural gas demand is the increasing demand for carbon capture and hydrogen technologies, which experience significant growth under accelerated energy transition scenarios due to their ability to decarbonising sectors which are difficult to electrify (**Figure 7-28**).

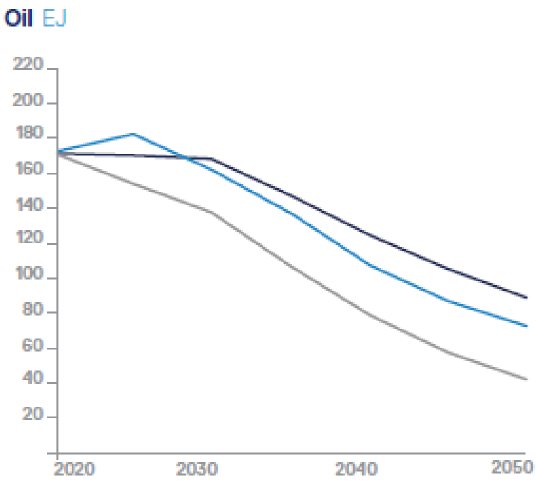


Figure 7-27: Oil and natural gas supply under accelerated energy transition scenarios – IEA World Energy Outlook 2021 Sustainable Development (SDS) and Net Zero by 2050 (NZE) scenarios and the IHS Markit Accelerated CCS scenario (ACCS)

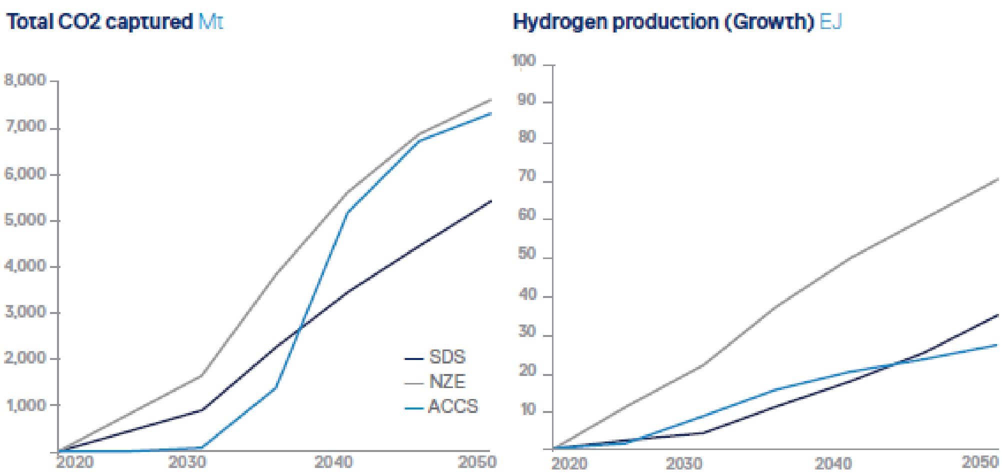


Figure 7-28: Carbon capture and hydrogen under accelerated energy transition scenarios – IEA World Energy Outlook 2021 Sustainable Development (SDS) and Net Zero by 2050 (NZE) scenarios and the IHS Markit Accelerated CCS scenario (ACCS)

In October 2022, the IEA released its updated World Energy Outlook for 2022 (IEA, 2022). The 2022 WEO explores the existing three scenarios (STEPS, APS and NZE) for the future, all of which are fully updated to include the latest energy market and cost data. The 2022 WEO no longer includes the Sustainable Development Scenario. Santos' will continue to consider the IEA and other global macro-economic scenarios to provide a framework for thinking about the future of energy and to test the robustness of Santos' climate change strategy and action plans.

7.2.6.5.3 Dorado Development in Context

Even under the most aggressive accelerated energy transition scenarios, there remains a requirement for investment in oil and gas production to maintain sufficient supply through the transition. In fact, US$10 trillion in oil and gas supply would be needed to meet the world's energy needs between 2022 and 2050 even under the IEAs Net Zero Emissions by 2050 (NZE) scenario (IEA

Net Zero by 2050, A Roadmap for the Global Energy Sector). In the NZE by 2050 scenario, an assumed rapid rise in low emissions fuels is one of the key reasons – along with greater efficiency and electrification – why the IEA claimed no new oil and gas fields would be required beyond those already approved for development. However, the IEA also noted that actual deployment of low emissions fuels is well off track. For example, despite increasing interest in low-carbon hydrogen, the pipeline of planned hydrogen projects falls short of the levels of use in 2030 implied by announced pledges, and even further short of the amounts required in the NZE (which are nine times higher than in the announced pledges scenario). The 2021 World Energy Outlook also states that “Oil and gas spending today is one of the very few areas that is reasonably well aligned with the levels seen in the NZE to 2030” and warns that the world is not investing enough to meet its future energy needs, and that uncertainties over policies and demand trajectories create a strong risk of a volatile period ahead for energy markets. Therefore, it is too simplistic to assert that no new oil developments will be required, even under the IEA NZE by 2050 scenario.

In its 2022 World Energy Outlook (IEA, 2022), when assessing the current global energy crisis, exacerbated by Russia’s invasion of Ukraine, the IEA acknowledges that immediate shortfalls in fossil fuel production will need to be replaced by production elsewhere – even in a world working towards net zero emissions by 2050. The IEA also discusses the need for a new energy security paradigm to maintain reliability and affordability while reducing emissions, where both energy systems (fossil fuels and clean energy) are required during the energy transition in order to deliver the energy services needed by consumers, even as their respective contributions change over time (IEA, 2022). The Dorado Development is well placed to make an important and necessary contribution across all scenarios through the energy transition, with supply of Australian oil to the market from 2027 for 20 years. The Asia-Pacific region is likely to be an important market for oil and oil-derived products from Dorado Phase 1 oil.

7.2.6.6 Dorado GHG Emissions Comparison

The currently observed global warming and associated climate changes, which are facilitated by the increased atmospheric concentrations of GHG, cannot be meaningfully linked to emissions from an individual project. Global climate change is the result of atmospheric accumulation of GHG emissions and sinks since the start of the industrial revolution. Making a prediction of GHG emissions’ impacts at the ecosphere level is an inherently complex exercise because of the influence of variables such as surface pressure, wind, temperature, humidity and rainfall within multiple ecosystems. The listed items are all interdependent variables that would have to be taken into consideration in determining a contribution to global temperature increase. For each variable a series of generalising assumptions would be required to be able to make a sensible calculation of the impacts. Considering the complex and dynamic natural processes within the ecosphere, there is substantial uncertainty in determining a specific increase in global temperature due to the Dorado project and its emissions. As such, it is equally speculative to suggest an isolated climate event, or series of climate events, that lead to a change to any environmental value or sensitivity within Australia (including Matters of National Environmental Significance (MNES), are solely attributable to a specific increase in global temperature. As such, it is not possible to isolate the influence of Dorado emissions to any conclusive impact on the Australian environment. This results in a lack of full scientific certainty about the potential impacts of Dorado GHG emissions.

Regardless of where the end-user emissions occur, combusting the Dorado oil contributes to global emissions which have effects that occur at a global level. Given the uncertainty of the scale, timing and location of any climate impact (or of the Dorado Phase 1 portion), it is reasonable to focus more on the emissions than the impacts, as the end-user is not known. It is appropriate to contextualise Dorado Phase 1 contribution to international and national GHG emissions.

The estimated annual average $CO_{2\text{-}e}$ emissions associated with Dorado Phase 1 are presented in **Table 7-46**. In contextualising the contribution of the emissions nationally in Australia and globally both to fossil fuel emissions and under the IEA Sustainable Development Scenario (SDS), which aligns with the goals of the Paris Agreement (refer to **Section 7.2.6.1**), the following peer-reviewed, published GHG emissions have been used:

+ 2021 Australian energy sector. Electricity (emissions from the combustion of fuel used to generate electricity), stationary energy, transport and fugitive emissions estimated by DISER to produce annual $CO_{2\text{-}e}$ emissions (as of March 2021) of 401.2 $MtCO_{2\text{-}e}$ (Commonwealth of Australia 2021);
+ 2021 global fossil fuel $CO_{2\text{-}e}$ emissions estimated by the Global Carbon Project to be 36,400 Mt (Friedlingstein et al. 2021). The Global Carbon Project is a global research project formed in the international science community to establish a common and mutually agreed knowledge base. It integrates knowledge of GHG for human activities and the Earth system, and establishes annual global GHG budget;
+ predicted world energy-related $CO_{2\text{-}e}$ emissions estimated by the International Energy Agency to be 33,861 Mt in 2040 (International Energy Agency 2022) should the current and announced policies and targets be met (this is referred to by the agency as the Stated Policies Scenario - STEPS). The agency is an autonomous intergovernmental organisation. Further information regarding the International Energy Agency scenarios is presented in **Section 7.2.6.5**;
+ predicted world energy-related $CO_{2\text{-}e}$ emissions estimated by International Energy Agency to be 16,441 Mt in 2040 (International Energy Agency 2021) should the policies and systems be in place to limit the global temperature rise to below 1.8°C (this is referred to by the agency as the Sustainable Development Scenario - SDS); and
+ predicted world energy-related CO2-e emissions estimated by International Energy Agency to be 5,799 Mt in 2040 (International Energy Agency 2022) should the policies and systems be in place to limit the global temperature rise to below 1.5°C (this is referred to by the agency as the Net Zero Emissions by 2050 Scenario - NZE).

Table 7-46: Dorado Phase 1 GHG emissions in context

Stage	Estimated Average Annual $CO_{2\text{-}e}$ Emissions Dorado Phase 1 (Mtpa)	Dorado Contribution (%)				
		Australian Energy-related $CO_{2\text{-}e}$ Emissions in 2021	Global Fossil Fuel $CO_{2\text{-}e}$ Emissions in 2021	2022 IEA WEO STEPS Predicted 2040 Global $CO_{2\text{-}e}$ Emissions	2021 IEA WEO SDS Predicted 2040 Global $CO_{2\text{-}e}$ Emissions	2022 IEA WEO NZE Predicted 2040 Global $CO_{2\text{-}e}$ Emissions
Drilling, installation and commissioning (Scope 1)	0.085	0.021	0.0002	0.0003	0.0005	0.001

Stage	Estimated Average Annual CO_{2-e} Emissions Dorado Phase 1 (Mtpa)	Dorado Contribution (%)				
		Australian Energy-related CO_{2-e} Emissions in 2021	Global Fossil Fuel CO_{2-e} Emissions in 2021	2022 IEA WEO STEPS Predicted 2040 Global CO_{2-e} Emissions	2021 IEA WEO SDS Predicted 2040 Global CO_{2-e} Emissions	2022 IEA WEO NZE Predicted 2040 Global CO_{2-e} Emissions
Operations and maintenance (Scope 1)	0.732	0.182	0.002	0.002	0.004	0.013
End-user combustion (Scope 3)	7.65	0*	0.021	0.023	0.047	0.132
Totals	8.467	0.203	0.023	0.025	0.051	0.146

* All end-user combustion of Dorado Phase 1 oil will occur outside Australia.

In a national context, Dorado Phase 1 emissions that are expected to contribute to Australian GHG emissions are the entire Scope 1 emissions. The total annual average CO_{2-e} emissions associated with Dorado Phase 1 (Scope 1) would equate to 0.203% of the 2021 national energy-related CO_{2-e} emissions.

In a global context, the estimated total annual average Dorado Phase 1 emissions CO_{2-e} emissions from all stages of Dorado Phase 1 (Scope 1 and Scope 3) equate to 0.023% of the 2021 global emissions from fossil fuel; and 0.025%, 0.051% and 0.146% of the predicted 2040 global CO_{2-e} emissions under the IEA Stated Policies Scenario, the IEA Sustainable Development Scenario and the IEA Net Zero emissions by 2050 scenario respectively.

As the annual average CO_{2-e} emissions from Dorado Phase 1 have been estimated to represent up to 0.203% (Scope 1) of the 2021 national energy-related emissions and 0.146% (Scope 1 and Scope 3) of the predicted 2040 global CO_{2-e} emissions in the Net Zero Emissions by 2050 scenario, it can be concluded that Dorado Phase 1 is not expected to be a significant GHG emissions contributor on a national or global scale.

As presented in “Use of Sold Products” in **Section 7.2.6.2.2**, the refining and fate of final products is not known definitively and therefore Santos has conservatively assumed that 100% of the refined products will be combusted (i.e. the carbon in the oil is most rapidly released when the oil is combusted) yielding the greatest potential “end-user combustion” emissions. Dorado Phase 1 oil being a sweet light oil (“Processing of Sold Products” in **Section 7.2.6.2.2**) is expected to require less processing to yield high-value fuel products, such as petrol and diesel. As a result, the actual energy and emissions associated with its processing are expected to be lower than the estimated value which is based on processing of heavier oils (Gordon et al. 2015). Dorado Phase 1 product is also expected to be used in the regional market (Asia), reducing the GHG emissions associated with downstream product transportation and distribution (compared with the estimated emissions which assumed transportation to more distant markets), further reducing the “end-user combustion” emissions (which accounts for 87% of the total Dorado Phase 1 CO_{2-e} emissions).

7.2.6.7 Details of Environmental Impacts and Risks

As presented in **Section 7.2.6.6**, the currently observed global warming trends and associated climate changes are reflective of the cumulative impact of GHG emissions from a range of human endeavours and industries and cannot be meaningfully attributed to an individual activity such as the Dorado development. This section provides a discussion of a wide range of predicted effects on global and Australian environments from human-induced climate change. Most marine and terrestrial systems are susceptible to impacts from climate change; however, the predicted impact is highly variable, both between ecosystems and within individual ecosystems. **Table 7-47** identifies the potentially impacted receptors as a result of increased global GHG emissions.

Table 7-47: Receptors potentially impacted by GHG emissions

Description of the Risk	Receptors
Potential indirect environmental impacts associated with GHG emissions as a result of Dorado Phase 1	Species-related Effects (Mammals, Birds, Reptiles, Amphibians, Fish, Invertebrates and Plants) refer to **Section 7.2.6.7.1** Ecosystem-related Effects refer to **Section 7.2.6.7.2**

As presented in **Section 7.2.6.6**, Dorado Phase 1 is not expected to be a significant national or global GHG emissions contributor; and it can be concluded that the associated potential incremental environmental impacts would be minor.

The Intergovernmental Panel on Climate Change (IPCC) published their 6th working report in August of 2021. The IPCC is known for published material based on the assessment of available scientific, technical, and socio-economic literature that is relevant to global warming and the increased surface temperatures. This report was the first to unequivocally relate climate change to human influences and the use of fossil fuels, the IPCC states with *high confidence* that many extreme heat events and global surface temperature rise would not have occurred without human influence.

Although there are some opportunities to limit future climate change and global temperature increases such as carbon dioxide removal (CDR), the removal of CO_2 from the atmosphere will not reverse all impacts from climate change. Some impacts cannot be reversed for centuries to millennia. These irreversible impacts include sea level rise, glacial melting, and polar melting. Due to these impacts being irreversible, the ecosystems that thrive in these conditions will be impacted. It has been shown that marine organisms are already being pushed to move into deeper marine depths due to the need for lower temperatures and these patterns will continue for the foreseeable future. Lasting impacts due to climate change should be addressed as these impacts have been shown to be difficult and/or impossible to repair.

The State of the Climate report (CSIRO and Bureau of Meteorology 2022) is forecasting that Australia will experience ongoing changes to its weather and climate:

+ Continued increase in air temperatures, more heat extremes and fewer cold extremes.
+ Continued decrease, on average, in cool season rainfall across many regions of southern and eastern Australia, which will likely lead to more time in drought, but with ongoing climate variability that will give rise to short-duration heavy-rainfall events at a range of timescales.
+ Continued increase in the number of dangerous fire weather days and a longer fire season for southern and eastern Australia.

- Further sea level rise and continued warming and acidification of the oceans around Australia.
- Increased and longer-lasting marine heatwaves that will affect marine environments, such as kelp forests, and increase the likelihood of more frequent and severe bleaching events in coral reefs around Australia, including the Great Barrier Reef and Ningaloo Reef.
- Fewer tropical cyclones, but a greater proportion is projected to be of high intensity, with large variations from year to year.
- Reduced average snow depth in alpine regions, but with variations from year to year.

7.2.6.7.1 Potential Species-related Effects

While climate change is expected to affect marine and terrestrial species, the effects are likely to be highly species-dependent and to vary geographically. At a broad-scale, fauna distribution patterns are likely to shift in response to climate change. The most frequently observed and cited ecological responses to climate change include species distributions shifting towards the poles and upwards in elevation and shifts in lifecycle events (Dunlop et al. 2012). Some of the predicted potential taxa-level effects (potential vulnerabilities) are presented in **Table 7-48.**

Table 7-48: Potential effects of climate change on future vulnerability of particular taxa

Taxa	Potential Vulnerability
Mammals	Narrow-ranged endemics susceptible to rapid climate change in situ; changes in competition between grazing macropods in tropical savannas mediated by changes in fire regimes and water availability; herbivores affected by decreasing nutritional quality of foliage as a result of CO_2 fertilisation
Birds	Changes in phenology of migration and egg-laying; increased competition of resident species with migratory species due to migratory birds staying longer at breeding grounds; breeding of waterbirds susceptible to reduction in freshwater flows into wetlands; top predators vulnerable to changes in food supply as a result of increased sea temperatures; rising sea levels affecting birds that nest on sandy and muddy shores, saltmarshes, intertidal zones, coastal wetlands and low-lying islands; saltwater intrusion into freshwater wetlands affecting breeding habitat
Reptiles	Warming temperatures may alter sex ratios of species with environmental sex determination (e.g. turtles and crocodiles); some species may modify their use of microhabitats to cope with warming in situ
Amphibians	Frogs may be the most at-risk terrestrial taxa; amphibians may experience altered interactions between pathogens, predators and fires
Fish	Freshwater species vulnerable to reduction in water flows and water quality; limited capacity for freshwater species to migrate to new waterways; all species susceptible to flow-on effects of warming on the phytoplankton base of food webs
Invertebrates	Expected to be more responsive than vertebrates due to short generation times, high reproduction rates and sensitivity to climatic variables
Plants	Climate change may impact various functional dynamics of plants due to changes in fires, plant phenology and insect life cycles and specific environmental characteristics; longer lived plants may be more vulnerable if climate change “moves” suitable establishment sites for seedlings beyond their dispersal distances; narrow-ranged endemic plants

Taxa	Potential Vulnerability
	requiring specific conditions will have limited capacity to disperse to sites with similar conditions

Source: Adapted from Steffen et al. (2009).

Climate change may not only change species distribution patterns but also life-history traits, such as migration patterns, reproductive seasonality and sex ratios. As an example, in marine turtles, cooler temperatures produce more male hatchlings while warmer temperatures produce more females. Research undertaken into the genetically distinct breeding population of green turtles on the northern and southern Great Barrier Reef has indicated that recent warming has led to an abundance of female turtles being born to the northern breeding population. The results showed turtles originating from warmer northern Great Barrier Reef nesting beaches were significantly female-biased, with female turtles accounting for 99.1% of juvenile, 99.8% of subadult, and 86.8% of adult-sized turtles (Jensen et al. 2018). In comparison, turtles originating from the cooler southern Great Barrier Reef nesting beaches showed a more moderate female sex bias, with female turtles accounting for 68% of juvenile, 65% of subadult, and 69% of adult-sized turtles (Jensen et al. 2018).

7.2.6.7.2 Potential Ecosystem-related Effects

As the biotic and abiotic components of ecosystems change, so too will the structure and function of the overall ecosystem. A summary of the predicted effects to key Australian ecosystems as a result of increased CO_2 and climate change is presented in **Table 7-49.** Most marine and terrestrial ecosystems are susceptible to climate change; however, the predicted impact is highly variable, both between ecosystems and within individual ecosystems.

Changes in climate, such as altering temperature, rainfall patterns and fire regimes, due to climate change is likely to result in changes in vegetation structure across all terrestrial ecosystems within Australia (Dunlop et al. 2012). Increases in fire regimes will impact Australian ecosystems by altering composition structure, habitat heterogeneity and ecosystem processes and may assist in the spread of introduced species (which may further alter or increase the incidence of fires). Changes in climate variability, as well as averages, could also be important drivers of altered species interactions (Dunlop et al. 2012).

Table 7-49: Predicted effects of GHG emissions increase and climate change on key Australian ecosystems

Key Component of Environmental Change	Predicted Effects
Coral Reefs	
CO_2 increases leading to increased ocean acidity	Reduction in ability of calcifying organisms, such as corals, to build and maintain skeletons.
Sea-surface temperature increases, leading to coral bleaching	If the frequency of bleaching events exceeds the recovery time, reefs will be maintained in an early successional state or be replaced by communities dominated by macroalgae. Warming will increase the susceptibility of corals to diseases. Potential for new reefs to develop at higher latitudes where suitable substrates are available and until light becomes limiting; potential decrease in beta diversity of coral

Key Component of Environmental Change	Predicted Effects
	communities as tropical-adapted taxa expand their range to the south, amplified by differential survival of different taxa.
Increases in cyclone and storm surge	Increased physical damage to reef structure.
Oceanic Systems (including planktonic systems, fisheries, sea mounts and offshore islands)	
Ocean warming	Many marine organisms are highly sensitive to small changes in average temperature (1 to 2°C), leading to effects on growth rates, survival, dispersal, reproduction and susceptibility to disease. Increasing temperatures reduce larval development time, potentially reducing dispersal distances; warm-water assemblages may replace cool-water communities.
Changed circulation patterns, including increase in temperature stratification and decrease in mixing depth, and strengthening of East Australian Current	Distribution and productivity of marine ecosystems is heavily influenced by the timing and location of ocean currents; currents transfer the reproductive phase of many organisms, thereby playing an important role in dispersal and maintenance of populations. Climate change may suppress upwelling in some areas and increase it in others, leading to shifts in location and extent of productivity zones.
Changes in ocean chemistry	Increasing CO_2 in the atmosphere is leading to increased ocean acidity and a parallel decrease in the availability of carbonate ions, which are the building blocks of calcium carbonate skeletons (such as those of many planktonic species and corals). Increased dissolved CO_2 may increase productivity.
Estuaries and Coastal Fringe (including benthic, mangrove, saltmarsh, rocky shore, and seagrass communities)	
Sea level rise	Landward movement of some species (particularly mangroves) as inundation provides suitable habitat; changes to upstream freshwater habitats will have flow-on effects to species such as wetland birds.
Increase in water temperature	Effects on phytoplankton production will affect secondary production in benthic communities.
Savannas and Grasslands	
Elevated CO_2	Shifts in competitive relationships between woody and grass species due to differential responses.
Increased rainfall in north and northwest regions	Increased plant growth will lead to higher fuel loads, in turn leading to fires that are more intense and more frequent, occur over large areas, and occur later in the dry season. Change to ecotonal boundaries between savanna woodlands, grasslands and monsoonal rainforest patches. Changes in rainfall seasonality are likely to be more important that changes in amount.
Tropical Rainforests	
Warming and changes in rainfall patterns	Increased probability of fires penetrating rainforest vegetation, resulting in shift from fire-sensitive vegetation to communities dominated by fire-tolerant species. Cool-adapted species forced to higher elevations, altering competitive interactions.
Change in length of dry season	Altered patterns of flowering, fruiting and leaf flush will affect resources for animals.

Key Component of Environmental Change	Predicted Effects
Increased intensity of storms or tropical cyclones	Increased physical disturbance to forests, which alters gap dynamics and succession rates; shallow-rooted tall rainforest trees are particularly susceptible to uprooting, breakage and defoliation.
Rising atmospheric CO_2	Differential response of different growth forms to enhanced CO_2 may alter structure of vegetation.
Temperate Forests	
Potential increases in frequency and intensity of fires	Changes in structure and species composition of communities with obligate seeders may be disadvantaged compared with vegetative resprouters.
Warming and changes in rainfall patterns	Potential increases in productivity in areas where rainfall is not limiting; reduced forest cover associated with soil drying projected for some Australian forests.
Rising atmospheric CO_2	Overall increase in productivity and vegetation thickening.
Inland Waterways and Wetlands	
Reductions in precipitation; increased frequency and intensity of drought	Reduced river flows and changes in seasonality of flows; reduction of the area available for waterbird breeding. More intense rainfall events will increase flooding, affecting movements of nutrients, pollutants and sediments, riparian vegetation, and erosion. Groundwater-dependent ecosystems may be negatively affected.
Changes in water quality, including changes in nutrient flows, sediment, oxygen and CO_2 concentration	May affect eutrophication levels, incidence of blue-green algal outbreaks; loss of cool-adapted species and increase in populations of warm-adapted species.
Sea level rise	Saltwater intrusion into low-lying floodplains, freshwater swamps and groundwater; replacement of existing riparian vegetation by mangroves.
Warming of water column; increase in depth of seasonal thermoclines in still water	Changes in abundance of temperature-sensitive species, such as algae and zooplankton; reduction in depth of lowest oxygenated zones in some instances.
Arid and Semi-arid Regions	
Increasing CO_2 coupled with drying in some regions	Interaction between CO_2 and water supply critical, as 90% of the variance in primary production can be accounted for by annual precipitation.
Shifts in seasonality or intensity of rainfall events	Any enhanced run-off redistribution will intensify vegetation patterning and erosion cell mosaic structure in degraded areas. Changes in rainfall variability and amount will also effect fire frequency. Dryland salinity could be affected by changes in the timing and intensity of rainfall.
Warming and drying, leading to increased frequency and intensity of fires	Reduction in patches of fire-sensitive mulga in spinifex grasslands potentially leading to landscape-wide dominance of spinifex.
Alpine Areas	

Key Component of Environmental Change	Predicted Effects
Reduction in snow cover depth and duration	Potential loss of species dependent on adequate snow cover for hibernation and protection from predators; increased establishment of plant species at higher elevations as snow pack is reduced.

Source: Adapted from Steffen et al. (2009).

Hoegh-Guldberg et al. (2018), in the IPCC (2018) Special Report, describe impacts of warming above pre-industrial levels to key receptor groups, including terrestrial ecosystems, mangroves, warm-water corals, unique and threatened systems, and arctic regions. These receptor groups show varying sensitivity to warming conditions, with a range of responses shown at 1°C warming, from corals suffering moderate impacts, to mangroves not showing any impacts that are detectable and attributable to climate change (Hoegh-Guldberg et al. 2018). Once warming reaches 1.5°C, all receptor groups show impacts attributable to climate change with severity ranging from moderate detectable impacts (mangroves) to severe and widespread impacts (warm-water corals) (Hoegh-Guldberg et al. 2018). At the point where global temperature rise reaches 2°C, increasing numbers of receptor groups suffer impacts that are high to very high and likely to be irreversible (terrestrial ecosystems, warm-water corals, unique and threatened systems, and arctic regions) (Hoegh-Guldberg et al. 2018). Some key impacts are discussed further in the following subsections.

Terrestrial Ecosystems

All terrestrial ecosystems are likely to be impacted by a changing climate (Dunlop et al. 2012; Hoegh-Guldberg et al. 2018; Hughes 2011; Steffen et al. 2009) (**Table 7-49**). The predicted impact of climate change on these ecosystems is highly variable, both between ecosystems and within individual ecosystems (Dunlop et al. 2012). A summary of impacts to key terrestrial ecosystems is provided below (other terrestrial ecosystems are summarised in **Table 7-49**).

Tropical Rainforests

Projections of future climate changes in the wet tropics of Australia under different scenarios are outlined by CSIRO and Bureau of Meteorology (2015). It is likely that temperatures in the wet tropics will become hotter and potentially fires and cyclones will be more intense. Consequently, there is an increased probability of fires penetrating into rainforest vegetation, resulting in a shift from fire-sensitive vegetation to communities dominated by fire-tolerant species, and changing rainforest disturbance regime as cyclones become more intense (Hughes 2011; Steffen et al. 2009). Changes in the timing of seasons (e.g. extended summer) could cause changes in the seasonal response of plants and alterations to species ranges and abundances (Hoegh-Guldberg et al. 2018).

Alpine/Montane Areas

Alpine systems are generally considered to be among the most vulnerable to future climate change (Hughes 2003). The extent of true alpine habitat in Australia is very small (0.15% of the Australian land surface) with limited high-altitude refuge (Hughes 2003).

Australian alpine regions are home to a variety of alpine vertebrates who rely on snow cover for their survival. There is evidence of a reduction in populations of dusky antechinus, broad-toothed rats and the mountain pygmy possum. The first two species are active under the snow throughout winter and are therefore subject to increased predation by foxes when snow is reduced (Hughes 2003). The pygmy possum depends upon snow cover for stable, low temperatures during hibernation (Hughes 2003).

Marine Ecosystems

Between 1920 and 2000, sea level is estimated to have risen on average by 1.2 mm per year due to climate change (Church et al. 2006). In addition to changes in sea level, oceanic warming has also served to alter ocean currents around Australia. In response to both ocean warming and stratospheric ozone depletion, the East Australian Current has increased in strength by about 20% since 1978 (Cai and Cowan 2006).

Sea-surface temperatures have increased across the globe over recent decades, which poses a significant threat to marine ecosystems, including changes to species abundance, community structure, and increased frequency and intensity of thermally induced coral bleaching events (CSIRO n.d.).

Sea-surface temperatures are projected to continue to increase, with estimates of warming of between 0.6 and 0.9°C in the southern Tasman Sea and between 0.3 and 0.6°C elsewhere along the Australian coast by 2030 (Church et al. 2006). Sea levels will increase by 18 to 59 cm by 2100 in response to both thermal expansion and melting of icesheets (Solomon et al. 2007). This will lead to some coastal inundation affecting mangroves, salt marshes and coastal freshwater wetlands. Furthermore, as CO_2 is gradually absorbed by oceans and fresh water, the water becomes more acidic, which increases the solubility of calcium carbonate, the principal component of the skeletal material in aquatic organisms (Steffen et al. 2009). Below is a summary of potential climate change impacts to two key ecosystems - mangroves and coral reefs.

Mangroves

Mangrove ecosystems in Australia will face higher temperatures, increased evaporation rates and warmer oceans (CSIRO and Bureau of Meteorology 2015), as well as an associated sea-level rise (Hoegh-Guldberg et al. 2018). Modelling indicates an increased likelihood of future severe and extended droughts across parts of northern Australia (Dai 2013). Consequently, mangrove ecosystems may increase their southern range as a result of warmer temperatures. However, higher temperatures and evaporation rates and extended droughts could lead to mangrove die-offs in northern Australia and a change in mangrove distribution and abundance (Duke et al. 2017). Mangrove systems should cope with rising sea level by accumulating more peat or mud, which will give them the opportunity to adjust (Field 1995).

Coral Reefs

Climate change has emerged as a threat to coral reefs, with temperatures over 4 to 6 weeks of just 1°C above the long-term summer maximum for an area being enough to cause mass coral bleaching and mortality (Baker et al. 2008; Hoegh-Guldberg et al. 2018; Hughes et al. 2017; Spalding and Brown 2015). Coral mortality or die off following coral bleaching events can stretch across thousands of square kilometres of ocean (Gilmour et al. 2016; Hoegh-Guldberg et al. 2018; Hughes et al. 2017). The impacts associated with a warming ocean, coupled with increasing acidification, are expected to undermine the ability of tropical coral reefs to provide habitat for fish and invertebrates, which together provide a range of ecosystem services (e.g. food, livelihoods, and coastal protection) (Hoegh-Guldberg et al. 2018).

KEFs, AMPs, Protected Places, Commonwealth Managed Fisheries, State Management Fisheries, Tourism and Recreation, and Coastal Settlements

Changes to climate can result in impacts to social receptors that have values that include the ecological receptors (discussed above). This includes KEFs and AMPs.

Climate change can also impact on the functions, interests or activities of other users that rely on ecological value, including commercial and recreational fisheries and tourism.

7.2.6.8 Summary of Impact Evaluation

It is not possible to directly attribute GHG emissions from Dorado Phase 1 with global climate change trends or climate-related impacts given:

- that it is the cumulative load of global GHG emissions across a range of human endeavours and industries that cause climate change and climate-related impacts;
- the contribution of estimated Scope 1 and Scope 3 emissions associated with Dorado Phase 1 is minor in the context of existing and future predicted global GHG emissions;
- the difficulty in predicting the amount of total future global GHG emissions and rate of increase/change over time; and
- the inability to predict future national and international initiatives on climate change, collective progress against these initiatives, and the impact they will have on total future global GHG emissions, including the minor contribution of GHG emissions from Dorado Phase 1.

Santos recognises the scientific consensus of climate change assessed by the Intergovernmental Panel on Climate Change and supports the objective of the Paris Agreement to limit global temperature rise to less than 2 degrees Celsius and pursue efforts to limit the temperature rise to 1.5 degrees Celsius. Santos has made the following commitments under its Climate Change policy:

- Work with governments and stakeholders in the design of climate change regulation and policies in support of low-cost abatement and incentivising innovation and investment in emissions reduction in an equitable manner;
- Factor carbon pricing and greenhouse gas emissions into all material business decision-making;
- Set greenhouse gas emission targets consistent with the objective of limiting global temperature rise to less than 2 degrees Celsius and in pursuit of 1.5 degrees Celsius;
- Identify and pursue opportunities to reduce greenhouse gas emissions within our operations and through the supply chain;
- Work with our customers to reduce their greenhouse gas emissions and sell the products we generate only to customers from countries that have a net-zero commitment or are signatories to the Paris Agreement;
- Avoid any unnecessary flaring from our activities and reduce flaring required for the safe conduct of our operations to as low as reasonably practicable;
- Make Final Investment Decision for new offshore greenfield projects from 2025 only if they abate and/or offset reservoir CO2 emissions;
- Identify and implement cost-effective opportunities to sequester carbon, integrate new technologies and offset greenhouse gas emissions, in pursuit of our emission reduction targets;
- Identify, manage and mitigate climate change risks for our activities and in doing so, continue to adapt and develop our operational, financial and strategic resilience;
- Report annually on the company's climate change governance, strategy, risk management and targets and metrics in a transparent manner in alignment with recommendations of the Task Force on Climate-related Financial Disclosures; and
- Provide our shareholders with an advisory vote, known as a ‘Say on Climate’ at regular intervals. As part of the Santos portfolio, Dorado Phase 1 is subject to the above commitments and will operate in a manner consistent with Santos’ GHG strategy.

Section 3A of the EPBC Act defines the following principles of ESD:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- the principle of intergenerational equity: that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and
- improved valuation, pricing and incentive mechanisms should be promoted.

As outlined in **Section 2.2.2.1**, these principles must be considered in the Dorado Development OPP. The principle of intergenerational equity is of particular relevance to Dorado Phase 1, which proposes to develop the Dorado resource to provide reliable and affordable energy for current generations to maintain adequate supply of traditional fuel sources throughout the energy transition while limiting the impact of global climate change for future generations. As was observed in 2021, an unbalanced focus on only limiting supply of traditional fuel sources has resulted in significant escalation of energy prices, often for the most vulnerable in our society, leading to the perverse outcome of an increased global coal-fired electricity generation by 9% to an all time high. Therefore, the Dorado development has an important contribution to make in supporting an orderly 'energy transition', to ensure near term access to reliable, affordable energy against the backdrop of a broader longer-term transition from traditional fossil fuels to cleaner fuels and energy sources as part of a collective global effort to achieve the goals and objectives of the Paris Agreement. In supporting an orderly energy transition, the Dorado development aligns with the intent of the principle of intergenerational equity.

Oil produced from Dorado Phase 1 is predicted to be used primarily as fuel for transportation, with some potentially used as feedstock for petrochemical manufacturing, and is not expected to be used for the generation of electricity. There are currently no renewable alternatives that can contribute significantly to meeting the needs of the present generation or near-term future generations for transportation fuel and petrochemical feedstocks. Significant progress is being made developing electric vehicles for road transportation; however, these vehicles are currently relatively expensive and beyond the reach of most of the world's population and cannot meet the existing or near-term future needs for transportation. There is currently no credible alternative to oil-based fuels for aviation. Hence, the need for oil for transportation fuel is expected to continue into the future and for the duration of Dorado Phase 1.

While the present and near-term future need for oil is clear, the consumption of oil resources results in the emission of GHGs that contribute to climate change. The predicted environmental impacts from climate change pose a risk to the maintenance of the health, diversity and productivity of the environment. Hence, the unmitigated consumption of fossil fuel resources is inconsistent with the principle of intergenerational equity defined in the EPBC Act.

Given the inherent uncertainties in linking Dorado Phase 1 emissions with global temperature change and resulting ecosystem impacts, and that the unmitigated impacts of climate change to ecosystems are unacceptable (RSAL1) – to ensure acceptable levels of impacts to key Australian ecosystems, Dorado Phase 1 GHG emissions will be managed under jurisdiction-specific NDC or NZE by 2050 emissions targets, and associated jurisdiction specific emissions regulations. This is possible because all jurisdictions where Dorado Phase 1 emissions will occur are signatories to the Paris Agreement or have a net-zero by 2050 commitment, including Australia and customer countries where Dorado Phase 1 product is sold. Dorado Phase 1 Scope 1 GHG emissions will be regulated under the Australian Government's safeguard mechanism which is designed to ensure facility emissions are capped at a prescribed level ie. facility baseline, and any emissions above the baseline limit are offset through surrender of accredited offsets. The implementation of the Safeguard Mechanism is such that it ensures emissions reductions from facilities covered by the Safeguard Mechanism make an appropriate contribution (through progressive ratcheting of baselines) towards economy wide emission reductions and achievement of Australia's Paris Agreement Nationally Determined Contributions (NDC) emission reduction targets.

Restricting sales of Dorado Phase 1 product to customers from countries that are signatories to the Paris Agreement, or have made a net-zero commitment, ensures that Dorado Phase 1 Scope 3 emissions are managed under export country regulation for management of their Scope 1 and 2 emissions in order to achieve their Paris Agreement NDC emissions reduction targets. Regulation and management of both Scope 1 and Scope 3 Dorado Phase 1 GHG emissions under Paris Agreement-aligned regulatory frameworks, ensures all sources of Dorado Phase 1 GHG emissions are managed in accordance with the Paris Agreement treaty which is designed to limit global temperature increase and ensure acceptable levels of impacts to ecosystems (inclusive of key Australian ecosystems).

In proposing to develop the Dorado oil resource, a consensus must also be obtained with stakeholders and regulators to agree that it is the most timely and appropriate use of the resources, while managing Dorado Phase 1 in a manner that reduces its GHG emissions to as low as reasonably practicable (emissions management measures are presented in **Section 7.2.6.8.1**) and in the context of international agreements, national policies and legislative frameworks. The process by which Santos is engaging stakeholders is presented in **Section 9**. Throughout the various stages of Dorado Phase 1, Santos will continue to proactively seek stakeholders' feedback on the proposed activities and will openly manage the feedback received. As part of developing Dorado Phase 1, Santos will seek all relevant regulatory approvals and assess the global demand for the Dorado oil. Through this process, Santos will engage with the required regulators and ensure that each regulator's concerns and requirements are satisfactorily addressed.

7.2.6.8.1 Greenhouse Gas Management and Mitigation Relating to Dorado Phase 1

Under the Australian Government Safeguard Mechanism, Dorado Phase 1 will be allocated a "benchmark" baseline for new facilities. Reporting Dorado Phase 1 Scope 1 GHG emissions to the Clean Energy Regulator under the NGER Act and managing compliance with the Safeguard Mechanism baseline, will ensure that Scope 1 GHG emissions from Dorado Phase 1 emissions are managed and reduced, as required, in order to achieve Australia's NDC emission reduction targets under the Paris Agreement, as part of economy wide emissions reductions. This section describes a range of initiatives to be implemented by Santos to manage Scope 1 emissions that will be covered under the facility baseline set by the Clean Energy Regulator.

Dorado Phase 1 will reinject the majority of the produced gas (approximately 235 MMscfd) back into multiple reservoir zones to enhance liquids recovery and to limit planned flaring to operation of the flare pilot (continuously). For Dorado Phase 1, further proposed management of direct (Scope 1) GHG emissions includes:

+ design optimisations during the engineering design stage, incorporating energy efficiency considerations to reduce direct GHG emissions to ALARP. These efficiencies could include

optimisation of equipment selection and configuration to include the use of waste heat recovery to avoid fuel gas combustion for additional electricity generation;
+ fuel and flare analyses, baselining and forecasting throughout the operational life;
+ ongoing optimisation of energy efficiency through periodic opportunity identification workshops and studies, evaluation and implementation; and
+ annual setting of energy-efficiency improvement and flare reduction strategies throughout the operational life.

To consider the contribution of Scope 3 emissions to climate change impacts requires consideration of variables that may or may not be reasonably predicted by Santos. Variables such as third-party modifications of the product, third-party combustion efficiencies, effectiveness of emissions-reduction policies in the emitting jurisdiction, and implications of the current and future supply cannot be reliably estimated. And consistent with a recent ruling in the NSW Land and Environment Court on another Santos Project (Mullaley Gas and Pipeline Accord Inc v Santos NSW (Eastern) Pty Ltd, 2021) Santos does not have operational control over Scope 3 emissions from Dorado Phase 1. For the oil sold to customers from Dorado Phase 1, Santos can make some broad assumptions about the potential end user and the emission-control regimes in potential end-user jurisdictions.

GHG emissions arising from third-party consumption of Dorado oil are managed through the international treaty established by the Paris Agreement, and in turn the national emissions policies and targets set by the customer countries agreed through their NDCs and other Paris Agreement commitments (Section 7.2.6.3).

In respect of end-user actions occurring internationally, two international environmental legal principles are of relevance: the principle of common but differentiated responsibilities and the principle of sovereignty and responsibility. It is upon these legal principles that the United Nations Framework Convention on Climate Change's global carbon accounting framework has been established, and it places the responsibility for mitigating end-user emissions on the emitting country. In identifying potential end users, Santos considers the Ichthys condensate to have a comparable grade with similar composition to the exported Dorado oil. Buyers of Ichthys condensate include PTT Public Company Limited (Rayong refinery in Thailand), Trafigura Group Pte. Ltd. (Napa refinery in Papua New Guinea), Exxon Mobil Corporation (Singapore Jurong refinery) and Taiyo Oil Co., Ltd. (Shikoku Refinery in Japan).

The Paris Agreement is a legally binding treaty on climate change that provides for management of Scope 3 emissions for those Paris-agreement nations that will be customer countries of Dorado Phase 1 oil, to ensure that international emissions are managed in line with the Paris Agreement long-term temperature goal. A condition of the sale of Dorado oil will require customer countries to either have a net-zero commitment or be signatories to the Paris Agreement and have NDCs to reduce or offset GHG emissions. Under the Paris Agreement and global GHG accounting conventions, each country is responsible for accounting for, reporting and reducing emissions that physically occur in its jurisdiction. The host countries of customers that purchase Dorado oil will be accountable for reporting against their commitments under the Paris Agreement. The Paris Agreement (**Section 7.2.6.3**) requires ratified parties to publish NDCs and review and improve emissions reduction targets and NDCs over time, reflecting their long-term commitment towards achieving the Paris Agreement temperature goal to mitigate the impacts of climate change to acceptable levels. The commitments under the relevant NDCs at the time of preparing the OPP for a sample of potential countries that customers of Dorado oil are domiciled are summarised in **Table 7-50**.

It is important to note that NDCs will differ between countries depending on their individual capabilities. Article 2 of the Paris Agreement states that "This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances". For some countries, this may mean that their NDC may not cover all GHG emissions across all sectors. The appropriateness of individual country NDCs is a matter for the Conference of Parties, and is assessed according to the cumulative impact of all NDCs across all countries that are parties to the Paris Agreement.

Table 7-50: Nationally determined contribution and policies/climate change action commitments for likely Dorado Phase 1 oil customer countries

Likely Customer Country	Nationally Determined Contributions and Climate Change Action Commitments
Thailand	Thailand intends to reduce its greenhouse gas emissions by 20% to 25% from the projected business-as-usual level by 2030. Long Term Strategy that states Thailand's ambition to move towards net zero emissions as early as possible within the second half of this century, and towards carbon neutrality by 2065. The Strategy is supported by sectoral action plans, with short, medium and long term sectoral targets.
Papua New Guinea	Papua New Guinea intends to reduce fossil fuel emissions in the electricity generation sector by transitioning as far as possible to using renewable energy, reaching 100% renewable energy by 2030, contingent on funding being made available. In addition, Papua New Guinea will improve energy efficiency sector-wide and reduce emissions where possible in the transport and forestry sectors. Papua New Guinea is a member of the Climate Ambition Alliance, under which members commit to reach net zero CO_2 emissions by 2050.
Japan	Japan will continue to aim at resolutely achieving reduction of GHG emissions by 46% by FY 2030 against baseline FY 2013 (which was a 25.4% reduction compared to FY 2005). Japan's NDC is aligned with the long-term goal of achieving net zero by 2050. Japan submitted an updated Long-Term Strategy (LTS) to the UNFCCC on 29 October 2021, '*Long-Term Strategy under the Paris Agreement*'. The LTS includes whole of economy, long term sector visions for net zero emissions by 2050, including cross-sectoral issues including: innovation; green finance; international cooperation; and carbon pricing. Japan's original LTS was submitted on 26 June 2019. Japan's *Global Warming Countermeasures Law 2021* legislated that "a decarbonised society will be realized by 2050".
Singapore	In its second NDC update, Singapore intends to reduce emissions to around 60 million tonnes of carbon dioxide equivalent (MtCO2e) in 2030 after peaking its emissions earlier. . Long Term Strategy that outlines targets to 2030 and 2050 and defines policies and measures across all sectors to achieve them. Singapore will focus on transformations in all sectors, driven by carbon pricing, adoption of low-emissions technologies, performance standards, targeted grants and international collaboration. In February 2022, Singapore's Finance Minister stated that Singapore will be bringing forward its net-zero target to "by or around mid-century". Singapore is a member of the Climate Ambition Alliance, under which members commit to reach net zero CO_2 emissions by 2050.

Santos understands the importance of setting GHG targets consistent with the Paris Agreement objective of limiting global temperature rise to less than 2°C and in pursuit of 1.5 degrees Celsius.

Santos will monitor the effectiveness of GHG emissions reduction efforts brought about by the Paris Agreement through the IPCC and Paris Agreement global stocktake process. A key outcome of the global stocktake process is the requirement for countries that have ratified the Agreement to strengthen their NDCs/ emissions reduction targets to meet the framework's goals. Santos will regularly monitor customer country compliance and progress towards the goals of the Paris Agreement by leveraging the transparency and reporting mechanisms under the Paris Agreement, including:

+ the enhanced transparency framework 5-yearly reporting (Article 13)
+ the 5-yearly Global Stocktake (Article 14) including emissions reports and projections published by independent international agencies such as the United Nations Environment Programme (UNEP); and
+ implementation and compliance committee annual reporting (Article 15).

If results of monitoring identify any Dorado Phase 1 customer countries are not meeting, or are not on track to meet, their NDC or NZE by 2050 emissions reduction targets, Dorado will cease to supply to those customers or take mitigation actions to offset their Dorado Phase 1 product emissions.

A summary of the potential impacts, adopted control measures and environmental performance outcomes (EPOs) are provided in **Table 7-51**.

Table 7-51: Summary of impacts, environmental performance outcomes, controls and consequence evaluation of GHG emissions during Dorado Phase 1

Environmental Performance Outcome (EPO)	
EPO13A: Dorado Phase 1 Scope 1 GHG emissions managed in accordance with the Safeguard Mechanism benchmark baseline set by the Clean Energy Regulator, in support of meeting the Australian Government's Paris Agreement Nationally Determined Contribution of net zero emissions by 2050. **EPO14A**: As the Paris Agreement is the most comprehensive global agreement to seek to limit global temperature rise as specified in Article 2 of the Agreement and no significant[34] impacts to the environment globally, including in Australia, Dorado Phase 1 oil is only sold to customers from countries that have: + a net-zero emissions by 2050 (NZE) commitment; and/or + are signatories to the Paris Agreement and have Nationally Determined Contributions (NDC) in place to reduce or offset GHG emissions.	
Receptor	**Impact**
Australian Environment	Potential impacts as a result of climate change have been modelled by CSIRO. The modelling indicates that temperatures will increase across Australia, rainfall patterns will change significantly and extreme events such as droughts, floods and wildfires will become more common. These changes are likely to impact on individual species, ecosystems and ecosystem services such as food and water availability. Within decades, environments across Australia may be substantially different (CSIRO 2015). As presented in **Section 7.2.6.5**, the annual average CO_{2-e} emissions (Scope 1 + Scope 3) from Dorado Phase 1 equate to 0.023% of the 2021 global emissions from fossil fuel, and 0.134%

[34] As defined by the significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

	of the predicted 2040 global CO2-e emissions under the International Energy Agency's Net Zero Emissions by 2050 scenario. Dorado Phase 1 is not expected to be a significant contributor to global GHG emissions and the associated potential incremental environmental impacts attributed to the Dorado Development would be minor. Management of Dorado Phase 1 Scope 1 emissions in accordance with the Safeguard Mechanism benchmark baseline set by the Clean Energy Regulator will ensure Dorado Scope 1 emissions are managed as part of broader Australian Government climate and energy policy settings to achieve Australia's Paris Agreement NDC of net zero emissions by 2050, in support of Paris Agreement Article 2 objectives to limit global temperature rise to less than 2°C while pursuing 1.5°C. With regard to Dorado Phase 1 Scope 3 emissions, Dorado oil will only be sold to countries that have a net zero commitment or are signatories to the Paris Agreement with NDCs to reduce or offset GHG emissions, ensuring that Dorado Scope 3 emissions are also managed in accordance with the Paris Agreement.

Controls

CM14: Flaring limited to operation of the flare pilot during steady state operations.

CM21: Optimise facilities design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable.

CM22: The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare, and direct them to be reinjected with the produced gas.

CM23: Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities.

CM24: During routine operations, reinject produced gas (other than safety flare and fuel gas) to recover liquids.

CM25: Embed fugitive emissions surveillance and management into facilities operations and maintenance

CM26: Undertake fuel and flare analysis, baselining and forecasting throughout Dorado Development operational life.

CM27: Establish annual setting of energy efficiency improvement and targets throughout the life of Dorado Phase 1 facilities.

CM28: Throughout the life of Dorado Phase 1 facilities undertake optimisation of energy efficiency through periodic opportunity identification workshops or studies, evaluation and implementation.

CM29: Dorado Phase 1 will report on Scope 1 GHG emissions as required per the National Greenhouse and Energy Reporting (NGER) Scheme.

CM30: Dorado Phase 1 will comply with the requirements of the Safeguard Mechanism, including purchase and/or surrender of Australian carbon credit units for any emissions above the baseline for the year, to support achievement of Australia's NDC emissions targets.

CM31: Dorado Phase 1 will implement a GHG management plan and energy management program that incorporates an adaptive management approach that facilitates a continuous cycle of monitoring, evaluating, and implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations including:

+ Evaluation of emissions monitoring data and ensuring the implemented controls deliver predicted emission reductions,
+ Seeking new and relevant data/information from external sources relevant to GHG emission management including Commonwealth legislation or policy,
+ Ensuring effectiveness of internal processes and procedures to reduce and manage GHG emissions;
+ Responding to changes from detailed engineering outcomes; and

+ Implementing corrective actions identified from the above. **CM32**: Dorado Phase 1 will limit sales to customers from countries that have a NZE commitment or are signatories to the Paris Agreement, and will cease to supply customers in countries that withdraw from the Paris Agreement or NZE commitments. **CM33:** Regular monitoring of Dorado Phase 1 customer country compliance with NZE or NDC emissions targets (Article 4) through the Paris Agreement monitoring and assurance mechanisms: + the enhanced transparency framework 5-yearly reporting (Article 13) + the 5-yearly Global Stocktake (Article 14); and + implementation and compliance committee annual reporting (Article 15). **CM34**: If results of CM33 identify gaps in customer country compliance against NZE or NDC emissions targets, Dorado will cease to supply those customers or take mitigation actions to offset their Dorado Phase 1 product emissions.

Consequence	Minor (B/II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.6.9 Demonstration of Acceptability

The acceptable level of impact for the receptors that may credibly be impacted by GHG emissions as a result of Dorado Phase 1 against receptor specific acceptable levels of impact and other considerations are summarised in **Table 7-52** and **Table 7-53** respectively. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**. The worst-case consequence for GHG emissions was evaluated as minor (**Table 7-51**). This consequence is considered to be acceptable when assessed against the Santos risk matrix (**Table 7-2**).

Through regular monitoring (CM33), Santos will identify customer countries that are not meeting, or are not on track to meet, their NDC or NZE by 2050 emissions reduction targets; or those customer-countries that are no longer signatories to the Paris Agreement or have withdrawn their net-zero commitment. If results of monitoring identify any Dorado Phase 1 customer countries are not meeting, or are not on track to meet, their NDC or NZE by 2050 emissions reduction targets, Santos will take action by ceasing to supply those customers. For those countries that are no longer signatories to the Paris Agreement or have withdrawn their net zero emissions commitment, Santos will also cease to supply customers from these countries.

The Paris Agreement provides the process for defining and adopting criteria applicable to the performance of customer countries in meeting GHG emissions reduction commitments and/or NDCs. For customer countries where Dorado oil would be sold, implementation and compliance with the Paris Agreement and NDCs is not within the operational control of Santos and is a matter for nation states and the UNFCCC framework. Santos' climate transition strategy and action plan to become a net-zero emissions energy and fuels business by 2040 is in step with the temperature goal of the UN Paris agreement on climate change. Santos' Climate Transition Action Plan is adaptive and will be periodically reviewed as required in support of the Paris Agreement objective to limit global temperature rise by 2100 to less than 2 degrees Celsius and pursue efforts to limit the temperature rise to 1.5 degrees Celsius above pre-industrial levels.

Based on the evaluation of impacts and risks in the context of Australia's NDC emissions reduction targets under the Paris Agreement and supporting policies and legislation (including the Safeguard

Mechanism), Santos' commitment to only sell Dorado oil to customer countries that have either made a net-zero emissions commitment or are signatories to the Paris Agreement; and Santos' commitment to cease to supply those customers or take mitigation actions to offset their Dorado Phase 1 product emissions for customers from countries that either withdraw from the Paris Agreement or their NZE commitment or are not on track to meet their NZE or NDC emissions targets, Santos considers the potential impacts that may result from Dorado Phase 1 GHG emissions to be acceptable.

Table 7-52: Demonstration of acceptability for GHG emissions

Acceptability Criteria	Justification
To meet the principles of ESD	The management of risks and impacts from Dorado Phase 1 GHG emissions are consistent with the principles of ESD: + meeting existing end-user demand for energy; + the environmental resources within Dorado Phase 1 Project area are not expected to be significantly impacted; + the global treaty (Paris Agreement) relevant to management of climate change impacts to future generations from GHG emissions have been considered, and supporting Australian policy and legislation, will be complied with; + the consideration and integration of both long and short-term economic, environmental, social and equity considerations in the Paris Agreement; + the precautionary principle has been applied, and studies have been undertaken where knowledge gaps were identified (**Attachment 12**); and + Santos' recognition that Dorado Phase 1 will contribute to global GHG emissions and proposed design and operations mitigation measures to reduce Dorado Phase 1 Scope 1 emissions Santos considers that the Australian Government as a party to the Paris Agreement, its NDCs target of net zero emissions by 2050 and supporting national policies and legislation, ensures a precautionary approach that addresses uncertainty in the quantification of any identifiable change in the environment. Furthermore, if Dorado Phase 1 Scope 1 emissions exceed the benchmark baseline set by the Clean Energy Regulator, offsets (in the form of Australian carbon credit units) are legally mandated to ensure no net-increase in emissions above what is permitted under the benchmark baseline. Through the Paris Agreement, customers to which the Dorado oil is sold must report and manage their Scope 1 and 2 GHG emissions (Dorado Phase 1 Scope 3 emissions) in compliance with customer country targets and policies to meet their net zero emissions commitments and/or NDCs as a party to the Paris Agreement. The principle of intergenerational equity is of particular relevance to Dorado Phase 1, which proposes to develop the Dorado resource to provide reliable and affordable energy for current generations to maintain adequate supply of traditional fuel sources throughout the energy transition while limiting the impact of global climate change for future generations. In supporting an orderly energy transition to ensure current generations are not unduly impacted by the aspirations of future generations, the Dorado development aligns with the intent of the principle of intergenerational equity.

Acceptability Criteria	Justification
Internal context	Santos has considered the internal context, including Santos' Climate Change policy, and commitments in the 2022 Climate Change Report (Santos 2022). The environmental performance outcomes and the controls that will be implemented are consistent with Santos' internal requirements. Dorado Phase 1 will be incorporated into the total emissions reporting by Santos once the project becomes operational. Climate change management is embedded within Santos' business strategy, including lowering operating emissions. Santos has committed to net-zero Scope 1 and 2 emissions by 2040, which will include Dcope1 emissions from Dorado Phase 1 operations, which has a 20-year project life and is scheduled to commence production in 2027.
External context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	The following material published in relation to threatened and migratory species within and adjacent to the Project Area identify climate change as a threat: *Threatened and migratory species:* **Conservation Advice:** + Conservation advice *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice Red Knot (*Calidris canutus*) (Threatened Species Scientific Committee 2016f) + Conservation Advice for the Abbott's Booby – *Papasula abbotti* (Threatened Species Scientific Committee 2020b) + Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Threatened Species Scientific Committee 2008b) + Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b) + Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee 2015c) **Recovery Plans:** Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPC, 2013b). This recovery plan identifies climate change as a threat to Whale Sharks, however, no relevant actions are listed. Wildlife Conservation Plan for Seabirds (DCCEEW 2022). This draft recovery plan identifies climate change as a threat to seabirds. Action 3D: investigate the impacts of climate variability and change on seabirds and their habitats, is relevant to Dorado Phase 1. Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australian 2015c). This recovery plan identifies climate change as a threat. Action 3B: Investigate the impacts of climate change on migratory shorebird habitat and populations in Australia. is relevant to Dorado Phase 1. Recovery plan for Marine Turtles in Australia (Commonwealth of Australia 2017a). This recovery plan identifies climate change and variability as a threat to marine turtles. Action Area A.2: continuing to meet Australia's international commitments to

Acceptability Criteria	Justification
	address the causes of climate change and identify, test and implement climate-based adaptive measures, is relevant to Dorado Phase 1. Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a). This recovery plan identifies climate change as a threat to Blue Whales. Action Area A.3: continuing to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica, is relevant to Dorado Phase 1. Dorado Phase 1 GHG emissions will not credibly result in significant impacts to threatened or migratory species. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify climate change as a key threat or do have explicit relevant objectives or management actions related to climate change. The objectives and actions of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives and Santos considers the impacts of greenhouse gas emissions to not be inconsistent with the EPBC management plans. GHG emissions from Dorado phase 1 will not credibly result in direct significant impacts to threatened or migratory species given that Dorado phase 1 emissions will be managed in accordance with the Safeguard Mechanism, as part of Australia's wider *whole of economy plan to achieve net zero emissions by 2050* under its Paris Agreement NDCs. Achievement of the Paris Agreement temperature goal to limit global temperature rise to 2 degrees Celsius and in pursuit of 1.5 degrees Celsius will limit ecosystem and species impacts to an acceptable level accordingly. *Commonwealth marine environment* The impacts and risks from Dorado Phase 1 GHG emissions on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Table 4-2**.
Other relevant requirements	Management of the impacts and risks from GHG emissions associated with Dorado Phase 1 are consistent with relevant legislative requirements, including: + Compliance with international conventions, including: - The Paris Agreement as agreed under the United Nations Framework Convention on Climate Change at the 21st Conference of the Parties in 2015, which sets an ambitious long-term temperature goal (Article 2) and establishes a global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change (Article 7). The Paris Agreement commits individual signatory countries to define their nationally determined contributions, reach peak GHG emissions as soon as possible (Article 4), adopt rules and procedures to mitigate GHG emissions, and adopt a compliance and reporting mechanism (Articles 13 and 15), as well as adaptive management and continuous improvement. + Compliance with Australian GHG emissions legislative requirements, including: - The regulatory mechanism of primary relevance to Dorado Phase 1 GHG emissions is the National Greenhouse and Energy Reporting (Safeguarding

Acceptability Criteria	Justification
	Mechanism) Rule 2015. This requires any Scope 1 emissions above a facility-specific baseline to be offset; - Relevant requirements of the National Greenhouse and Energy Reporting Act 2007 (or contemporary requirements at the time); and + Further to the management commitments made in the OPP, the Environment Regulations provide the future legislative mechanism for EP assessments for the Dorado Phase 1 activities that: - requires a detailed evaluation of all activity-specific environmental risks and impacts, including those associated with GHG emissions and global climate change, and requires demonstration that GHG emissions will be reduced to ALARP and acceptable levels; and - provides for the regulator to further assess measures proposed by Santos for Dorado Phase 1 oil, in order to meet the established EPOs, which will be subject to regular review and compliance monitoring. + Implementation of recognised industry standard practice, such as: - Preventative maintenance system; - Optimise planned and unplanned flaring to enable the safe and efficient operation of the facility; and - Equipment selection in design, to achieve emissions efficiencies.

Table 7-53: Demonstration of acceptability of GHG emissions against receptor-specific acceptable levels of impacts

Receptor-specific Acceptable Levels	Justification
RSAL1: No significant[35] impacts to key Australian ecosystems attributable to Dorado Phase 1 GHG emissions.	To ensure no significant impacts to key Australian ecosystems from climate change, Dorado Phase 1 GHG emissions (Scope 1 and Scope 3) will be managed under country-specific emissions reduction policies and regulation that are aligned with the long-term temperature goal of the Paris Agreement , both nationally via the Australian Government's Paris Agreement NDC emissions reduction targets (covering Dorado Scope 1 emissions) and internationally through customer country Paris Agreement NDC emissions targets (covering Dorado Scope 3 emissions). The Paris Agreement is the established legally binding treaty on climate change to limit temperature increase to below 2 degrees in order to prevent and/or limit environmental impacts, including significant impacts to key Australian ecosystems. As a party to the Paris Agreement, Australia has committed to achieving its Nationally Determined Contributions (NDCs), which were most recently revised in 2022, and includes both 2030 and 2050 targets. Achievement of net zero emissions by 2050 is premised on implementation of a range of measures across all sectors of the economy which when implemented collectively enable the net zero target to be achieved. The Safeguard Mechanism is one such measure,

[35] As defined by the significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

	which provides a framework for Australia's largest emitters to measure, report and manage their emissions, including a requirement to offset any emissions above the facility baseline. The Safeguard Mechanism is complemented by a suite of Australian Government climate and energy policy measures that collectively are designed to achieve net zero emissions by 2050. Although a Safeguard Mechanism baseline has not yet been set by the Clean Energy Regulator for Dorado Facilities (which wouldn't be expected at the OPP assessment stage of a new development), it is the role of the Clean Energy Regulator (as Regulator for the Safeguard Mechanism) to determine a suitable baseline for Dorado facilities in the context of broader government climate and energy policy and achievement of Australia's NDC emissions reduction targets. Dorado's Phase 1 Scope 1 GHG emissions will be regulated under the Australian Government's safeguard mechanism which is designed to ensure facility emissions are capped at a prescribed level ie. facility baseline, and any emissions above the baseline limit are offset through surrender of accredited offsets. The design of the Safeguard Mechanism is such that it ensures emissions reductions from facilities covered by the Safeguard Mechanism make an appropriate contribution (through progressive ratcheting of baselines) towards economy wide emission reductions and achievement of Australia's Paris Agreement Nationally Determined Contributions (NDC) emission reduction targets. By restricting sales of Dorado Phase 1 product to customers from countries that are signatories to the Paris Agreement or have made a net-zero commitment, this ensures that the Dorado Scope 3 emissions are managed under export country policies and regulation for management of their Scope 1 and 2 emissions in order to achieve their Paris Agreement NDC emissions reduction targets. Regulation and management of both domestic and export Dorado Phase 1 GHG emissions under a Paris-aligned framework, ensures all sources of Dorado Phase 1 GHG emissions are managed in accordance with the Paris Agreement treaty which is designed to limit global temperature increase (Article 2) to prevent significant impacts to ecosystems (inclusive of key Australian ecosystems).Net-zero emissions commitments and/or Paris Agreement NDCs by Dorado Phase 1 customer countries provide the most certain pathway to achieving the Paris Agreement temperature goal (Article 2), which, based on the available science, is the most credible means of ensuring acceptable levels of impact to Australian ecosystems from the impacts of global climate change (RSAL1). However, while it is in Santos' control to elect to only sell Dorado Phase 1 oil to customers from countries with net-zero emissions by 2050 commitments and/or Paris Agreement NDCs to reduce or offset emissions (EPO14A), it is not within Santos' control to ensure customer countries comply with net-zero emissions commitments and/or Paris Agreement NDCs. In the event that Dorado Phase 1 customer countries withdraw from the Paris Agreement or their NZE by 2050 commitment, Santos will cease to supply to those customers. And if monitoring through Paris Agreement monitoring and assurance mechanisms reveals Dorado Phase 1 customer countries are not on track to meet their NZE or NDC targets, Santos will cease to supply those customers or take mitigation actions to offset their Dorado Phase 1 product emissions. Even under the most aggressive accelerated energy transition scenarios, including the IEA Net Zero by 2050 scenario, there remains a requirement for

	investment in oil and gas production to maintain sufficient supply through the transition. The 2021 World Energy Outlook states that "Oil and gas spending today is one of the very few areas that is reasonably well aligned with the levels seen in the NZE to 2030" and warns that the world is not investing enough to meet its future energy needs, and that uncertainties over policies and demand trajectories create a strong risk of a volatile period ahead for energy markets. Therefore, it is too simplistic to assert that no new oil developments will be required, even under the IEA NZE by 2050 scenario. In its 2022 World Energy Outlook (IEA, 2022), when assessing the current global energy crisis, exacerbated by Russia's invasion of Ukraine, the IEA acknowledges that immediate shortfalls in fossil fuel production will need to be replaced by production elsewhere – even in a world working towards net zero emissions by 2050. The IEA also discusses the need for a new energy security paradigm to maintain reliability and affordability while reducing emissions, where both energy systems (fossil fuels and clean energy) are required during the energy transition in order to deliver the energy services needed by consumers, even as their respective contributions change over time (IEA, 2022). In summary, the environmental impacts from Dorado Phase 1 GHG emissions will be of an acceptable level because: + All Dorado Phase 1 GHG emissions (Scope 1 and Scope 3) will be managed under jurisdiction-specific Paris Agreement aligned emissions reduction regulatory frameworks, in step with the temperature goal of the UN Paris Agreement on climate change to ensure acceptable levels of impact to ecosystems (inclusive of key Australian ecosystems). + Even under the most aggressive accelerated energy transition scenarios, including the IEA Net Zero by 2050 scenario, there remains a requirement for investment in oil and gas production to maintain sufficient supply through the transition; + Renewable fuels alone cannot meet current energy and product needs, and probably cannot meet projected global energy and product needs, before the planned end to Dorado production in 2047; + Both traditional forms of fossil fuel energy and new clean energy sources are required throughout the energy transition to maintain reliability and affordability while reducing emissions.
RSAL2: Dorado Phase 1 is an insignificant $CO_{2\text{-}e}$ emissions contributor to Australian and Global $CO_{2\text{-}e}$ emissions	Dorado Phase 1 (Scope 1) emissions contribution to Australia's national $CO_{2\text{-}e}$ emissions will be less than 0.5%. Dorado Phase 1 (Scope 1 + Scope 3) emissions contribution to Global $CO_{2\text{-}e}$ emissions will be less than 0.25%.

7.2.7 Emissions – Atmospheric

Non-GHG atmospheric emissions refer to the emissions of nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), volatile organic compounds (VOCs) and particulate matter (less than 10 µm (PM_{10}) and less than 2.5 µm ($PM_{2.5}$)) with potential resultant impacts on natural ecosystems and human health or amenity. These emissions may cause effects at a local and regional scale. Non-GHG atmospheric emissions are hereafter referred to as atmospheric emissions. GHG emissions are discussed in **Section 7.2.6**.

7.2.7.1 Description of the Event

Atmospheric emissions will be generated in the Project Area during all stages of Dorado Phase 1 (from development drilling to decommissioning). The main sources where atmospheric emissions will be generated are the Dorado WHP, FPSO, MODU, and support and installation vessels. The following activities will generate atmospheric emissions:

- combustion emissions from power generation and processing facilities (including all equipment and generators);
- periodic emissions from flaring of gas during commissioning, start-up and shutdown activities on the FPSO;
- periodic emissions from venting (release of non-combusted gas for overpressure release, facility depressurisation events, and systems pressure testing);
- fugitive emissions (unplanned emissions from pressurised piping components and equipment leaks, which are not regarded as venting);
- emissions from transportation activities, such as vessel and helicopter movements; and
- on-vessel atmospheric emissions, including internal combustion engines, fugitive emissions and onboard incinerators.

The following sections provide some context to Dorado Phase 1 atmospheric emissions.

7.2.7.1.1 Combustion Emissions

Fuel combustion for power generation in internal combustion engines will occur on a routine basis on all vessels, MODUs and the FPSO. Vessels, MODUs and the FPSO, when not producing or not on station, will be powered by MDO. During normal operating conditions, power on the Dorado WHP, however, will be provided by the FPSO via the umbilical. During specific maintenance campaigns, a MDO-fuelled power generation kit may be used on the Dorado WHP. Under normal operating conditions, the FPSO will use field gas as a fuel source. SO_x and particulate-matter emissions are heavily influenced by the type of fuel used and its relative sulphur content. For instance, combustion of MDO releases a greater volume of atmospheric emissions than the combustion of produced gas. Thus, the use of produced gas as fuel is expected to represent a reduction in atmospheric emissions when compared to using MDO. It will nevertheless be required to use MDO as fuel during commissioning, when the FPSO is disconnected from the DTM, when production is stopped during events such as shutdown, and to operate safety-critical equipment such as fire pumps. The use of MDO is expected to occur sporadically for discrete time periods.

Depending on the vessel used, MDO, intermediate fuel oil (IFO) and HFO may be used as fuel. IFO and HFO are only expected to be used on certain installation vessels, such as the heavy-lift vessel. It is expected that the MODU will use MDO as fuel. Lower atmospheric emissions are expected from the combustion as fuel of MDO than from IFO and less from IFO than from HFO. Emissions produced by support and installation vessels are also expected to be substantially less than that of the MODU or FPSO.

On board the vessels and MODU, another combustion source might be the incinerators. Incinerators are shipboard facilities designed for the incineration of wastes to reduce waste to ash for disposal. The type and quantities of material that can be disposed of in incinerators are regulated via the International Maritime Organization.

7.2.7.1.2 Flaring and Venting Emissions

Flaring is expected to occur during the development drilling and operations and maintenance stages. On the MODU, flaring will be required during well-cleaning and testing activities. For this assessment, it has been conservatively assumed that flaring will be continuous during the drilling campaign. During the operations and maintenance stage, the FPSO flare will not be routinely operated, except for the safety flare pilot flame (for which small quantities of produced gas will be used). Flaring is anticipated during start-ups, shutdowns, and process upsets or in emergency events (refer to **Section 7.2.6.2.1**).

Venting (emissions of non-combusted gas) is also expected on the Dorado WHP during facility depressurisation events (such as controlled shutdown, emergency conditions, and pressure-relief events) and for overpressure release (passive safety system, which ensures tanks and other vessels on a facility are not overpressured and therefore safeguarding a facility's systems integrity). Venting from facility depressurisation and overpressure release on the FPSO will be directed to the flare. On both the Dorado WHP and FPSO, venting will occur during systems pressure testing (generally nitrogen is used during flowline or equipment pressure testing to identify potential leak pathways prior to introducing hydrocarbons). For both the WHP and the FPSO venting sources, the inventory is expected to be small.

7.2.7.1.3 Fugitive Emissions

Fugitive emissions are unintentional emissions of non-combusted gas (i.e. they are not occurring due to the design of the equipment or operational practices). As hydrocarbons are gathered, processed and stored on the Dorado WHP and FPSO, it is a reasonable expectation that there will be some fugitive emissions from non-point sources (such as valves or flanges) on those facilities.

7.2.7.1.4 Atmospheric Emissions Estimation

A quantification study was undertaken to inform the assessment of the potential impacts and risks from the atmospheric emissions associated with Dorado Phase 1 (**Attachment 12**). To estimate the atmospheric emissions, guidance manuals developed by the National Pollutant Inventory were used (such as the Emission Estimation Technique Manual for Oil and Gas Extraction and Production – Version 2.0 (DSEWPAC 2013c)). The guidance manuals were used for both the method and emission factors. This allowed the quantification of NOx, SOx, CO, VOCs, and particulate-matter emissions associated with each stage of Dorado Phase 1. It also allowed the comparison of atmospheric emissions per project stage on a uniform metric basis. The activities generating atmospheric emissions in the Project Area and activities assumptions are those presented in **Attachment 12**. To better categorise emissions aligned with comparable sources across the stages of Dorado Phase 1, they have been grouped as follows:

- drilling, installation, and commissioning – including development drilling, installation, hook-up and commissioning;
- operations and maintenance (for a duration of 20 years); and
- decommissioning.

The expected atmospheric emissions throughout the Dorado Phase 1 lifecycle are presented in **Table 7-54.**

Table 7-54: Expected atmospheric emissions by emission type and project stage

Emission	Total Atmospheric Emissions (t) by Stage		
	Drilling, Installation, and Commissioning	Operations and Maintenance	Decommissioning
NO_x	8,470	25,100	3,020
SO_x	0	33	0
CO	3,570	25,100	803
VOCs	506	15,100	75.8
PM_{10}	255	155	94
$PM_{2.5}$	249.8	154	91.8

The majority of the atmospheric emissions are predicted to occur during the operations and maintenance stage (**Figure 7-29**), with most of the total atmospheric emissions being comprised of NO_x and CO (44% and 36% respectively). VOCs represent 19% of the atmospheric emissions, with SO_x and particulate matter representing less than 1%.

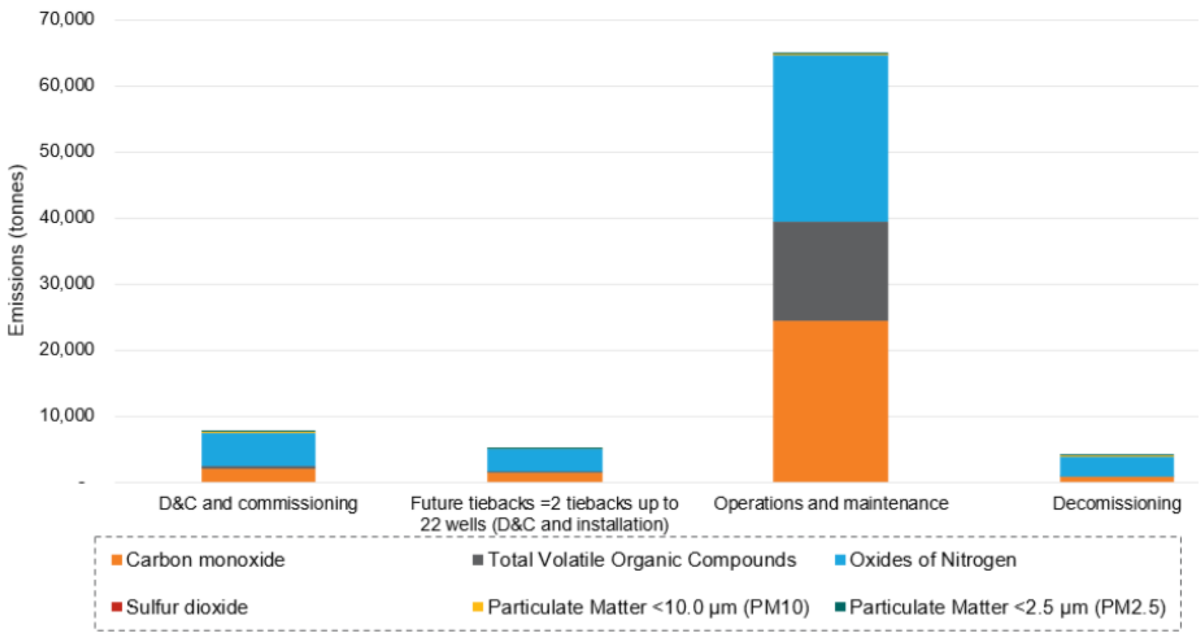


Figure 7-29: Summary of atmospheric emissions during Dorado Phase 1 stages

7.2.7.2 Details of Environmental Impacts and Risks

A summary of the analysis of the environmental impact of atmospheric emissions as a result of Dorado Phase 1 is provided in **Table 7-55**. Atmospheric emissions are not expected to impact the biological environment or socio-economic environment.

Atmospheric emissions can cause direct impacts to fauna if the fauna are close to the area of discharge. Given that these emissions will be remote from any sensitive locations, including significant seabird habitats, there are no expected impacts to the biological environment. Given the offshore location, atmospheric emissions are not likely to result in socio-economic impacts, such as visual amenity, nuisance or health issues.

Table 7-55: Receptors potentially impacted by atmospheric emissions

Description of the Risk	Receptor Categories
Potential environmental impacts associated with atmospheric emissions as a result of	Air Quality – **Section 7.2.7.2.1** Birds – Section

7.2.7.2.1 Air Quality

Most of the total atmospheric emissions in Australian waters associated with Dorado Phase 1 are related to the operations of the FPSO (up to 97%). The quantity of emissions emitted during the operations of the FPSO are relatively low as the gas recovered from the reservoir (with the exception of the fraction taken for fuel gas and keeping the flare pilot flame lit) will be reinjected into the reservoir formation. It is expected that, under normal circumstances, these emissions will be quickly dissipated into the surrounding environment through natural dispersion (e.g. wind and mixing). In general terms, the sensitivity of local air quality in the Project Area is considered low due to the absence of existing emissions sources and the absence of sensitive receptors. Considering the location of the Dorado Development in the open ocean, which is well-removed from the nearest residential or sensitive populations of the Western Australian coast (the proposed FPSO is 110 km from the nearest coast and 143 km from Port Hedland), and the localised nature of the emissions, it is considered that atmospheric emissions will not result in significant impacts to ambient air quality at a local or regional scale.

Atmospheric emissions will result in a minor deterioration in local air quality and are not considered to have a detectable local-scale impact. Taking into account the low sensitivity of the receiving environment subject to local and regional air quality changes (absence of receptors in the open offshore context), the residual impact is concluded to be minor.

7.2.7.2.2 Birds

Atmospheric emissions can cause direct impacts to fauna such as seabirds and migratory shorebirds, if they are present in the immediate vicinity of significant releases. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a). The nearest roosting site for seabirds and migratory shorebird is Bedout Island (70 km) and Eighty Mile Beach (146 km) so large numbers of seabirds or migratory shorebirds are not expected to occur in close proximity to the WHP and FPSO. Given that atmospheric emissions will be typical of other operating facilities and equipment, and that seabird and migratory shorebird numbers will be low at the FPSO location no lasting impact to seabirds and migratory shorebirds as a result of atmospheric emissions is expected.

7.2.7.3 Summary of Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-56**.

Table 7-56: Summary of impacts, environmental performance outcomes, controls and consequence evaluation for atmospheric emissions during Dorado Phase 1

Environmental Performance Outcome (EPO)	
EPO15A: No significant[36] impacts to air quality throughout the lifecycle of Dorado Phase 1	
Receptor	**Impact**
Air Quality	Change in air quality
Controls	
CM14: Flaring limited to operation of the flare pilot during steady state operations. **CM21:** Optimise facility design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable. **CM22:** The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare, and direct them to be reinjected with the produced gas. **CM23:** Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities. **CM25:** Embed fugitive emissions surveillance and management into facilities operations and maintenance. **CM35**: The MODU, vessels, and FPSO will comply with MARPOL Annex VI (Prevention of Air Pollution from Ships), the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and subsequent Marine Orders, which require vessels to have a valid International Air Pollution Prevention Certificate (for vessels more than 400 tonnage), and to use low-sulphur fuel. **CM36:** Ozone-depleting substances onboard vessels and the facilities will comply with relevant MARPOL 73/78 (Annex VI - air pollution), Navigation Act 2012, Protection of the Sea (Prevention of Pollution) Act 1983 and subsequent Marine Order requirements (as appropriate for vessel classification). **CM37**: Measure, monitor or estimate facility fuel and flare emissions (in accordance with the National Pollutant Inventory) to inform and optimise management practices and minimise environmental impact of emissions. **CM38**: National Pollutant Inventory reporting records (or contemporary requirements at the time of the activities) will be complied with during the project.	
Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.

7.2.7.4 Demonstration of Acceptability

The acceptable levels of potential impact for the receptors that may be credibly impacted by atmospheric emissions as a result of Dorado Phase 1 compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-57** and **Table 7-58.** The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

[36] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

The worst-case consequence for atmospheric emissions were evaluated as minor (**Table 7-56**). This consequence is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential from the atmospheric emissions aspect of Dorado Phase 1 are acceptable.

Table 7-57: Demonstration of acceptability for atmospheric emissions

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	The environmental impacts of atmospheric emissions as a result of Dorado Phase 1 are consistent with the principles of ESD based on the following points: + the environmental resources within the Dorado Development Project Area are not expected to be significantly impacted; and + the precautionary principle has been applied, and studies have been undertaken where knowledge gaps were identified (**Attachment 12**).
Internal context	The management of atmospheric emissions is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPO and the controls that will be implemented are consistent with Santos' internal requirements.
External context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	Recovery Plans / Conservation Advice for species that may occur in the project area do not identify atmospheric emissions as a key threat or have explicit relevant objectives or management actions. Atmospheric emissions will not credibly result in significant impacts to threatened or migratory species.
Other relevant requirements	Compliance with international conventions, including: + MARPOL 73/78: Annex VI: Regulations for the prevention of air pollution from ships. Compliance with Australian legislation and requirements, including: + Navigation Act 2012 and Protection of the Sea (Prevention of Pollution from Ships) Act 1983; + Marine Order 97 (Marine Pollution Prevention – Air Pollution); and + Relevant requirements of the National Pollutant Inventory National Environmental Protection Measure.

Table 7-58: Demonstration of acceptability of atmospheric emissions against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL7: No substantial changes in air quality that may adversely impact on biodiversity, ecological	Impacts to air quality from atmospheric emissions associated with Dorado Phase 1 will be localised. Given the remoteness of the Dorado

integrity, social amenity or human health as a result of Dorado Phase 1.	Development Project Area, there is no potential for significant environmental impacts to occur.

7.2.8 Physical Presence – Interactions with Other Users

7.2.8.1 Description of the Event

Dorado Phase 1 will require a range of facilities and supporting project vessels to be present within the Project Area, such as:

- support and installation vessels;
- the MODU (jack-up for drilling the Dorado field, jack-up or semi-submersible MODU for tiebacks);
- the Dorado WHP;
- the FPSO facility, including associated DTM, mooring lines and anchors;
- subsea infrastructure, such as flowlines and umbilicals; and
- Future tieback infrastructure including WHPs (if required), flowlines, umbilicals.

Each of these facilities will temporarily exclude some activities by other maritime users, such as shipping and commercial fishing, within the Project Area, both in the short-term during installation/drilling operations, and over the long term during production operations over ~20 years. This exclusion is required to ensure the safety of other users and of the vessels and facilities associated with Dorado Phase 1. Project activities, such as drilling and installation, will be undertaken by relatively large vessels that are easily detectable.

The FPSO and Dorado WHP are large steel structures and they will be clearly visible at a long range under most metocean conditions in the Project Area. The main deck height of the FPSO is 36 m above sea level, which will be visible on the horizon approximately 21 km away. The flare tower (110 m above sea level) will be visible on the horizon approximately 37 km from the FPSO; further when flaring (**Attachment 9**).

The decommissioning concept for Dorado Phase 1 has not been selected at this stage in the development planning however, decommissioning of the infrastructure in the Dorado field will be conducted in accordance with accepted decommissioning practices and regulatory requirements at the time of decommissioning.

7.2.8.2 Details of Environmental Impacts and Risks

Table 7-59 identifies the potentially impacted receptors as a result of interactions with other users within the Project Area.

Table 7-59: Receptors potentially impacted by Dorado Development Infrastructure and Activities

Description of the Risk	Receptor Categories
Displacement of other users within the Project Area during installation and drilling activities. Exclusion of other users from within gazetted PSZs during production operations	Commercial Fisheries – **Section 7.2.8.2.1** Maritime Industry – **Section 7.2.8.2.2**

There are no tourism activities within the Project Area. The Project Area does not overlap any designated Department of Defence areas or any existing oil and gas facilities (**Section 3**). Hence, these receptors will not credibly be impacted.

Vessels will be required to comply with relevant international and Australian maritime navigation and safety requirements at all times. Santos has an existing marine assurance framework that stipulates these requirements prior to third party vessels being contracted for undertaking project activities. Temporary or short-term project activities that may result in interactions with other users (e.g. tieback drilling) will typically be undertaken with a Notice to Mariners issued by the Australian Hydrographic Service in place. These Notices will communicate the nature, location and expected duration of these activities. This, along with Santos' stakeholder consultation program, will provide a sufficient level of communication to other marine users regarding Dorado Phase 1 activities to be conducted within the Project Area.

Dorado Phase 1 facilities will also be clearly marked on nautical charts once installed. The FPSO will maintain a manned control room and will be able to detect and communicate with other maritime users that may come within proximity of the FPSO and Dorado WHP. The FPSO will also have a support vessel on standby much of the time, which will maintain a watch for other vessels and implement the PSZ. As such, the Dorado WHP and FPSO will be readily detectable by other maritime users and the FPSO will maintain the ability to communicate with other users at all times.

The FPSO and Dorado WHP will be lit and will maintain navigation aids in accordance with maritime safety requirements. The large size and material (predominantly steel) of these facilities is expected to provide a strong radar return for other maritime users.

7.2.8.2.1 Commercial Fisheries

A number of Western Australian managed fisheries overlap the Project Area. Of these, the following fisheries were recorded as being active within the Project Area based on spatial catch and effort (FishCube) data maintained by DPIRD and confirmed with WAFIC through consultation (refer **Section 9.1.4.1**):

+ Mackerel Managed Fishery (Area 2 - Pilbara) (State), and
+ Pilbara Demersal Scalefish Fishery comprising:
    - Pilbara Fish Trawl (Interim) Managed Fishery (State);
    - Pilbara Line Fishery (State); and
    - Pilbara Trap Managed Fishery (State).

None of the Commonwealth fisheries (which includes the Western Tuna and Billfish Fishery, Western Skipjack Tuna Fishery and the Southern Bluefin Tuna Fishery) that overlap the Project Area have been active within the Project Area in recent years. Effort in these fisheries is typically concentrated in areas outside of the Project Area. Therefore, no interactions with participants in these fisheries are expected to occur during Dorado Phase 1.

Potential impacts to commercial fisheries as a result of Dorado Phase 1 range from operational inconveniences (e.g. manoeuvring around transiting vessels) to longer term (i.e. for the life of Dorado Phase 1) loss of access to fishing areas due to presence of WHP/FPSO infrastructure. Displacement may result in reduced catches and income, or increased costs to operate elsewhere (i.e. relocation costs). Through engagement with WAFIC key concerns raised or requiring clarification included the exclusion zones proposed by Dorado Phase 1 (**Section 8**).

Dorado Phase 1 is not expected to result in any decline in fish resources targeted by commercial fishing. There is also evidence that indicates petroleum infrastructure provides habitat that supports more diverse and abundant fish assemblages and that the exclusion zones associated with the facilities provide an area protected from fishing (Bond et al. 2018; McLean et al. 2017).

FishCube data are available for Western Australian fisheries in 60 nm x 60 nm and in 10 nm x 10 nm CAES blocks. The fishery data provided includes weight of fish catch, vessel count and fishing day count – which is a measure of fishing effort, represented by the number of days when one or more vessels fished in a CAES block during the period. The dataset provides an understanding of the relative distribution of fishing effort. For the fisheries that overlap the Project Area, fishing effort (fishing day count) has been mapped for each fishery for the 10-year (2009 to 2019) dataset to assess the potential impact to the commercial fisheries associated with Dorado Phase 1 infrastructure and petroleum activities (see the following sub-sections).

Mackerel Managed Fishery (Area 2)

The Mackerel Managed Fishery operates throughout the nearshore waters of the Pilbara and the vessel and gear types make them relatively mobile. Fishing effort is distributed along the Pilbara and Kimberley coasts, with areas of significant effort located off Eighty Mile Beach, Port Hedland, Dampier, and near Barrow Island and the Montebello Islands (**Section 3.4.3**).

An assessment of FishCube data for the 10 nm CAES for the Mackerel Managed Fishery indicates 4 fishing blocks overlap the Project Area (**Figure 7-30**). The data indicates a low level of fishing effort within these blocks, with less than three vessels recorded in these Mackerel Managed Fishery 10 nm fishing blocks between 2014 to 2018. There was no recorded activity overlapping with the planned Dorado WHP/ FPSO PSZ.

Fishing effort for this fishery is typically restricted to water depths less than 60 m. This was corroborated in 2019 during stakeholder consultation for the Keraudren 3-D marine seismic survey in the Bedout Basin (Santos 2019). The entire Project Area is more than 60 m water depth (i.e. beyond the typical depths in which fishers operate). Participants in the Mackerel Managed Fishery may experience operational inconvenience or area displacement from the PSZs, however, the loss of fishing ground due to the PSZ is a small area for the life of Dorado Phase 1 and is not expected to result in any notable decline in total catch.

Pilbara Fish Trawl Interim Managed Fishery

Fishing effort for the Pilbara Fish Trawl Interim Managed Fishery occurs throughout the Project Area and beyond. The areas of greatest historical fishing effort in the fishery are in Area 1 and Area 2 (**Figure 7-31**), located approximately 223 km and 114 km west of the Dorado WHP respectively. These areas are closest to the home ports of the fishers (Exmouth and Point Samson near Karratha). Two trawl fishing companies are understood to operate across the entire fishery. The area of the fishery is 86,000km^2.

An assessment of FishCube data for the 10 nm CAES indicated there are 19 fishing blocks that overlap the Project Area (**Figure 7-31**). Across the Project Area, fishing occurred in all the years from 2014 to 2018, and recently across all months. All the blocks had fishing activity. Dorado Phase 1 will restrict fishing within the PSZ (3.25km^2 in area), which represents approximately 1% of the overall fishing block area (Block 19184 is 324km^2 in area). Approximately 99% of block 19184 would remain accessible for the Pilbara Fish Trawl Interim Managed Fishery.

The benthic habitats within the proposed PSZs are widely represented within the Project Area. The associated fish assemblages targeted by the Pilbara Fish Trawl Interim Managed Fishery are likely to also be widely distributed within the Project Area. No fish species targeted by the fishery were observed at the WHP location during benthic habitat surveys, although targeted fish were observed elsewhere within the Project Area (RPS 2020d). Given the widespread, homogeneous nature of benthic habitats within the Project Area, and the small loss of fishing ground due to the PSZ, the displacement of operators in the fishery is not expected to result in any reduction in total catch within the fishery.

Pilbara Line Fishery

FishCube data for the Pilbara Line Fishery was available in 60 nm CAES block resolution (**Figure 7-32**). CAES data indicates that effort in the fishery is concentrated in waters between North West Cape and Dampier, with highest effort around Barrow Island and the Montebello Islands. Santos understands that there were nine licences within the fishery for the 2018/2019 season, which were held by seven operators.

A review of FishCube data (**Figure 7-32**), indicates 3 fishing blocks overlap the Project Area, one block overlaps the PSZ. Fishing occurred periodically in 2014, 2015 and 2016 within the block overlapping the PSZ. All blocks recorded less than three vessels between 2014 and 2018.

Participants in the fishery may experience operational inconvenience or area displacement from the PSZs, however, this is not expected to result in any notable decline in total catch due to the relatively low levels of fishing effort within the Project Area and PSZ.

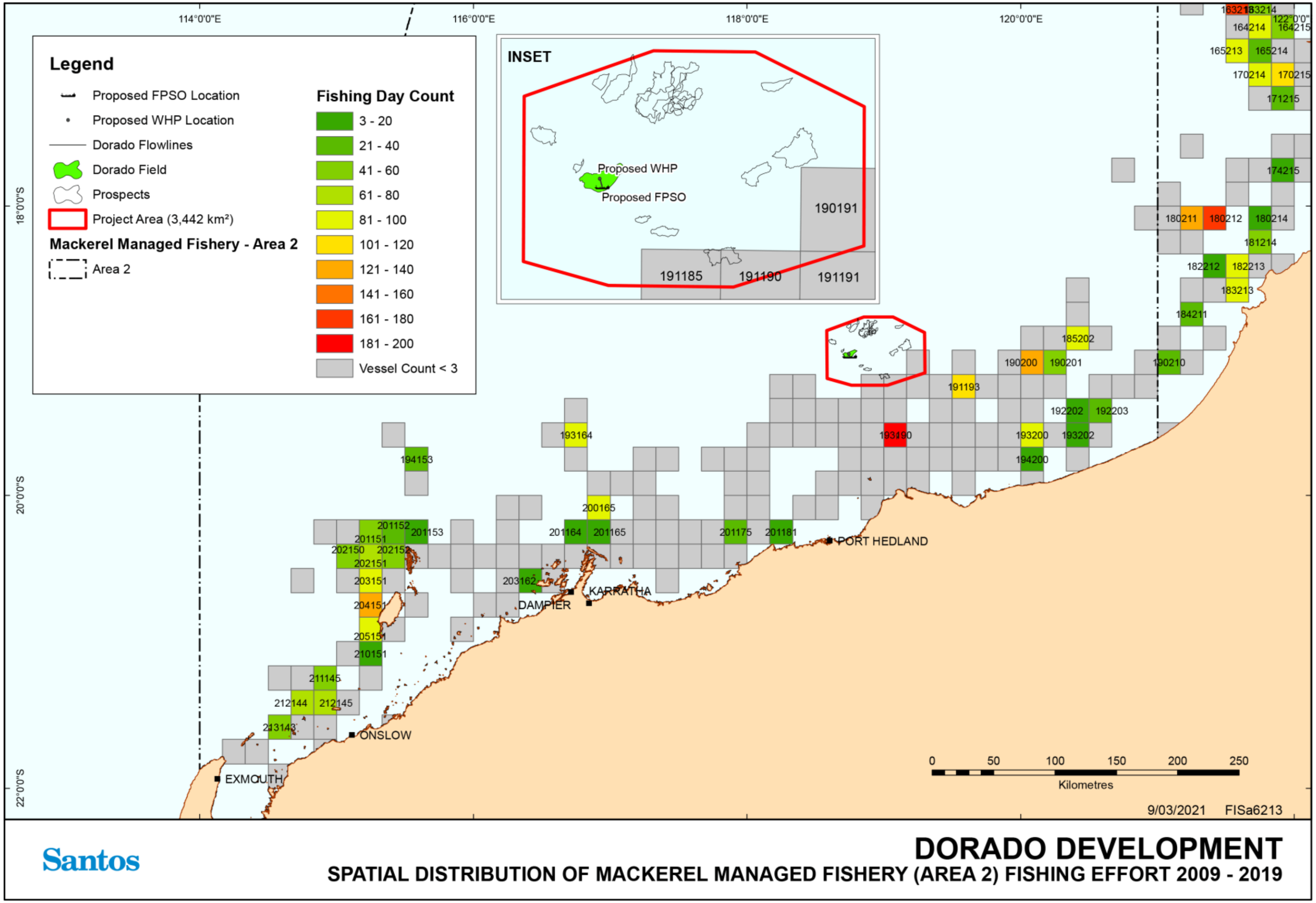


Figure 7-30: Spatial distribution of mackerel managed fishery (Area 2) fishing effort

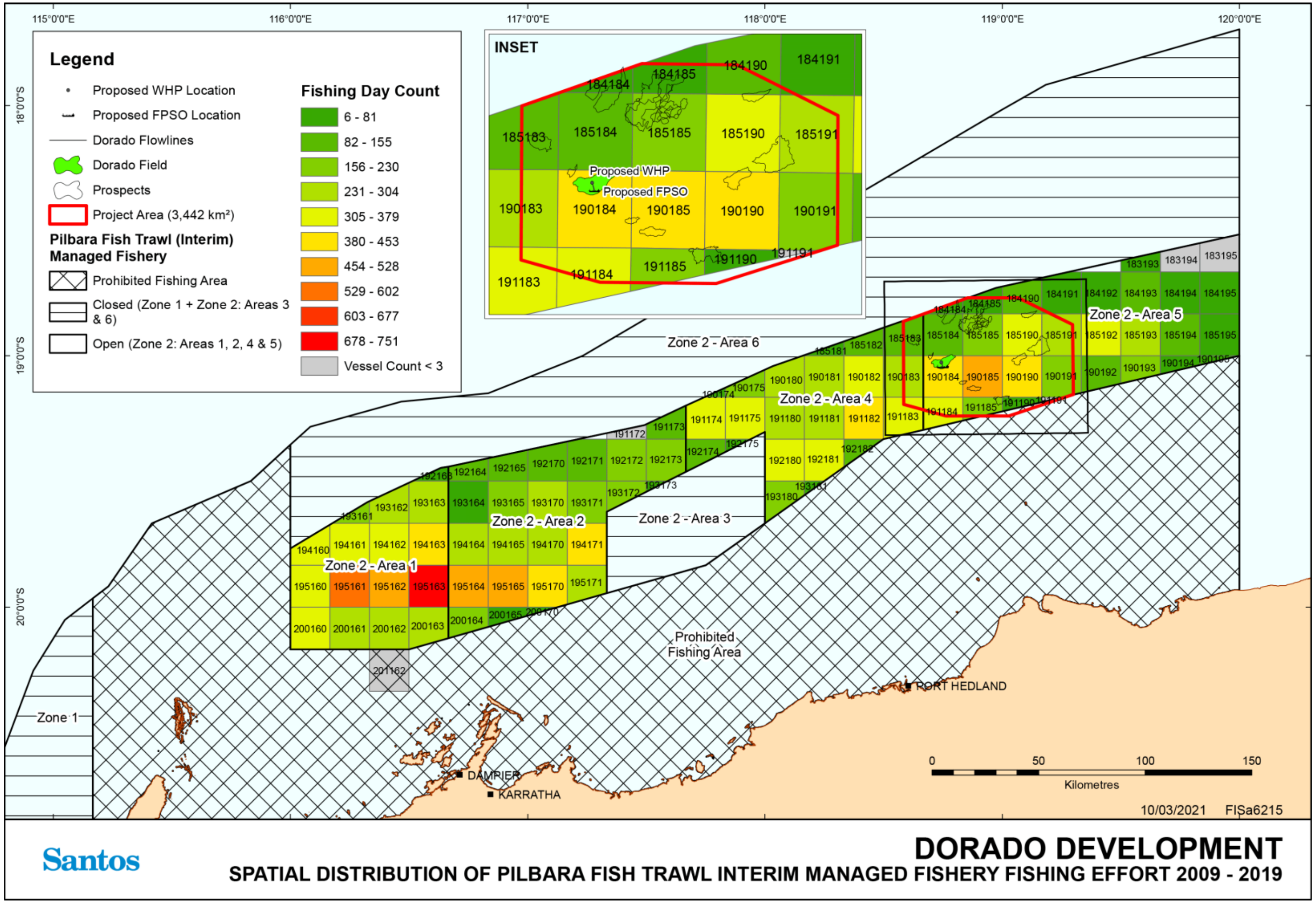


Figure 7-31: Pilbara fish trawl (interim) managed fishery fishing effort

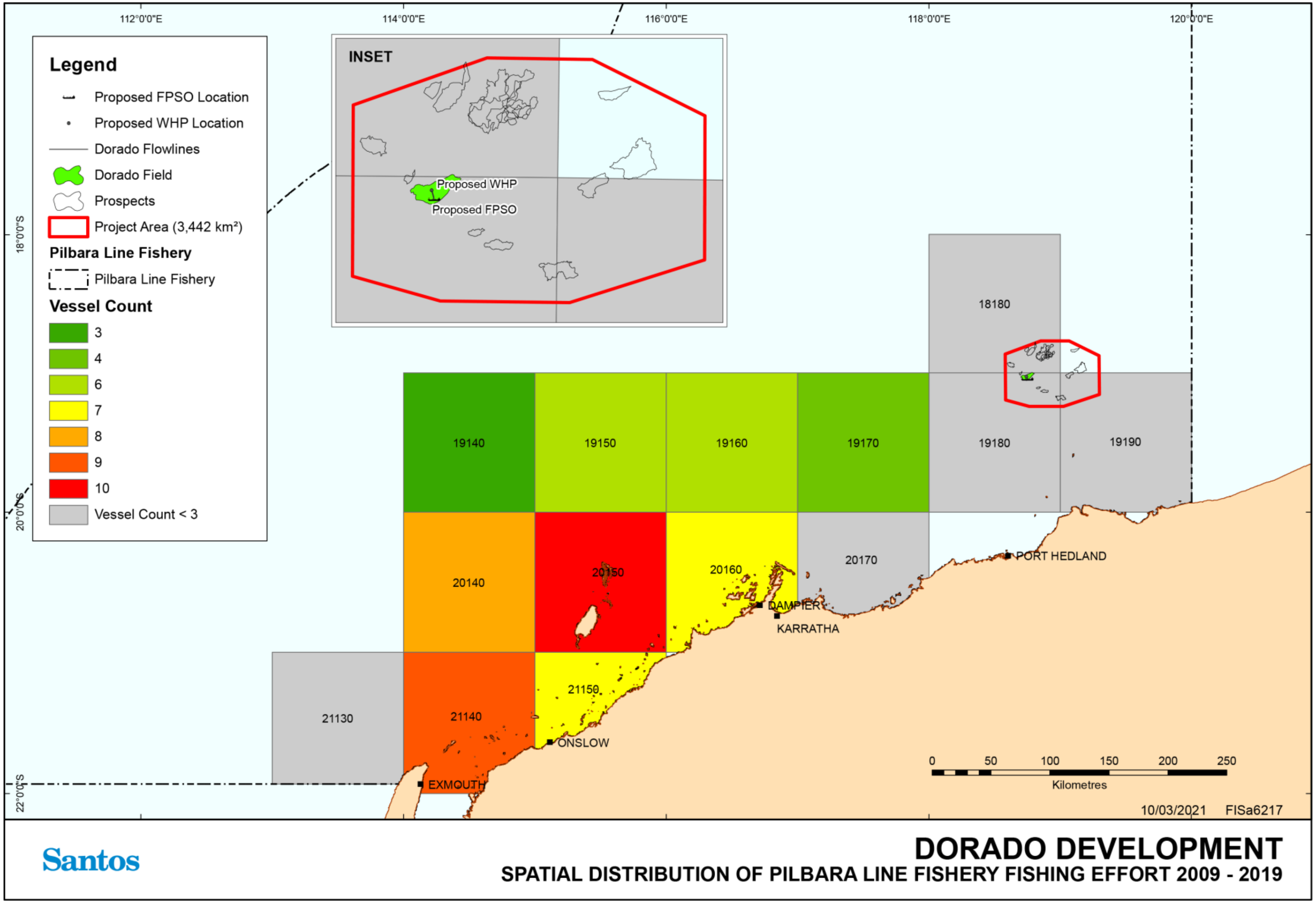


Figure 7-32: Pilbara line fishery fishing effort

Pilbara Trap Managed Fishery

FishCube data for the Pilbara Trap Managed Fishery was available in 60 nm CAES block resolution (**Figure 7-33**). The data indicated four Pilbara Trap Managed Fishery fishing blocks overlap the Project Area, and only one block overlaps the PSZ around the WHP, flowlines and FPSO. The data indicates fishing effort in the overlapping blocks was periodic (in different months) in all years 2014 to 2018. FishCube data suggests less than three vessels have operated in fishing blocks overlapping the Project Area between 2014 to 2018.

Participants in the fishery may experience operational inconvenience or area displacement from the PSZs, however, the loss of fishing ground due to the PSZ is a small area for the life of Dorado Phase 1 and is not expected to result in any notable decline in total catch.

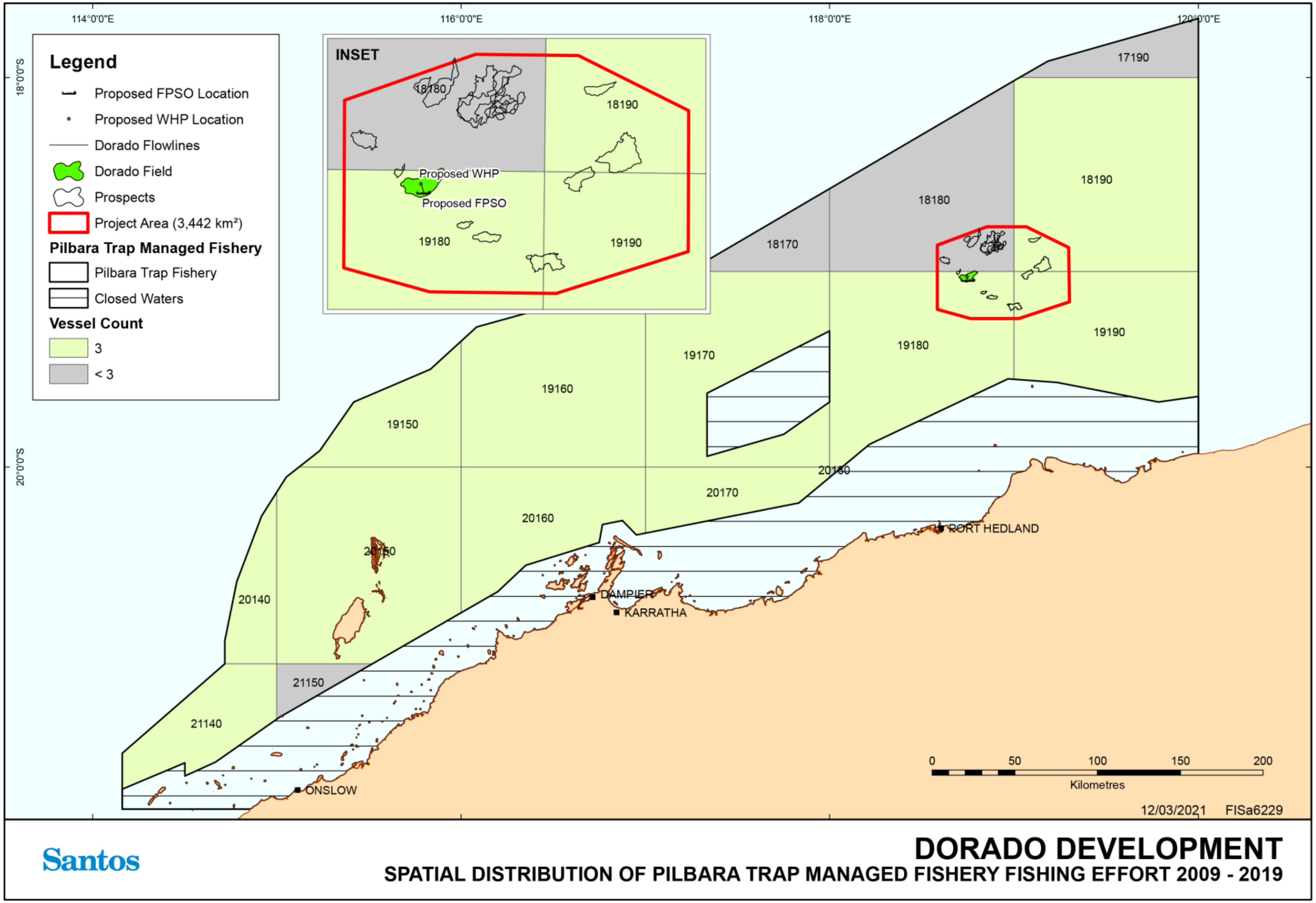


Figure 7-33: Pilbara trap managed fishery fishing effort

7.2.8.2.2 Maritime Industry

Shipping

The proposed Dorado WHP and FPSO locations and associated PSZ is located between two AMSA fairways leading to the port of Port Hedland. Shipping traffic is concentrated in these fairways, with vessel traffic outside the fairway significantly lower than within the fairway (**Section 3.4.6**). These fairways are intended to reduce the risk of collisions in areas of high commercial shipping traffic. Use of the fairways is not mandatory, but is strongly recommended. Shipping traffic data within the Project Area available from AMSA shows that commercial shipping in the Project Area is concentrated within the fairways (**Figure 3-24**).

The proposed PSZ around the WHP, flowlines and FPSO is located beyond the fairways and hence outside the areas of highest vessel traffic. The closest component of the proposed PSZ to either of these fairways is the FPSO, which is located approximately 12 km from the eastern-most fairway in the Project Area. Waters in the Project Area have no restrictions to navigation aside from the recommended fairways (e.g. shallow water, channels, banks etc.) and vessels attempting to avoid the Dorado PSZ will not have any natural restrictions on their ability to manoeuvre around them.

The presence of Dorado Phase 1 may impact shipping activity due to exclusion of vessels from areas designated as a PSZ. Also, the presence of vessels to support the petroleum activities can create navigational hazards that may disturb other marine activities, especially vessels that may have restricted manoeuvrability. Local vessels may have to alter course as a result, increasing journey time and fuel consumption.

The locations of potential future tiebacks have not yet been determined. In the event that a future tieback is located within or near a shipping fairway, there may be potential interactions between commercial shipping and tieback activities. There is therefore a potential for temporary displacement of shipping traffic around the tieback while it is being installed, commissioned, operated and decommissioned.

Petroleum

Santos is the Operator for the petroleum titles that overlap the Project Area. Hence, interactions with other petroleum titleholders as a result of Dorado Phase 1 are not expected to occur. The closest operational oil and gas facility to the Project Area is Woodside's Angel platform, located approximately 231 km west of the WHP.

Telecommunications

The Project Area overlaps the North West Cable System, connecting offshore oil and gas facilities in the Browse, Bonaparte and Carnarvon Basins to onshore locations. There is no proposed activity overlapping the North West Cable System.

7.2.8.3 Summary of Impact Evaluation

A summary of the outcomes of impact evaluation, including adopted control measures and EPOs is provided in **Table 7-60.**

Table 7-60: Summary of impacts, environmental performance outcomes, controls and consequence evaluation of interactions with other users during Dorado Phase 1

EPOs	
EPO16A: No adverse interactions[37] between Santos' activities and other maritime users within the Project Area. **EPO17A**: The installation and drilling operations, production operations and decommissioning activities of the project will be managed in a manner that does not interfere with other marine users within the Project Area to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties of Santos under the Dorado petroleum titles. **EPO18A:** Decommissioning of Dorado facilities in compliance with Section 572 (3) of the Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2009.	
Receptor	**Impact**
Commercial fisheries	Displacement of other users from exclusion zones within the Project Area during installation/drilling operations. Exclusion of other users from within the gazetted PSZ during production operations
Maritime industry	
Controls	
CM39: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the Navigation Act 2012 and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM40**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM41**: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM42**: Should potential future tiebacks overlap within AMSA fairways Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way. **CM43**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM44**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM45**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development facilities.	

[37] Whether an interaction constitutes an adverse interaction will be determined on a case by case basis. Examples of adverse interactions may include substantiated complaints by other marine users to Santos or NOPSEMA, vessel collisions, or damage to unsupervised fishing equipment (e.g. traps). Interactions where other users have not taken reasonable measures to avoid the interaction (e.g. third-party vessel not adhering to standard maritime requirements or ignoring advice provided during consultation) are not considered to be adverse.

CM46: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3)of the OPGGS Act. **CM47:** Exclusion zones/petroleum safety zones will be limited to the minimum area necessary to exercise rights and perform duties under project specific petroleum titles. **CM48:** Residual impacts to other marine users of the environment are managed to not interfere with their rights.		
Consequence	Minor (B/ II) Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.	

7.2.8.4 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by interactions with other users as a result of Dorado Phase 1 against receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-61** and **Table 7-62** respectively. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case consequence for interactions with other users was evaluated as minor (**Table 7-60**). This consequence is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from interactions with other users are acceptable.

Table 7-61: Demonstration of acceptability for interactions with other users

Acceptability Criteria	Justification
To meet the principles of ESD	The environmental impacts of interactions with other users as a result of Dorado Phase 1 are consistent with the principles of ESD based on the following points: + Dorado Phase 1 does not impinge upon the rights of other parties to access environmental resources (e.g. commercial fishers) in an unacceptable way. + The precautionary principle has been applied, and analysis undertaken (e.g. analysis of FishCube data and consultation with fishers) where knowledge gaps were identified. This knowledge has been applied during the evaluation of environmental impacts and risks.
Internal Context	The management of interactions with other users is aligned with Santos' policies and standards. The worst-case consequence is minor, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of potential impacts and risks. Santos has been working with commercial fishing interests for over 7 years as of 2022, as part of ongoing exploration activities in the Bedout basin. Relatively small scale exclusion zones associated with short term exploration drilling and seismic activities have not impacted the economic viability for commercial fishers given the large fishing area.

Acceptability Criteria	Justification
MNES	The following material published in relation to threatened and migratory species within and adjacent to the Project Area identify anthropogenic disturbance as a threat: **Conservation Advice:** + Conservation Advice Red Knot (Calidris canutus) (Threatened Species Scientific Committee 2016f) **Recovery Plans:** Wildlife Conservation Plan for Seabirds (DCCEEW 2022). This recovery plan identifies anthropogenic disturbance as a threat to seabirds. Action 2D: ensure all areas of important habitat for seabirds are considered in the development assessment process; and 2E: manage the effects of anthropogenic disturbance to seabird breeding and roosting areas, are relevant to Dorado Phase 1. Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australian 2015c). This recovery plan identifies anthropogenic disturbance as a threat to migratory shorebirds. Action 3C: Investigate the significance of cumulative impacts on migratory shorebird habitat and populations in Australia; and Action 3F: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes, are relevant to Dorado Phase 1. The guidelines, conservation advice and recovery plans for MNES that may occur within the Project Area do not identify interactions with other users as a threat. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify anthropogenic disturbance as a key threat or have explicit relevant objectives or management actions related to anthropogenic disturbance. The objectives and actions of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The environmental impacts of interactions with other users as a result of Dorado Phase 1 will not result in impacts to the environmental values of the Commonwealth marine environment. None of the significant impact criteria for the Commonwealth marine environment (**Table 4-2**) will be met as a result of interactions with other users.
Other Relevant Requirements	Management of the environmental impacts of interactions with other users as a result of Dorado Phase 1 are consistent with relevant legislative requirements, including compliance with international maritime conventions and Australian legislation, including: + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + International Convention for the Safety of Life at Sea 1974, and + International Regulations for Preventing Collisions at Sea 1972. + *Navigation Act 2012*, including: - Marine Order 21 (Safety and emergency arrangements) - Marine Order 30 (Prevention of Collisions), and - Marine Order 71 (Masters and Deck Officers).

Acceptability Criteria	Justification
	Santos will not interfere with the rights of other marine users to a greater extent than is necessary for the reasonable exercise of Dorado Phase 1, as per Section 280 of the OPGGS Act as committed in **EPO17A** and **CM47**. NOPSEMA administer the petroleum safety zones in accordance with Chapter 6, Part6.6 of the OPGGS Act (NOPSEMA Safety Zone Assessments Policy Document No N-04800-PL0886 A196273, April 2020. Key features of NOPSEMA's approach to administration include: + only considering safety zones for petroleum or greenhouse gas wells, structures or items of equipment as provided for in Sections 616 and 617 of the OPGGS Act + formal processes incorporating decision making criteria and timeframes; + a requirement for applicants to demonstrate effective consultation with parties which may be directly impacted + a mechanism for interested parties to be informed of notices being gazetted.

Table 7-62: Demonstration of acceptability of interactions with other users against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Justification
RSAL19: No negative impacts to the economic viability of the commercial fish resources. **RSAL20**: Short-term displacement of commercial fishing activities from exclusion zones within the Project Area (excluding the gazetted PSZ) during installation/drilling operations is acceptable. **RSAL21**: Long-term exclusion (up to 20 years) of commercial fishing activities from the gazetted PSZ during production operations is acceptable.	The Australian Government actively promotes investment in offshore oil and gas exploration through its annual release of petroleum exploration acreage. Through Santos' Dorado petroleum permits (WA-437-P and WA-438-P), it has obligations to explore, appraise and if commercially viable, develop the associated petroleum resources. Australian Commonwealth waters is home to many different commercial, recreational and marine conservation endeavours; and inevitably there will be instances where there are multiple parties with differing objectives competing for access to Commonwealth waters resources. Installation, operations and decommissioning of petroleum facilities requires a level of exclusion from other marine users for the mutual safety of both petroleum operators and other marine users. As a result, some level of impact, by way of exclusion, to other marine users is unavoidable in order to safely develop petroleum resources. While Operators such as Santos take all reasonable and practicable measures through consultation with relevant stakeholders to avoid or minimise impacts to other marine users, some level of residual impact is mostly unavoidable. These residual impacts are the by-product of necessary trade-offs between the needs of multiple users with access to a common resource. Facilities installation and drilling operations outside of the gazetted petroleum safety zone will be of short-term duration, in the order of several weeks/months approximately. Therefore impacts from displacement of
RSAL26: Short-term displacement of commercial shipping within the Project Area (excluding the gazetted PSZ) during installation/drilling operations is acceptable. **RSAL27**: Long-term (up to 20 years) exclusion of commercial shipping from the gazetted safety zone during production operations is acceptable.	

	commercial fishing activities due to exclusion zones during installation/drilling operations will be limited. The areas where commercial fishing activity will be excluded from longer term production operations through the gazetted petroleum safety zone (PSZ) represents a very small portion of the managed fishery areas. The Dorado facilities PSZ (3.25 km^2) represents 0.01% of the total Dorado Project area that would be excluded from commercial fishing during production operations. If the PSZ is extended to future tieback facilities the area excluded from commercial fishing would still represent less than 1% of the total Project area. With respect to specific managed fisheries, even though the Project area overlaps with ~15% of the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF), the area excluded from fishing activity due to the PSZ (3.25 km^2) during production operations represents ~0.004% of the total area of the PFTIMF (86,000km^2). Under NOPSEMA's administration of PSZs as provided for in Chapter 6, Part 6.6 of the OPGGS Act, NOPSEMA will assess future applications for Dorado Phase 1 petroleum safety zones, both for the Dorado field and future tiebacks. The assessment of applications by NOPSEMA will consider parties directly impacted by the nominated PSZ and related stakeholder consultation undertaken by the applicant. The assessment of the PSZ application by NOPSEMA, and eventual gazettal will inform the acceptable level of impact to commercial fishers. Santos considers the displacement of other defence activities from relatively small areas of the open ocean environment in Dorado Phase 1 area to be acceptable. There are no designated defence areas within the Project Area. Fishing effort within the Project Area has historically been relatively low, with the exception of the Pilbara Fish Trawl Interim Managed Fishery. Santos considers that in developing Dorado it is not expected that the PFTIMF will experience any notable decline in total catch. While there is considerable shipping activity in the Project Area, the WHP and FPSO PSZs are not located within any existing shipping fairway. The open sea environment does not impose any constraints on the ability for vessels to manoeuvre to avoid components of Dorado Phase 1 that may present an obstacle to navigation. The controls Santos will implement will provide other maritime users with sufficient information to be aware of, and avoid, petroleum activities within Dorado Phase 1.

7.2.9 Physical Presence – Seabed Disturbance

7.2.9.1 Description of the Event

Seabed disturbance is expected throughout the life cycle of Dorado Phase 1, and will include changes to the existing physical (e.g. substrate) and biological (e.g. habitat) values of the environment. Seabed disturbance may result in short-term (e.g. temporary changes in water quality due to sediment resuspension) and/or long-term impacts (e.g. modification of benthic habitats). Installation, decommissioning and other works, such as anchoring, associated with the following components of the project will disturb areas of the seabed:

+ Dorado WHP jacket;
+ FPSO anchor spread;
+ MODUs spud cans;
+ drilling and installation of wells;
+ subsea system (e.g. flowlines and subsea connectors); and
+ potential future facilities associated with tieback infrastructure (e.g. wells, flowlines, and WHP).

A temporary stand-by mooring may also be installed within the Project Area to assist reducing vessels diesel consumption.

During the operation stage, seabed disturbance associated with activities such as maintenance, repair and well intervention are expected. To develop potential future tiebacks semi-submersible MODU and some vessels, which may be held in place using anchors, may be required. The exact anchoring configuration will vary for each MODU/ vessel. Physical disturbance of the seabed will mainly be associated with laying and retrieval of anchors and chains. Decommissioning activities such as well plug and abandonment, removal of subsea infrastructure, disconnection of the Dorado WHP will also generate seabed disturbances.

Section 572 of the OPGGS Act obliges titleholders to remove property when it is neither used nor to be used on connection with current or future operations. The policy of the Department of Industry, Science, Energy and Resources is that "*complete removal of infrastructure is the 'base case'*" for decommissioning of offshore petroleum infrastructure (Department of Industry, Science, Energy and Resources 2020). As such, Dorado Phase 1 infrastructure above the seabed will be designed such that removal of the infrastructure is feasible for decommissioning.

The policy of the Department of Industry, Science, Energy and Resources (2020) and NOPSEMA's draft policy *Section 572 Maintenance and removal of property* (2020b) may permit Santos to make alternative arrangements for decommissioning, provided that the alternative arrangements (e.g. decommissioning of infrastructure in situ) are expected to have equal or better environmental outcomes when compared to the removal of property. The existing regulatory frameworks requires Santos to demonstrate that alternative arrangements will result in equal or better environmental outcomes when compared to the removal of property in an EP. NOPSEMA's acceptance of an EP proposing alternative arrangements would mean that the removal of obligations under Section 572 of the OPPGS Act are met with respect to the property covered under the EP.

If decommissioning *in situ* is undertaken, the modification of the seabed by the decommissioned infrastructure will effectively be long term (i.e. many decades to potentially hundreds of years) before reverting to a condition consistent with the natural seabed. The infrastructure remaining *in situ* will provide artificial hard substrates for colonisation of biota.

The expected approximate area extent of direct seabed disturbance is provided in **Table 7-63.**

Table 7-63: Proposed Direct Seabed Disturbance

Facility/Infrastructure	Approximate Area of Disturbance (km^2)
Initial Development	
Jack-up MODU – spudcans	0.00078 km^2 (780 m^2)
Wells (based on cumulative cuttings discharges of 12 wells)	9.81 km^2
Dorado WHP jacket (including additional footprint which may be required for activities such as mattressing, wet parking, and surveying), noting this is within the well cuttings footprint.	0.01 km^2 (10,000 m^2)
Vessel anchoring (including mooring)	0.00013 km^2 (130 m^2)
FPSO – moorings	2 km^2
Subsea system – flowlines, umbilicals, and manifolds (including stabilisation support, if required), based on 250m wide corridor within which the subsystem is laid.	0.55 km^2
Total Area Foundation Dorado Development	**Approximately 12.4 km^2**
Future Tiebacks	
Semi-submersible MODU – anchoring and mooring lines, assumed as this has a larger footprint than a jackup rig.	0.01 km^2 (10,000 m^2)
Wells (Assume that a maximum number of wells from a single slot would be 12 wells)	9.81 km^2
Vessel anchoring (including mooring)	0.00013 km^2 (130 m^2)
WHP (including additional footprint which may be required for activities such as mattressing, wet parking, and surveying)	0.01 km^2 (10,000 m^2) (per WHP or subsea facilities, such as a subsea gathering system)
Subsea system – flowlines, umbilicals, and manifolds (including stabilisation support, if required) based on 250 m wide corridor within which the subsystem is laid, and a maximum distance of up to 50 km (to identified prospects within the Project Area) from the Dorado WHP/ FPSO to tieback to (refer **Figure 0-2**).	12.5 km^2 – maximum expected area per tieback.
Total Area Per Future Tieback	**Approximately 22.3 km^2**
Total Area Dorado Phase 1 (Foundation Development and 2 future tiebacks)	**Approximately 57.1 km^2**

Indirect seabed disturbance may also occur as a result of localised sedimentation and turbidity generated from activities associated with the controlled placement of infrastructure on the seabed, such as the Dorado WHP jacket and FPSO anchoring piles and the flowlines. In addition, the planned discharge of drilling cuttings and fluids during development drilling will also result in a temporary increase in sedimentation and turbidity levels.

The seabed disturbance from the discharge of drilling fluids and cuttings has been assessed in **Section 7.2.1** and is not considered here. The physical presence of components of Dorado Phase 1 may also result in interactions with other users. The potential impacts of interactions with other users are assessed in **Section 7.2.8**.

7.2.9.2 Details of Environmental Impacts and Risks

A summary of the analysis of the environmental impact of the seabed disturbance as a result of Dorado Phase 1 is provided in this section. **Table 7-64** identifies the potentially impacted receptors as a result of seabed disturbance within the Project Area.

Seabed disturbance from the installation, operation and decommissioning stages and activities (**Section 7.2.9.1**) required for Dorado Phase 1 is not expected to result in impacts to marine mammals, reptiles or birds. These fauna species are typically associated with surface waters and the water column. Observations of the benthic habitats within the Project Area made during environmental surveys (**Attachment 2**) do not suggest these habitats are important foraging areas for marine mammals, reptiles or birds.

Table 7-64: Receptors potentially impacted by seabed disturbance

Description of the Impact	Receptor Categories
Temporary, localised decrease in water quality during installation and removal of components on the seabed. Localised, minor modification of sediment characteristics, such as geological origin and particle size distribution. Localised, minor modification of benthic habitats from the introduction of artificial hard substrates. Increased fish diversity and abundance due to modification of benthic habitats.	Water Quality – **Section 7.2.9.2.1** Sediment Quality – **Section 7.2.9.2.2** Benthic Habitats – **Section 7.2.9.2.3** Fishes – **Section 7.2.9.2.4**

7.2.9.2.1 Water Quality

Impacts to water quality from seabed disturbance of Dorado Phase 1 are likely to be restricted to localised turbidity during deployment and recovery of MODU spud cans, project vessel and semi-submersible MODU anchors and moorings, installation of WHP piles, FPSO piles and mooring lines, and installation of the subsea system. Decommissioning activities are expected to have the same level of suspended sediments and increased turbidity levels as during installation.

Sediment plumes from these activities may result in a slight and temporary decrease in water quality due to increase in suspended sediments close to the point of disturbance. The amount of sediment suspended will be proportional to the size of the structure and the speed (i.e. force) it is placed on the seabed. Considering the placement of infrastructure and equipment will be controlled (i.e. slow descent) it is expected that only small amounts of sediment will be resuspended. Sediments in the Project Area are characterised by a relatively high portion of sand-sized particles (Attachment 4), which are likely to settle out within close proximity of the disturbed area. These localised, temporary impacts to water quality will not impact biodiversity or ecological integrity within the Project Area and are considered to be of minor consequence.

7.2.9.2.2 Sediment Quality

Impacts to sediment quality from physical presence during all stages of Dorado Phase 1 are not expected to be significant. Changes to physical properties, such as particle size distribution and geological origin, are not expected to occur beyond the immediate footprint of the components presented in **Table 7-63**. Fouling organisms growing on subsea components may alter the geological origin of sediments, with an increase in biogenic sediments as a result of these organisms (e.g. increases in sediment derived from mollusc shells). These changes will not impact biodiversity or ecological integrity within the Project Area.

7.2.9.2.3 Benthic Habitats

The majority of the Project Area consists of habitats composed largely of sediments characterised by sand-sized particles with varying portions of mud- and gravel-sized particles (typically more than 90% cover) but it also contains some areas of exposed limestone pavement, which may host filter feeders such as whip corals, gorgonians and sponges (**Attachment 2**). These habitats are widely represented throughout the NWS and are not considered to be sensitive benthic habitats. No known seabed features (e.g. shoals, banks) or habitats of high environmental value were identified within the Project Area.

The Project Area deliberately avoids overlapping the Ancient Coastline at 125 m water depth KEF (**Figure 6-2**). The water depths within the Project Area (approximately 70 to 120 m) are not expected to support benthic primary producer habitats due to insufficient light penetration to the seabed, although macroalgae and corals are expected to grow as biofouling on the WHP structure in the shallower photic zone.

The seabed at the WHP location is characterised by featureless soft sediment habitat, while the FPSO location is represented by soft sediment interspersed by hard substrate habitat. The presence of the subsea infrastructure will create hard substrate habitat layered over any soft sediments and will have a localised disturbance to hard substrate communities present.

The presence of the WHP, DTM moorings, subsea infrastructure and any materials placed on the seabed (such as flowlines or gravel bags) will provide hard substrate for the settlement of marine organisms that would not otherwise be successful in colonising the area. Over time the colonisation of this infrastructure can lead to the development of a 'fouling' community, which subsequently provides predator or prey refuges, foraging resources for pelagic fish species and artificial reefs potentially supporting fish aggregations (Forteath et al. 1982; Gallaway et al. 1981; Todd et al. 2016).

The decommissioning concept for Dorado Phase 1 has not been determined and all facilities will be designed, installed and operated so that they can be removed. A potential decommissioning concept is to partially retain end-of-life facilities, such as the Dorado WHP jacket, in the sea following the removal of all hazardous materials. This may occur in situ, or they may be moved to another location. These end-of-life facilities can then provide hard substrate for the development of artificial reefs.

The majority of the Project Area consists of habitats composed largely by sediments characterised by sand-sized particles with varying portions of mud- and gravel-sized particles (typically more than 90% cover) but it also contains some areas of exposed limestone pavement, which may host filter feeders such as whip corals, gorgonians and sponges (**Attachment 2**). These habitats are widely represented throughout the NWS and are not considered to be sensitive benthic habitats. No known seabed features (e.g. shoals, banks) of habitats of high environmental value were identified within the Project Area. The seabed at the foundation WHP location is characterised by featureless soft sediment habitat, while the FPSO location is represented by soft sediment interspersed by hard substrate habitat.

As described in **Section 3.3.1.1**, the Project Area overlaps three ecotypes that are all widely represented adjacent to or outside of the Project Area, and across the northwest shelf. Based on the location of the potential prospects and the foundation Dorado development, it is expected at a worse case that up to 45km^2 in area may be impacted within a single ecotype (refer **Figure 3-9**). This is conservatively based on assuming 2 future tiebacks may occur within the same ecotype, including the subsea system (flowline corridor). Given that Ecotype 3 covers 916km^2 of the Project Area, and this is the smallest (Ecotype 4 covers 991 km^2 and Ecotype 5 covers 1532km^2) less than 5% of the ecotype within the Project Area will be impacted, and excludes that this ecotype (as well as Ecotype 4 and 5) extends well beyond the Project Area.

The Project Area deliberately avoids directly overlapping the Ancient Coastline at 125 m water depth KEF (**Figure 6-2**), so there is no direct seabed disturbance associated with infrastructure.

The water depths within the Project Area (70 to 120 m) are not expected to support benthic primary producer habitats due to insufficient light penetration to the seabed, although macroalgae and corals are expected to grow as biofouling on the WHP structure in the shallow photic zone.

The potential living in situ of infrastructures will continue to provide hard substrate for the settlement of marine organisms that would not otherwise be successful in colonising the area. Over time the colonisation of this infrastructure can lead to the development of a 'fouling' community, which subsequently provides predator or prey refuges, foraging resources for pelagic fish species and artificial reefs potentially supporting fish aggregations (Forteath et al. 1982; Gallaway et al. 1981; Todd et al. 2016). These reefs may have a range of environmental benefits, such as increased abundance and diversity of marine biota, increased commercially and recreationally important fish stocks (Boswell et al. 2010).

Potentially living in situ infrastructures after decommissioning is expected to provide additional habitats to benthic communities, and the resulting potential environmental impacts were assessed as minor.

Overall, the potential impacts to benthic habitats from seabed disturbance will be limited to modification of bare sediment and hard substrate habitats within the Project Area, which will be replaced by artificial hard substrate. This is expected to modify existing habitats, with the structures likely to develop fouling communities over time. The potential impact to alteration of the benthic environment from flowline activities is expected to be highly localised (i.e. within the footprint of the components). There will be no installation of infrastructure or equipment in sensitive benthic habitats, such as KEFs. On this basis, impacts to benthic habitats from seabed disturbance will be minor.

7.2.9.2.4 Fishes

The modification to benthic habitats from the presence of components of Dorado Phase 1 has the potential to modify fish assemblages within the immediate vicinity of the components. These components will provide relatively complex artificial structural habitat in an area otherwise devoid of complex seabed features. This will likely result in an increase in the diversity and abundance of fish assemblage in the immediate vicinity of the project infrastructure. This effect has been observed in response to the establishment of pipelines and platforms, although the increase in diversity and abundance is generally localised to the infrastructure (Bond et al. 2018; Boswell et al. 2010; McLean et al. 2017).

Santos considers that the changes in fish assemblages in response to the modification of benthic habitats is likely to have a net environmental benefit due to the increases in fish abundance and diversity, particularly within the proposed exclusion zones that will exclude fishing activity.

The Project Area overlaps a foraging BIA for whale sharks shown in the National Conservation Values Atlas (DAWE 2020). Whale sharks are known to congregate around geomorphic features to feed, such as reefs and islands, with steeply sloping seabeds in close proximity to relatively deep water (Copping et al. 2018). These congregations are particularly notable during periods of high food availability, such as coral spawning off Ningaloo Reef and land crab spawning off Christmas Island (Meekan et al. 2009; Taylor and Pearce 1999). The Project Area does not exhibit the geomorphic or biological features associated with whale shark aggregations (**Section 3.3.1.1**), and tagging studies of whale sharks congregating off Ningaloo Reef do not show whale sharks congregating near or migrating through the Project Area (Meekan and Radford 2010; Wilson et al. 2006) (**Figure 3-17**).

The *Conservation advice* Rhincodon typus *whale shark* (Threatened Species Scientific Committee 2015d) identifies the following conservation action: "*Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath (as set out in the Conservation Values Atlas, DotE, 2014).*" Based on the lack of features consistent with known whale shark congregations and the lack of episodic high food availability (e.g. mass spawning of invertebrates) within the Project Area, whale sharks are very unlikely to aggregate in the Project Area. Tagging studies do not show whale sharks migrating through the Project Area, or along the mid and inner continental shelf in the region, with all whale sharks tagged at Ningaloo Reef travelling away from the congregation area in water considerably deeper than the Project Area (Meekan and Radford 2010; Wilson et al. 2006). As such, Dorado Phase 1 is consistent with the conservation advice, as the Development does not occur in areas close to marine features likely to correlate with whale shark aggregations, nor does it overlap the northward migration route along the 200 m isobath, as the water depth in the deepest part of the Project Area is approximately 118 m.

7.2.9.2.5 Fisheries

End-of-life facilities retained in the sea have the potential to modify fish assemblages within the immediate vicinity of the facilities. These facilities will provide relatively complex artificial structural habitat in an area otherwise devoid of complex seabed features. This will likely result in an increase in the diversity and abundance of fish assemblage in the immediate vicinity of the project infrastructure. This may result in benefits to fishers such as enhanced recruitment of targeted species and increased catches. These effects may be localised to the location of the facility (Boswell et al. 2010).

Santos considers that the changes in fish assemblages in response to the modification of benthic habitats will have a net environmental benefit due to the increases in fish abundance and diversity, and assessed the resulting potential environmental impacts as minor.

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7.2.9.3 Summary of Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-65.**

Table 7-65: Summary of impacts, EPOs, controls and consequence evaluation of seabed disturbance during Dorado Phase 1

<table>
<tr><th colspan="3">EPOs</th></tr>
<tr><td colspan="3">EPO2B: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area.
EPO18B: Decommissioning of Dorado facilities in compliance with Section 572 (3) of the Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2009.
EPO3F: No mortality or significant[38] impacts to EPBC act listed threatened, and migratory species as a result of Dorado Phase 1 seabed disturbance.
EPO19A: Impacts to sediment quality and water quality as a result of seabed disturbance from Dorado Phase 1 restricted to a1 km radius from Dorado facilities.</td></tr>
<tr><th>Receptor</th><th colspan="2">Impact</th></tr>
<tr><td>Water Quality</td><td colspan="2">Temporary, localised decrease in water quality during installation and removal of components on the seabed.</td></tr>
<tr><td>Sediment Quality</td><td colspan="2">Localised, minor modification of sediment characteristics, such as geological origin and particle size distribution.</td></tr>
<tr><td>Benthic Habitats</td><td colspan="2">Localised, minor modification of benthic habitats from the introduction of artificial hard substrates.</td></tr>
<tr><td>Fishes</td><td colspan="2">Localised increase in fish diversity and abundance due to modification of benthic habitats.</td></tr>
<tr><td>Fisheries</td><td colspan="2">Potential enhanced recruitment of targeted species and increased catches.</td></tr>
<tr><th colspan="3">Controls</th></tr>
<tr><td colspan="3">CM49: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3) of the OPGGS Act.
CM50: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints.
CM51: Undertake benthic habitat surveys for future tieback locations and proposed subsea infrastructure corridors prior to development to identify and avoid sensitive benthic habitat where practicable within technical and safety constraints.</td></tr>
<tr><th colspan="2">Consequence</th><td>Minor (B/ II)
Detectable but insignificant change to local population, industry or ecosystem factors. Localised effects.</td></tr>
</table>

[38] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

7.2.9.4 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by seabed disturbance as a result of Dorado Phase 1 compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-66** and **Table 7-67**. The method by which these acceptable levels were determined, along with a justification as to why these are considered acceptable, are discussed in **Section 4**.

The worst-case consequence for seabed disturbance was evaluated as minor (**Table 7-65**). This consequence is considered to be acceptable when assessed against the acceptable levels of risk defined in Santos risk matrix **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from seabed disturbance are acceptable.

Table 7-66: Demonstration of acceptability of seabed disturbance

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD.	Management of seabed disturbance from Dorado Phase 1 is consistent with the principles of ESD because: + there is no threat of serious or irreversible environmental damage, + the environmental resources within the Project Area will not be significantly impacted, and + biological diversity and ecological integrity will be maintained.
Internal Context.	The management of seabed disturbance is aligned with Santos' policies and standards. The consequence is minor, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context.	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of potential impacts and risks with respect to vessel collisions with marine fauna.
MNES	The Dorado Phase 1 benthic environment contains no known seabed features (e.g. shoals, banks) or habitats of high environmental value within the Project Area, including no overlap with KEFs. The below conservation advice and recovery plans identify habitat degradation as a threat to threatened species. Impacts to the marine environment from seabed disturbance will be highly localised. The marine environment that may be affected is widely distributed throughout the Project Area and beyond. As such, Santos considers the impacts of seabed disturbance to not be inconsistent with these conservation advice and recovery plans. **Conservation Advice** + Approved conservation advice for *Pristis clavata* (dwarf sawfish) (Threatened Species Scientific Committee 2009), + Approved conservation advice for *Pristis pristis* (largetooth sawfish) (Threatened Species Scientific Committee 2014b), and + Approved conservation advice for green sawfish (Threatened Species Scientific Committee 2008a).

	+ Conservation advice for *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b) + Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee 2015c) **Recovery Plans** Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b) - This recovery plan identifies habitat degradation as a threat to sawfish. Impacts to benthic habitats from the discharge of seabed disturbance will be highly localised within the Project Area. The benthic habitats that may be affected are very widely distributed throughout the Project Area and beyond. The closest Sawfish BIA (for pupping, nursing and foraging) is approximately 87 km from the southern extent of the Project Area. Santos considers the impacts of seabed disturbance to not be inconsistent with the recovery plan. Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a) - This recovery plan identifies habitat modification as a threat to marine turtles. Impacts from seabed disturbance may result in a temporary, localised impact to the benthic environment, which will recover rapidly. Santos considers the impacts of seabed disturbance to not be inconsistent with the recovery plan. Recovery Plan for the White Shark (Carcharodon carcharias) (DSEWPac, 2013b) – This recovery plan identifies habitat modification as a potential threat to White Sharks. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from seabed disturbance may result in a temporary, localised impact to the benthic environment, which will recover rapidly. Santos considers the impacts of seabed disturbance to not be inconsistent with the recovery plan. Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a) – This recovery plan identifies habitat modification as a threat to Blue Whales. The species is highly mobile and transitory in nature and the area impacted is small compared to the amount of habitat available. Impacts from seabed disturbance may result in a temporary, localised impact to the benthic environment, which will recover rapidly. Santos considers the impacts of seabed disturbance to not be inconsistent with the recovery plan. Recovery Plans / Conservation Advice for other species that may occurring the Project Area do not identify habitat degradation as a key threat; or have any explicit relevant objectives or management actions related to habitat degradation.
Other Relevant Requirements	No other relevant requirements

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Table 7-67: Demonstration of acceptability of seabed disturbance against receptor-specific acceptable levels of impact

Acceptability Criteria	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[39] are acceptable. **RSAL4**: Substantial[40] impacts to water quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	The evaluation of impacts from the seabed disturbance show that impacts are likely to be restricted to very localised sediment plumes, and a slight and temporary decrease in water quality could be experienced due to increase in suspended sediment. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity will be maintained beyond 1 km of the disturbance location. Given the widespread nature of the open water environment in the region, the seabed disturbance from Dorado Phase 1 will not result in impacts to water quality that result in a loss of ecological integrity.
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity[38] are acceptable. **RSAL6**: Substantial[39] impacts to sediment quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	The evaluation of impacts from the seabed disturbance show that changes to sediment physical properties, such as particle size distribution and geological origin, are not expected to occur beyond the immediate footprint of the components installed on the seabed. It is also expected that a high level of ecological integrity will be maintained beyond 1 km of the disturbance location. Given the widespread nature of the open water environment in the region, seabed disturbance will not result in impacts to sediment quality that result in a loss of ecological integrity.
RSAL8: No significant[41] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities.	The benthic habitats in the Project Area are widely represented throughout the NWS and are not considered to be sensitive benthic habitats. The potential impacts to benthic habitats are expected to be limited to modification of bare sediment and hard substrate habitats within the Project Area, which will be replaced by artificial hard substrate. These potential impacts have been identified as minor. The Project Area has been designed to avoid potential overlap with any KEFs (such as ancient coastline at 125 m depth contour).
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1	The assessment of impacts from seabed disturbance shows that Dorado Phase 1 may result in an increase in the diversity and abundance of fish assemblage in the immediate vicinity of the project infrastructure. Mortality of or significant impacts to threatened or migratory species is not expected to occur.

[39] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[40] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

[41] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

RSAL14: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	Seabed disturbance has not been identified as a threat in any recovery plans or conservation advice for threatened and migratory species.

7.3 Risk Assessment of Unplanned Events

7.3.1 Accidental Release – Hydrocarbon and Chemical Spills

7.3.1.1 Description of the Event

7.3.1.1.1 Hydrocarbons

There is a risk that unplanned (i.e. accidental) events may occur and result in hydrocarbon spills to the marine environment. Unplanned hydrocarbon releases of Dorado oil, gas, MDO and HFO could unintentionally be released into the marine environment. These unplanned spill events have a very low probability of occurring and are caused by accidental events, vessel collisions (particularly with errant third-party vessels) or emergency conditions (Det Norske Veritas 2011). Activities and facilities associated with Dorado Phase 1 that may result in the unplanned discharge of hydrocarbons to the marine environment are:

+ drilling operations (MODU and vessel operations);
+ installation and commissioning activities (vessel operations);
+ FPSO and WHP operations including:
  - hydrocarbon extraction and processing;
  - intervention drilling (MODU and vessel operations); and
  - oil export (offtake tanker operations); and
+ decommissioning (MODU and vessel operations).

These activities and facilities and their relation to possible hydrocarbon or chemical spills is set out in **Table 7-68**.

To support the environmental risk assessment, Santos considered the worst-case credible spill scenarios associated with each stage of Dorado Phase 1. Santos has identified a Loss of well control as the worst-case type of credible oil release scenario that could potentially occur during the activity. A loss of well control incident may discharge directly to the sea surface or at the seabed, depending on the type of failure that occurs. Each stage of the development may have other spill scenarios (refer to **Table 7-69** and **Table 7-70**) that result in smaller spills than the worst-case credible spills presented in this section. Santos has used a combination of Loss of well control spill scenarios defined as the worst case credible for the Dorado Activity, whereby all other spill scenarios fit within. The combination of these spill scenarios determine the EMBA described in **Section 3.1.1** and associated environmental impacts and risks described in the sections below. The worst-case spill scenarios include:

+ A loss of well control from the Dorado Development (refer to **Table 7-69)**; and
+ A loss of well control from Future Tieback Reservoirs (**Table 7-70)**.

Given that the potential consequences of the other spills are much smaller, they have not been modelled or further assessed for impact in this section.

Table 7-68: Activities and facilities and their relation to possible hydrocarbon or chemical spills

Drilling Operations Dorado Phase 1 involves the drilling, completion, and production from wells. Drilling will take place both before the FPSO arrives on location and then during operations (intervention drilling, infill well drilling, and drilling of potential future tieback wells). The Dorado field drilling campaign has an expected duration of two years, with future wells requiring approximately 40 days to drill and complete each well. **The type of well (production v reinjection) is not relevant to the magnitude of loss of hydrocarbon events and the associated impact assessment. The throughput capacity of the FPSO is the limiting factor for the volume of hydrocarbon that could be released at any one time in a loss of containment event rather than the number of wells or the number of each well-type.**	
Loss of Well Control	Santos has engineering standards to manage loss of well control events to very low levels of impact; however, there is a possibility that a loss of well control may occur during the drilling and operation stages of Dorado Phase 1. Even though the likelihood is very small, a complete loss of well control (a well blowout) has the potential to release significant volumes of condensate into the environment (assuming no mitigation or spill response is implemented), which may result in significant environmental damage. During the Conceptual D&C design phase, consideration was given to the largest credible Worst-Case Discharge (WCD) scenario, and dynamic well kill capabilities across various proposed casing schemes. An alternate case of a 12-1/4" hole section was also modelled and whilst provided a larger WCD volume, confirmed that the well was still able to be killed by a single relief well. Thus, on the basis of a smaller WCD the 8-1/2" hole has been selected for Dorado. Controls and commitments relating to this risk will be discussed in the Well Operations Management Plan (WOMP), and [if relevant] the Environment Plan (EP). Santos has extensive experience with safe and environmentally responsible drilling and reservoir engineering and has a detailed understanding of the Dorado field through seismic surveys and drilling activities. The offshore oil and gas industry has improved environmental performance since the Macondo and Montara events, and Australian regulations require that all environmental risks be managed to a level that is ALARP and acceptable. This is done through NOPSEMA's EP framework (refer **Section 2.2.1.1.2**). All petroleum activities considered in this OPP will be undertaken under an accepted EP that has been submitted and assessed prior to the drilling and completion campaigns. All wells will be drilled and operated in accordance with an accepted well operations management plan, in accordance with the OPGGS Act. The likelihood and potential release volumes of a loss of well event will change during different stages of Dorado Development. Industry statistics from wells using similar controls that will be applied during development drilling of and production from the wells within the scope of this OPP indicate the likelihood of a well blowout from development drilling and completions is much smaller than during production (Det Norske Veritas 2011). This is consistent with well blowout data observations in Australia and similar jurisdictions around the world. Most loss of well control incidents do not result in a worst-case well blowout scenario, and typically release relatively small volumes of hydrocarbons. Whilst the duration of the drilling campaign is 2 years, only a small

	percentage of this time is spent drilling into the reservoir. Once the drilling of the reservoir is completed, tested barriers are in place which significantly reduce the likelihood of a loss of well control. A loss of well containment could result in hydrocarbons released either at the sea surface or at the seabed (summarised in **Table 7-69**). The causes of a surface loss of well containment during drilling are the same as a subsea loss of well containment; however, the reservoir fluids travel up the riser and are released on the MODU instead of at the seabed. This results in the oil spilling to the sea surface instead of within the water column. A surface loss of well containment during production could occur as a result of well interventions (e.g. workover activities) or failure of the topside components of the well (e.g. leak from a Christmas tree valve in event subsea wells are drilled for future tiebacks). As with subsea loss of well containment, surface loss of well containment during production typically releases much smaller volumes of hydrocarbons than releases during drilling activities. Subsea loss of well containment during production is very uncommon, with industry statistics indicating the volumes released by such events are typically much smaller than the volumes released during drilling (ExproSoft 2017). Subsea loss of well containment during production may be caused by external impacts, such as dropped objects. Given that the Dorado WHP wells will be protected by the platform jacket, external impacts to these wells resulting in a loss of well containment is highly unlikely to occur. If the future tieback wells are subsea, they may be more vulnerable to external impacts; however, such an event is also very unlikely to occur. Given that the OPP includes for developing the Dorado reservoir, and also potential future tiebacks (following successful appraisal drilling), Santos has conservatively undertaken the potential environmental impact assessment based on the worst-case credible spill scenario that could occur from a complete well blowout (loss of well control) during the drilling and completion of the production wells in the Dorado reservoir and future tiebacks within the Project Area. The future tieback loss of well control scenario has been described and assessed in the publicly available Bedout Multi-Well Drilling Environment Plan (accepted by NOPSEMA), and detailed in **Section 7.3.1.1.4**. This loss of well control scenario for the Dorado reservoir consists of a 98 day uncontrolled release of 2,031,794m^3 of Dorado oil (20,733m^3 per day). The loss of well control scenario for future tiebacks, based on the current known information for these tiebacks (described in the Bedout Multi-Well Drilling Environment Plan) consists of a 77 day uncontrolled release of 2, 102, 831m^3 of Dorado oil. The duration is based on the credible worst-case time required to control the well (either by capping or drilling of a relief well) and the volume is based on the maximum credible rate of release derived from the proposed well design and reservoir characteristics. While a loss of well control scenario is very unlikely, using the worst-case credible spill from both the Dorado reservoir (appraised) and future tiebacks (not yet appraised) as the basis for the risk assessment provides an environmentally conservative assessment of the potential impacts and risks posed by the Dorado Development. Santos has undertaken numerical modelling to inform the risk assessment (**Section 7.3.1.3**).
Vessel Collision	Drilling activities will require support vessels. It is considered credible that a release of MDO to the marine environment could occur as the result of a collision between the support vessels, between a support vessel and the MODU, or between a passing third-party vessel and the MODU or a support vessel. The

	worst-case environmental incident resulting from a vessel collision is the rupturing of a vessel fuel tank resulting in the release of marine diesel oil (MDO) or marine gas oil (MGO) to the environment. Vessel collision could occur due to factors such as human error, poor navigation, vessel equipment failure or poor weather. A maximum credible spill volume has been determined based on technical guidance provided by AMSA (2015). This guidance states that, for a vessel other than an oil tanker, the maximum credible spill from a collision can be determined from the volume of the largest single fuel tank. In reviewing the general arrangements and fuel tank capacities of typical vessels likely to be utilised for the drilling activities, the largest single fuel tank capacity identified was no greater than approximately 650 m^3 of MDO for support vessels. This scenario would result in a spill of diesel at the sea surface.
Refuelling Spill	During drilling operations there will be a requirement to refuel the MODU. There is potential for a loss of MDO during these activities as a result of fuel hose failure or rupture, coupling failure or tank overfilling where fuel bunkering would need to be stopped manually. Fuel released prior to the cessation of pumping, as well as fuel remaining in the transfer line, may escape to the environment. The AMSA (2015) Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities provides guidance for calculating a maximum credible spill volume for a refuelling spill. The guidance provided by AMSA (2015) for a refuelling spill under continuous supervision is considered appropriate given refuelling will be constantly supervised. The maximum credible spill volume during refuelling is calculated as: transfer rate (150 m^3/hr) x 15 minutes of flow giving a volume of 37.5 m^3. The detection time of 15 minutes is seen as conservative but applicable following failure of multiple barriers followed by manual detection and isolation of the fuel supply.
Installation and Commissioning Activities Dorado Phase 1 will require support from a range of vessels. The types of vessels, and the durations of the activities varies with each stage. Installation and decommissioning will be peak periods of vessel activity, and vessels will include heavy-lift and construction vessels. Installation and commissioning activities have an expected duration of up to six months.	
Vessel Collision	The nature and scale of the environmental risks and impacts from a loss of fuel from a vessel varies significantly based on the vessel type and activities. Typically, construction and installation vessels store relatively large quantities of fuel. Often these types of vessels are fuelled using relatively heavy fuel oils, such as heavy fuel oil (HFO). Smaller vessels, such as support vessels, typically store smaller quantities of fuel and are fuelled using lighter fuel oils, such as MDO, which are less persistent in the environment than heavier fuel oils. Santos determined that the worst-case credible release from a loss of containment of fuel would be the loss of HFO. This worst-case credible spill scenario is considered to provide an environmentally conservative assessment of the potential impacts and risks from a loss of containment of fuel from a vessel. Dorado Phase 1 will require the use of a range of project vessels ranging from relatively small (e.g. platform support vessels) to very large (e.g. heavy-lift vessels). A high-energy collision with a project vessel was identified as potentially resulting in the loss of containment of vessel fuel. Such collisions are very uncommon and typically of insufficient force to cause damage to a fuel tank. Most project vessels are expected to use MDO as the fuel source for the main engines. This type of fuel spreads on the sea surface when spilled and readily evaporates and disperses. Some very large vessels (e.g. heavy-lift vessels) may use HFO or intermediate fuel oil (IFO). These fuels are much more viscous and if spilled persist in the environment for much longer than MDO.

	The worst-case credible spill from a vessel collision was determined to be an instantaneous release of the entire contents (1,800 m^3) of HFO at the surface (summarised in **Table 7-69**). This is based on the complete loss of the largest single HFO tank that could credibly be onboard a vessel involved in Dorado Phase 1. This volume is very conservative; the largest single HFO or IFO tanks onboard vessels undertaking Dorado Phase 1 are expected to be considerably smaller. Santos has undertaken numerical modelling to inform the risk assessment (**Section 7.3.1.5**).
Refuelling Spill	While it is unlikely, there may be a requirement for refuelling of support vessels within the operational area during Installation and Commissioning activities, refer refuelling spill under Drilling Operations (above) for further detail. There will be no HFO refuelling activities.
Operations and Maintenance The commissioning and operations stages will involve relatively low vessel activity when compared with the installation and commissioning stage of Dorado Phase 1. The Operations stage for Dorado Development is 20 years, with short maintenance campaigns throughout this period.	
Drilling	Given that drilling of infill wells, well intervention activities or drilling of future tieback wells (dependant on exploration results) will be undertaken during the Operations and Maintenance stage of the project, the worst-case credible spill scenario associated with this stage will be a complete well blowout during development drilling either infill drilling the Dorado reservoir, or development drilling of a future tieback (as per the development drilling stage). Potential loss of well control events associated with drilling future tiebacks are described the publicly available Bedout Multi-Well Drilling Environment Plan and detailed in **Section 7.3.1.1.4**. The duration for the infill wells and tieback drilling campaigns will depend on the number of wells drilled. Each development well is estimated to take approximately 40 days to complete. Refer Drilling Operations above for further information.
Cargo Offtake	Spills may occur during the transfer of oil from the FPSO to an offtake tanker (summarised in **Table 7-69**). This scenario assumes the loss of the entire contents of the transfer hose. Cargo transfers will always take place within controlled circumstances (e.g. within weather limits and under the supervision of trained crew). Spills during transfer operations may occur due to partial or total failure of a bulk transfer hose or fittings during transfer.
Vessel Collision	The FPSO will store large quantities of Dorado oil, up to 650,000 barrels. The Dorado FPSO will process and store the well liquids before transfer to an offtake tanker. This will result in large volumes of processed oil being stored in the cargo tanks of the FPSO. A loss of containment from an FPSO cargo tank may result in processed oil being released to the marine environment. The worst-case scenario of a loss of oil from a cargo tank is the complete loss of a single tank (summarised in **Table 7-69**). The complete loss of a full cargo tank is incredibly unlikely and would only occur as a result of a catastrophic failure of the FPSO's structure.
Loss of pipeline integrity	A loss of containment of the flowline between the FPSO and the WHP, or from future tiebacks to the WHP or FPSO, may result in the release of hydrocarbons to the marine environment (summarised in **Table 7-69**). Flowline loss events can range from a 'pinhole' leaks (e.g. due to degradation) through to complete rupture of the flowline (e.g. due to significant mechanical impacts such as a semi-submersible MODU anchor being dragged over the flowline). The loss of a significant volume of hydrocarbons from a flowline would

	trigger alerts on the FPSO and result in the control valves on the WHP being closed. These valves are always closed when the FPSO is not on location.
Refuelling Spill	While it is unlikely, there may be a requirement for refuelling of support vessels within the operational area during Operations, refer refuelling spill under Drilling Operations (above) for further detail.

7.3.1.1.2 Chemicals

A range of process and non-process chemicals will routinely be transferred to, and stored on, vessels and facilities undertaking Dorado Phase 1. Chemicals may also be transferred via the umbilical from the FPSO to the WHP during operations for use in wells and the subsea system. The volumes of chemicals may vary throughout Dorado Phase 1, but will be substantially smaller than the hydrocarbon inventories on the FPSO. The quantities of chemicals stored and used during Dorado Phase 1 will generally be limited to those required to meet operational needs.

All chemicals will be subject to Santos' chemical selection process, which requires chemicals to pose the lowest environmental risk while meeting technical requirements. Chemical storage areas will typically be set up in cabinets or bunded storage areas to contain any releases to deck from transportable containers (e.g. intermediate bulk containers, barrels, drums, pails etc.).

The quantities of chemicals stored and used during Dorado Phase 1 will generally be limited to those required to meet operational needs. Indicative chemical inventories onboard the FPSO are provided below:

+ demulsifier – 25 m^3
+ de-oiler/water polisher – 3 m^3
+ biocide – 5 m^3
+ scale inhibitor – 5 m^3
+ wax inhibitor – 10 m^3 (space only)
+ antifoam – 15 m^3
+ corrosion inhibitor – 36 m^3
+ methanol – 35 m^3
+ asphaltene inhibitor – 25 m^3

Relatively small accidental releases may occur during the transfer, storage and use of chemicals (less than 5m^3).

Non-process chemicals, such as cleaning chemicals, are typically stored on the FPSO, vessels and MODUs in much smaller volumes (usually less than 200 L). Spills of these chemicals onboard the FPSO, vessels or the MODU will typically be captured by the drainage systems and not be released to the environment. If they were to be accidentally released to the environment, the credible spill volumes are less than 200 L.

The impacts from accidental chemical spills are expected to be similar to those of from a spill of a similar volume of hydrocarbons. These impacts may include a reduction in water quality and acute toxic effects on marine biota. The credible volumes of chemicals that may accidentally be spilled are much smaller than the worst-case credible hydrocarbon spill described below. As such, the assessment of environmental impacts and risks for the worst-case hydrocarbon spills is considered to encompass any potential impacts and risks from an accidental chemical spill. Hence, the impacts and risks from an accidental chemical spill have not been considered separately from those of a hydrocarbon spill.

7.3.1.1.3 Summary of Worst-Case Credible Hydrocarbon Spill Scenarios Dorado Development

A total of six worst-case hydrocarbon spill scenarios that could occur were identified and modelled based on the activities that will be undertaken during Dorado Phase 1. These worst-case spills are summarised in **Table 7-69**. The methods used to determine these worst-case spills were consistent with guidance provided by AMSA (2015).

These hydrocarbon spill scenarios do not encompass all possible spills; rather, these worst-case spills are based on the maximum volume of hydrocarbons that could credibly be spilled in a given event during Dorado Phase 1 activities including drilling, construction and installation, operations and decommissioning. These scenarios make no allowance for any spill prevention, control, containment or clean-up measures (i.e. the scenarios are entirely unmitigated) and are considered conservative and worst case. Industry experience shows that worst-case spills are extremely rare, and only occur as the result of a catastrophic failure or event. Incidental spills, such as refuelling spills, small spills on vessel decks and so on have not been modelled, as the volumes of such spills are typically very small and of negligible environmental consequence. Industry experience shows that hydrocarbon spills are uncommon events and typically involve much smaller volumes than those shown in **Table 7-69.**

Based on the spill modelling results (**Attachment 8**), this section presents the impact assessment based on 4 of the modelled scenarios, being both a subsea and surface loss of well control event (Caley crude), loss of containment of HFO from support vessels mobilised for the installation campaign, and a loss of containment of the FPSO cargo tank (Caley crude). These scenarios represent the greatest potential environment impacts associated with unplanned hydrocarbon and chemical spills.

Both the worst-case scenario of subsea loss of well containment and a worst-case scenario of surface loss of well containment are presented. While the spill duration, hydrocarbon type and release volume for both scenarios were similar, the fate of the spilled hydrocarbon differed considerably between these scenarios. The subsea scenario has a much greater potential for spilled oil to become entrained within the water column, which can slow the weathering of the oil compared to a surface release. A subsea release may also have a greater amount of oil in the dissolved and entrained phases when compared to a surface release.

The spill location for the hydrocarbon spill scenarios assessed in this section are based on the foundation Dorado facilities (the WHP and FPSO) and the potential future tiebacks. The release from the tieback scenarios have been assessed based on the NOPSEMA accepted Bedout Multi-Well Drilling Environment Plan. This plan assesses the drilling of exploration and appraisal wells within the Bedout Basin, which the Project Area overlaps. The location selected for the tieback scenario LOWC modelling was the Apus-1 exploration well location as it is the closest of the two proposed exploration wells to the receptors of Bedout Island and the Australian mainland. Of the wells assessed by Santos for this activity, the worst-case discharge rates during a LOWC incident are predicted to occur at the Pavo-1 well. Despite this, Santos has defined a LOWC event at the Apus-1 well to represent the worst-case scenario in terms of potential environmental impacts[42]. Given that the future tiebacks if progressed are up to approximately 50km from the WHP, and that a key determining factor in the EMBA size definition for hydrocarbon spills is the reservoir characteristics,

[42] The higher Pavo-1 flow rate was applied to the Apus-1 release location.

rather than the location of the spill, the EMBA for a loss of well control event at any future tiebacks would not be significantly different to that presented in the following sections.

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Table 7-69: Summary of worst-case hydrocarbon spill scenarios for Dorado Development

Phase of Activity or Duration	Description	Modelled	Modelled Scenario Number (Attachment 8)	Location	Hydrocarbon Type	Maximum Flow Rate (m^3/day)	Total Volume Released (m^3)	Release Duration	Release Depth (m)
Drilling or well intervention	Subsea loss of well control	Yes	Scenario 1	WHP	Caley crude	Approx. 20,733*	2,031,794	98 days**	91 (seabed)
	Surface loss of well control	Yes	Scenario 2	WHP	Caley Crude	Approx. 20,733*	2,031,794	98 days **	Surface
	Surface spill from support vessel collision	Not modelled based on the spill volume and nature of hydrocarbon		WHP	MDO/ MGO	N/A (instantaneous)	650	Instantaneous	Surface
	Surface spill from refuelling	Not modelled based on the spill volume and nature of hydrocarbon		WHP	MDO/ MGO	150 m^3/hr	37.5	15 minutes	Surface
Construction/ Installation	Surface spill from construction vessel collision	Yes	Scenario 5	WHP/ FPSO/ flowlines	HFO	N/A (instantaneous)	1,800	Instantaneous	Surface
	Surface spill from support vessel collision	Not modelled based on the spill volume and nature of hydrocarbon		WHP/ FPSO/ flowlines	MDO/ MGO	Instantaneous	650	Instantaneous	Surface
	Surface spill from refuelling	Not modelled based on the spill volume and nature of hydrocarbon		WHP/ FPSO/ flowlines	MDO/ MGO	150 m^3 /hr	37.5	15 minutes	Surface

Phase of Activity or Duration	Description	Modelled	Modelled Scenario Number (Attachment 8)	Location	Hydrocarbon Type	Maximum Flow Rate (m^3/day)	Total Volume Released (m^3)	Release Duration	Release Depth (m)
Operations/ Maintenance	Subsea loss of flowline control	Yes	Scenario 3	Flowlines between WHP and FPSO	Caley crude	N/A (instantaneous)	1,080	1 hour	91 (seabed)
	Surface spill during cargo offtake	Yes	Scenario 4	FPSO	Caley Crude	N/A (instantaneous)	225	Instantaneous	Surface
	Surface spill from FPSO loss of structural integrity	Yes	Scenario 6	FPSO	Caley Crude	N/A (instantaneous)	10,108	Instantaneous	Surface
	Surface spill from FPSO loss of integrity diesel storage tanks	Not modelled based on the spill volume and nature of hydrocarbon		FPSO	MDO/ MGO	N/A (instantaneous)	3,000	Instantaneous	Surface
	Surface spill from refuelling	Not modelled based on the spill volume and nature of hydrocarbon		FPSO	MDO/ MGO	150 m^3 /hr	37.5	15 minutes	Surface

* Modelled as a decreasing discharge rate over time

**The duration of this scenario (98 days) was based on the time estimated to drill a relief well, which is considered to be the worst-case scenario for bringing a subsea loss of well containment under control. This duration is based on a range of factors, such as MODU availability, formation depth and drilling rates.

7.3.1.1.4 Summary of Worst-Case Credible Hydrocarbon Spill Scenarios Future Tieback Reservoirs

Should exploration and appraisal activities of prospects within the Project Area be successful and development of the reservoirs commercially viable, the drilling of the future tieback wells will likely be undertaken during the Operations phase of the project. To be conservative Santos has included the assessment of the worst-case credible spill scenarios associated with this phase based on currently described loss of well control scenarios presented in the Bedout Multi-Well Drilling Environment Plan which assesses for the proposed appraisal drilling activities within the Dorado Project Area **(Table 7-70**) – Apus-1 well location being the most representative.

The impact assessment presented in the OPP is based on the spill modelling results presented in the Bedout Multi-Well Drilling Environment Plan and summarised in **Section 7.3.1.5** for 2 of the modelled scenarios (subsea and surface loss of well control event of Caley crude at the Apus-1 location which is within the Dorado Project Area and therefore the most relevant). These scenarios represent the largest potential environment impacts associated with a potential hydrocarbon release in the event that future tiebacks are drilled and connected back to the Dorado WHP and FPSO.

Both the worst-case credible scenario of subsea loss of well containment and a worst-case scenario of surface loss of well containment are presented. While the spill duration, hydrocarbon type and release volume for both scenarios were similar, the fate of the spilled hydrocarbon differed between these scenarios. The subsea scenario has a much greater potential for spilled oil to become entrained within the water column, which can slow the weathering of the oil compared to a surface release. A subsea release may also have a greater amount of oil in the dissolved and entrained phases when compared to a surface release, while the surface release resulted in more accumulated hydrocarbons on surrounding shorelines.

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Table 7-70: Summary of worst-case hydrocarbon spill scenarios for future tieback reservoirs

Phase of Activity/ Duration	Description	Modelled	Location	Hydrocarbon Type	Total Volume Released (m^3)	Release Duration	Release Depth (m)
Drilling future tieback reservoirs	Subsea loss of well control	Yes	50 km from WHP	Caley crude	1, 745, 986	77 days	99 (seabed)
	Surface loss of well control	Yes	50 km from WHP	Caley Crude	1, 746, 355	77 days	Surface

7.3.1.2 Hydrocarbon Characteristics

This section describes the characteristics of the Caley Crude oil and Heavy Fuel Oil which are the 2 hydrocarbons in the modelled worst case spill scenarios.

7.3.1.2.1 Caley Crude Oil

Of the crudes produced from the Dorado reservoir (Archer Formation), the Caley Crude is expected to be the most persistent oil produced by Dorado Phase 1 and will constitute the majority of the oil produced from the Dorado reservoir. On this basis, the Caley crude has been adopted as the proxy for Dorado oil and properties of Caley Crude have been used for the modelling of hydrocarbon spill scenarios associated with Dorado oil. The Caley crude is also considered a representative analogue for future tiebacks based on the reservoir properties, geochemistry and pressures of the surrounding fields inferred from the seismic data interpretation and the Bedout basin geology. The prospects identified for exploration target the Archer Formation, which is the formation within which the Dorado Reservoir is located.

The crude is characterised by a low viscosity and is considered a Group II light persistent oil, as per the grouping classification presented by AMSA (2015). If spilt on the sea surface, the crude would rapidly spread and thin out resulting in a large surface area of hydrocarbon available for evaporation. The volatile component of Group II oils tend to dissipate through evaporation within a few hours (International Tanker Owners Pollution Federation 2011b). Based upon the Caley crude assay (boiling point range in **Table 7-71**), up to 48% of the hydrocarbon would evaporate over the first few hours or day, with up to 67% evaporated after a few days when on the sea surface. Fifteen percent of the crude is considered persistent, which would eventually breakdown due to the decay. When on the surface Caley crude may also become entrained into the water column in the presence of moderate winds (above 10 knots) and in turn breaking waves, however, it would resurface under calm conditions (less than 10 knots). An indicative weathering plot of a surface release of Caley crude oil is provided as **Figure 7-34**.

Table 7-71: Characteristics of Caley crude

Oil Name			Caley Crude
Initial density (g/cm^3) (15°C)			0.773
Viscosity (cP) (20°C)			1.45
Wax content (whole oil)			9%
Wax Content (residual oil fraction)			29%
Pour-point for the residual oil fraction			more than 45 °C
Persistence	Component	Boiling Point (°C)	% of Whole Oil
Non-persistent	Volatiles (%)	less than 180 (C4 to C10)	48.0
	Semi-volatiles (%)	180 to 265 (C11 to C15)	19.0
	Low Volatility (%)	265 to 380 (C16 to C20)	18.0
Persistent	Residual (%)	more than 380 (more than C20)	15.0

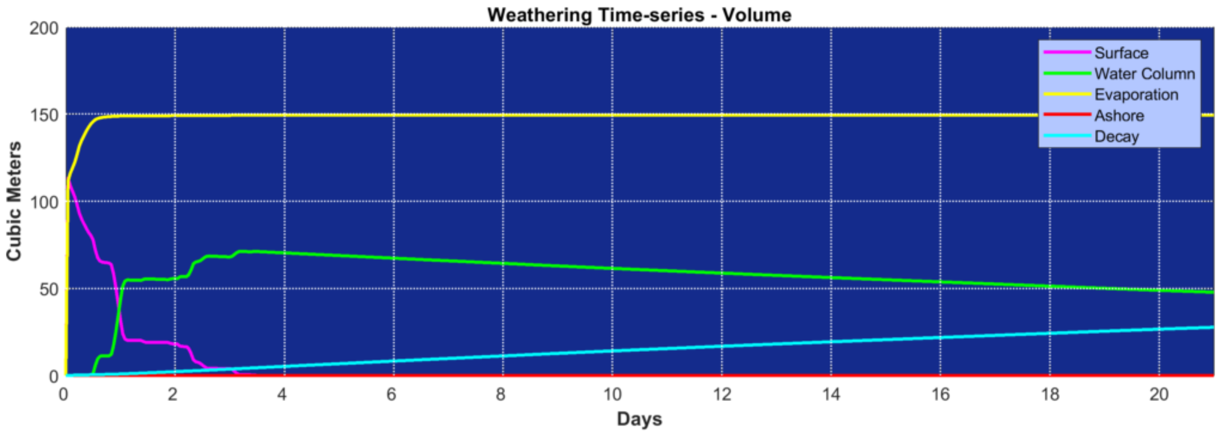

Figure 7-34: Predicted weathering and fates graph for the single spill trajectory from an indicative surface spill scenario of Caley crude oil (loss of containment during cargo offtake)

7.3.1.2.2 Heavy Fuel Oil

HFO is comprised of a high percentage of persistent components (82.8%), which will not evaporate. When spilt at sea the HFO will initially remain as a liquid as sea surface temperatures above its pour point during all seasons. The volatile components (1%) are immediately lost via evaporation and the physical properties will change quickly as the lighter more fluid components evaporate and disperse by the action of wind and waves (**Table 7-72**). The residual component (approximately 83%) is expected to become semi-solid to solid at ambient temperatures and is susceptible to decay overtime (**Figure 7-35**).

The toxic potential of weathered HFO is low in comparison to other crudes, MDO and condensates as weathered oil is insoluble, and the bioavailable portion of the oil is soon lost through evaporation. Solid residues can persist in the marine environment for extended periods and its longevity is dependent on its unique physio-chemical properties.

Table 7-72: Characteristics of heavy fuel oil (Attachment 8)

Oil Name			HFO
Initial density (g/cm³) (15°C) **API Gravity**			0.9749 12.3
Viscosity (cP) (25°C)			3,180
Persistence	**Component**	**Boiling Point (°C)**	**% of Whole Oil**
NON-PERSISTENT	**Volatiles (%)**	**less than 180 (C4 to C10)**	1.0
	Semi-volatiles (%)	**180 to 265 (C11 to C15)**	4.9
	Low Volatility (%)	**265 to 380 (C16 to C20)**	11.3
PERSISTENT	**Residual (%)**	**more than 380 (more than C20)**	82.8

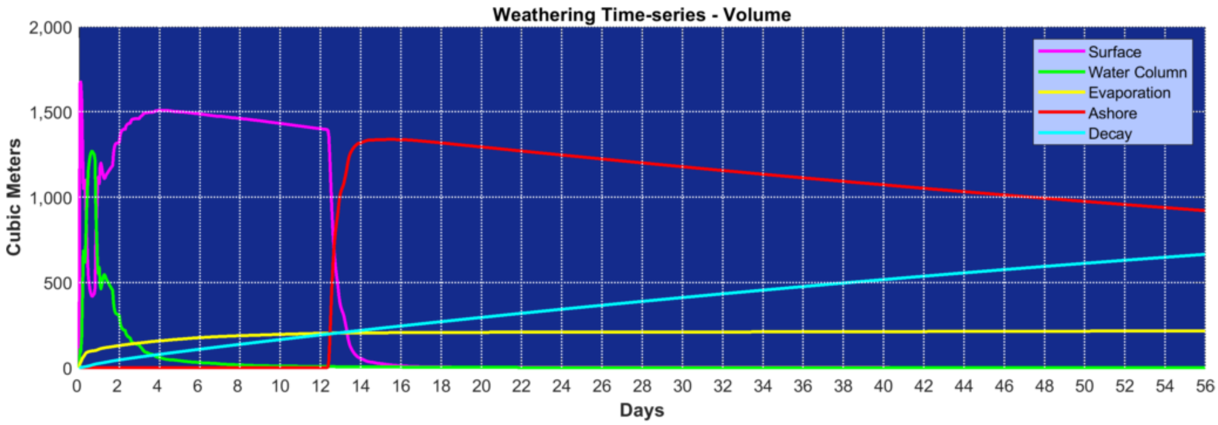

Figure 7-35: Predicted weathering and fates graph for the single spill trajectory from an indicative surface spill scenario of heavy fuel oil (loss of containment due to vessel collision).

7.3.1.3 Overview of Hydrocarbon Spill Modelling

Stochastic and deterministic modelling was undertaken to predict the potential environmental impacts for the worst-case credible scenarios for the Dorado development and future reservoir tieback drilling based on proposed exploration and appraisal drilling described in Bedout Multi-Well Drilling Environment Plan. The difference between these types of modelling approaches, and the results they yield, is important to understand when interpreting tabulated and visually displayed modelling results and applying them to an environmental risk assessment. NOPSEMA has also provided information on the difference between stochastic and deterministic modelling, which may be useful for readers seeking further information (NOPSEMA 2018). Importantly, no single oil spill scenario will result in an area contacted as large as the EMBA. For the Dorado Development and future tieback drilling, the EMBA is the combined boundary of multiple possible spill simulations, done separately for each of the spill scenarios (refer **Section 3.1.1**).

The modelling studies for the Dorado development (**Attachment 8)**, and the future tieback reservoirs (Bedout Multi-Well Drilling Environment Plan) and summarised in **Section 7.3.1.5)** contain details on the modelling methods including hydrocarbon characteristics, metocean modelling, oil spill weathering and subsea plume modelling, summarised in **Table 7-73.**

Table 7-73: Modelling concepts for the worst-case credible scenarios

Modelling Concepts and Parameters	Dorado Development	Future Tie-back Reservoirs
Spill Model	Used SIMAP's spill model which provides detailed predictions of the three-dimensional trajectory, fate, biological effects, and other impacts of spilled oil and fuels.	Used SINTEF's OSCAR (Oil Spill Contingency and Response) model which provides a 3-dimensional dynamic, simulation tool for planning for and response to oil spills.
Spill Model Simulation Structure	The spill modelling simulation structure is designed for development activities associated with Dorado, using a total of 300 deterministic runs to generate stochastic modelling results. The start date of each deterministic modelling run was varied by randomly selecting the start time of each run (stratified within seasons) over a 10-year period hindcast metocean model. This incorporates variability in meteorological and oceanographic conditions into the results set. The results provide a robust, conservative method for identifying environmental values and sensitivities that may be at risk from a spill event. For the Dorado Development, the potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (October to March), (ii) the transitional periods (April and September) and (iii) winter (May to August). Each season is represented by 100 possible spill simulations. This approach assists with identifying the environmental values and sensitivities that would be at potential risk of exposure on a	The spill modelling simulation structure for the future tie-back reservoirs is based on the exploration/ appraisal activities for the Bedout North well (overlaps with the Project Area) as described in the Bedout Multi-Well Drilling Environment Plan. The OSCAR model was configured in stochastic mode to simulate a range of environmental conditions. The start dates for the stochastic simulations were staggered approximately fortnightly across five years of hydrodynamic and wind data. A total of 150 individual 'realisations' made up the full stochastic simulation set for each of the spill scenarios. For each set of 150 stochastic realisations, OSCAR spatially tracked the surface oil, total submerged oil in the water column, dissolved oil and oil on shorelines. The 'total submerged oil' is comprised of dissolved oil and entrained oil (or droplets), and therefore provides a conservative (over) representation of the NOPSEMA (2019) thresholds for entrained oil described in the hydrocarbon impact thresholds section below.

<table>
<tr><th>Modelling Concepts and Parameters</th><th>Dorado Development</th><th>Future Tie-back Reservoirs</th></tr>
<tr><td></td><td>seasonal basis. The oil is tracked as surface oil, accumulated oil on shorelines, dissolved oil and entrained oil.</td><td></td></tr>
<tr><td>Stochastic Modelling Approach</td><td colspan="2">Stochastic Modelling is used to predict the fate of a discharge in the environment when the environmental conditions at the time of discharge are unknown, which is the case for predicting impacts from potential oil spill scenarios. One single modelled spill would not be a reliable method to identify the range of possible environmental values and sensitivities that may be affected. Under different metocean and environmental conditions, each single model run differs in spill direction, extent, and duration (i.e. area of exposure). Stochastic oil spill modelling is created by overlaying a great number of individual computer-simulated hypothetical releases, creating the EMBA.</td></tr>
<tr><td rowspan="2">Deterministic Modelling Approach</td><td colspan="2">Deterministic modelling is used to predict the fate of a discrete hydrocarbon spill event, either in an actual event or for the purposes of informing a risk assessment of the worse case spill from a single event. The outputs of a deterministic model are completely dependent on the inputs. If the inputs to a deterministic model are unchanged, the output will be the same every time the model is run (i.e. there is no variability in the results given the same starting conditions).

If the input parameters are consistent with environmental conditions, and the model is a realistic simulation of environmental processes, outputs from the deterministic model will provide a realistic indication of the fate of the discharge. This makes deterministic models useful where there is a high degree of confidence in the initial conditions, but less useful where the initial conditions are variable, such as dynamic meteorological and oceanographic conditions in the Project Area.</td></tr>
<tr><td>The criteria used to identify the worst-case deterministic model runs for selected Dorado Development worst-case oil spill scenarios include:
(i) largest volume of oil accumulated ashore;
(ii) longest length of shoreline upon which oil was predicted to accumulate; and
(iii) largest area of floating oil above 10 g/m^2 (only considered where no shoreline accumulation was predicted to occur).</td><td>Deterministic modelling was also carried out on the simulation for each of the LOWC scenarios that resulted in the highest shoreline loading, as well as the one LOWC simulation that resulted in the greatest mass of surface oil exceeding a containment and recovery response threshold of 50 g/m^2 to further characterise impacts and to inform response planning.</td></tr>
</table>

7.3.1.3.1 Hydrocarbon Exposure Values

Spilled hydrocarbons can exist as a range of fates, or phases, in the marine environment:

+ floating;
+ entrained;
+ dissolved; and
+ accumulated (i.e. stranded onshore).

Each of these fates, or phases, can interact with the environment in different ways due to different pathways to receptors and impact mechanisms.

A series of impact thresholds for floating, entrained, dissolved and accumulated hydrocarbons were determined. These thresholds were applied to the hydrocarbon spill modelling studies and used to inform the assessment of potential impacts and risks. Thresholds applied to each fate, or phase, of hydrocarbons are described in **Table 7-74**. These thresholds are aligned with guidance from NOPSEMA (NOPSEMA 2019b).

The EMBA is based on stochastic modelling using various impact thresholds (**Table 7-74**) for each hydrocarbon fate providing the basis for determining the EMBA for the environmental risk assessment of hydrocarbon spills. The low thresholds are typically not expected to result in impacts to environmental receptors, but are used for evaluating socio-economic impacts and will also be used in Santos' oil spill response preparations (e.g. operational and scientific monitoring) and response arrangements which will be detailed in the activity specific EPs prepared subsequent to this OPP.

Table 7-74: Oil spill modelling exposure thresholds

Exposure Level	Threshold	Justification
Floating Hydrocarbon (Surface)		
Low	1 g/m^2	A surface oil concentration of 1 g/m^2 (equivalent to a thickness of 0.001 mm or 1 ml of oil per m^2) is visible as a rainbow sheen on the sea surface. Although this is lower than the exposure value for ecological impacts, it may be relevant implementing environmental monitoring of oil spills and hence was used in the modelling studies. This exposure value has been used to define the spatial extent of the environment that might be contacted (EMBA) from floating oil.
Moderate	10 g/m^2	There is a paucity of data on surface oil concentrations with respect to impacts to marine organisms. Hydrocarbon concentrations for registering biological impacts resulting from contact of surface slicks have been estimated by different researchers at about 10 to 25 g/m^2 (French et al. 1999; Koops et al. 2004; National Oceanic and Atmospheric Administration 1996). The impact of surface oil on birds is better understood than on other receptors. This floating hydrocarbon threshold was used to identify environmental values and sensitivities that may be at risk of impacts from floating oil.
High	50 g/m^2	At greater thicknesses the potential for impact of surface oil to wildlife increases.
Shoreline Accumulation		

Exposure Level	Threshold	Justification
Low	10 g/m^2	An accumulated concentration of oil above 10 g/m^2 on shorelines is considered to represent a level of socio-economic effect: e.g. reduction in visual amenity of shorelines. This value has been used in previous studies to represent a low contact value for interpreting shoreline accumulation modelling results (French-McCay et al. 2005).
Moderate	100 g/m^2	A shoreline accumulated concentration of 100 g/m^2 is derived from levels likely to cause adverse impacts to marine or coastal fauna and habitats. Environmental risk assessment studies (French-McCay 2009) report that an oil thickness of 0.1 mm (100 g/m^2) on shorelines is assumed as the lethal exposure value for invertebrates on hard substrates (rocky, artificial or man-made) and sediments (mud, silt, sand or gravel) in intertidal habitats.
High	1000 g/m^2	At greater thicknesses the potential for impact of accumulated oil to shoreline receptors increases. Similar thresholds have been found in studies assessing oil impacts on mangroves (Grant et al. 1993; Suprayogi and Murray 1999).
Dissolved Aromatic Hydrocarbon		
Low	10 ppb	Dissolved hydrocarbons include the monoaromatic hydrocarbons (compounds with a single benzene ring such as BTEX) and PAHs (compounds with multiple benzene rings such as naphthalenes and phenanthrenes). These compounds have a greater bioavailability that other components of oil and are the main contributors to oil toxicity. The toxicity of dissolved hydrocarbons is a function of the concentration and the duration of exposure by sensitive receptors with greater concentration and exposure time causing more sever impacts. Although this is lower than the exposure value at which ecological impacts are expected to occur, it may be relevant implementing environmental monitoring of oil spills and hence was used in the modelling studies.
Moderate	50 ppb	Approximates potential toxic effects, particularly sublethal effects to sensitive species. For most marine organisms, a concentration of between 50 and 400 ppb is considered to be more appropriate for risk evaluation.
High	400 ppb	Approximates toxic effects including lethal effects to sensitive species.
Entrained Hydrocarbon / total submerged hydrocarbon (for future tieback scenario's)[43]		
Low	10 ppb	The 10 ppb exposure value represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in water quality guidelines (Commonwealth of Australia et al. 2018). Although this is lower than the exposure value at which most ecological impacts are expected to

[43] The GHD modelling presents 'total submerged oil', which is comprised of dissolved oil and entrained oil (or droplets), and therefore provides a conservative (over) representation of the NOPSEMA (2019) thresholds for entrained oil.

Exposure Level	Threshold	Justification
		occur, it may be relevant implementing environmental monitoring of oil spills and hence was used in the modelling studies.
Moderate	100 ppb	The 100 ppb exposure value is considered to be representative of sub-lethal impacts to most species and lethal impacts to sensitive species based on toxicity testing. This is considered conservative as toxicity to marine organisms from oil is likely to be driven by the more bioavailable dissolved aromatic fraction, which is typically not differentiated from entrained hydrocarbon in toxicity tests using dissolved hydrocarbons. Given entrained hydrocarbon is expected to have lower toxicity than dissolved aromatics, especially over time periods where these soluble fractions have dissolved from entrained hydrocarbon, the moderate exposure value is considered appropriate for environmental risk assessment.

Source : NOPSEMA (2019b)

7.3.1.4 Spill Risk Assessment Approach

The spill risk assessment approach adopted is based on Santos' Oil Spill Risk Assessment and Response Planning Procedure (QE-91-II-20003).

A consistent risk assessment approach is applied to unplanned hydrocarbon release scenarios. The spill risk assessment approach is based on Santos' Oil Spill Risk Assessment and Response Planning Procedure (QE 91 II-20003). The procedure describes the spill risk assessment process as follows:

- Identify the spatial extent of the EMBA. This has been completed for this OPP as part of the assessment of the existing environment and receptors that are known to occur or may occur within the EMBA are described in **Section 3.1.1**;
- Identify areas of high environmental value (HEV) within the EMBA (HEVs are described in **Section 7.3.1.4.2**); and
- Identify and then risk assess hot spots. Hot spots are effectively a subset of HEVs, and their determination is described in **Section 7.3.1.4.3**.

7.3.1.4.1 Spill environment that may be affected

Defining the EMBA by an oil spill is the first step in oil spill risk and impact assessment. For activities where there is the potential for multiple spill scenarios, the spill scenario, or combination of spill scenarios, resulting in the greatest spatial extent is used to define the overall EMBA for the activity. The EMBA is further described in **Section 3.1.1**. To determine the potential impact to receptors within the EMBA, the moderate threshold EMBA is used to determine them as described in **Section 3.1.1**.

7.3.1.4.2 Areas of high environmental value

Santos has predetermined areas of HEV (**Figure 7-36** and **Figure 7-37**) along the Australian coastline by ranking these areas based on:

- Protected area status – This is used as an indicator of the biodiversity values contained within that area, where a World Heritage Area, RAMSAR Wetland and Marine Protected Area will score higher than areas with no protection assigned; and

- BIAs of listed threatened species – These are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour, such as breeding, feeding, resting or migration. Each one of these within the predefined areas contributes to the score.

Further input to determine areas of HEV included:

- sensitivity of habitats to impact from hydrocarbons in accordance with the guidance document Sensitivity Mapping for Oil Spill Response produced by IPIECA, the International Maritime Organisation and International Association of Oil and Gas Producers;
- sensitivities of receptors with respect to hydrocarbon-impact pathways;
- status of zones within protected areas (IUCN (1A) and sanctuary zones compared to IUCN (VI) and multiple use zones);
- listed species status and predominant habitat (surface versus subsurface); and
- social values, socio-economic and heritage features (such as commercial fishing, recreational fishing, amenities, aquaculture).

Tallied scores for each predefined area along the Western Australian coastline were then ranked from 1 to 5, with an assignment of 1 representing areas of the highest environmental value and those with 5 representing the areas of the lowest environmental value.

7.3.1.4.3 Hot spots

While the entire Moderate Exposure Value EMBA in **Figure 3-1** will be considered during risk assessment, it is best practice to concentrate greatest effort and level of detail on those parts of the EMBA that have the:

- greatest intrinsic environmental value – considered by Santos to be HEV areas ranked 1 to 3;
- highest probability of contact by oil (either floating, entrained or dissolved aromatic); and
- greatest potential concentration or volume of oil arriving at the area.

These areas are termed 'hot spots'. Defining hot spots is typically the first step in undertaking detailed spill risk assessment and spill response planning. Hot spots are a subset of HEV areas that:

- have the highest probability of contact (at least higher than 5%) above the impact assessment exposure value for surface hydrocarbons and shoreline accumulation based on modelling results; and
- receive the greatest concentration or volume of oil, either floating or stranded oil, entrained/total submerged oil or DAH above contact exposure values described in **Section 7.3.1.3.1**.

During a hotspot workshop, an environment consequence assessment is conducted against each of the hotspots identified, using the Santos risk assessment process identified in **Section 7.1**, the outcome of this is provided in **Attachment 8 – 2**.

Additional hotspots may be included through discretion of workshop attendees where they do not strictly meet all of the above criteria. E.g. a HEV ranked 1-3 with <5% probability, or a HEV ranked 4 or 5 with >5% probability, depending on the concentrations and volumes of hydrocarbons presented in the modelling report.

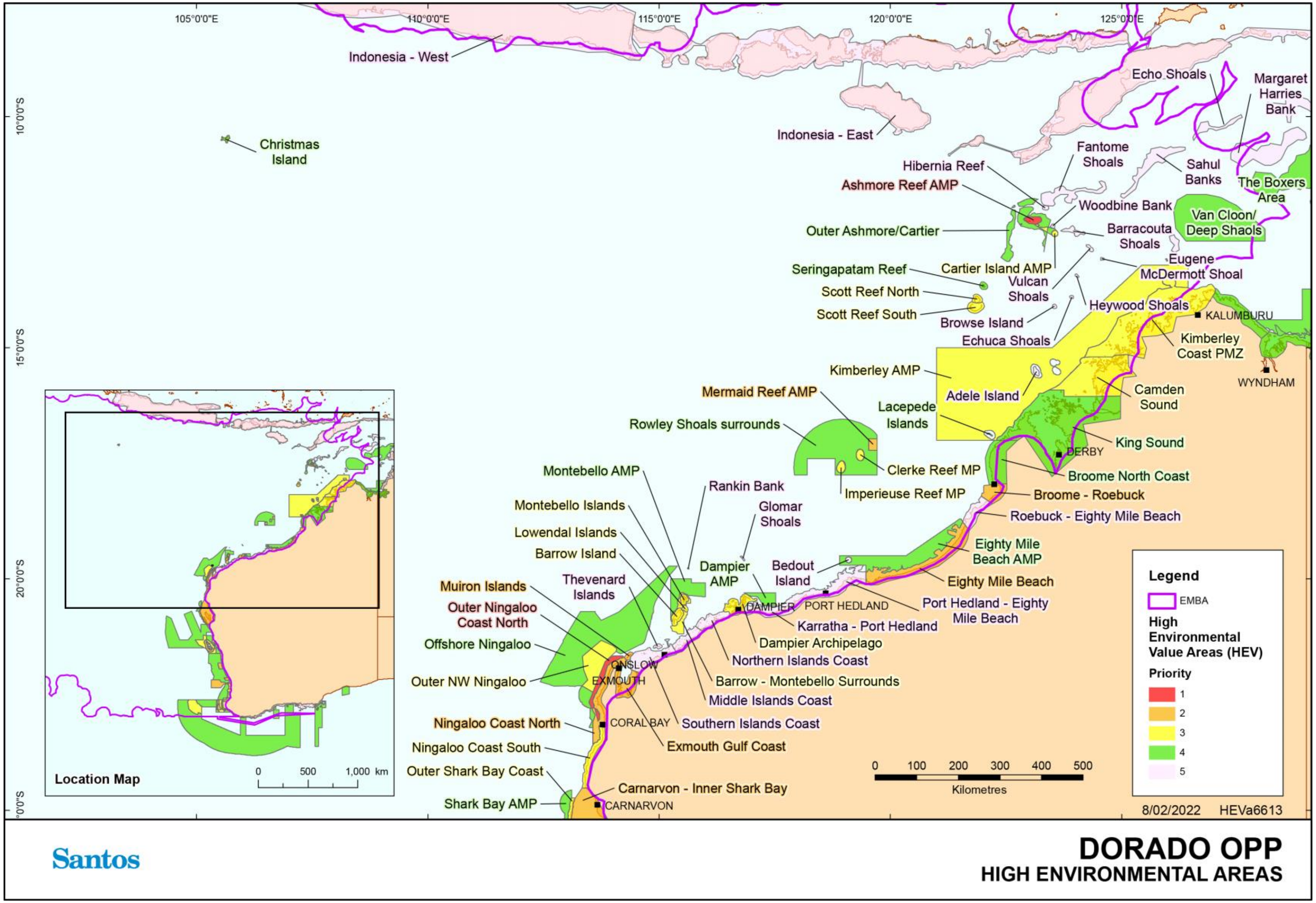

Figure 7-36: High environmental values within the northern part of the environment that may be affected

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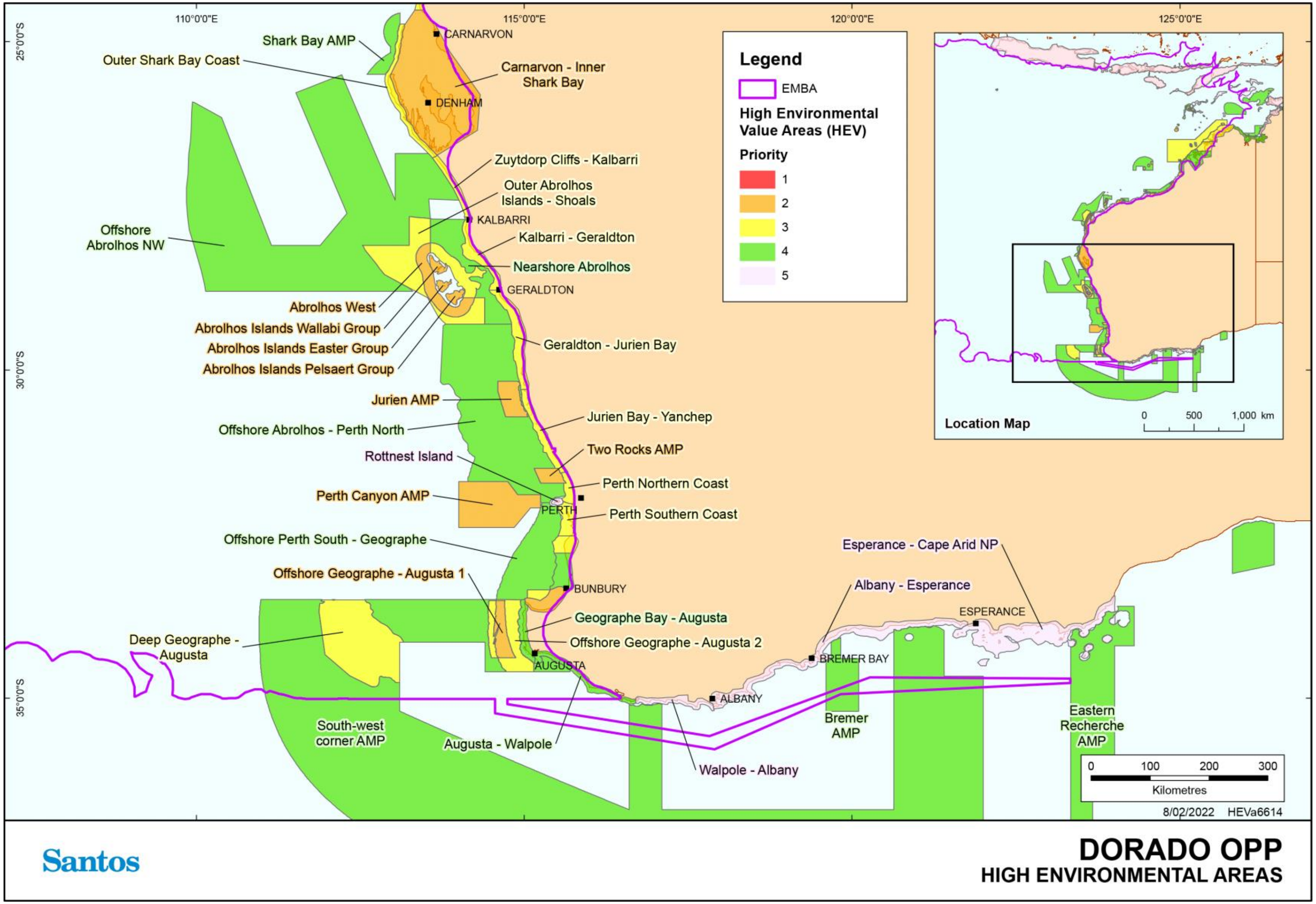

Figure 7-37: High environmental values within the southern part of the environment that may be affected

7.3.1.4.4 Potential Impact Pathways and values and sensitivities

To help inform the hydrocarbon spill risk assessment environmental values and sensitivities and potential impact pathways have been defined (**Table 7-75** and **Table 7-76**). The potential impact pathways consider physical and chemical pathways. Physical pathways include contact from floating oil, accumulated shoreline oil, or entrained oil droplets. Chemical pathways include ingestion, inhalation or contact from any hydrocarbon phase. These are summarised in **Table 7-76** and the information is drawn upon within the hydrocarbon risk assessment for the spill scenario.

Table 7-75: Summary of environmental values and sensitivities potentially contacted by hydrocarbons from worst-case spill scenarios during Dorado Phase 1

Oil Phase	Physical			Biological					Socio-economic				
	Water Quality	Sediment Quality	Air Quality	Communities and Habitats	Fishes	Mammals	Reptiles	Birds	Protected Areas	Fisheries	Heritage	Tourism	Maritime Industry
Floating	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Shoreline Accumulation	-	✓	✓	✓	-	-	✓	✓	✓	-	✓	✓	-
Entrained	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dissolved	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 7-76: Physical and chemical pathways for hydrocarbon exposure and potential impacts to receptors

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Rocky shorelines	Shoreline loading and attachment may result in thin and sporadic coating of hydrocarbon residues. Degree of oil coating is dependent upon the energy of the shoreline area, the type of the rock formation and continual biodegradation of the oil.	Impacts to flora and fauna further described below.	Chemical pathway to fauna and flora via adsorption through cellular membranes and soft tissue, ingestion, irritation/ burning on contact and inhalation.	Impacts to flora and fauna further described below.
Sandy beaches	Shoreline loading and water movement may allow hydrocarbon residue to filter down into sediments, continue to biodegrade on the surface or remobilise into surf zone. Degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the sandy shore and continual weathering of the oil.	Indirect impacts to nesting and foraging habitats for birds and turtles. Direct impacts to infauna.	Chemical pathway to fauna and flora via adsorption through cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation.	Indirect impacts to nesting and foraging habitats for birds and turtles. Direct impacts (mortality) to infauna through toxic effects and smothering.
Intertidal platforms	Shoreline loading and water movement may allow hydrocarbon residue to filter down into sediments or continue to biodegrade on the surface or remobilise into surf zone. Degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the substrate and continual weathering of the oil.	Indirect impacts to foraging habitats for birds and turtles. Direct impacts to infauna.	Chemical pathway to fauna and flora via adsorption through cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation.	Indirect impacts to foraging habitats for birds. Direct impacts (mortality) to infauna through toxic effects and smothering.
Shallow sub-tidal soft sediments	Hydrocarbon residue in the shallow waters adjacent to shorelines may settle to filter down into sediments. Degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the substrate and continual weathering of the oil.	Indirect impacts to foraging habitats for turtles and fish. Direct impacts to infauna.	Adsorption via cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation.	Indirect impacts to foraging habitats for turtles and fish. Direct impacts (mortality) to infauna through toxic effects and smothering.

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Mangroves	Coating of root system reducing air and salt exchange. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the substrate and continual weathering of the oil.	Yellowing of leaves. Defoliation. Increased sensitivity to stressors. Tree death. Reduced growth. Reduced reproductive output. Reduced seed viability.	External contact by oil and adsorption across cellular membranes.	Yellowing of leaves. Defoliation. Increased sensitivity to stressors. Tree death. Reduced growth. Reduced reproductive output. Reduced seed viability. Growth abnormalities.
Seagrasses and macroalgae	Coating of leaves/thalli reducing light availability and gas exchange. Degree of coating depends upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the oil.	Bleaching or blackening of leaves. Defoliation. Reduced growth.	External contact by oil and adsorption across cellular membranes.	Mortality. Bleaching or blackening of leaves. Defoliation. Disease. Reduced growth. Reduced reproductive output. Reduced seed/propagule viability.

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Hard corals (coral reefs)	Coating of polyps, shading resulting in reduction on light availability. Degree of coating is dependent upon the metocean conditions, dilution, if corals are emergent at all and continual weathering of the oil.	Bleaching. Increased mucous production. Reduced growth.	External contact by oil and adsorption across cellular membranes.	Mortality. Cell damage. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities.
Non-coral benthic invertebrates	Coating of adults, eggs and larvae. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the oil.	Mortality. Behavioural disruption. Impaired growth.	Ingestion and inhalation. External contact and adsorption across exposed skin and cellular membranes. Uptake of DAH across cellular membranes. Reduced mobility and capacity for oxygen exchange.	Mortality. Cell damage. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities. Behavioural disruption.

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Sharks, rays and fish	Coating of adults but primarily eggs and larvae – reduced mobility and capacity for oxygen exchange.	Mortality. Oxygen debt. Starvation. Dehydration. Increased predation. Behavioural disruption.	Ingestion. External contact and adsorption across exposed skin and cellular membranes. Uptake of DAH across cellular membranes (for example, gills).	Mortality. Cell damage. Flesh taint. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities. Behavioural disruption.
Birds (seabirds and shorebirds)	Contact possible in the water and onshore. Onshore, the degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the oil.	Feather and skin irritation and damage.	Ingestion (during feeding or preening). External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Growth abnormalities. Behavioural disruption.

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Marine reptiles	Contact possible in the water and onshore. Onshore, the degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the oil.	Behavioural disruption particularly during turtle nesting periods.	Inhalation. Ingestion. External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced hatchling success. Reduced reproductive output. Growth abnormalities. Behavioural disruption.
Marine mammals	Fur damage and matting, reduced mobility and buoyancy (for applicable species). Coating of feeding apparatus in some species (baleen whales).	Behavioural disruption such as deviation from migration pathways and commonly frequented feeding grounds. For smooth skinned marine mammals more susceptible to chemical pathways than physical pathways.	Inhalation. Ingestion. External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Growth abnormalities. Behavioural disruption.
Plankton	Coating of feeding apparatus. Reduced mobility and capacity for oxygen exchange.	Mortality. Behavioural disruption (for example, reduced mobility).	Inhalation. Ingestion. External contact.	Mortality. Impairment of biological activities (for example, feeding, respiration). Reduced mobility.

Receptor	Potential Physical pathway	Potential impacts	Potential Chemical pathway	Potential impacts
Water quality and sediment quality	Presence of hydrocarbon residue in the water, which may filter down to sediments or continue to biodegrade on the surface. Degree of loading in the water column is dependent upon the influence of wave energy and tidal range. Degree of loading in sediments also dependent on movement at the seabed.	Impacts to flora and fauna, as discussed in rows above.	Adsorption via cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation. Impacts to flora and fauna, as discussed in rows above.	Impacts to flora and fauna, as discussed in rows above.
Protected areas	Coating of benthic habitats, shoreline habitats and marine fauna/flora within protected areas as discussed in above.	Mortality, injury or behavioural disruption to marine fauna. Death or impairment of habitats within protected areas. Reduction in the quality of the marine environment within protected areas. Environmental value of protected areas is degraded.	Impacts to flora and fauna, as discussed above.	Mortality, injury or behavioural disruption to marine fauna. Death or impairment of habitats within protected areas. Reduced growth of benthic habitats. Reduction in the quality of the marine environment within protected areas. Environmental value of protected areas is degraded.
Socio-economic environment (fisheries, tourism, shipping, defence, shipwrecks, Indigenous users, oil and gas)	Presence of hydrocarbon residue in the water, which may filter down to sediments or continue to biodegrade on the surface. Coating of benthic habitats, shoreline habitats and marine fauna/flora within protected areas as discussed in above.	Degradation of cultural or maritime heritage sites. Disruption to tourism, recreation or shipping activities. Reduction in resource available for commercial and recreational fisheries.	Impacts to flora, fauna and the physical environment as discussed above. Commercial/recreational fish species – refer to 'fish' as discussed above.	Degradation of cultural or maritime heritage sites. Disruption to tourism, recreation or shipping activities. Reduction in resource available for commercial and recreational fisheries.

7.3.1.5 Summary of Spill Modelling Results

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (October to the following March), (ii) the transitional periods (April and September) and (iii) winter (May to August). The EMBA for the worst-case deterministic and stochastic modelling results are shown for each of the worst-case spill scenarios.

7.3.1.5.1 Subsea Loss of Well Containment Dorado Development

Stochastic modelling results from the worst-case subsea loss of well containment scenario for the Dorado Project are shown in **Figure 7-38** and **Figure 7-39**. The worst-case deterministic runs, based on the largest volume of oil onshore and longest length of shoreline accumulation are shown in **Figure 7-58** and **Figure 7-42**, and a summary of the results included in **Table 7-77**.

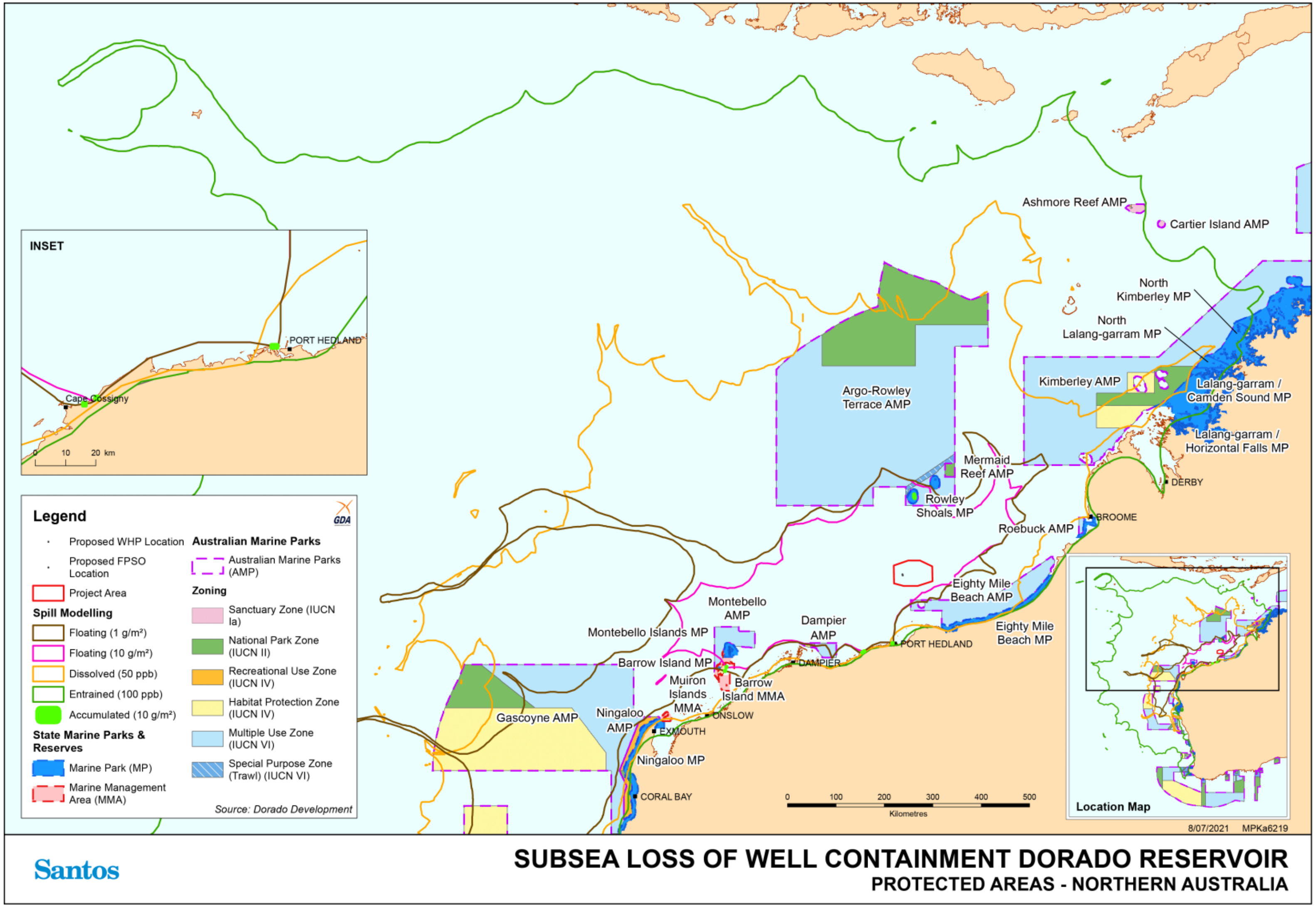

Figure 7-38: EMBA derived from stochastic modelling for floating, entrained, dissolved and shoreline accumulation oil phases for a worst-case subsea loss of well containment (Dorado Reservoir) – protected areas north

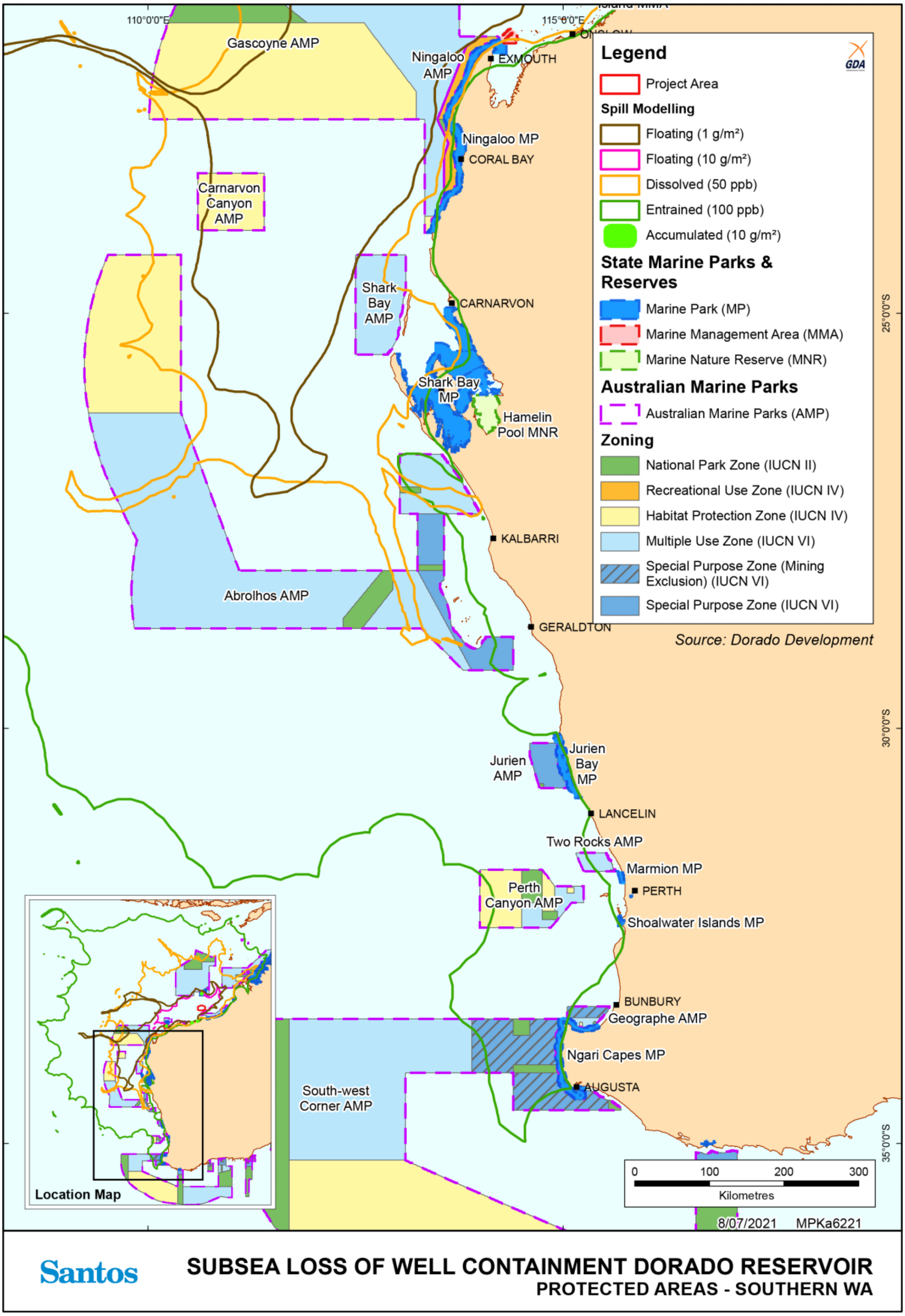

Figure 7-39: EMBA derived from stochastic modelling for floating, entrained, dissolved and shoreline accumulation oil phases for a worst-case subsea loss of well containment (Dorado Reservoir) – protected areas south.

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Table 7-77: Subsea LOWC during production well drilling

<table>
<tr><th>Impact Thresholds (NOPSEMA, 2019b)</th><th colspan="3">Predicted impacts and risks based on:
1) Stochastic model predictions = footprint (trajectory and fate) encompassing 300 releases (100 spill simulations in summer, 100 in winter and 100 in transitional season)</th></tr>
<tr><td colspan="4">FLOATING OIL (SURFACE)</td></tr>
<tr><td rowspan="2">Low
1 g/m²
Visible but no biological effects.
Lower than the exposure value for ecological impacts
Relevant for implementing environmental monitoring in event of oil spills</td><td colspan="3">Figure 7-38 and Figure 7-39 how the stochastic modelling predictions for floating oil at 1 g/m² (low threshold) and 10 g/m² (moderate threshold). Further information is located in Section 9.1.3.1 of Attachment 8-1. The seasonal assessment below is based on 100 spill simulations for each season. Maximum extents predicted in Summer.</td></tr>
<tr><td>Summer
+ Maximum extent from release location – 1278km, west southwest.
+ Based on all 100 simulations combined - 7 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 18%, with Montebello AMP being most probable (18% in minimum time of 12 days after spill), followed by Argo-Rowley Terrace (11% in minimum time of 7 days after spill). The shortest time to contact predicted at Argo-Rowley Terrace within 7.54 days.
+ 6 to 11% probability of contacting 2 State Marine Parks (Montebello Islands and Rowley Shoals) in minimum time of 9 to 12 days after spill.
+ 12% probability of entering State Waters in minimum time of 9 days after spill
+ 2 to 7% probability of contacting shorelines at Barrow Island, Cunningham Island, Hermite Island, Imperieuse Reef and Port Hedland in minimum time of 11 to 40 days after spill.
+ 3 to 7% probability of contacting reefs, shoals and banks (Glomar Shoal, Imperieuse Reef, Rankin</td><td>Transition
+ Maximum extent from release location – 499km, west southwest.
+ Based on all 100 simulations combined - 2 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 7%, with Montebello AMP being most probable (7% in minimum time of 20 days after spill)
+ <1% probability of contact with State Marine Parks.
+ 1% probability of entering State Waters in minimum time of 2 days after spill
+ 1% probability of contacting shorelines at Port Hedland in minimum time of 2 days after spill.
+ 1 % probability of contacting Rankin Bank in minimum time of 35 days after the spill.
+ KEFs are seabed or near seabed features and not contacted by floating oil.</td><td>Winter
+ Maximum extent from release location – 413km west.
+ Based on all 100 simulations combined - 2 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2 to 5%, with Montebello AMP being most probable (5% in minimum time of 62 days after spill)
+ <1% probability of contact with State Marine Parks.
+ 1% probability of entering State Waters in minimum time of 61 days after spill
+ <1% probability of contacting shorelines
+ <1% probability of contacting reef, shoals or banks.
+ KEFs are seabed or near seabed features and not contacted by floating oil.</td></tr>
</table>

	Bank, Tryal Rocks (7% probability)) in minimum time of 14 to 64 days after spill + KEFs are seabed or near seabed features and not contacted by floating oil.		
Moderate 10 g/m^2 Environmental values and sensitivities may be at risk of impacts from floating oil.	Summer + Maximum extent from release location – 528km, west southwest. + Based on all 100 simulations combined - 3 AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 5 to 18%, with Montebello AMP more probable (18% in minimum time of 12 days) and Argo-Rowley Terrace 11% in 7 days. + 2 to 10% probability of contacting 2 State Marine Parks (Montebello Islands and Rowley Shoals) in minimum time of 10 to 58 days after spill. + 12% probability of entering State Waters in minimum time of 9 days after spill + 2 to 7% probability of contacting shorelines at Barrow Island, Cunningham Island and Port Hedland in minimum time of 11 to 40 days after spill. + 1 to 3% probability of contacting reefs, shoals and banks (Imperieuse Reef, Tryal Rocks) in minimum time of 14 to 56 days after spill + KEFs are seabed or near seabed features and not contacted by floating oil.	Transition + Maximum extent from release location – 499km, west southwest. + Based on all 100 simulations combined - 4% probability of contacting Montebello AMP in minimum time of 19 days after spill + <1% probability of contact with State Marine Parks. + 1% probability of entering State Waters in minimum time of 2 days after spill + 1% probability of contacting shorelines at Port Hedland in minimum time of 2 days after spill. + <1% probability of contacting reefs, shoals and banks. + KEFs are seabed or near seabed features and not contacted by floating oil.	Winter + Maximum extent from release location – 413km west. + Based on all 100 simulations combined - 3% probability of contacting Montebello AMP in minimum time of 61 days after spill + <1% probability of contact with State Marine Parks. + <1% probability of contact with State Waters. + <1% probability of contact with shoreline + <1% probability of contacting reefs, shoals and banks. + KEFs are seabed or near seabed features and not contacted by floating oil.
High 50 g/m^2 Potential for impact of surface oil to wildlife	+ Maximum extent from release location – 305km, west southwest. + Based on all 100 simulations combined - Probability of exposure to Argo-Rowley Terrace AMP – 11% in minimum time of 7 days after spill. + <1% probability of contacting State Marine Parks. + <1% probability of entering State Waters. + <1% probability of contacting shorelines.	+ Maximum extent from release location – 305km, west southwest. + <1% probability of contacting AMPs + <1% probability of contacting State Marine Parks. + 1% probability of entering State Waters in minimum time of 2 days after spill	+ Maximum extent from release location – 221km northeast. + <1% probability of contacting AMPs + <1% probability of contacting State Marine Parks. + <1% probability of entering State Waters. + <1% probability of contacting shorelines.

	+ <1% probability of contacting reefs, shoals and banks.	+ 1% probability of contacting shoreline of Port Hedland in minimum time of 2 days. + <1% probability of contacting reefs, shoals and banks.	+ <1% probability of contacting reefs, shoals and banks.
SHORELINE ACCUMULATION			
Low 10 g/m^2	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-38** and **Figure 7-39**). **Figure 7-40** shows the shoreline accumulation at 10 g/m^2 (low threshold). Further information is located in Section 9.1.3.2 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		

Represents a level of socio-economic effect

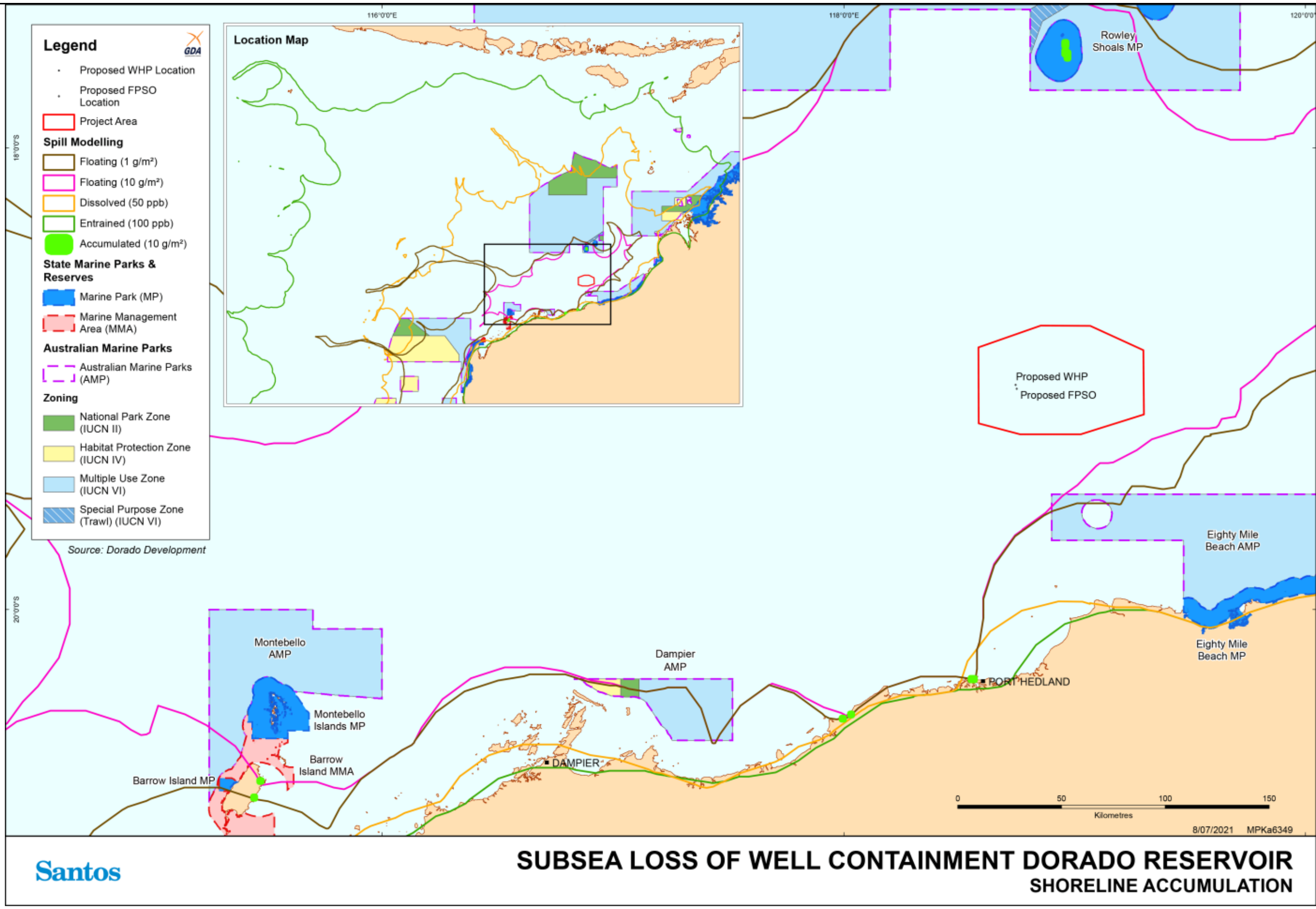

Figure 7-40: Stochastic modelling shoreline accumulation for a worst-case subsea loss of well containment (Dorado Reservoir)

Summer	Transition	Winter
+ Greatest volume of oil accumulation ashore 35.8 m^3 + 10% probability of shoreline accumulation in minimum time of 11 days + Maximum length of shoreline accumulation 6 km	+ Greatest volume of oil accumulation ashore 64.7 m^3 + 1% probability of shoreline accumulation in minimum time of 2 days	+ <1% probability of shoreline accumulation

	+ Based on all 100 simulations combined - 4 shoreline receptors with probability of exposure to each ranging from 2 to 7%. - Port Hedland to the south (7% within 11 days, peak loading 2,781g/m^2, with a peak volume of 34.3m^3, and a maximum length of shoreline loading @ 3km). - Imperieuse Reef to the north (4% within 36 days, peak loading 260 g/m^2, with a peak volume of 2.1 m^3, and a maximum length of shoreline loading @ 1km). - Cunningham Island (3% within 35 days, peak loading 108 g/m^2, with a peak volume of 3.7m^3, and a maximum length of shoreline loading @ 2km). - Barrow Island (2% within 40 days, peak loading 22 g/m^2, with a peak volume of 0.3m^3, and a maximum length of shoreline loading @ 1km).	+ Maximum length of shoreline accumulation was 2 km + Based on all 100 simulations combined - 1 shoreline receptor with probability of exposure of 1% - Port Hedland to the south within 2 days, peak loading 3,061g/m^2, with a peak volume of 64.7 m^3, and a maximum length of shoreline loading @ 2km.	
Moderate 100 g/m^2 Likely to cause adverse impacts to marine or coastal fauna and habitats	+ Maximum length of shoreline accumulation 2 km + Based on all 100 simulations combined - 3 shoreline receptors with probability of exposure to each ranging from 2 to 7% - Port Hedland, Imperieuse Reef and Cunningham Island. - Port Hedland to the south (7% within 11 days, peak loading 2,781g/m^2, with a peak volume of 34.3m^3, and a maximum length of shoreline loading @ 3km). - Imperieuse Reef to the north (2% within 49 days, peak loading 260 g/m^2, with a peak volume of 3.7 m^3, and a maximum length of shoreline loading @ 1km). - Cunningham Island (3% within 35 days, peak loading 108 g/m^2, with a peak volume of 2.1 m^3, and a maximum length of shoreline loading @ 1km).	+ Maximum length of shoreline accumulation 2 km + Based on all 100 simulations combined - 1 shoreline receptor with probability of exposure of 1% - Port Hedland to the south within 2 days, peak loading 3,061g/m^2, with a peak volume of 64.7 m^3, and a maximum length of shoreline loading @ 2km.	+ <1% probability of shoreline accumulation

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High 1000 g/m² Impacts to shoreline receptors	+ Maximum length of shoreline accumulation was 1 km + Based on all 100 simulations combined - 1 shoreline receptor with probability of exposure of 7% - Port Hedland to the south within 11 days, peak loading 2,781g/m^2, with a peak volume of 34.3m^3, and a maximum length of shoreline loading @ 1km.	+ Maximum length of shoreline accumulation 2 km + Based on all 100 simulations combined - 1 shoreline receptor with probability of exposure of 1% - Port Hedland to the south within 11 days, peak loading 3,061g/m^2, with a peak volume of 64.7 m^3, and a maximum length of shoreline loading @ 2km.	+ <1% probability of shoreline accumulation
DISSOLOVED AROMATIC HYDROCARBONS			
Low 10 ppb Lower than the exposure value at which ecological impacts are expected to occur. Relevant for implementing environmental monitoring in event of oil spills	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-38** and **Figure 7-39**). The figures show the dissolved hydrocarbons at 50ppb (low threshold). Further information is located in Section 9.1.3.4 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	Summer + Maximum extent from release location – 1,581km southwest + Based on all 100 simulations combined - 12 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 61 to 3%, with Montebello AMP being most probable (61% in minimum time of 12 days after spill), followed by Gascoyne (44% in minimum time of 16 days after spill). The shortest time to contact predicted at Argo-Rowley Terrace within 7.5 days. Maximum dissolved concentrations of 2,449 ppb at Argo-Rowley Terrace AMP. + 1 to 38% probability of contacting 7 State Marine Parks. 38% probability at Rowley Shoals in minimum time of 9 days after spill and a maximum concentration of 922 ppb. The maximum dissolved concentration was 1,122 ppb at Montebello Islands.	Transition + Maximum extent from release location – 1,321km south southwest + Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 55 to 2%, with Montebello AMP being most probable (55% in minimum time of 4 days after spill), followed by Argo Rowley Terrace (48% in minimum time of 10 days after spill). The shortest time to contact predicted at Dampier within 3 days. Maximum dissolved concentrations of 1,007 ppb at Argo-Rowley Terrace AMP. + 1 to 43% probability of contacting 7 State Marine Parks. 43% probability at Rowley Shoals in minimum time of 14 days after spill and a maximum concentration of 1,100 ppb. + 43% probability of entering State Waters in minimum time of 2.8 days after spill, and maximum dissolved hydrocarbon 1,100ppb.	Winter + Maximum extent from release location – 1,339km west + Based on all 100 simulations combined - 12 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 35%, with Argo-Rowley Terrace AMP being most probable (74% in minimum time of 13 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 6.6 days. Maximum dissolved concentrations of 1,947 ppb at Gascoyne AMP. + 1 to 64% probability of contacting 6 State Marine Parks. 64% probability at Rowley Shoals in minimum time of 16 days after spill and a maximum concentration of 408 ppb. The maximum dissolved concentration was 711 ppb at Montebello Islands.

	+ 38% probability of entering State Waters in minimum time of 9 days after spill, and maximum dissolved hydrocarbon 2,947ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 37 receptors within the EMBA are predicted to be exposed. The greatest probability being 72% at Rankin Bank within 13 days, and a maximum dissolved hydrocarbon concentration of 1,048 ppb. + 1 Ramsar receptor within the combined simulations is potentially exposed with the probability of 12% at Eighty Mile Beach within 31 days with a maximum dissolved hydrocarbon concentration of 323ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 12% within 27 days and a maximum dissolved hydrocarbon concentration of 209 ppb. Highest probability of dissolved contact at Imperieuse Reef of 35% within 12 days. Maximum dissolved hydrocarbon concentration of 2,257 ppb at Legendre Island. + Based on all 100 simulations combined - 3 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs ranged from 28%, at Houtman Abrolhos Islands (within 33 days at 492 ppb maximum) and 1% at Western Rock Lobster (within 33 days @ 18 ppb). The probability of exposure at the 125m water depth Ancient Coastline adjacent to the Project Area was <1%.	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 19 receptors within the EMBA are predicted to be exposed. The greatest probability being 80% at Glomar Shoals within 4 days, and a maximum dissolved hydrocarbon concentration of 834 ppb. + <1% probability of Ramsar receptors being contacted by dissolved hydrocarbons. + Bedout Island (closest nearshore receptor to the south) with probability of 1% within 18 days and a maximum dissolved hydrocarbon concentration of 26 ppb. Highest probability of dissolved contact at Cunningham Island of 37% within 17 days. Maximum dissolved hydrocarbon concentration of 444 ppb at Clerke Reef. + Based on all 100 simulations combined - 4 of the KEFs within the EMBA are predicted to be exposed, probability of greatest exposure is 14%, at Glomar Shoals (within 4 days at 549 ppb maximum). The probability of exposure at the 125m water depth Ancient Coastline adjacent to the Project Area was <1%.	+ 64% probability of entering State Waters in minimum time of 10 days after spill, and maximum dissolved hydrocarbon 1,426ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 15 receptors within the EMBA are predicted to be exposed. The greatest probability being 95% at Glomar Shoals within 10 days, and a maximum dissolved hydrocarbon concentration of 518 ppb. The maximum dissolved hydrocarbon concentration is at Rankin Bank of 1,004ppb. + 1 Ramsar receptor within the combined simulations is potentially exposed with the probability of 1% at Roebuck Bay within 114 days with a maximum dissolved hydrocarbon concentration of 14 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 3% within 11 days and a maximum dissolved hydrocarbon concentration of 49 ppb. Highest probability of dissolved contact at Imperieuse Reef of 53% within 20 days. Maximum dissolved hydrocarbon concentration of 485 ppb at Hermite Island. + Based on all 100 simulations combined - 3 of the KEFs within the EMBA are predicted to be exposed, the highest probability of exposure at Glomar Shoals (11 % within 9 days at 425 ppb maximum). the probability of exposure at

			the 125m water depth Ancient Coastline adjacent to the Project Area was <1%.
Moderate 50 ppb Approximates potential toxic effects, particularly sublethal effects to sensitive species.	Summer + Maximum extent from release location – 1,342km southwest + Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, with Montebello AMP being most probable (34% in minimum time of 12 days after spill), followed by Argo-Rowley Terrace at 24% within 7.5 days. + 6 to 18% probability of contacting 4 State Marine Parks. 18% probability at Rowley Shoals in minimum time of 9 days after spill + 18% probability of entering State Waters in minimum time of 9 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 19 receptors within the EMBA are predicted to be exposed. The greatest probability being 44% at Rankin Bank within 13 days. + 1 Ramsar receptor within the combined simulations is potentially exposed with the probability of 6% at Eighty Mile Beach within 32 days. + Bedout Island (closest nearshore receptor to the south) with probability of 4% within 27 days. Highest probability of dissolved contact at Imperieuse Reef and Barrow Island of 11% within 12 days and 15 days respectively. + Based on all 100 simulations combined - 3 of the KEFs within the EMBA are predicted to be exposed, probability of 12%,at Houtman Abrolhos Islands (within 99 days).	Transition + Maximum extent from release location – 1,124km southwest + Based on all 100 simulations combined - 10 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 26 to 1%, with Montebello and Argo-Rowley Terrace AMPs being most probable (26% in minimum time of 4 days and 11 days respectively after spill), The shortest time to contact predicted at Dampier within 3 days. + 1 to 14% probability of contacting 4 State Marine Parks. 14% probability at Rowley Shoals in minimum time of 16 days after spill. + 14% probability of entering State Waters in minimum time of 2.8 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 11 receptors within the EMBA are predicted to be exposed. The greatest probability being 56% at Glomar Shoals within 5 days. + <1% probability of Ramsar receptors being contacted by dissolved hydrocarbons. + <1% probability of Bedout Island (closest nearshore receptor to the south) being contacted by dissolved hydrocarbon. The highest probability for nearshore contact is Clerke Reef at 12% within 17 days. + Based on all 100 simulations combined - 1 KEFs within the EMBA is predicted to be	Winter + Maximum extent from release location – 1,171km southwest. + Based on all 100 simulations combined - 11 of the AMPs within the EMBA greatest probability of exposure at Argo-Rowley Terrace AMP (35% in minimum time of 16 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 7.2 days. + 2 to 30% probability of contacting 3 State Marine Parks. Greatest probability of exposure at Rowley Shoals (30 % in minimum time of 18 days. + 30% probability of entering State Waters in minimum time of 10 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 10 receptors within the EMBA are predicted to be exposed. The greatest probability being 57% at Glomar Shoals within 10 days. + <1% probability of Ramsar receptors being contacted by dissolved hydrocarbons. + <1% probability of Bedout Island (closest nearshore receptor to the south) being contacted by dissolved hydrocarbons. Highest probability of dissolved contact at Imperieuse Reef of 22% within 24 days. + Based on all 100 simulations combined - 2 of the KEFs within the EMBA are predicted to be exposed, the highest

		exposed with a probability of exposure of 3%, at Glomar Shoals (within 4 days).	probability of exposure at Glomar Shoals (2% within 10 days).
High 400 ppb Approximates toxic effects including lethal effects to sensitive species	Summer + Maximum extent from release location – 930km west southwest + Based on all 100 simulations combined – 8 of the AMPs within the EMBA are predicted to be exposed, with Argo Rowley Terrace AMP being most probable (7% in minimum time of 7.5 days. + <1% probability of State marine parks being contacted at the high exposure threshold. + 6% probability of entering State Waters in minimum time of 11 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 4 receptors within the EMBA are predicted to be exposed. The greatest probability being 44% at Rankin Bank within 13 days. + 1 Ramsar receptor within the combined simulations is potentially exposed with the probability of 6% at Eighty Mile Beach within 32 days. + Bedout Island (closest nearshore receptor to the south) with probability of 4% within 27 days. Highest probability of dissolved contact at Imperieuse Reef and Barrow Island of 11% within 12 days and 15 days respectively. + Based on all 100 simulations combined - 3 of the KEFs within the EMBA are predicted to be exposed, probability of 12%,at Houtman Abrolhos Islands (within 99 days).	Transition + Maximum extent from release location – 582km, west southwest + Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2 to 1%, with Argo-Rowley Terrace AMP being most probable (2% in minimum time of 13.8 days after spill), The shortest time to contact predicted at Kimberley within11 days. + 1 State Marine Park is predicted to be contacted with a probability of 2 %, Rowley Shoals in minimum time of 19 days after spill. + 2% probability of entering State Waters in minimum time of 29 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 3 receptors within the EMBA are predicted to be exposed. The greatest probability being 5% at Glomar Shoals within 11.8 days. + <1% probability of Ramsar receptors being contacted by dissolved hydrocarbons. + <1% probability of Bedout Island (closest nearshore receptor to the south) being contacted by dissolved hydrocarbon. The highest probability for nearshore contact is Clerke Reef at 1% within 31 days. + Based on all 100 simulations combined - 1 KEFs within the EMBA is predicted to be exposed with a probability of exposure of 1%, at Glomar Shoals (within 11 days).	Winter + Maximum extent from release location – 843km southwest + Based on all 100 simulations combined - 6 of the AMPs within the EMBA greatest probability of exposure at Argo-Rowley Terrace, Eighty Mile Beach and Montebello AMPs (3% in minimum time of 19 days, 10 days and 62 days respectively after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 10 days. + 1% probability of contacting 2 State Marine Parks, Montebellos and Rowley Shoals (in minimum time of 86 and 80 days respectively). + 3% probability of entering State Waters in minimum time of 61 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 3 receptors within the EMBA are predicted to be exposed. The greatest probability being 3% at Rankin Bank within 72 days. + <1% probability of Ramsar receptors being contacted by dissolved hydrocarbons. + <1% probability of Bedout Island (closest nearshore receptor to the south) being contacted by dissolved hydrocarbons. Highest probability of dissolved contact at Hermite Island of 1% within 100 days,

			only sensitive nearshore receptor with probability of exposure. + Based on all 100 simulations combined - the KEF within the EMBA predicted to be exposed is Glomar Shoals (1% within 18 days).
ENTRAINED HYDROCARBON			
Low 10 ppb Lower than the exposure value at which most ecological impacts are expected to occur,. Relevant for implementing environmental monitoring in event of an oil spill.	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-38** and **Figure 7-39**). The figures show the entrained hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. Further information is located in Section 9.1.3.3 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	<u>Summer</u> + Maximum extent from release location – 2,635km + Based on all 100 simulations combined - 20 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 95 to 3%, with Montebello AMP being most probable (95% in minimum time of 12 days after spill), followed by Gascoyne (93% in minimum time of 13 days after spill). The shortest time to contact predicted at Eighty Mile Beach and Argo-Rowley Terrace within 7.5 days. Maximum concentrations of 15,871 ppb at Argo-Rowley Terrace AMP and 10,823 ppb at Montebello AMP. + 7 to 81% probability of contacting 15 State Marine Parks (Ningaloo and Rowley Shoals) in minimum time of 13 to 8 days after spill and a maximum concentration of 2,073 ppb and 10,088ppb. + 81% probability of entering State Waters in minimum time of 8 days after spill, and maximum entrained hydrocarbon 10,088ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 103 receptors within the EMBA are predicted to be	<u>Transition</u> + Maximum extent from release location – 2,498km + Based on all 100 simulations combined - 20 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 97 to 1%, with Argo-Rowley Terrace AMP being most probable (97% in minimum time of 8.5 days after spill), followed by Montebello AMP (94% in minimum time of 4 days after spill). The shortest time to contact predicted at Dampier AMP within 3.6 days. Maximum concentrations of 9,076 ppb at Argo-Rowley Terrace AMP and 6,204 ppb at Mermaid Reef AMP. + 1 to 81% probability of contacting 15 State Marine Parks (Rowley Shoals and Montebello MP) in minimum time of 11 to 31 days respectively after spill and a maximum concentration of 7,567 ppb at Rowley Shoals and 1,710 ppb at Montebellos.	<u>Winter</u> + Maximum extent from release location – 2878km (west- northwest). + Based on all 100 simulations combined - 19 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 100 to 1%, with Argo-Rowley Terrace AMP being most probable (100% in minimum time of 11 days after spill), followed by Montebello AMP (98% in minimum time of 16 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 6 days. Maximum concentrations of 8,867 ppb at Argo-Rowley Terrace AMP and 8,439 ppb at Montebello AMP. + 1 to 94 % probability of contacting 14 State Marine Parks. Rowley Shoals (94% probability in a minimum time 12 days with a maximum concentration of 7,130 ppb). Montebello (87% probability in a minimum time 22 days with a maximum concentration of 1,146 ppb).

	exposed. The greatest probability being 97% at Rankin Bank within 12 days, and a maximum entrained hydrocarbon concentration of 10,233 ppb. + 4 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 23% at Eighty Mile Beach within 15 days with a maximum entrained hydrocarbon concentration of 3,157ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 37% within 17 days and a maximum entrained hydrocarbon concentration of 2,008 ppb. Highest probability of contact at Imperieuse Reef of 67% within 10 days. + Based on all 100 simulations combined - 8 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs ranged from 89%, at Houtman Abrolhos Islands (within 32 days at 5,215 ppb maximum) and 1% at Sahul Shelf (within 85 days @ 17 ppb). The 125m water depth Ancient Coastline adjacent to the Project Area has a probability of exposure of 5% within 1 day, at a maximum concentration of 31 ppb.	+ 81% probability of entering State Waters in minimum time of 2.7 days after spill, and maximum entrained hydrocarbon 7,253 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 83 receptors within the EMBA are predicted to be exposed. The greatest probability being 94% at Rankin Bank within 6 days, and a maximum entrained hydrocarbon concentration of 5,576 ppb, followed by Imperieuse Reef at 81% probability, and a maximum concentration of 6,406 ppb. + 3 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 11 % at Peel-Yalgorup System within 68 days and maximum concentration of 65ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 17 days and a maximum entrained hydrocarbon concentration of 199 ppb. Highest probability of contact at Imperieuse Reef of 79% within 13 days at 3,776 ppb maximum. + Based on all 100 simulations combined - 7 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs ranged from 79% at Houtman Abrolhos Islands (within 55 days at 776 ppb maximum) and Geographe Bay (within 79 days @ 19 ppb).	+ 94% probability of entering State Waters in minimum time of 9 days after spill, and maximum entrained hydrocarbon 6,609 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 74 receptors within the EMBA are predicted to be exposed. The greatest probability being 94% at Rankin Bank within 6 days, and a maximum entrained hydrocarbon concentration of 5,576 ppb, followed by Imperieuse Reef at 81% probability, and a maximum concentration of 6,406 ppb. + 5 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 10 % at Ashmore Reef Nature Reserve within 97 days with a maximum concentration of 32ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 17 days and a maximum entrained hydrocarbon concentration of 199 ppb. Highest probability of contact at Imperieuse Reef of 79% within 13 days at 3,776 ppb maximum. + Based on all 100 simulations combined - 7 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs ranged from 79% at Houtman Abrolhos Islands (within 55 days at 776 ppb maximum) and Geographe Bay (within 79 days @ 19 ppb).

Moderate 100 ppb Representative of sub-lethal impacts to most species and lethal impacts to sensitive species. Considered appropriate for environmental risk assessment. (NOPSEMA 2019)	+ Maximum extent from release location – 1964km + Based on all 100 simulations combined - 18 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 85 to 1%, with Montebello AMP being most probable (85% in minimum time of 12 days after spill), followed by Gascoyne (81% in minimum time of 14 days after spill). The shortest time to contact predicted at Eighty Mile Beach and Argo-Rowley Terrace within 7.5 days. + 1 to 57% probability of contacting 13 State Marine Parks (Ningaloo and Rowley Shoals) in minimum time of 15.5 to 9 days respectively after the spill. + 57% probability of entering State Waters in minimum time of 9 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 53 receptors within the EMBA are predicted to be exposed. The greatest probability being 90% at Rankin Bank within 12 days. + 4 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 16 % at Eighty Mile Beach within 15 days. + Bedout Island (closest nearshore receptor to the south) with probability of 33% within 15 days. Highest probability of contact at Imperieuse Reef of 53% within 11 days. + Based on all 100 simulations combined - 5 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs of 50% at Houtman Abrolhos Islands (within 32 days) and 3% at Glomar Shoals (within 11 days and a maximum concentration of 226ppb).	+ Maximum extent from release location – 1,739km + Based on all 100 simulations combined - 13 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 88 to 1%, with Argo-Rowley Terrace AMP being most probable (88% in minimum time of 9 days after spill), followed by Montebello AMP (75% in minimum time of 4 days after spill). The shortest time to contact predicted at Dampier AMP within 2.5 days. + 1 to 55% probability of contacting 10 State Marine Parks (Rowley Shoals and Montebello MP) in minimum time of 11 to 7 days respectively after spill. + 55% probability of entering State Waters in minimum time of 2.7 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 28 receptors within the EMBA are predicted to be exposed. The greatest probability being 84% at Rankin Bank within 6 days, followed by Imperieuse Reef at 53% probability, within 14 days. + No exposure of Ramsar receptors. + Bedout Island (closest nearshore receptor to the south) with probability of 3% within 23 days. Highest probability of contact at Imperieuse Reef of 50% within 14 days. + Based on all 100 simulations combined - 5 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs of 37% at Houtman Abrolhos Islands (within 56 days) and 4% at Glomar Shells	+ Maximum extent from release location – 2158km (west- northwest). + Based on all 100 simulations combined - 12 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 97 to 2%, with Argo-Rowley Terrace AMP being most probable (97% in minimum time of 12 days after spill), followed by Montebello AMP (88% in minimum time of 17 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 6 days. + 1 to 55% probability of contacting 10 State Marine Parks (Rowley Shoals and Montebello MP) in minimum time of 11 to 7 days respectively after spill. + 81% probability of entering State Waters in minimum time of 10 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 23 receptors within the EMBA are predicted to be exposed. The greatest probability being 92% at Rankin Bank within 16 days, followed by Imperieuse Reef at 80% probability, within 17 days + 1 Ramsar receptor within the combined simulations potentially exposed with the probability of 2% at Roebuck Bay within 109 days. Probability of exposure at Eighty Mile Beach of 1% within 97 days. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 11 days. Highest probability of

		within 3 days at maximum concentration of 216 ppb.	contact at Imperieuse Reef of 79% within 18 days. + Based on all 100 simulations combined - 2 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs of 6% at offshore Ningaloo Reef (within 33 days) and 4% at Glomar Shells within 9 days at maximum concentration of 264 ppb.

Predicted impacts and risks based on deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in:

1) **largest volume of oil ashore**
2) **longest length of shoreline with oil accumulation**

Largest volume of oil ashore (Figure 7-41)	Longest length of shoreline accumulation (Figure 7-47)
+ Floating oil exposure predicted north/northeast and west/southwest from the spill location. + Maximum volume onshore of 64.7m^3 occurring 3 days after the spill. + Shoreline accumulation at Port Hedland. + Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 58 days after spill started, approximately 330 km^2. + At end of spill, 61% spilled oil lost to the atmosphere through evaporation, 31% predicted to have decayed, 8% remained in the water column and 22m^3 (<0.1%) predicted to remain on the shoreline.	+ Floating oil exposure predicted northeast and west/southwest from the spill location + Shoreline accumulation at Port Hedland, Cunningham Island and Imperieuse Reef. + Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 46 days after the spill started approximately 559 km^2. + Maximum length of actionable shoreline oiled (above 100 g/m^2) at any given time was 2 km, at approximately 80 days after the spill. + At end of spill, 62% spilled oil lost to the atmosphere through evaporation. 29% predicted to have decayed, 8% remained in the water column and 15 m^3 (<0.1%) predicted to remain on the shoreline.

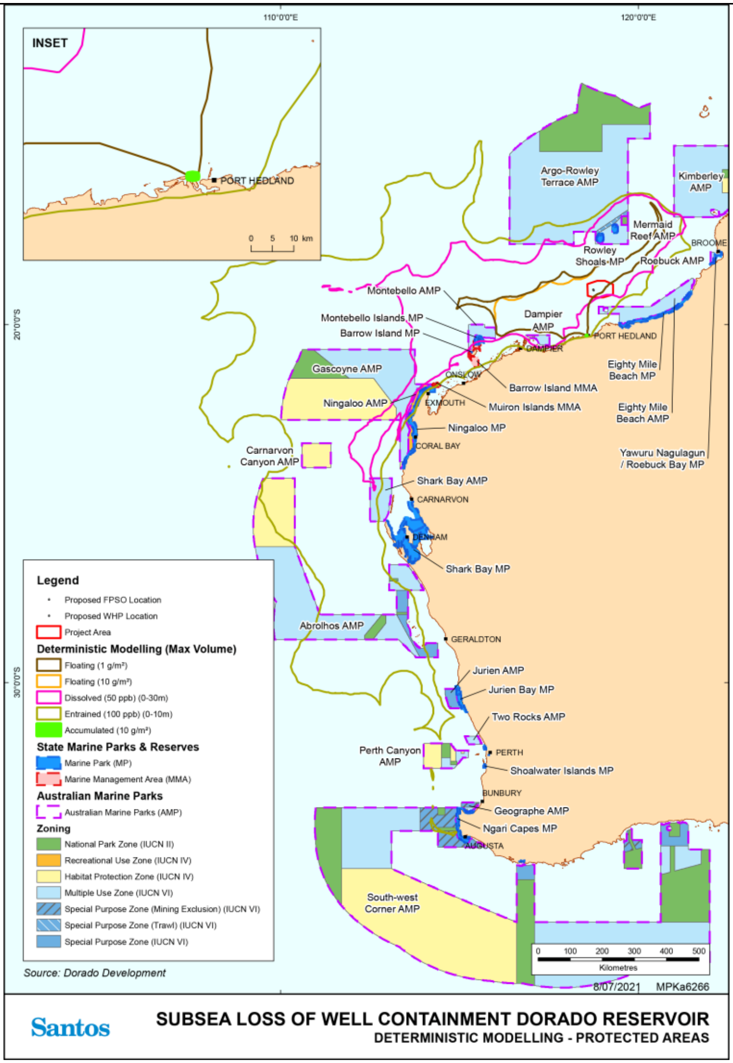

Figure 7-41 Worst-case deterministic model results based on largest volume of shoreline oil ashore (Dorado Reservoir)

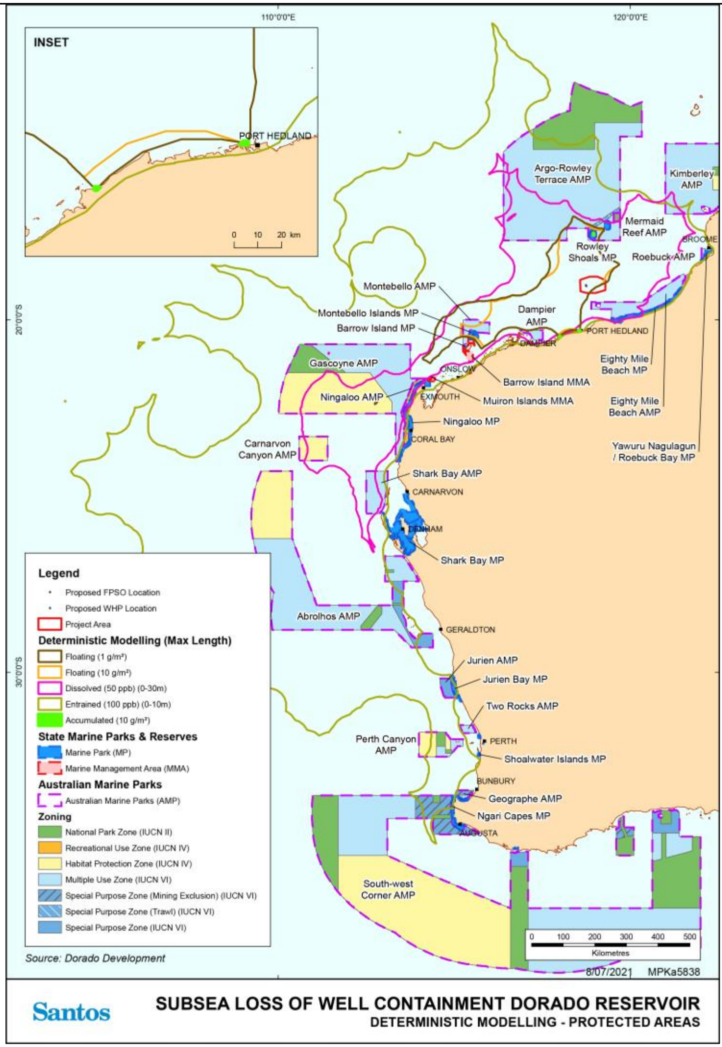

Figure 7-42: Worst-case deterministic model results based on maximum length of shoreline contact (Dorado Reservoir)

7.3.1.5.2 Surface Loss of Well Containment Dorado Development

Stochastic modelling results from the worst-case surface loss of well containment scenario are shown in **Figure 7-43** and **Figure 7-44.** A summary of the stochastic modelling results for floating oil, shoreline accumulation, dissolved and entrained hydrocarbons for a subsea loss of well containment for each season is provided in **Table 7-78.**The worst-case deterministic runs, based on the largest volume of oil onshore and longest length of shoreline accumulation are shown in **Figure 7-46** and **Figure 7-47** and a summary of the results included in **Table 7-78.**

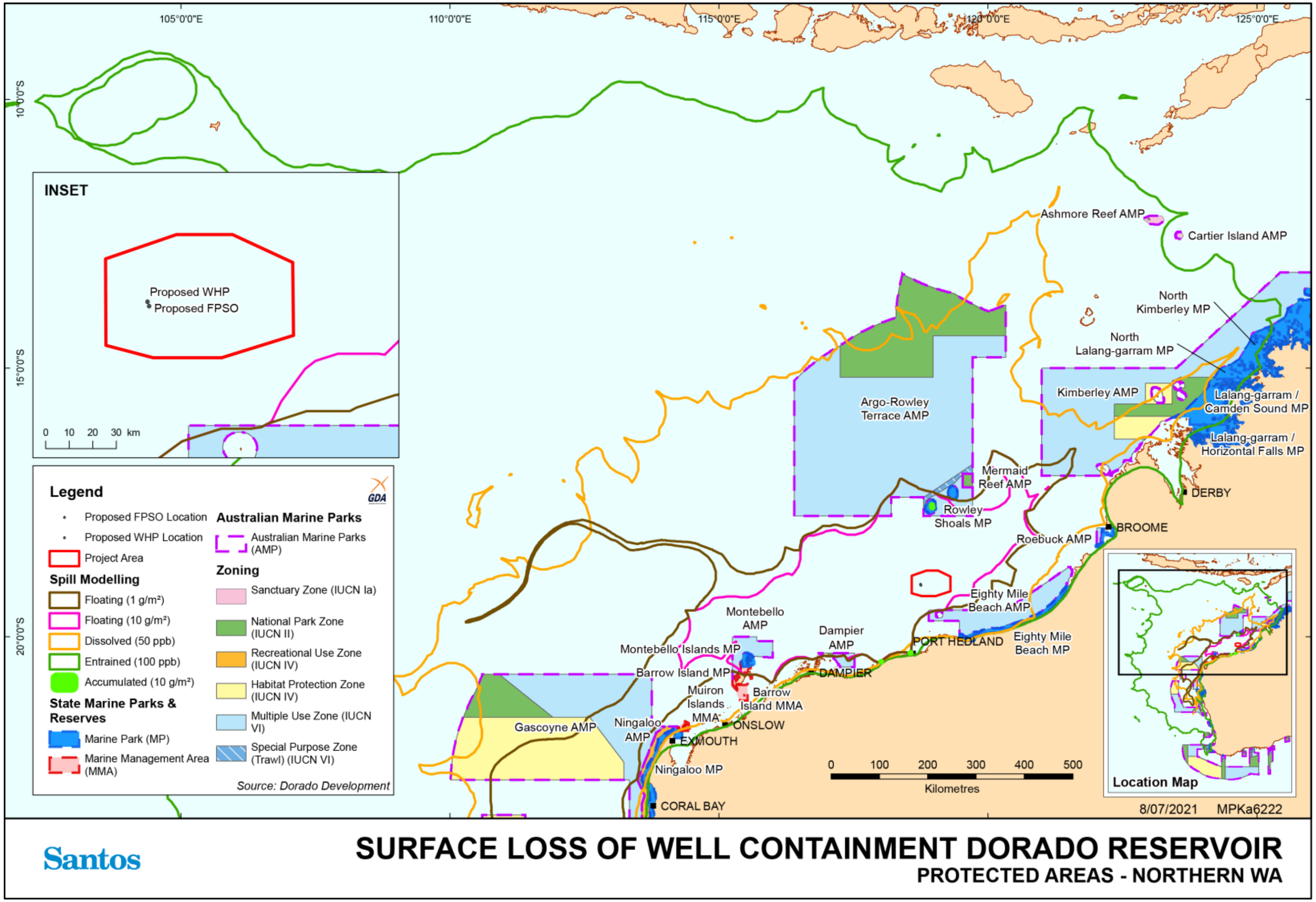

Figure 7-43: EMBA derived from stochastic modelling for floating, entrained, dissolved and shoreline accumulation oil phases for a worst-case surface loss of well containment (Dorado Reservoir) – protected areas north

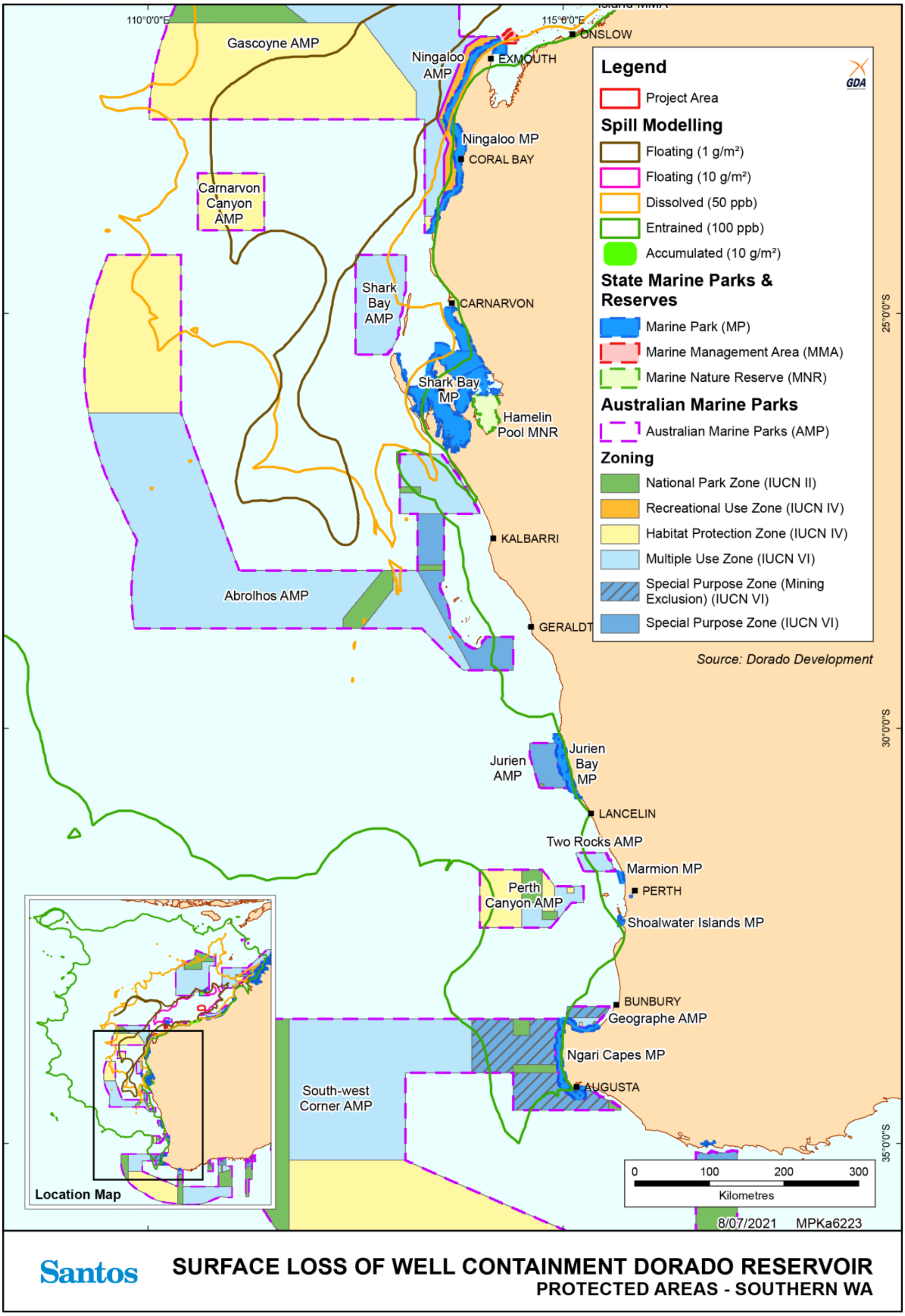

Figure 7-44: EMBA derived from stochastic modelling for floating, entrained, dissolved and shoreline accumulation oil phases for a worst-case surface loss of well containment (Dorado Reservoir) – protected areas south

Table 7-78: Surface LOWC during production well drilling

<table>
<tr><th>Impact Thresholds (NOPSEMA, 2019b)</th><th colspan="3">Predicted impacts and risks based on stochastic model predictions = footprint (trajectory and fate) encompassing 300 releases (100 in summer, 100 in winter and 100 in transitional season).</th></tr>
<tr><td colspan="4">FLOATING OIL (SURFACE)</td></tr>
<tr><td rowspan="2">Low
1 g/m²
Visible but no biological effects.
Lower than the exposure value for ecological impacts
Relevant for implementing environmental monitoring in event of oil spills</td><td colspan="3">Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer Figure 7-43 and Figure 7-44. The figures show the floating oil at 1 g/m² (low threshold) and 10 g/m² (moderate threshold). Further information is located in Section 9.2.3.1 of Attachment 8-1. The seasonal assessment below is based on 100 spill simulations for each season. Maximum extents predicted in Summer.</td></tr>
<tr><td><u>Summer</u>
+ Spill direction - Southwesterly
+ Maximum distance 1201km from release site
+ Based on all 100 simulations combined - 6 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 18%, with Montebello AMP being most probable (18% in minimum time of 12 days after spill). The shortest time to contact at Argo-Rowley Terrace AMP in 7.5 days.
+ 1 to 11% probability of contacting 2 State Marine Parks (Montebello Islands and Rowley Shoals respectively) in minimum time of 95 days and 10 days after spill respectively.
+ 12% probability of entering State Waters in minimum time of 10 days after spill
+ 1 to 9% probability of contacting shorelines at Barrow Island, Cunningham Island, Imperieuse Reef and Port Hedland in minimum time of 11 days (Port Hedland) to 45 days (Imperieuse Reef) after spill.
+ 4 to 9% probability of contacting reefs, shoals and banks (Imperieuse Reef, Rankin Bank, Tryal Rocks) in minimum time of 12 to 62 days after spill</td><td><u>Transition</u>
+ Spill direction West – Southwesterly
+ Maximum distance 508km from release site
+ Based on all 100 simulations combined - Montebello AMP exposed with 8% probability of exposure in minimum time of 7 days
+ No predicted contact with State Marine Parks.
+ 1% probability of entering State Waters in minimum time of 2 days after spill
+ 1 % probability of contacting shorelines at Port Hedland in minimum time of 2 days (Port Hedland) after spill.
+ 4% probability of contacting reefs, shoals and banks - Rankin Bank in minimum time of 24 days after spill
+ No KEFs contacted by floating oil.</td><td><u>Winter</u>
+ Spill direction – Northeast
+ Maximum distance 413km from release site
+ Based on all 100 simulations combined - 4 AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2 to 5%, with Montebello AMP being most probable (5% in minimum time of 61 days after spill). The shortest time to contact at Argo-Rowley Terrace AMP within 45 days.
+ No predicted contact with State Marine Parks.
+ 1% probability of entering State Waters in minimum time of 62 days after spill
+ No predicted contact with shorelines or Reef, shoals and banks.
+ No KEFs contacted by floating oil.</td></tr>
</table>

	+ No KEFs contacted by floating oil.		
Moderate 10 g/m^2 (environment values and sensitivities may be at risk)	+ Spill direction West – Southwesterly, maximum distance 408km from release site + Based on all 100 simulations combined - 3 AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 6 to 11%, with Argo-Rowley Terrace AMP being most probable (11% in minimum time of 7 days after spill), the shortest time to contact at Argo-Rowley Terrace AMP in 7.5 days. + 10% probability of contact with Rowley Shoals State Marine Park (minimum time of 10 days after the spill). + 12% probability of entering State Waters in minimum time of 10 days after spill + 1 to 8% probability of contacting shorelines at Barrow Island, Imperieuse Reef and Port Hedland in minimum time of 11 days (Port Hedland) to 45 days (Imperieuse Reef) after spill. + 4 to 2% probability of contacting reefs, shoals and banks (Imperieuse Reef and Tryal Rocks) in minimum time of 12 to 14 days respectively after spill + No KEFs contacted by floating oil.	+ Spill direction West – Southwesterly, maximum distance 497km from release site + Based on all 100 simulations combined- Montebello AMP within the EMBA are predicted to be exposed with 5% probability of exposure in minimum time of 7 days + No predicted contact with State Marine Parks. + 1% probability of entering State Waters in minimum time of 2 days after spill + 1 % probability of contacting shorelines at Port Hedland in minimum time of 2 days (Port Hedland) after spill. + 2 % probability of contacting reefs, shoals and banks at Rankin Bank in minimum time of 24 days after spill + No KEFs contacted by floating oil.	+ Spill direction – Northeast, maximum distance 375km from release site + 1% probability of contacting Dampier AMP or Montebello AMP in minimum time of 60 days and 61 days respectively after spill + No predicted contact with State Marine Parks. + 1% probability of entering State Waters in minimum time of 62 days after spill + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks + No KEFs contacted by floating oil.
High 50 g/m^2 (Impacts and actionable)	+ Spill direction West – Southwesterly + Maximum distance 217km from release site + One AMP exposed, Argo-Rowley Terrace with 11% probability of exposure in minimum time of 7 days + No predicted contact with State Marine Parks. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks + No KEFs contacted by floating oil.	+ Spill direction West – Southwesterly + Maximum distance 304km from release site + No predicted contact with AMPs + No predicted contact State Marine Parks. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks + No KEFs contacted by floating oil.	+ Spill direction – Northeast + Maximum distance 221km from release site + No predicted contact with AMPs + No predicted contact State Marine Parks. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks + No KEFs contacted by floating oil.

SHORELINE ACCUMULATION	
	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-43** and **Figure 7-44**. **Figure 7-45** shows the shoreline accumulation at 10 g/m^2 (low threshold). Further information is located in Section 9.2.3.3 of **Attachment 8-1.** The seasonal assessment below is based on 100 spill simulations for each season.

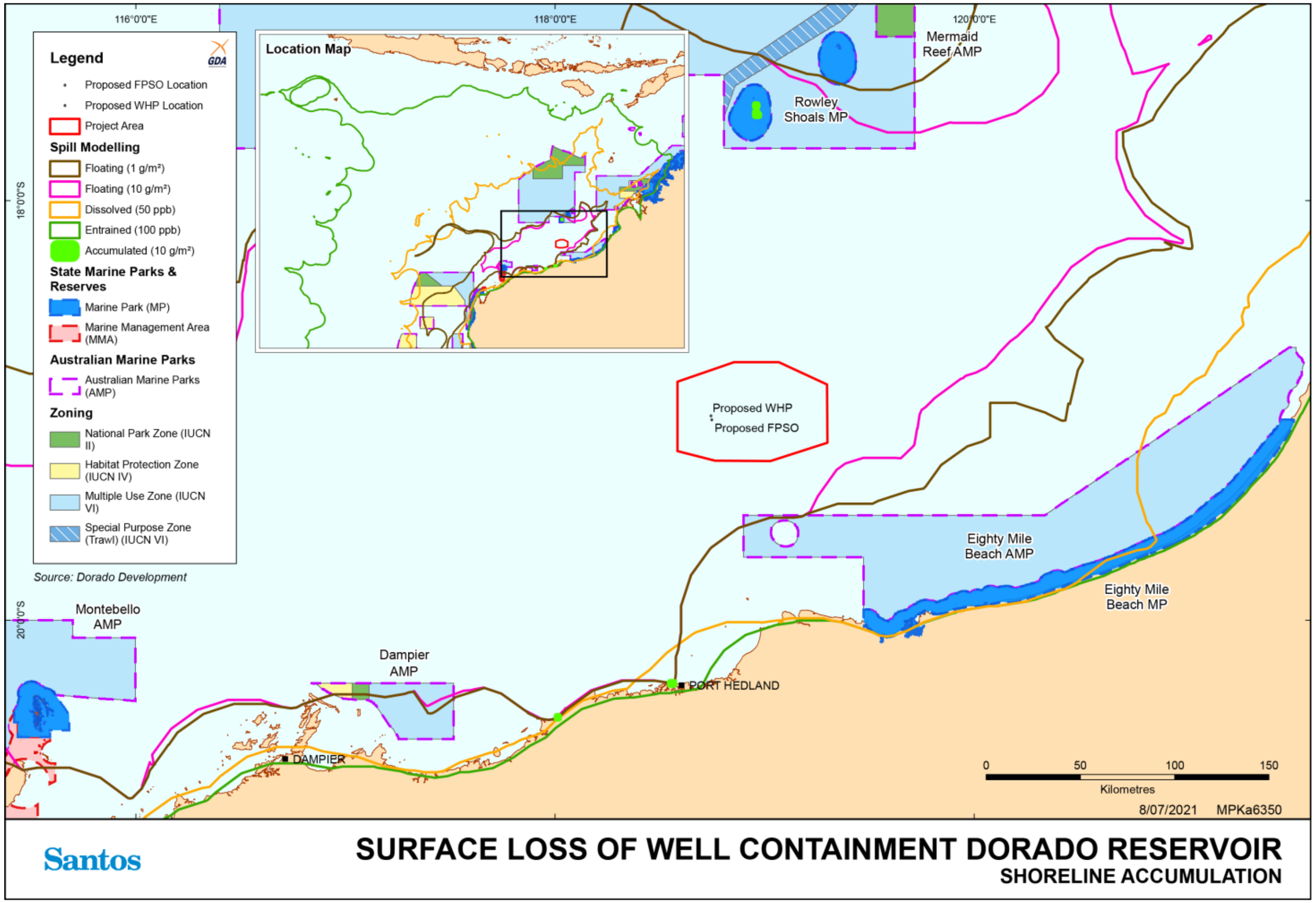

Figure 7-45: Stochastic modelling shoreline accumulation for a worst-case subsea loss of well containment (Dorado Reservoir)

Low 10 g/m² Represents a level of socio-economic effect	<u>Summer</u> + 11% probability of shoreline accumulation in minimum time of 11 days + 9% probability of shoreline accumulation at Port Hedland in minimum time of 11 days, 38m^3 maximum volume of oil ashore + Maximum length of shoreline accumulation at a sensitive receptor was 3 km at Port Hedland, with a peak shoreline loading of 2,320 g/m^2.	<u>Transition</u> + 1% probability of shoreline accumulation in minimum time of 2.8 days + 1% probability of shoreline accumulation at Port Hedland in minimum time of 2days, 10m^3 maximum volume of oil ashore + Maximum length of shoreline accumulation at a sensitive receptor was 1 km at Port Hedland, with a peak shoreline loading of 854 g/m^2	<u>Winter</u> + No predicted shoreline accumulation
Moderate 100 g/m^2 Likely to cause adverse impacts to marine or coastal fauna and habitats	+ 9% probability of shoreline accumulation at Port Hedland in minimum time of 11 days, along 3 km + Maximum length of shoreline accumulation was 4 km	+ 1% probability of shoreline accumulation at Port Hedland in minimum time of 3 days, along 1km	+ No predicted shoreline accumulation
High 1000 g/m^2 Impacts to shoreline receptors	+ 6% probability of shoreline accumulation at Port Hedland in minimum time of 11 days, along 2 km + Maximum length of shoreline accumulation was 2 km	+ No predicted shoreline accumulation	+ No predicted shoreline accumulation
DISSOLOVED AROMATIC HYDROCARBONS			
Low 10 ppb Lower than the exposure value at which ecological impacts are	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-43** and **Figure 7-44**. The figures show the dissolved hydrocarbons at 50ppb (moderate threshold). Further information is located in Section 9.2.3.4 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	<u>Summer</u> + Maximum extent from release location – 1,509km west-southwest.	<u>Transition</u> + Maximum extent from release location – 1,334km west southwest.	<u>Winter</u> + Exposure predicted up to maximum distance of 1,334km west southwest

expected to occur. Relevant for implementing environmental monitoring in event of oil spills	+ Based on all 100 simulations combined - 12 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 64 to 3%, with Montebello AMP being most probable (64% in minimum time of 12 days after spill and a maximum hydrocarbon concentration of 1,366ppb), followed by Gascoyne (43% in minimum time of 15.5 days after spill). The shortest time to contact predicted at Argo-Rowley Terrace within 7.5 days. Maximum dissolved concentrations of 3,000 ppb at Argo-Rowley Terrace AMP. + 1 to 38% probability of contacting 7 State Marine Parks. 39% probability at Rowley Shoals in minimum time of 8.8 days after spill and a maximum concentration of 982 ppb. The maximum dissolved concentration was 1,124 ppb at Montebello Islands. + 39% probability of entering State Waters in minimum time of 9 days after spill, and maximum dissolved hydrocarbon 1,799ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 32 receptors within the EMBA are predicted to be exposed. The greatest probability being 70% at Rankin Bank within 13 days, and a maximum dissolved hydrocarbon concentration of 1,469 ppb. + 2 Ramsar receptor within the combined simulations is potentially exposed with the probability of 12% at Eighty Mile Beach within 13 days with a maximum dissolved hydrocarbon concentration of 393ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 10% within 15 days and a maximum dissolved hydrocarbon concentration of 290ppb. Highest probability of dissolved	+ Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 57 to 1%, with Montebello AMP being most probable (57% in minimum time of 4.1 days after spill, maximum concentration of 608ppb), followed by Argo-Rowley Terrace AMP (47% in minimum time of 10 days after spill). The shortest time to contact predicted at Dampier AMP within 2.7 days. Maximum concentrations of 1,449 ppb @ Argo-Rowley Terrace AMP. + 2 to 46% probability of contacting 7 State Marine Parks, 46% at Rowley Shoals in minimum time of 13.5 days after spill and a maximum concentration of 571 ppb. The shortest time to contact was 9 days at the Montebello Islands. + 46% probability of entering State Waters in minimum time of 2.8 days after spill, and maximum entrained hydrocarbon 699 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 22 receptors within the EMBA are predicted to be exposed. The greatest probability being 78% at Glomar Shoal within 4 days, and a maximum entrained hydrocarbon concentration of 1,005 ppb, followed by Rankin Bank at 62% probability, within 6.8 days and a maximum concentration of 555 ppb. + <1% probability of exposure to Ramsar receptors. + Bedout Island (closest nearshore receptor to the south) with probability of 2% within	+ Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 78 to 4%, with Argo-Rowley Terrace AMP being most probable (78% in minimum time of 15.7 days after spill), followed by Montebello AMP (52% in minimum time of 18 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 7 days. Maximum concentrations of 2,387 ppb at Montebello AMP. + 1 to 64 % probability of contacting 6 State Marine Parks. Rowley Shoals (64% probability in a minimum time 16.5 days with a maximum concentration of 464 ppb). Montebello (7% probability in a minimum time 29 days with a maximum concentration of 804 ppb). + 64% probability of entering State Waters in minimum time of 10.75 days after spill, and maximum entrained hydrocarbon 1,735 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 14 receptors within the EMBA are predicted to be exposed. The greatest probability being 93% at Glomar within 9.4 days, and a maximum entrained hydrocarbon concentration of 494 ppb, followed by Rankin Bank at 66% probability (within 16 days), and a maximum concentration of 440 ppb. + 1 Ramsar receptor within the combined simulations potentially exposed with the

	contact at Imperieuse Reef of 37% within 12 days. Maximum dissolved hydrocarbon concentration of 1,556 ppb at Legendre Island, and the shortest time to contact of 11.5 days. + Based on all 100 simulations combined - 4 of the KEFs within the EMBA are predicted to be exposed, probability of exposure to individual KEFs, maximum probability of 24% at Ningaloo Reef (within 16 days @ 215 ppb). The probability of exposure at the 125m water depth Ancient Coastline adjacent to the Project Area was <1%.	18 days and a maximum entrained hydrocarbon concentration of 70ppb. Highest probability of contact at Imperieuse Reef of 38% within 18 days at 150 ppb maximum. The shortest time to contact was at Karratha in 2.96 days, and the maximum entrained hydrocarbon was at Karratha of 699ppb. + Based on all 100 simulations combined - 14 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 100% for the ancient coastline at 125m depth contour, within 1.5 days, and a maximum hydrocarbon concentration of 5,374ppb.	probability of 1% at Roebuck Bay within 115 days with a maximum concentration of 10 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 7% within 12 days and a maximum entrained hydrocarbon concentration of 296 ppb. Highest probability of contact at Imperieuse Reef of 55% within 19 days at 232 ppb. The maximum dissolved concentration at Hermite Island, within 29 days at 607ppb. + Based on all 100 simulations combined - 11 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 100% for the ancient coastline at 125m depth contour, within 0.9 days, and a maximum hydrocarbon concentration of 7,116 ppb.
Moderate 50 ppb Approximates potential toxic effects, particularly sublethal effects to sensitive species.	<u>Summer</u> + Maximum extent from release location – 1,265km, southwest. + Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, with Montebello AMP being most probable (35% in minimum time of 12 days after spill), followed by Argo-Rowley Terrace at 26% within 7.5 days. + 6 to 18% probability of contacting 4 State Marine Parks. 18% probability at Rowley Shoals in minimum time of 9 days after spill + 18% probability of entering State Waters in minimum time of 10 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 19 receptors within the EMBA are predicted to be	<u>Transition</u> + Maximum extent from release location – 1,117km west southwest. + Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 26 to 1%, with Montebello AMP being most probable (26% in minimum time of 5 days after spill). The shortest time to contact predicted at Dampier AMP within 2.75 days. + 1 to 14% probability of contacting 3 State Marine Parks, 14% at Rowley in minimum time of 13.5 days. + 14% probability of entering State Waters in minimum time of 2.9 days after spill.	<u>Winter</u> + Maximum extent from release location – 1,181km west. + Based on all 100 simulations combined - 11 of the AMPs within the EMBA are predicted to be exposed, maximum probability of exposure at Argo-Rowley Terrace of 33% in minimum time of 16 days after spill), followed by Montebello AMP (12% in minimum time of 20 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 8 days. + 1 to 64% probability of contacting 6 State Marine Parks, 64% at Rowley Shoals in minimum time of 16.5 days after the spill.

	exposed. The greatest probability being 44% at Rankin Bank within 14 days. + 1 Ramsar receptor within the combined simulations is potentially exposed with the probability of 5% at Eighty Mile Beach within 14 days. + Bedout Island (closest nearshore receptor to the south) with probability of 5% within 31 days. Highest probability of dissolved contact at Imperieuse Reef and Barrow Island of 11% within 12 days and 31 days respectively. + Based on all 100 simulations combined - 2 of the KEFs within the EMBA are predicted to be exposed, probability of 5%, at Ningaloo Reef (within 16 days).	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 11 receptors within the EMBA are predicted to be exposed. The greatest probability being 30% at Rankin Bank within 6.9 days. + No exposure of Ramsar receptors. + Highest probability of contact to nearshore receptor at Karratha of 1% within 3.5 days. + Based on all 100 simulations combined - 5 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 94% for the ancient coastline at 125m depth contour, within 1.8 days.	+ 28% probability of entering State Waters in minimum time of 10 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 23 receptors within the EMBA are predicted to be exposed. The greatest probability being 92% at Glomar Shoals within 9 days, followed by Rankin Bank at 92% probability, within 16 days + 1 Ramsar receptor within the combined simulations potentially exposed with the probability of 3% at Roebuck Bay within 82 days. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 12 days. Highest probability of contact at Imperieuse Reef of 79% within 19 days. + Based on all 100 simulations combined - 11 of the KEFs within the EMBA are predicted to be exposed, maximum probability of exposure at 100% at the ancient coastline at 125m depth contour, within 0.9 days
High 400 ppb Approximates toxic effects including lethal effects to sensitive species	Summer + Maxim west southwestern extent from release location – 892km + Based on all 100 simulations combined – 7 of the AMPs within the EMBA are predicted to be exposed, with Argo Rowley Terrace AMP being most probable (8% in minimum time of 7.5 days. + 1 to 3% probability of contacting 3 State Marine Parks. 3% probability at Eighty Mile Beach in minimum time of 13 days after spill.	Transition + Maximum extent from release location – 509km west + Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 3% to 1%, with Argo-Rowley AMP being most probable (3% in minimum time of 13.6 days after spill.	Winter + Maximum extent from release location – 975km, southwest. + Based on all 100 simulations combined - 6 of the AMPs within the EMBA are predicted to be exposed, maximum probability of exposure at Montebello AMP of 3% in minimum time of 43 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 8 days.

	+ 5% probability of entering State Waters in minimum time of 11 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 3 receptors within the EMBA are predicted to be exposed. The greatest probability being 4% at Rankin Bank within 14 days. + <1% probability of exposure to Ramsar receptors. + 4% probability of exposure at nearshore receptors of Legendre Island and Haury Island within 12 days and 43 days respectively. <1% probability of contact at Bedout Island + <1% probability of exposure to the KEFs within the EMBA.	+ 1 % probability of contacting 1 State Marine Parks, 1% at Rowley Shoals in minimum time of 17 days. + 1% probability of entering State Waters in minimum time of 3.5 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 3 receptors within the EMBA are predicted to be exposed. The greatest probability being 5% at Glomar Shoals within 12 days. + No exposure of Ramsar receptors. + Highest probability of contact to nearshore receptor at Karratha of 1% within 3.5 days. + Based on all 100 simulations combined - 5 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 94% for the ancient coastline at 125m depth contour, within 1.8 days.	+ 1 to 2% probability of contacting 2 State Marine Parks, 2% at Montebello MP in minimum time of 66 days after the spill. + 3% probability of entering State Waters in minimum time of 25 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – only 1 receptor, with a probability of 1% at Glomar Shoals within 45 days. + No exposure of Ramsar receptors. + Highest probability of contact at Hermite Island of 2% within 67 days, <1% probability of contact at Bedout Island. + Based on all 100 simulations combined - 6 of the KEFs within the EMBA are predicted to be exposed, maximum probability of exposure at 100% at the ancient coastline at 125m depth contour, within 0.9 days
ENTRAINED HYDROCARBON			
Low 10 ppb Lower than the exposure value at which ecological impacts are expected to occur. Relevant for implementing environmental monitoring in	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-43** and **Figure 7-44**. The figures show the entrained hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. Further information is located in Section 9.2.3.3 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	<u>Summer</u> + Maximum extent from release location – 2,600km + Based on all 100 simulations combined - 20 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 95 to 5%, with Montebello AMP being most probable (95% in minimum time of 12 days after spill, maximum entrained hydrocarbon concentration of 10,713 ppb), followed by Gascoyne (93% in minimum time of 13	<u>Transition</u> + Maximum extent from release location – 2,488km + Based on all 100 simulations combined - 20 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 96 to 1%, with Argo-Rowley Terrace AMP being most probable (96% in minimum time of 8 days after spill), followed by Montebello AMP	<u>Winter</u> + Exposure predicted up to maximum distance of 2,932km west-northwest + Based on all 100 simulations combined - 19 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 100 to 1%, with Argo-Rowley Terrace AMP being most probable (100% in minimum time of 13 days after spill),

event of oil spills	days after spill). The shortest time to contact predicted at Eighty Mile Beach and Argo-Rowley Terrace within 7.5 days. + 7 to 83% probability of contacting 15 State Marine Parks, 83% probability at Ningaloo AMP in minimum time of 13.7 days after spill and a maximum concentration of 1,992ppb. Rowley Shoals had the shortest time to contact within 9 days and the maximum entrained hydrocarbon concentration of 10,648ppb. + 4 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 26% at Roebuck Bay within 44 days with a maximum entrained hydrocarbon concentration of 673ppb. Eighty Mile Beach is contacted in the shortest timeframe of 12.5 days, and has a maximum entrained hydrocarbon concentration of 2,912ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 104 receptors within the EMBA are predicted to be exposed. The greatest probability being 96% at Rankin Bank within 12.8 days, and a maximum entrained hydrocarbon concentration of 9,809 ppb. Imperieuse Reef is contacted within 10 days, and has the maximum entrained hydrocarbon concentration of 10,648ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 38% within 15 days and a maximum entrained hydrocarbon concentration of 1,743ppb. Highest probability of contact at Exmouth of 75% within 16 days. The shortest time to contact is at Delambre Island within 12 days, and Cunningham Island had the maximum entrained concentration of 10,648ppb. + Based on all 100 simulations combined - 7 of the KEFs within the EMBA are predicted to be	(94% in minimum time of 4 days after spill). The shortest time to contact predicted at Dampier AMP within 2.6 days. Maximum concentrations of 9,274 ppb @ Argo-Rowley Terrace AMP. + 1 to 81% probability of contacting 15 State Marine Parks, 81% at Rowley Shoals in minimum time of 10.8 days after spill and a maximum concentration of 7,374 ppb. The shortest time to contact was 7 days at the Montebello Islands. + 81% probability of entering State Waters in minimum time of 2.7 days after spill, and maximum entrained hydrocarbon 7,350 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 88 receptors within the EMBA are predicted to be exposed. The greatest probability being 97% at Glomar Shoal within 3 days, and a maximum entrained hydrocarbon concentration of 6,044 ppb, followed by Rankin Bank at 94% probability, within 6.2 days and a maximum concentration of 4,973 ppb. + 3 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 11 % at Peel-Yalgorup System within 79 days and maximum concentration of 70ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 17 days and a maximum entrained hydrocarbon concentration of 203 ppb. Highest probability of contact at Imperieuse Reef of 79% within 14 days at 3,953 ppb	followed by Montebello AMP (97% in minimum time of 16 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 6 days. Maximum concentrations of 9,426 ppb at Argo-Rowley Terrace AMP and 8,658 ppb at Montebello AMP. + 1 to 93 % probability of contacting 14 State Marine Parks. Rowley Shoals (93% probability in a minimum time 13.9 days with a maximum concentration of 6,812 ppb). Montebello (86% probability in a minimum time 22 days with a maximum concentration of 1,235 ppb). + 93% probability of entering State Waters in minimum time of 8.75 days after spill, and maximum entrained hydrocarbon 6,812 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 75 receptors within the EMBA are predicted to be exposed. The greatest probability being 99% at Glomar within 9 days, and a maximum entrained hydrocarbon concentration of 5,576 ppb, followed by Rankin Bank at 97% probability (within 16 days), and a maximum concentration of 10,764 ppb. + 5 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 11 % at Ashmore Reef Nature Reserve within 76 days with a maximum concentration of 30 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 18%

	exposed, probability of exposure of 79%, at Ningaloo Reef (within 14 days at 1,707 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted. + 83% probability of entering State Waters in minimum time of 8 days after spill, and maximum entrained hydrocarbon 10,648ppb.	maximum. The shortest time to contact was at Delambre Island in 2.75 days, and the maximum entrained hydrocarbon was at Clerke Reef of 5,829 ppb. + Based on all 100 simulations combined - 21 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 100% for the ancient coastline at 125m depth contour, within 1.2 days, and a maximum hydrocarbon concentration of 61,797ppb. The Continental Slope Demersal Communities KEF also has a probability of 100% for exposure, within 7 days, and a maximum entrained hydrocarbon concentration of 7,096ppb.	within 11 days and a maximum entrained hydrocarbon concentration of 199 ppb. Highest probability of contact at Imperieuse Reef and Cunningham Island of 92% within 18 and 19 days respectively at 3,460 ppb and 2,652ppb maximum concentrations respectively. + Based on all 100 simulations combined - 21 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 100% for the ancient coastline at 125m depth contour, within 1 days, and a maximum hydrocarbon concentration of 48,104ppb. The Continental Slope Demersal Communities KEF also has a probability of 100% for exposure, within 8.4 days, and a maximum entrained hydrocarbon concentration of 14,247 ppb.
Moderate 100 ppb	+ Maximum extent from release location – 1,994km + Exposure predicted at 18 AMPs, maximum probability of exposure 85% (Montebello AMP in minimum time of 12 days after spill) + Exposure predicted at 12 State Marine Parks maximum probability of exposure 57% (Rowley Shoals MP and Ningaloo MP, 57% and 36% respectively) in minimum time of 9 days and 15 days after spill respectively. + 57% probability of entering State Waters in minimum time of 9 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 50 receptors within the EMBA are predicted to be exposed. The greatest probability being 89% at Rankin Bank within 12 days.	+ Maximum extent from release location – 1,735km + Based on all 100 simulations combined - 13 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 87 to 1%, with Argo-Rowley Terrace AMP being most probable (87% in minimum time of 9 days after spill). The shortest time to contact predicted at Montebello AMP within 4.1 days. + 1 to 56% probability of contacting 8 State Marine Parks, 56% at Rowley in minimum time of 11.3 days, and a maximum entrained hydrocarbon concentration of 7,374ppb.	+ Exposure predicted up to maximum distance of 2,169km west-northwest + Based on all 100 simulations combined - 12 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 98 to 2%, with Argo-Rowley Terrace AMP being most probable (98% in minimum time of 14 days after spill), followed by Montebello AMP (87% in minimum time of 17 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP within 7 days. + 1 to 82% probability of contacting 9 State Marine Parks, 82% at Rowley Shoals in minimum time of 16 days after the spill.

	+ 4 Ramsar receptors within the combined simulations are potentially exposed with the greatest probability of 15% at Eighty Mile Beach within 19 days. + Bedout Island (closest nearshore receptor to the south) with probability of 33% within 15 days. Highest probability of contact at Imperieuse Reef of 53% within 12 days. The shortest time to contact is at Delambre Island within 12 days. + Based on all 100 simulations combined - 5 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 30%, at Ningaloo Reef (within 14 days). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.	+ 56% probability of entering State Waters in minimum time of 2.7 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 26 receptors within the EMBA are predicted to be exposed. The greatest probability being 86% at Rankin Bank and Glomar Shoals within 6.5 and 3.8 days respectively. + No exposure of Ramsar receptors. + Bedout Island (closest nearshore receptor to the south) with probability of 4% within 24 days. Highest probability of contact at Imperieuse Reef of 50% within 14 days. + Based on all 100 simulations combined - 17 of the KEFs within the EMBA are predicted to be exposed, probability of exposure of 100% for the ancient coastline at 125m depth contour, within 1.2 days. The Continental Slope Demersal Communities KEF has a probability of 94% for exposure, within 7 days.	+ 81% probability of entering State Waters in minimum time of 10 days after spill. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 23 receptors within the EMBA are predicted to be exposed. The greatest probability being 92% at Glomar Shoals within 9 days, followed by Rankin Bank at 92% probability, within 16 days + 1 Ramsar receptor within the combined simulations potentially exposed with the probability of 3% at Roebuck Bay within 82 days. + Bedout Island (closest nearshore receptor to the south) with probability of 6% within 12 days. Highest probability of contact at Imperieuse Reef of 79% within 19 days. + Based on all 100 simulations combined - 11 of the KEFs within the EMBA are predicted to be exposed, maximum probability of exposure at 100% at the ancient coastline at 125m depth contour, within 0.7 days.

Predicted impacts and risks based on Deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in:

1) **largest volume of oil ashore**
2) **longest length of shoreline with oil accumulation**

Largest volume of oil ashore (Refer Figure 7-46)	**Longest length of shoreline accumulation (Refer Figure 7-47)**
+ Floating oil exposure predicted north/northeast and west/southwest from the spill location + Shoreline accumulation from Day 42. + Maximum area of floating oil sea surface at 1g/m^2 is on Day 9 of 650m^3. + Shoreline accumulation at Port Hedland.	+ Floating oil exposure predicted northeast and west/southwest from the spill location + Shoreline accumulation at Port Hedland, Cunningham Island and Imperieuse Reef.

+ Maximum length of shoreline accumulation (at 100g/m^2) of 3km. + At end of spill, 61% spilled oil lost to the atmosphere through evaporation, 31% predicted to have decayed, 8% remained in the water column and 15 m^3 (<0.1%) predicted to remain on the shoreline.	+ Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 42 days after the spill started approximately 550 km^2. + Maximum length of actionable shoreline oiled (above 100 g/m^2) at any given time was 2 km, at approximately 76 days after the spill. + Largest volume of oil onshore at the low threshold (10g/m^2), 12m^3 on Day 75. + At end of spill, 60% spilled oil lost to the atmosphere through evaporation. 31% predicted to have decayed, 8% remained in the water column and 5 m^3 (<0.1%) predicted to remain on the shoreline.

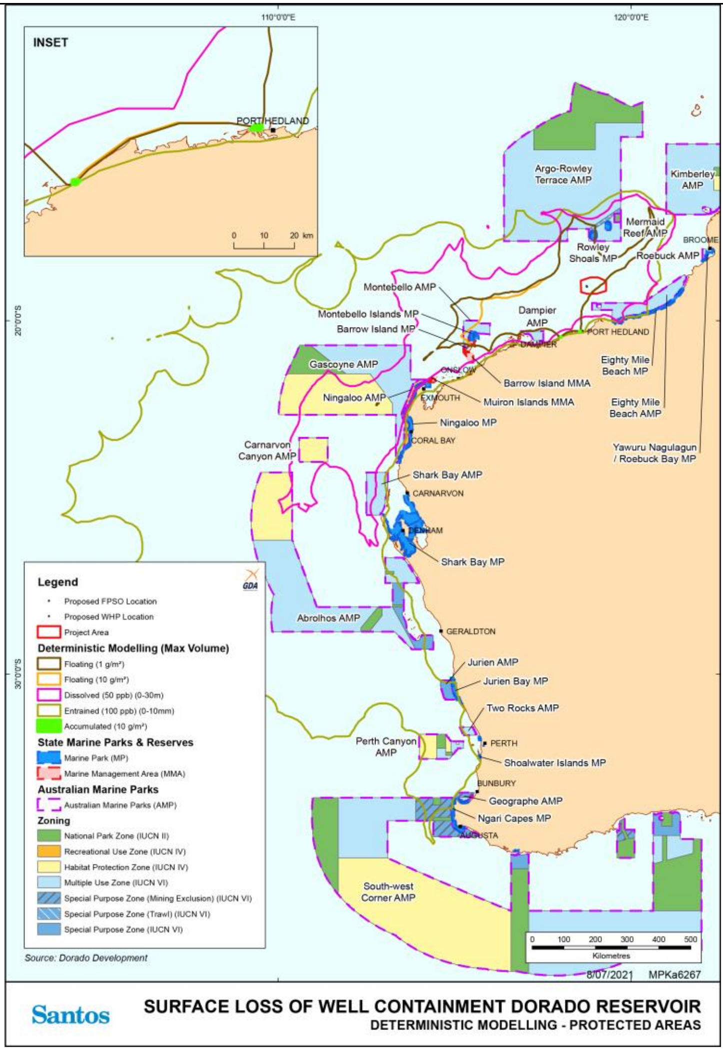

Figure 7-46: Worst-case deterministic model results for floating oil phase for a worst-case surface loss of well containment (Dorado Reservoir) based on largest volume of shoreline oil

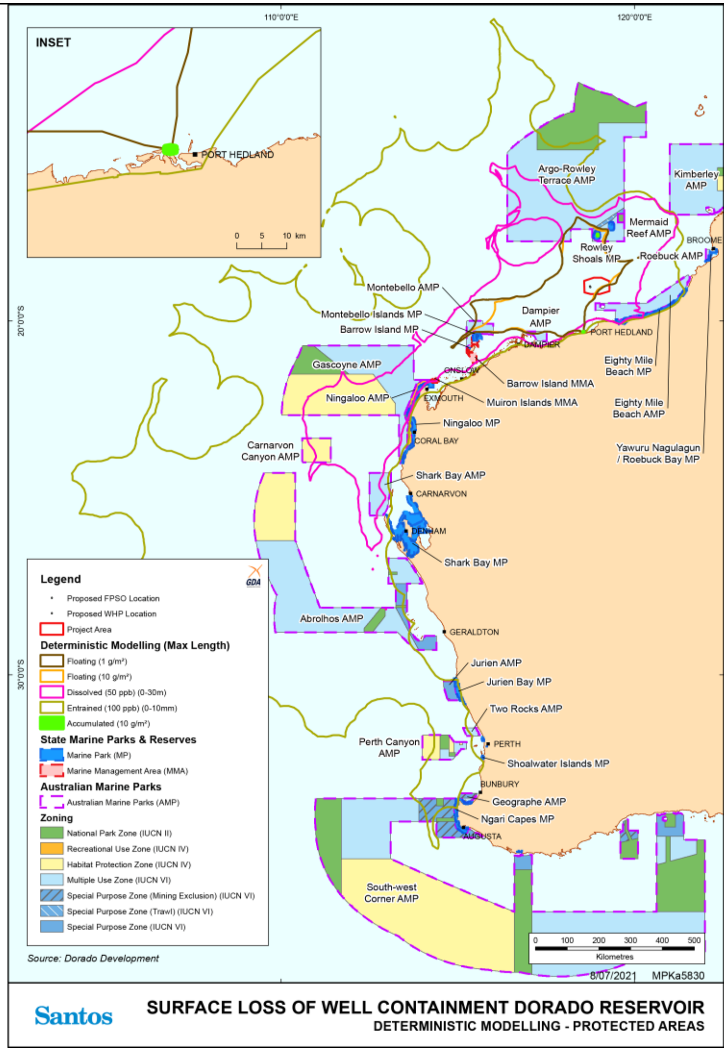

Figure 7-47: Worst-case deterministic model results for floating oil phase for a worst-case surface loss of well containment (Dorado Reservoir) based on largest maximum length of shoreline contact

7.3.1.5.3 Loss of Containment HFO due to Vessel Collision

Stochastic modelling results from the worst-case loss of containment due to a vessel collision scenario are shown in **Figure 7-48.** A summary of the stochastic modelling results for floating oil, shoreline accumulation, dissolved and entrained hydrocarbons for a subsea loss of well containment for each season is provided in **Table 7-79**. The worst-case deterministic runs, based on the largest volume of oil onshore and longest length of shoreline accumulation are shown in **Figure 7-50** and **Figure 7-51** and a summary of the results included in **Table 7-79**.

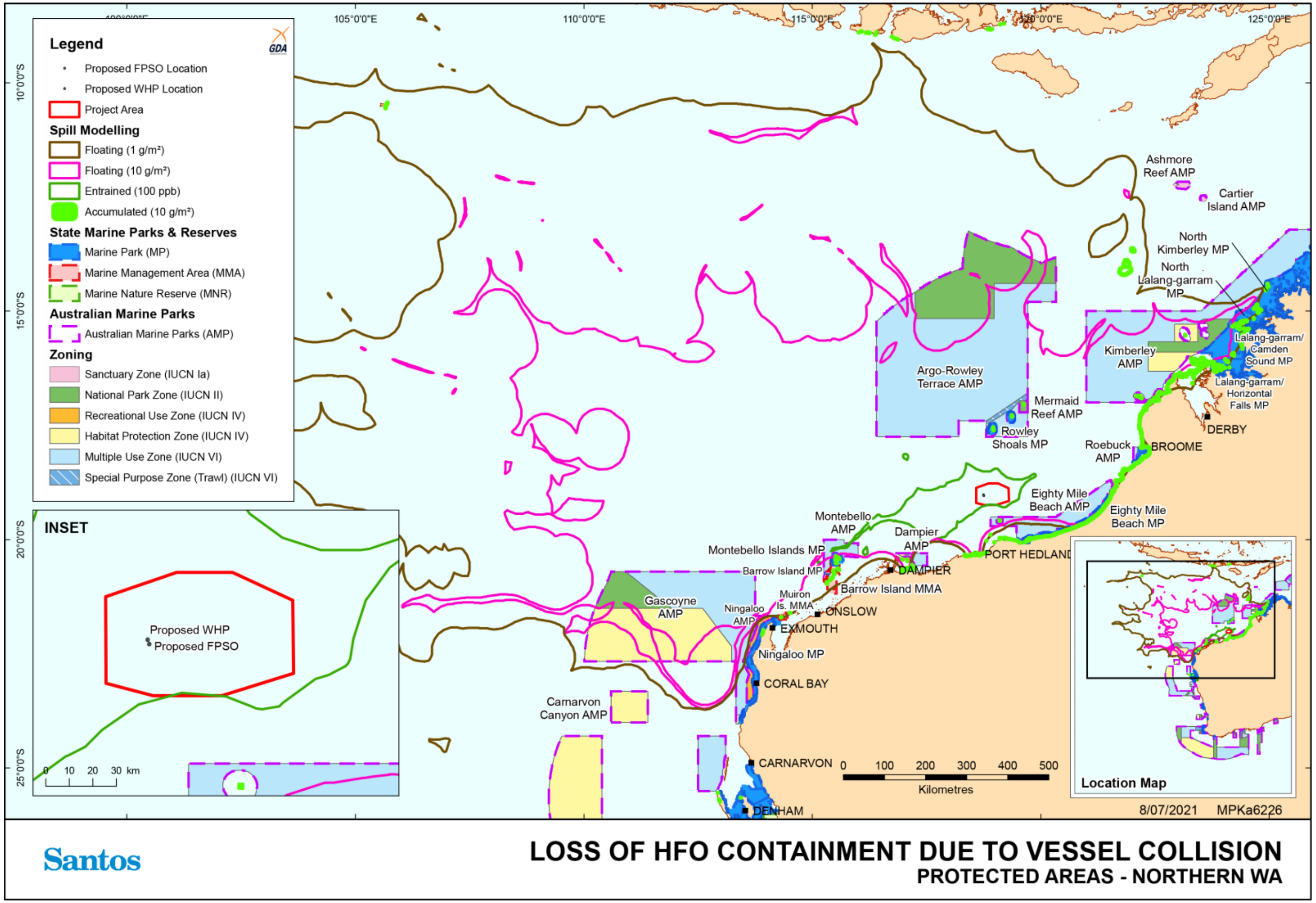

Figure 7-48: EMBA derived from stochastic modelling for floating, entrained and dissolved oil phases for a worst-case loss of containment HFO due to vessel collision

Table 7-79: Loss of Containment of HFO due to Vessel Collision

<table>
<tr><th>Impact Thresholds (NOPSEMA, 2019b)</th><th colspan="3">Predicted impacts and risks based on stochastic model predictions = footprint (trajectory and fate) encompassing 300 releases (100 in summer, 100 in winter and 100 in transitional season).</th></tr>
<tr><td colspan="4">FLOATING OIL (SURFACE)</td></tr>
<tr><td rowspan="2">Low
1 g/m^2
Visible but no biological effects.
Lower than the exposure value for ecological impacts
Relevant for implementing environmental monitoring in event of oil spills</td><td colspan="3">Stochastic model predictions (EMBA is for all seasons combined, Figure 7-48. Further information is located in Section 9.5.3.1 of Attachment 8-1. The seasonal assessment below is based on 100 spill simulations for each season.</td></tr>
<tr><td><u>Summer</u>
+ Spill direction – west-northwest at maximum distance 1433km from release site
+ Based on all 100 simulations combined - 9 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 27%, with Argo-Rowley Terrace AMP being most probable (27% in minimum time of 11 days after spill). The shortest time to contact at Montebello AMP in 5 days.
+ 1 to 15% probability of contacting 8 State Marine Parks (15% at both Rowley Shoals and Yawuru Nagulagun/ Roebuck Bay) in minimum time of 17 days and 12 days after spill respectively.
+ 69% probability of entering State Waters in minimum time of 11 days after spill
+ 1 to 42% probability of contacting shorelines, 42% at Broome within 12 days. Bedout Island has a probability of contact of 1% in 17 days after the spill.</td><td><u>Transition</u>
+ Spill direction west-northwest at maximum distance 2143km from release site
+ Based on all 100 simulations combined - 6 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 53%, with Argo-Rowley Terrace AMP being most probable (53% in minimum time of 7 days after spill). The shortest time to contact at Montebello AMP in 3.9 days.
+ 2 to 23% probability of contacting 2 State Marine Parks, maximum of 23% at Rowley Shoals, in minimum time of 10 days after the spill.
+ 25% probability of entering State Waters in minimum time of 10 days after spill
+ 1 to 16% probability of contacting shorelines, maximum of 16% at Imperieuse Reef and Cunningham Island within 13.6 days. < 1% probability of contact at Bedout Island.
+ 1 to 20% probability of contacting four sensitive reefs, shoals and banks (maximum probability of 20% at Imperieuse Reef within 11.5 days)
+ 1% probability of contacting Ramsar receptor Roebuck Bay within 36 days.</td><td><u>Winter</u>
+ Spill direction – west-northwest at maximum distance 1923km from release site
+ Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 49%, with Argo-Rowley Terrace AMP being most probable and the shortest time to contact (49% in minimum time of 7.6 days after spill).
+ 10% probability of contacting 1 State Marine Parks, Rowley Shoals, in minimum time of 12.2 days after the spill.
+ 22% probability of entering State Waters in minimum time of 12.2 days after spill
+ 1 to 6% probability of contacting shorelines, maximum of 6% at Cunningham Island within 13.9 days. < 1% probability of contact at Bedout Island.
+ 1 to 8% probability of contacting 3 sensitive reefs, shoals and banks (maximum probability of 8% at Imperieuse Reef within 13.4 days)
+ <1% probability of contacting Ramsar receptors.</td></tr>
</table>

	+ 1 to 11% probability of contacting reefs, shoals and banks (maximum probability of 11% at Imperieuse Reef within 12.5 days) + 14% probability of contacting Ramsar receptors at Roebuck Bay within 18 days, and 8% probability of contact at Eighty Mile Beach in 16 days. + No KEFs contacted by floating oil.	+ No KEFs contacted by floating oil.	+ No KEFs contacted by floating oil.
Moderate 10 g/m^2 Environmental values and sensitivities may be at risk of impacts from floating oil.	Summer + Spill direction West – southwest at maximum distance 1010km from release site + Based on all 100 simulations combined - 8 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 12%, with Argo-Rowley Terrace AMP being most probable (12% in minimum time of 11.5 days after spill). The shortest time to contact at Montebello AMP in 5 days. + 1 to 7% probability of contacting 7 State Marine Parks (7% at Yawuru Nagulagun/ Roebuck Bay) in minimum time of 18 days. + 44% probability of entering State Waters in minimum time of 11 days after spill + 1 to 31% probability of contacting shorelines, 31% at Broome within 12 days. Bedout Island has a probability of contact of 1% in 17.5 days after the spill. + 1 to 3% probability of 4 contacting reefs, shoals and banks (maximum probability of 3% at Imperieuse Reef within 12.9 days) + 7% probability of contacting Ramsar receptors at Roebuck Bay within 19 days, and 4% probability of contact at Eighty Mile Beach in 16 days.	Transition + Spill direction West – northwest at maximum distance 1489km from release site + Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 40%, with Argo-Rowley Terrace AMP being most probable (40% in minimum time of 7.5 days after spill). The shortest time to contact at Montebello AMP in 3.9 days. + 2 to 23% probability of contacting 2 State Marine Parks, maximum of 9% at Rowley Shoals, in minimum time of 11 days after the spill. + 11% probability of entering State Waters in minimum time of 11 days after spill + 2% probability of contacting 3 sensitive shorelines at Broome, Cunningham Island and Imperieuse Reef, within 13.8 days. < 1% probability of contact at Bedout Island. + 1 to 20% probability of contacting 2 sensitive reefs, shoals and banks (maximum probability of 6% at Imperieuse Reef within 11.9 days) + <1% probability of contacting Ramsar receptors.	Winter + Spill direction – west-northwest at maximum distance 1707km from release site + Based on all 100 simulations combined - 3 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 30%, with Argo-Rowley Terrace AMP being most probable and the shortest time to contact (30% in minimum time of 7.6 days after spill). + 6% probability of contacting 1 State Marine Parks, Rowley Shoals, in minimum time of 12.7 days after the spill. + 6% probability of entering State Waters in minimum time of 12.7 days after spill + 1 % probability of contacting shorelines, at Imperieuse Reef within 13.4 days. + 1 to 2% probability of contacting 2 sensitive reefs, shoals and banks, Imperieuse Reef within 13.4 days, and 2% at Mermaid Reef within 22 days.

High 50 g/m^2 Potential for impact of surface oil to wildlife	Summer + Spill direction West – Southwest at maximum distance 984km from release site + Based on all 100 simulations combined - 7 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 5%, with Montebello AMP being most probable (5% in minimum time of 5 days). + 1% probability of contacting Yawuru Nagulagun/ Roebuck Bay state marine park in minimum time of 18 days. + 4% probability of entering State Waters in minimum time of 17 days after spill + 1 to 2% probability of contacting shorelines, 2% at Broome within 17 days. < 1% probability of contact at Bedout Island. + 1% probability of contact of one sensitive reefs, Shoals and Banks – Mermaid Reef, within 20 days. + No KEFs contacted by floating oil.	Transition + Spill direction West – Southwest at maximum distance 1013km from release site + Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 10%, with Argo-Rowley Terrace AMP being most probable (10% in minimum time of 7.7 days after spill). The shortest time to contact at Montebello AMP in 3.9 days. + 2% probability of contacting Rowley Shoals State Marine Park in minimum time of 12.6 days after the spill. + 2% probability of entering State Waters in minimum time of 12.6 days after spill + 1% probability of contacting 1 sensitive shoreline at Imperieuse Reef, within 14 days. + 1 % probability of contacting 1 sensitive reefs, shoals and banks at Imperieuse Reef within 14 days.	Winter + Spill direction – west at maximum distance 695km from release site + Based on all 100 simulations combined – one AMPs within the EMBA is predicted to be exposed, probability of exposure 3% at Argo-Rowley Terrace AMP minimum time of 7.7 days after spill. + No predicted contact State Marine Parks. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks
SHORELINE ACCUMULATION			
	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-49**. shows the shoreline accumulation at 10 g/m^2 (low threshold). Further information is located in Section 9.5.3.2 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		

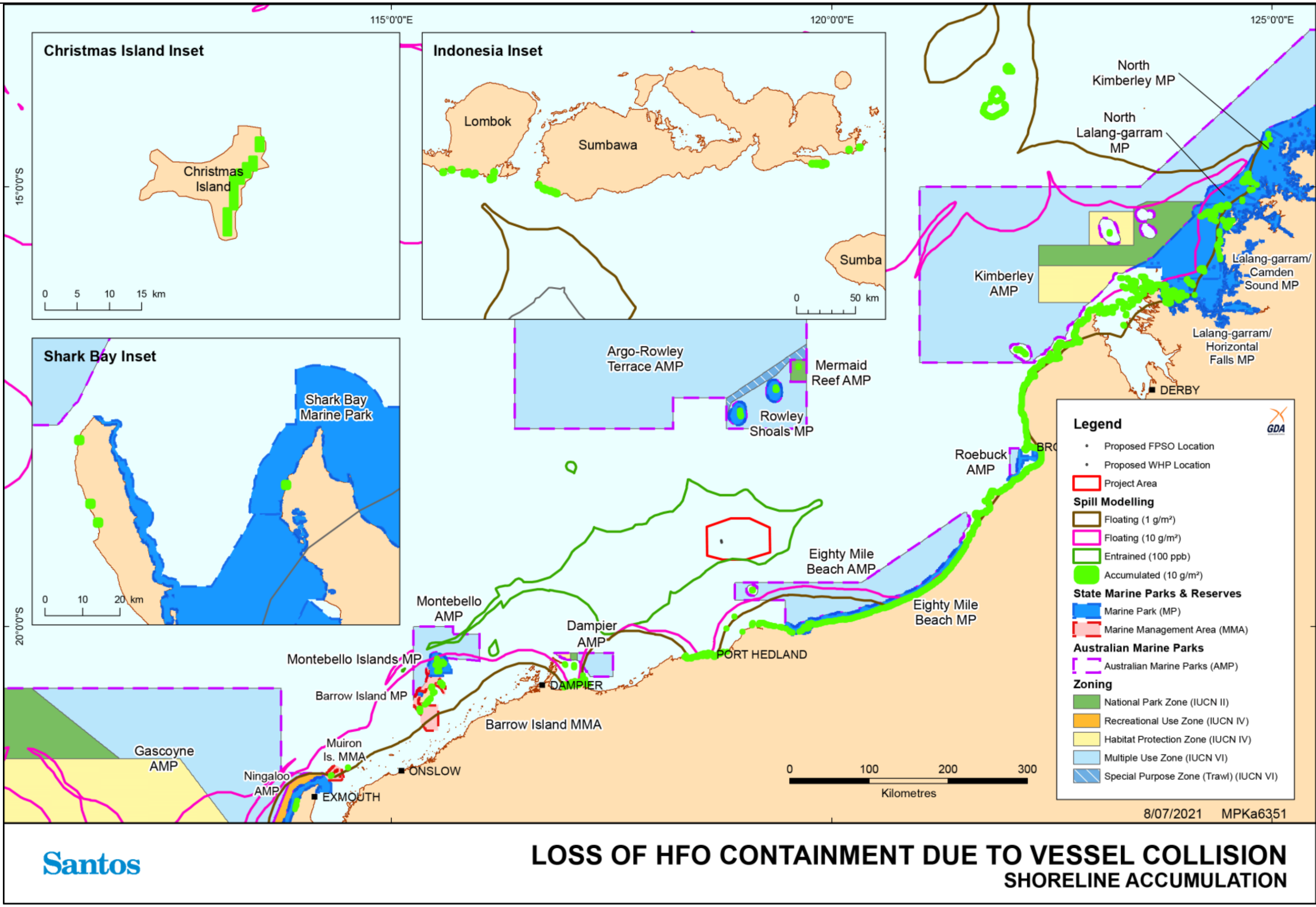

Figure 7-49: Stochastic modelling shoreline accumulation for a worst-case FPSO loss of HFO containment

Low 10 g/m² Represents a level of socio-economic effect	Summer + 72% probability of shoreline accumulation in minimum time of 12.3 days, maximum volume of oil ashore 1,684.5 m³ + Maximum length of shoreline accumulation 259km. + Maximum probability of 45% at sensitive receptor shoreline - Broome, within 12.3 days, peak shoreline loading 17,532g/m², peak volume 1,684m³, with a maximum length of 252km.	Transition + 31% probability of shoreline accumulation in minimum time of 11.7 days, maximum volume of oil ashore 1,383 m³ + Maximum length of shoreline accumulation 159km. + Maximum shoreline loading at sensitive receptor Broome of 10,684g/m², with a maximum length of shoreline accumulation of 118km. + Maximum probability of 21% at sensitive receptor shorelines – - Imperieuse Reef within 11.6 days, peak shoreline loadings of 17,468g/m², peak volume of 440m³ with a maximum length of 5km. - Cunningham Island within 12 days, peak shoreline loading of 3,991 g/m², peak volume of 1,383m³, with a maximum length of 2km.	Winter + 16% probability of shoreline accumulation in minimum time of 13.4 days, maximum volume of oil ashore 958 m³ + Maximum length of shoreline accumulation 112km. + Maximum shoreline loading at sensitive receptor Mermaid Reef of 10,149 g/m², with a maximum length of shoreline accumulation of 2km. + Maximum probability of 10% at sensitive receptor shorelines – - Cunningham Island within 13.9 days, peak shoreline loadings of 4,975 g/m², peak volume of 110 m³ with a maximum length of 2km. - Mermaid Reef within 15 days, peak shoreline loading of 10,149 g/m², peak volume of 225m³, with a maximum length of 2km.
Moderate 100 g/m² Likely to cause adverse impacts to marine or coastal fauna and habitats	+ Maximum length of shoreline accumulation 160km. + Maximum probability of 44% at sensitive receptor shoreline - Broome, within 12.3 days, with a maximum length of 148km.	+ Maximum length of shoreline accumulation 77km. + Maximum probability of 12% at sensitive receptor shoreline of Imperieuse Reef within 13.7 days, with a maximum length of 5km.	+ Maximum length of shoreline accumulation 84km + Maximum probability of 10% at sensitive receptor shorelines – - Cunningham Island within 14 days with a maximum length of 2km. - Imperieuse Reef within 13.5 days with a maximum length of 5km.

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High 1000 g/m^2 Impacts to shoreline receptors	+ Maximum length of shoreline accumulation 44km. + Maximum probability of 41% at sensitive receptor shoreline - Broome, within 12.4 days, with a maximum length of 44km.	+ Maximum length of shoreline accumulation 31km. + Maximum probability of 12% at sensitive receptor shoreline of Imperieuse Reef within 13.7 days, with a maximum length of 5km.	+ Maximum length of shoreline accumulation 28km + Maximum probability of 5% at sensitive receptor shoreline of Imperieuse Reef within 13.6 days, with a maximum length of 3km.
DISSOLOVED AROMATIC HYDROCARBONS			
Low 10 ppb	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-48**. The figures show the dissolved hydrocarbons at 50 ppb (moderate threshold). Further information is located in Section 9.5.3.4 of **Attachment 8**. The seasonal assessment below is based on 100 spill simulations for each season.		
	Summer + Maximum extent from release location 42km northwest. + No predicted of contact of sensitive receptors	Transition + Maximum extent from release location 215km north-northwest. + No predicted of contact of sensitive receptors	Winter + No dissolved hydrocarbon exposure + No predicted of contact of sensitive receptors
Moderate 50 ppb	+ Maximum extent from release location 375km west. + No predicted of contact of sensitive receptors	+ No predicted of contact of sensitive receptors	+ No predicted of contact of sensitive receptors
High 400 ppb	+ No predicted of contact of sensitive receptors	+ No predicted of contact of sensitive receptors	+ No predicted of contact of sensitive receptors
ENTRAINED HYDROCARBON			
Low 10 ppb Lower than the exposure value at which most ecological impacts are expected to occur.	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-48**. The figures show the entrained hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. Further information is located in Section 9.5.3.3 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	Summer + Maximum extent from release location 850km southwest. + Based on all 100 simulations combined - 3 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs was 1%, Montebello AMP being	Transition + Maximum extent from release location 506km + Based on all 100 simulations combined - 1 of the AMPs within the EMBA is predicted to be exposed, probability of exposure of 2%, Montebello AMP being contacted in the shortest	Winter + Maximum extent from release location 290km + No predicted of contact of sensitive receptors

Relevant for implementing environmental monitoring in event of an oil spill.	contacted in the shortest time of 5 days and a maximum concentration of 141 ppb. + No predicted contact State Marine Parks. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks + No predicted contact with Ramsar receptors or KEFs	time of 6.255 days and a maximum concentration of 92ppb. + No predicted contact State Marine Parks. + One Ramsar receptors within the combined simulations is potentially exposed with the probability of 2% at Rankin Bank within 7 days and maximum concentration of 37ppb. + No predicted entry to State Waters + No predicted contact with shorelines + No predicted contact with reefs, Shoals and Banks. + No predicted contact with KEFs	
Moderate 100 ppb Representative of sub-lethal impacts to most species and lethal impacts to sensitive species. Considered appropriate for environmental risk assessment.	+ Maximum extent from release location 411km west southwest. + Based on all 100 simulations combined - 1 of the AMPs within the EMBA is predicted to be exposed, probability of exposure of 1%, Montebello AMP being contacted in the shortest time of 5 days.	+ Maximum extent from release location 175km + No predicted of contact of sensitive receptors	+ Maximum extent from release location 125km + No predicted of contact of sensitive receptors

Predicted impacts and risks based on deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in:

1) **largest volume of oil ashore**
2) **longest length of shoreline with oil accumulation**

Largest volume of oil ashore refer Figure 7-50	Longest length of shoreline accumulation refer Figure 7-51
+ Floating oil exposure predicted northeast from the spill location, with accumulation along the Broome shoreline. + Maximum volume ashore 1,684m^3, 16 days after spill.	+ Floating oil exposure predicted northeast from the spill location, with accumulation along the Broome shoreline. + Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 12 days after the spill started approximately 424 km^2.

- Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 11 days after spill started, approximately 320 km^2.
- Maximum length of shoreline accumulation 48km on Day 17.
- At end of spill, 12% spilled oil lost to the atmosphere through evaporation, 37% predicted to have decayed, <0.1% remained in the water column and 921m^3 (51%) predicted to remain on the shoreline.

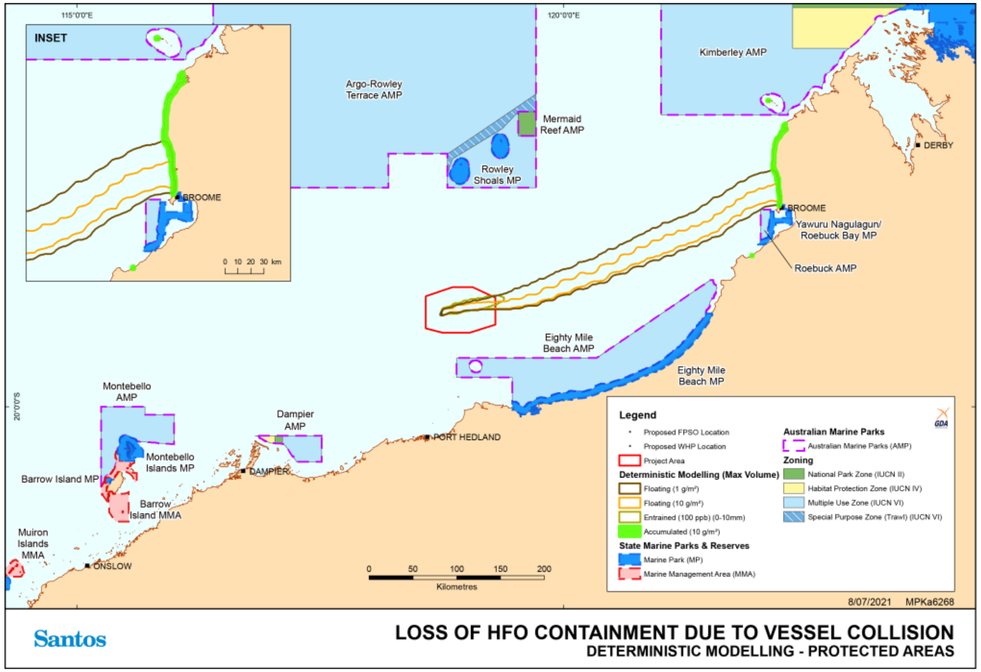

Figure 7-50: Worst-case deterministic model results for floating oil phase for a worst-case loss of HFO containment due to vessel collision based on the largest volume of oil ashore

- Shore accumulation from day 37. Maximum shoreline accumulation length of 155km from Day 50. Largest volume onshore (10 g/m^2) on Day 50 of 950m^3.
- At end of spill, 13% spilled oil lost to the atmosphere through evaporation. 37% predicted to have decayed, <0.1% remained in the water column and 895 m^3 (50%) predicted to remain on the shoreline.

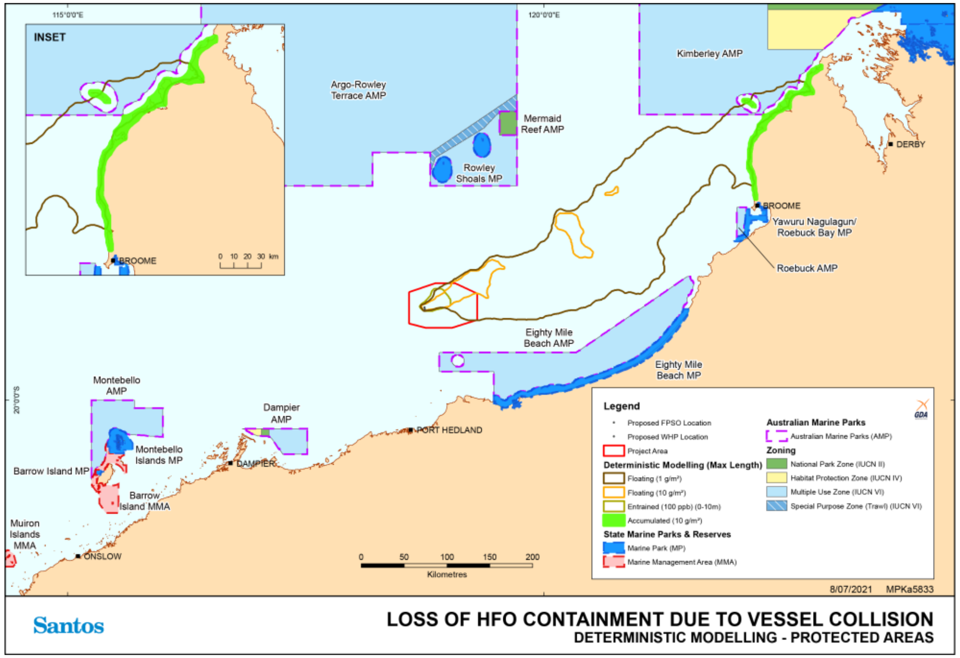

Figure 7-51: Worst-case deterministic model results for floating oil phase for a worst-case loss of HFO containment due to vessel collision based on the longest length of shoreline accumulation

7.3.1.5.4 Loss of Containment of FPSO Cargo Tank

Stochastic modelling results from the worst-case loss of containment due to a vessel collision scenario are shown in **Figure 7-52.** A summary of the stochastic modelling results for floating oil, shoreline accumulation, dissolved and entrained hydrocarbons for a subsea loss of well containment for each season is provided in **Table 7-80**. The worst-case deterministic model runs, based on the largest area of floating oil and largest area of entrained oil, are shown in **Figure 7-53** and **Figure 7-54.**

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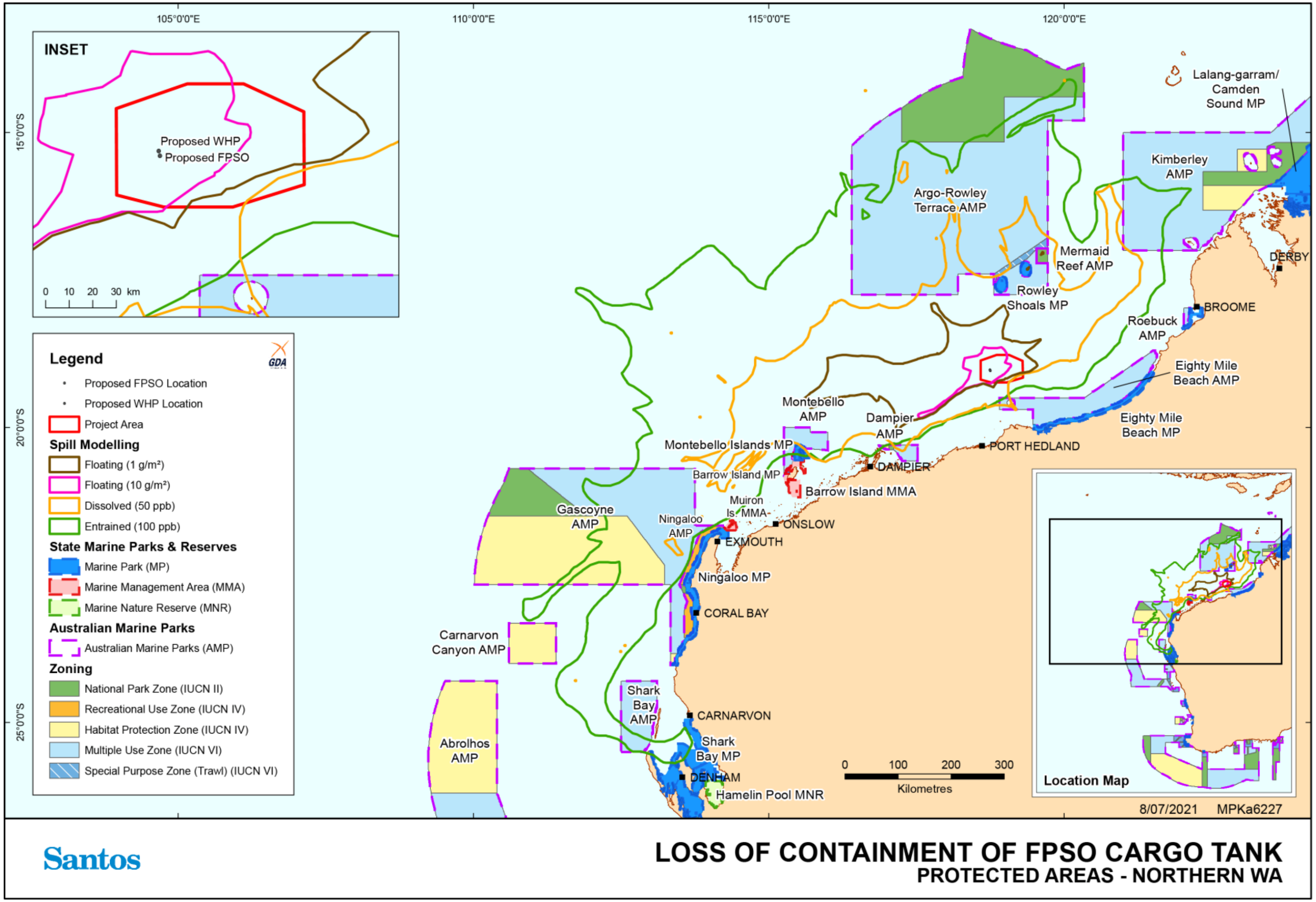

Figure 7-52: EMBA derived from stochastic modelling for floating, entrained and dissolved oil phases for a worst-case loss of containment of FPSO cargo tank

Table 7-80: Loss of Containment of FPSO Cargo Tank

<table>
<tr><th>Impact Thresholds (NOPSEMA, 2019b)</th><th colspan="3">Predicted impacts and risks based on stochastic model predictions = footprint (trajectory and fate) encompassing 300 releases (100 in summer, 100 in winter and 100 in transitional season).</th></tr>
<tr><td colspan="4">FLOATING OIL (SURFACE)</td></tr>
<tr><td rowspan="2">Low
1 g/m^2
Visible but no biological effects.
Lower than the exposure value for ecological impacts
Relevant for implementing environmental monitoring in event of oil spills</td><td colspan="3">Stochastic model predictions (EMBA is for all seasons combined, Figure 7-52. Further information is located in Section 9.6.3.1 of Attachment 8-1. The seasonal assessment below is based on 100 spill simulations for each season.</td></tr>
<tr><td><u>Summer</u>
+ Spill direction – west-southwest at maximum distance 326km from release site
+ Based on all 100 simulations combined - 1 of the AMPs within the EMBA predicted to be exposed, probability of exposure Mermaid Reef AMP of 1% in minimum time of 24.5 days after spill.
+ No predicted entry to State Waters
+ No predicted contact with shorelines
+ No predicted contact with reefs, Shoals and Banks
+ No predicted contact of Ramsar Receptors
+ No predicted contact of KEFs
+ No predicted contact State Marine Parks.</td><td><u>Transition</u>
+ Spill direction west at maximum distance 361km from release site
+ No predicted contact of Australian Marine Parks (AMPs) or State Marine Parks.
+ No predicted entry to State Waters
+ No predicted contact with shorelines
+ No predicted contact with reefs, Shoals and Banks
+ No predicted contact of Ramsar Receptors
+ No predicted contact of KEFs</td><td><u>Winter</u>
+ Spill direction –northwest at maximum distance 163km from release site
+ No predicted contact of Australian Marine Parks (AMPs) or State Marine Parks.
+ No predicted entry to State Waters
+ No predicted contact with shorelines
+ No predicted contact with reefs, Shoals and Banks
+ No predicted contact of Ramsar Receptors
+ No predicted contact of KEFs</td></tr>
</table>

Moderate 10 g/m² Environmental values and sensitivities may be at risk of impacts from floating oil.	Summer + Spill direction West – northwest at maximum distance 50.5km from release site + No predicted contact with sensitive receptors	Transition + Spill direction West – west-southwest at maximum distance 152km from release site + No predicted contact with sensitive receptors	Winter + Spill direction – north-northeast at maximum distance 48km from release site + No predicted contact with sensitive receptors
High 50 g/m² Potential for impact of surface oil to wildlife	Summer + Spill direction West – northwest at maximum distance 43km from release site + No predicted contact with sensitive receptors	Transition + Spill direction west-southwest at maximum distance 151.5km from release site + No predicted contact with sensitive receptors	Winter + Spill direction west-southwest at maximum distance 39.5km from release site + No predicted contact with sensitive receptors
SHORELINE ACCUMULATION			
	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-52**. There is no shoreline accumulation for this spill scenario.		
DISSOLOVED AROMATIC HYDROCARBONS			
Low 10 ppb	Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer **Figure 7-52**. The figures show the dissolved hydrocarbons at 50ppb (moderate threshold). Further information is located in Section 9.6.3.4 of **Attachment 8-1**. The seasonal assessment below is based on 100 spill simulations for each season.		
	Summer + Maximum extent from release location 940km west-southwest + Based on all 100 simulations combined – 6 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 5%, with Kimberley AMP and Argo-Rowley Terrace AMP being most probable (5% in minimum time of 16.9	Transition + Maximum extent from release location 978km southwest. + Based on all 100 simulations combined – 8 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 7%, with Argo Rowley Terrace being most probable (7% in minimum time of 9.8 days after spill, maximum entrained	Winter + Maximum extent from release location 967km northwest. + Based on all 100 simulations combined – 5 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 6%, with Montebello AMP being most probable (6% in minimum

	and 8 days respectively after spill, maximum entrained hydrocarbon concentration of 47 and 154 ppb respectively), Montebello AMP being contacted in the shortest time of 8 days and a maximum concentration of 39 ppb. + 1-3 % probability of contacting 2 State Marine Parks, 3% probability at Rowley Shoals in minimum time of 10.8 days after spill and a maximum concentration of 108 ppb. + 3% probability of entering State Waters in minimum time of 8 days after spill + Highest probability of shoreline contact at sensitive receptors Clerke Reef, Cunningham Island and Imperieuse Reef of 2% at each, within 11, 16 and 16 days respectively. The shortest time to contact is at Cunningham Island, and Clerke Reef had the maximum entrained concentration of 82 ppb. Bedout Island is not predicted to be contacted. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 6 receptors within the EMBA are predicted to be exposed. The greatest probability being 5% at Glomar Shoal within 6.9 days, and a maximum entrained hydrocarbon concentration of 21 ppb. Clerke Reef has the maximum entrained hydrocarbon concentration of 82 ppb. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 1%, at Glomar Shoals (within 1 days at 15 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.	hydrocarbon concentration of 104 ppb. Dampier AMP being contacted in the shortest time of 4 days and a maximum concentration of 39 ppb. Montebello AMP had the highest concentration of dissolved hydrocarbon at 163ppb. + 1-7 % probability of contacting 3 State Marine Parks, 7% probability at Rowley Shoals in minimum time of 12.3 days after spill and a maximum concentration of 79 ppb. Montebello Islands had the shortest time to contact within 7.8 days and the maximum entrained hydrocarbon concentration of 25 ppb. + 7% probability of entering State Waters in minimum time of 4.6 days after spill + Bedout Island (closest nearshore receptor to the south) with probability of 1% within 11.5 days and a maximum entrained hydrocarbon concentration of 48 ppb. Highest probability of shoreline contact at sensitive receptor Clerke Reef of 6% within 12.8 days. The shortest time to contact is at Hermite Island within 7.9 days (at 22ppb), and Mermaid Reef had the maximum entrained concentration of 55 ppb. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 5 receptors within the EMBA are predicted to be exposed. The greatest probability being 6% at Clerke Reef within 12.5 days, and a maximum entrained hydrocarbon concentration of 53 ppb. Mermaid Reef has the maximum entrained hydrocarbon concentration of 55 ppb. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 2%, at Glomar Shoals (within 1.8 days at 28 ppb maximum).	time of 10 days after spill, maximum entrained hydrocarbon concentration of 74 ppb). + 3% probability of contacting Rowley Shoals state marine park in minimum time of 22.4 days. + 3% probability of entering State Waters in minimum time of 22.4 days after spill + Highest probability of shoreline contact at sensitive receptors Cunningham Island and Imperieuse Reef of 1% at each, within 24 and 23 days respectively. Imperieuse Reef had the maximum entrained concentration of 11ppb. Bedout Island is not predicted to be contacted. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 4 receptors within the EMBA are predicted to be exposed. The greatest probability being 13% at Glomar Shoal within 5.6 days, and a maximum entrained hydrocarbon concentration of 102 ppb. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 6%, at Glomar Shoals (within 0.8 days at 63 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.

		The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.	
Moderate 50 ppb	Summer + Maximum extent from release location 564km north northeast + Based on all 100 simulations combined – 1 of the AMPs within the EMBA is predicted to be exposed, probability of exposure of 2%, at Argo-Rowley Terrace AMP in minimum time of 9.5 days after spill. + 1% probability of contacting Rowley Shoals Marine Park (only) in minimum time of 11 days after spill. + 1% probability of entering State Waters in minimum time of 11.5 days after spill + Highest probability of shoreline contact at sensitive receptors Clerke Reef only, with a probability of 1% in 12.2 days. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – Clerke Reef only is predicted to be contacted with a probability of 1% in a minimum time of 11.6 days. + No predicted contact with Ramsar receptors or KEFs	Transition + Maximum extent from release location 931km southwest. + Based on all 100 simulations combined – 5 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to all AMPs was 1%, with Montebello AMP being contacted in the shortest timeframe of 4.63 days. + 1% probability of contacting Rowley Shoals state marine park in minimum time of 13.3 days. + 1% probability of entering State Waters in minimum time of 4.6 days after spill + Highest probability of shoreline contact at sensitive receptor Mermaid Reef of 1% within 15.8 days. + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 2 receptors within the EMBA are predicted to be exposed. Both Mermaid Reef and Clerke Reef at a probability of 1% within 15 and 19 days respectively. + No predicted contact with Ramsar receptors or KEFs	Winter + Maximum extent from release location 573km west. + Based on all 100 simulations combined – 2 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to both Argo-Rowley Terrace and Montebello AMP of 1%, in minimum time of 18 and 12 days respectively after spill, + Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – Glomar Shoal only is predicted to be contacted with a probability of 1% in a minimum time of 6.08 days. + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 1%, at Glomar Shoals within 1.29 days. + No predicted contact with State Marine Parks + No predicted contact with State Waters.
High 400 ppb	Summer + Maximum extent from release location 45km west southwest + No predicted of contact of sensitive receptors	Transition + Maximum extent from release location 58km west + No predicted of contact of sensitive receptors	Winter + Maximum extent from release location 88km west southwest + No predicted of contact of sensitive receptors
ENTRAINED HYDROCARBON			

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<table>
<tr><td rowspan="2">Low
10 ppb
Lower than the exposure value at which most ecological impacts are expected to occur.
Relevant for implementing environmental monitoring in event of an oil spill.</td><td colspan="3">Stochastic model predictions (EMBA is for all seasons that is 300 spill simulations, refer Figure 7-52. The figures show the entrained hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. Further information is located in Section 9.5.3.3 of Attachment 8-1. The seasonal assessment below is based on 100 spill simulations for each season.</td></tr>
<tr><td><u>Summer</u>
+ Maximum extent from release location 1,017km southwest.
+ Based on all 100 simulations combined - 8 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2 to 12%, with Kimberley AMP being most probable (12% in minimum time of 15 days after spill, maximum entrained hydrocarbon concentration of 440 ppb), Argo-Rowley Terrace AMP being contacted in the shortest time of 7.9 days and a maximum concentration of 1,107 ppb.
+ 1-8 % probability of contacting 4 State Marine Parks, 8% probability at Rowley Shoals in minimum time of 10.9 days after spill and a maximum concentration of 1,082 ppb. Montebello Islands had the shortest time to contact within 10.9 days and the maximum entrained hydrocarbon concentration of 188ppb.
+ 8% probability of entering State Waters in minimum time of 6.9 days after spill
+ Highest probability of shoreline contact at sensitive receptors Clerke Reef, Cunningham Island and Imperieuse Reef of 5% at each, within 12, 15 and 16 days respectively. The shortest time to contact is at Legendre Island within 7 days, and Clerke Reef had the maximum entrained concentration of 1,020 ppb. Bedout Island is not predicted to be contacted.</td><td><u>Transition</u>
+ Based on all 100 simulations combined - 10 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 15%, with Argo Rowley Terrace and Montebello AMPs being most probable (15% in minimum time of 4 and 9 days respectively after spill, maximum entrained hydrocarbon concentration of 1,319 and 2,305 ppb respectively). Dampier AMP being contacted in the shortest time of 3 days and a maximum concentration of 29 ppb.
+ 1-8 % probability of contacting 5 State Marine Parks, 11% probability at Rowley Shoals in minimum time of 11.2 days after spill and a maximum concentration of 950 ppb. Montebello Islands had the shortest time to contact within 7.8 days and the maximum entrained hydrocarbon concentration of 232ppb.
+ 11% probability of entering State Waters in minimum time of 4.6 days after spill
+ Bedout Island (closest nearshore receptor to the south) with probability of 1% within 11.5 days and a maximum entrained hydrocarbon concentration of 14 ppb. Highest probability of shoreline contact at sensitive receptor Clerke Reef of 11% within 12 days. The shortest time to contact is at Hermite Island within 7.8 days, and Clerke Reef had the maximum entrained concentration of 888 ppb.
+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined</td><td><u>Winter</u>
+ Based on all 100 simulations combined - 9 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 20%, with Montebello AMP being most probable (20% in minimum time of 9 days after spill, maximum entrained hydrocarbon concentration of 505 ppb), Eighty Mile Beach AMP being contacted in the shortest time of 4.13 days and a maximum concentration of 92 ppb. Argo-Rowley Terrace had the maximum entrained concentration of 539ppb.
+ 1-15% probability of contacting 3 State Marine Parks, 15% probability at Rowley Shoals in minimum time of 18.7 days after spill and a maximum concentration of 227 ppb.
+ 15% probability of entering State Waters in minimum time of 18.7 days after spill
+ Highest probability of shoreline contact at sensitive receptors Cunningham Island and Imperieuse Reef of 12% at each, within 21 and 20 days respectively. Imperieuse Reef had the maximum entrained concentration of 222 ppb. Bedout Island is not predicted to be contacted.
+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 8 receptors within the EMBA are predicted to be exposed. The greatest probability being 29% at Glomar Shoal within 5.3 days, and a maximum entrained hydrocarbon concentration of 1,369 ppb.</td></tr>
</table>

	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 9 receptors within the EMBA are predicted to be exposed. The greatest probability being 12% at Rankin Bank within 8 days, and a maximum entrained hydrocarbon concentration of 466 ppb. Clerke Reef has the maximum entrained hydrocarbon concentration of 1,069 ppb. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 21%, at Glomar Shoals (within 6.5 days at 641 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.	– 10 receptors within the EMBA are predicted to be exposed. The greatest probability being 25% at Glomar Shoal within 7 days, and a maximum entrained hydrocarbon concentration of 469 ppb. Clerke Reef has the maximum entrained hydrocarbon concentration of 936 ppb. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – 2 KEFs within the EMBA are predicted to be exposed, with a probability of exposure of 24%, at Glomar Shoals (within 3.7 days at 1,835 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.	+ No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 26%, at Glomar Shoals (within 5.2 days at 457 ppb maximum). The 125m water depth Ancient Coastline adjacent to the Project Area is not predicted to be contacted.
Moderate 100 ppb Representative of sub-lethal impacts to most species and lethal impacts to sensitive species. Considered appropriate for environmental risk assessment.	+ Maximum extent from release location 939km west-southwest. + Based on all 100 simulations combined - 7 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 6%, with Kimberley AMP being most probable (6% in minimum time of 16 days after spill), Argo-Rowley Terrace AMP being contacted in the shortest time of 8.3 days. + 1-3 % probability of contacting 3 State Marine Parks, 3% probability at Rowley Shoals in minimum time of 11 days. + 3% probability of entering State Waters in minimum time of 11 days after spill + Highest probability of shoreline contact at sensitive receptors Clerke Reef and Cunningham Island of 2% at each, within 11.5 and 17 days respectively.	+ Maximum extent from release location 973km. + Based on all 100 simulations combined - 5 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 8%, with Argo Rowley Terrace AMPs being most probable (8% in minimum time of 9 days after spill. Montebello AMP being contacted in the shortest time of 4.6 days. + 1-9 % probability of contacting 3 State Marine Parks, 9% probability at Rowley Shoals in minimum time of 11.5 days. Montebello Islands had the shortest time to contact within 7.8 days. + 11% probability of entering State Waters in minimum time of 4.6 days after spill + No predicted contact at Bedout Island (closest nearshore receptor to the south). Highest probability of shoreline contact at sensitive receptor Clerke Reef of 11% within 12 days.	+ Maximum extent from release location 754km. + Based on all 100 simulations combined - 4 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 6%, with Argo-Rowley Terrace AMP being most probable (6% in minimum time of 17.6 days), Eighty Mile Beach AMP being contacted in the shortest time of 9.3 days. + 5% probability of contacting one State Marine Parks, 5% probability at Rowley Shoals in minimum time of 20.6 days. + 4% probability of entering State Waters in minimum time of 20.6 days after spill + Highest probability of shoreline contact at sensitive receptors Cunningham Island and Imperieuse Reef of 1% at each, within 28 days at both.

	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 4 receptors within the EMBA are predicted to be exposed. The greatest probability being 6% at Rankin Bank within 8 days. + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 2%, at Glomar Shoals within 6.5 days.	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 6 receptors within the EMBA are predicted to be exposed. The greatest probability being 11% at Glomar Shoal within 11.2 days. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 6%, at Glomar Shoals within 3.7 days.	+ Reef, shoal and bank receptors vary between seasons, based on all 100 simulations combined – 3 receptors within the EMBA are predicted to be exposed. The greatest probability being 14% at Glomar Shoal within 5.4 days. + No predicted contact with Ramsar receptors + Based on all 100 simulations combined – one KEF within the EMBA is predicted to be exposed, with a probability of exposure of 11%, at Glomar Shoals within 5.4days.

Predicted impacts and risks based on deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in:

1) **Largest area of floating oil (above 50g/m^2)**
2) **Largest area of entrained hydrocarbons**

Largest area of floating oil refer Figure 7-53	Largest area of entrained hydrocarbons refer Figure 7-54
+ Floating oil exposure predicted northwest from the spill location, up to a maximum distance of 59km (1-10 g/m^2) + Maximum area of coverage of visible oil (>1g/m^2) on the sea surface predicted 4 days after spill started, approximately 86 km^2. + Maximum length of shoreline accumulation 48km on Day 17. + At end of spill, 66% spilled oil lost to the atmosphere through evaporation, 20% predicted to have decayed, 14% remained in the water column. No floating oil remaining after 5 days.	+ Maximum distance of entrained hydrocarbons at the low threshold (10-100ppb) extend 1,010km to the northwest. + At end of spill, 41% spilled oil lost to the atmosphere through evaporation. 43% predicted to have decayed, 16% remained in the water column.

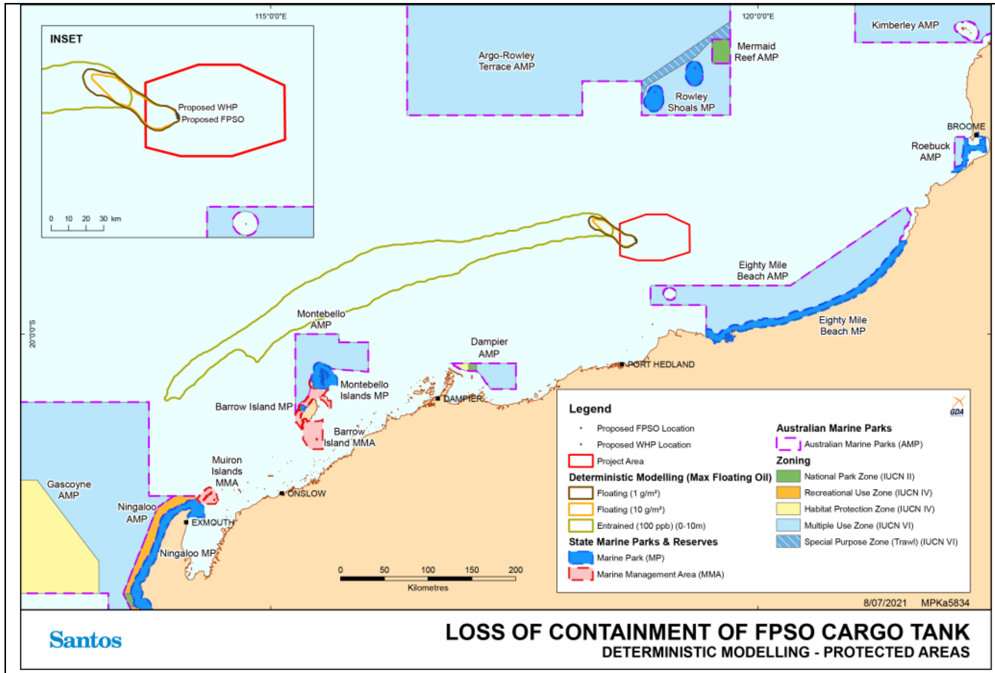


Figure 7-53: Worst-case deterministic model results for floating oil phase for a worst-case loss of Caley crude containment due to vessel collision based on the largest area of floating oil

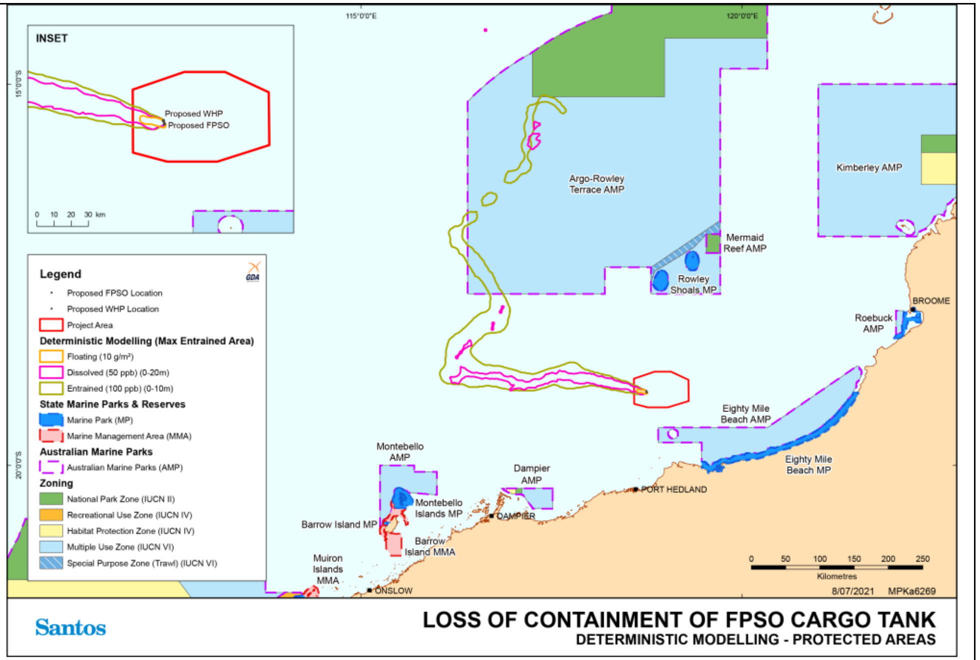


Figure 7-54: Worst-case deterministic model results for floating oil phase for a worst-case loss of Caley crude containment due to vessel collision based on the largest area of entrained hydrocarbon

7.3.1.5.5 Subsea Loss of Well Containment from Future Tieback (based on the Bedout Multi Well EP)

Results from the worst-case subsea loss of well containment scenario for the Bedout Apus-1 well location as described and presented in the Bedout exploration activity (Bedout Multi-Well Drilling Environment Plan) and representing future tiebacks for Dorado Phase 1, are shown in **Figure 7-55** and **Figure 7-56**. A summary of the stochastic modelling results for floating oil, shoreline accumulation, dissolved and total submerged hydrocarbons for a subsea loss of well containment for each season is provided in. The worst-case deterministic runs, based on the largest volume of oil onshore are shown in **Figure 7-58.**

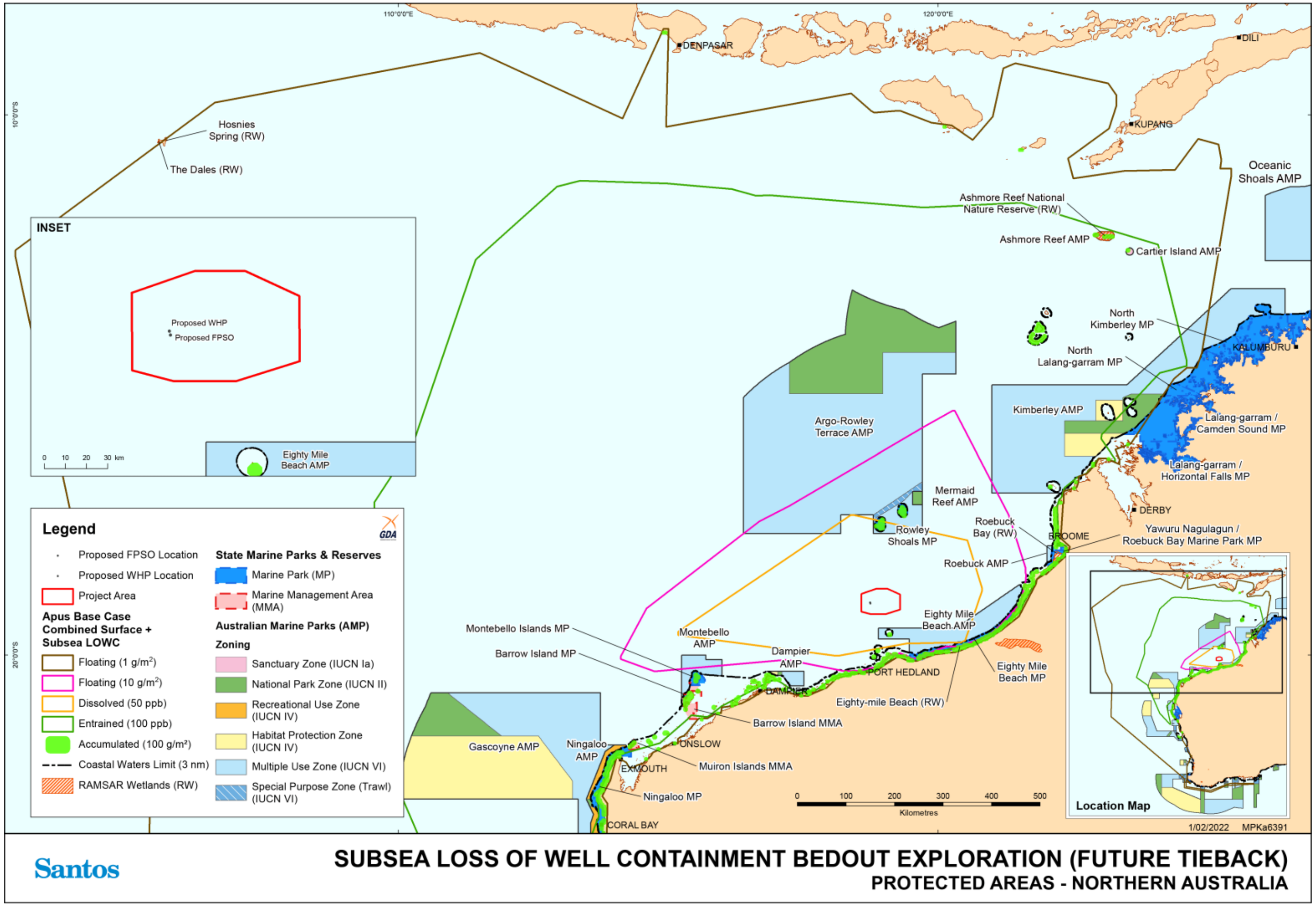


Figure 7-55: EMBA derived from stochastic modelling for floating, dissolved, total submerged oil and shoreline accumulation oil phases for a worst-case subsea loss of well containment (representing future tiebacks for Dorado Phase 1) – protected areas north

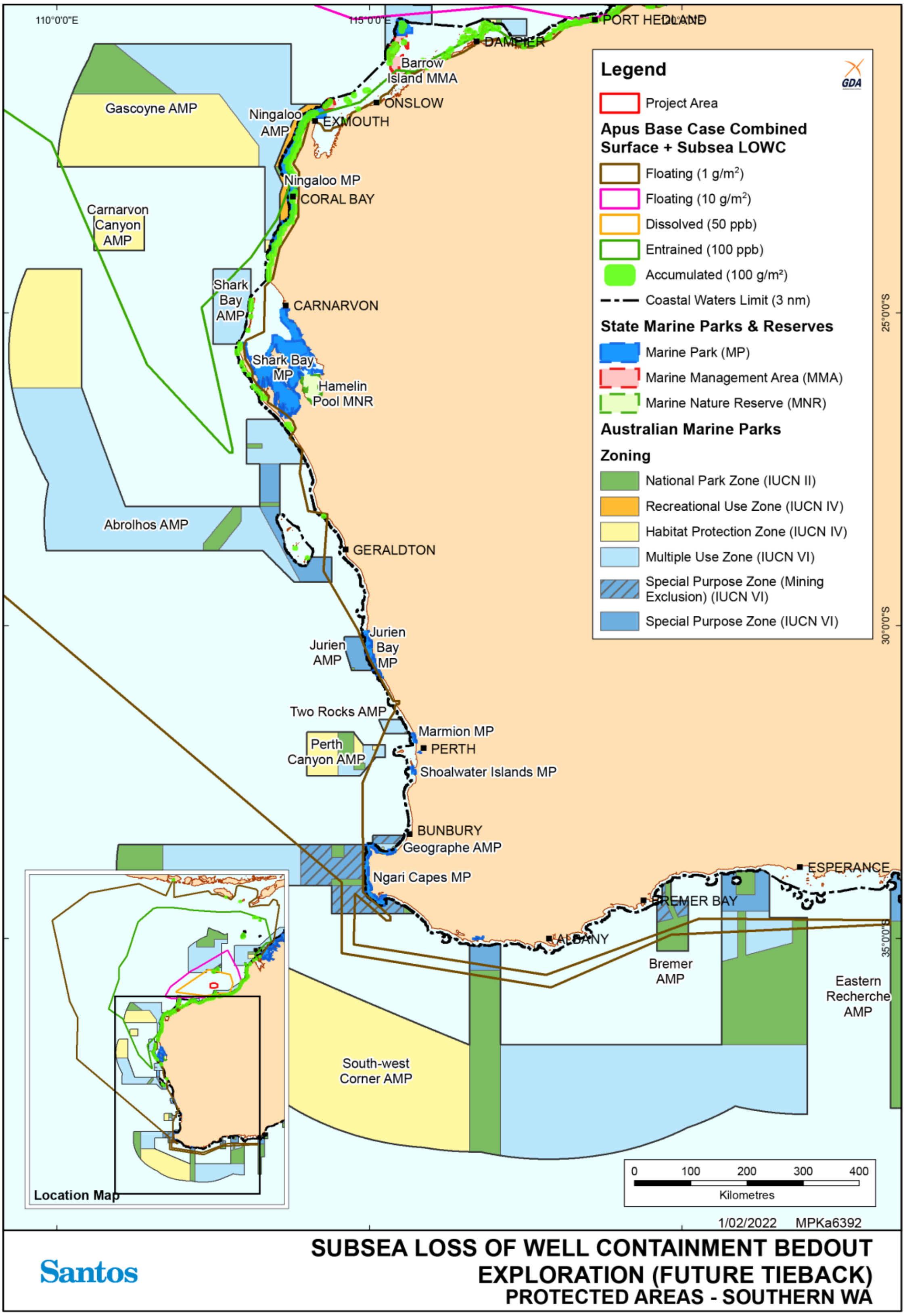
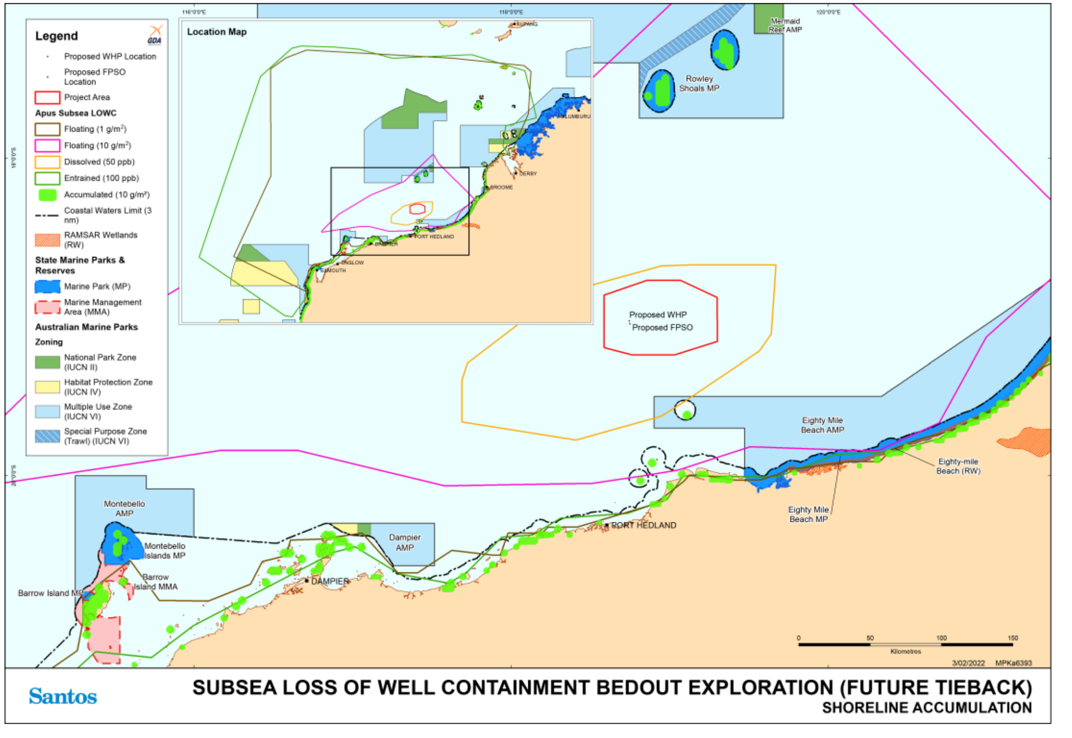


Figure 7-56: EMBA derived from stochastic modelling for floating, dissolved, total submerged oil and shoreline accumulation oil phases for a worst-case subsea loss of well containment (representing future tiebacks for Dorado Phase 1) – protected areas south

Table 7-81: Worst-case subsea loss of well containment scenario for Bedout exploration activity (representing future tiebacks for Dorado Phase 1)

Impact Thresholds (NOPSEMA, 2019b)	Predicted impacts and risks based on stochastic model predictions = footprint (trajectory and fate) encompassing 150 releases (staggered approximately fortnightly across five years of hydrodynamic and wind data). A total of 150 individual 'realisations' made up the full stochastic simulation set.
FLOATING OIL (SURFACE)	
Low 1 g/m^2 Visible but no biological effects. Lower than the exposure value for ecological impacts Relevant for implementing environmental monitoring in event of oil spills	**Figure 7-55** and **Figure 7-56** show the stochastic modelling predictions for floating oil at 1 g/m^2 (low threshold) and 10 g/m^2 (moderate threshold). Maximum extents predicted at the 1 g/m^2 threshold + Maximum extent from release location – 1,100 km, west southwest. + Based on all 150 simulations - 5 of the AMPs within the EMBA are predicted to be exposed. Probability of exposure to individual AMPs ranged from 16% to 91%, with Eighty Mile Beach AMP being most probable (91% in minimum time of 1.8 days after spill), followed by Roebuck – Eighty Mile Beach AMP (27% in minimum time of 16.1 days after spill). The shortest time to contact predicted at Eighty Mile Beach AMP at 1.8 days. + 1 to 37% probability of contacting shorelines at King sound, Broome North Coast, Port Hedland-Eighty Mile Beach, Eighty Mile Beach Northern Island Coast, Ningaloo Coast North and Southern Island Coast in minimum time of 6 to 89 days after spill. + 1% to 63% probability of contacting reefs, shoals, islands and banks (Barracouta Shoals, Browse Island, Bedout Island, Montebello Islands Seringapatam Reef, Scot Reef North, Scott Reef South, Clerke Reef, Imperieuse Reef, Glomar Shoals, Ranking Bank and Rowley Shoals in minimum time of 3 to 94 days after spill. + KEFs at seabed or near seabed features are not contacted by floating oil.
Moderate 10 g/m^2 Environmental values and sensitivities may be at risk of impacts from floating oil.	+ Maximum extent from release location – 550 km, west. + Based on all the 150 simulations - 2 AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1 to 54%, with Eighty Mile Beach AMP more probable (54% in minimum time of 1.8 days) and Mermaid Reef AMP 1 % in 17.5 days. + 23% probability of contacting Bedout Island in minimum time of 3.3 days after spill. + 4 to 5% probability of contacting reefs, shoals and banks (Glomar Shoals and Rowley Shoals) in minimum time of 18 to 23 days after spill + KEFs are seabed or near seabed features are not contacted by floating oil.

High 50 g/m² Potential for impact of surface oil to wildlife	+ Maximum extent from release location – 225 km, west northwest. + Contact limited to Eighty Miley Beach AMP (7% probability with a minimum time of 3.8 days) and Bedout island (3.3% probability with a minimum time of 13.6 days).
SHORELINE ACCUMULATION	
Low 10 g/m² Represents a level of socio-economic effect	Stochastic model predictions EMBA is for the 100 simulations in **Figure 7-55** and **Figure 7-56**. **Figure 7-57** shows the shoreline accumulation at 10 g/m² (low threshold). The seasonal assessment below is based on 150 simulations annualised.  **Figure 7-57: Stochastic modelling shoreline accumulation for a worst-case subsea loss of well containment (representing future tiebacks for Dorado Phase 1)**

	+ Maximum shoreline accumulation is 2, 054 tonnes. + Highest probability of contact is 82% with the minimum time of 3.5 days + Maximum length of shoreline accumulation 210 km + Based on 150 replicate simulations combined - 37 shoreline receptors with probability of exposure to each ranging from 1 to 81%. Key receptors with highest probability of contact and minimal arrival time include: - Bedout Island (82% contact within 3.5 days, peak loading 27, 259 g/m^2, with peak volume 324 tonnes, maximum length of shoreline loading @5.7 km). - Imperieuse (58% within 13.5 days, peak loading 33,593 g/m^2, with a peak volume of 1,014 tonnes, and a maximum length of shoreline loading @ 56.9km). - Dampier Archipelago (55% within 15 days, peak loading 21, 712 g/m^2, with a peak volume of 848.9 tonnes, and a maximum length of shoreline loading @ 91 km). - Montebello Island (49% within 22 days, peak loading 12, 989 g/m^2, with a peak volume of 337 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (44% within 24 days, peak loading 17,043 g/m^2, with a peak volume of 473 tonnes, and a maximum length of shoreline loading @ 73km). - Southern Island Coast (41% within 26 days, peak loading 12, 788, with peak loading of 315 tonnes, and maximum length of shoreline loading 22.7 km). - Ningaloo Coast North (41% contact within 31 days, peak loading 7, 498g/m^2, with peak volume of 400 tonnes, and maximum length of shoreline loading @ 210 km)
Moderate 100 g/m^2 Likely to cause adverse impacts to marine or coastal fauna and habitats	+ Maximum shoreline accumulation is 2, 054 tonnes. + Highest probability of contact is 81% with the minimum time of 3.5 days + Maximum length of shoreline accumulation 187 km + Based on 150 replicate simulations combined - 31 shoreline receptors with probability of exposure to each ranging from 1 to 81%. Key receptors with highest probability of contact and minimal arrival time include: - Imperieuse (57% within 13.5 days, peak loading 27, 259 g/m^2, with a peak volume of 1014 tonnes, and a maximum length of shoreline loading @ 56.9km). - Dampier Archipelago (55% within 15 days, peak loading 21, 712 g/m^2, with a peak volume of 849 tonnes, and a maximum length of shoreline loading @ 85.3 km). - Montebello Island (46% within 19 days, peak loading 17, 238 g/m^2, with a peak volume of 419 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (42% within 24 days, peak loading 12, 989 g/m^2, with a peak volume of 337 tonnes, and a maximum length of shoreline loading @ 68km). - Ningaloo Coast North (40% contact within 30 days, peak loading 7, 498 g/m^2, with peak volume of 397 tonnes, and maximum length of shoreline loading @ 187 km)

	- Bedout Island (81% contact within 3.5 days, peak loading 28, 497 g/m2, with peak volume 324 tonnes, maximum length of shoreline loading @5.7 km).
High 1000 g/m² Impacts to shoreline receptors	+ Maximum shoreline accumulation is 2, 040 tonnes. + Highest probability of contact is 70% with the minimum time of 5.7 days + Maximum length of shoreline accumulation 68 km + Based on 150 replicate simulations combined - 22 shoreline receptors with probability of exposure to each ranging from 1 to 70%. Key receptors with highest probability of contact and minimal arrival time include: - Imperieuse (45% within 13.5 days, peak loading 27, 259 g/m², with a peak volume of 1008 tonnes, and a maximum length of shoreline loading @ 56.9km). - Dampier Archipelago (51% within 15 days, peak loading 27, 712 g/m², with a peak volume of 833 tonnes, and a maximum length of shoreline loading @ 68 km). - Montebello Island (38% within 17 days, peak loading 17, 238 g/m², with a peak volume of 417 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (33% within 24 days, peak loading 12, 989 g/m², with a peak volume of 331 tonnes, and a maximum length of shoreline loading @ 51 km). - Southern Island Coast (31% within 29 days, peak loading 17, 788, with peak loading of 27 tonnes, and maximum length of shoreline loading 17.1 km). - Ningaloo Coast North (26% contact within 31 days, peak loading 7, 498 g/m², with peak volume of 307 tonnes, and maximum length of shoreline loading @ 68 km) - Bedout Island (70% contact within 3.5 days, peak loading 24,165 g/m2, with peak volume 274 tonnes, maximum length of shoreline loading @5.7 km).
DISSOLOVED AROMATIC HYDROCARBONS	
Low 10 ppb Lower than the exposure value at which ecological impacts are expected to occur. Relevant for implementing environmental monitoring in event of oil spills	Stochastic model predictions EMBA is based on 100 spill simulations, refer to **Figure 7-55** and **Figure 7-56**. The figures show the dissolved hydrocarbons at 50 ppb (moderate threshold).
	+ Maximum extent from release location – 350 km northeast + Based on all 150 simulations combined – Eighty Mile Beach was the only AMP contacted (47% probability) + Bedout island was the only other shoreline contacted at low probability (1.3%)
Moderate	+ Maximum extent from release location – 150 km northeast

50 ppb Approximates potential toxic effects, particularly sublethal effects to sensitive species.	+ Eighty Mile Beach AMP was the only receptor contacted at low probability (5%)
High 400 ppb Approximates toxic effects including lethal effects to sensitive species	+ Maximum extent from release location – 100 km northeast + No contact above the high exposure value (400 ppb) for dissolved hydrocarbons.
Total Submerged Oil	
Low 10 ppb Lower than the exposure value at which most ecological impacts are expected to occur. Relevant for implementing environmental monitoring in event of an oil spill.	Stochastic model predictions (EMBA is for 150 spill simulations, refer **Figure 7-55** and **Figure 7-56.** The figures show the total submerged hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. + Maximum extent from release location – 1800 km + Based on all 150 simulations combined - 9 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2% to 99%, with Eighty Mile Beach AMP with the highest probability and shortest time to contact (99% in minimum time of 2.2 days after spill). + 14 Reef, shoal and bank receptors within the EMBA are predicted to be exposed. The greatest probability being 93% at Glomar Shoals within 9.3 days, and a maximum concentration of 128.4 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 95% within 3.8 days and a maximum hydrocarbon concentration of 320.4 ppb.
Moderate 100 ppb Representative of sub-lethal impacts to most species and lethal impacts to sensitive species. Considered appropriate for environmental risk assessment.	+ Maximum extent from release location – 1100 km + Based on all 150 simulations combined - 6 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 2% to 99%, with Eighty Mile Beach AMP with the highest probability and shortest time to contact (99% in minimum time of 2.2 days after spill). + 4 Reef, shoal and bank receptors within the EMBA are predicted to be exposed. The greatest probability being 58% at Glomar Shoals within 11 days, and a maximum concentration of 872 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 73% within 4 days.

(NOPSEMA 2019)	

Predicted impacts and risks based on deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in the largest volume of oil ashore and longest length of shoreline with oil accumulation (Figure 7-58)

- Stochastic realisation 24 of the Apus Base Case Subsea LOWC scenario resulted in the highest accumulated shoreline load (for that scenario) of 2,054 tonnes (of which the entire accumulated load exceeded 10 g/m^2 and 100 g/m^2).
- Shoreline loading greater than 10 and 100 g/m^2 extended up to ~350 km of the release site (**Figure 7-58**).
- Total submerged oil exceeding 100 ppb extended up to ~700 km in sparse patches that travelled to the north-east of the release site, while the majority of exceedances were confined to within ~300 km of the release site (**Figure 7-58**).
- Dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~50 km from the release location **(Figure 7-58**).

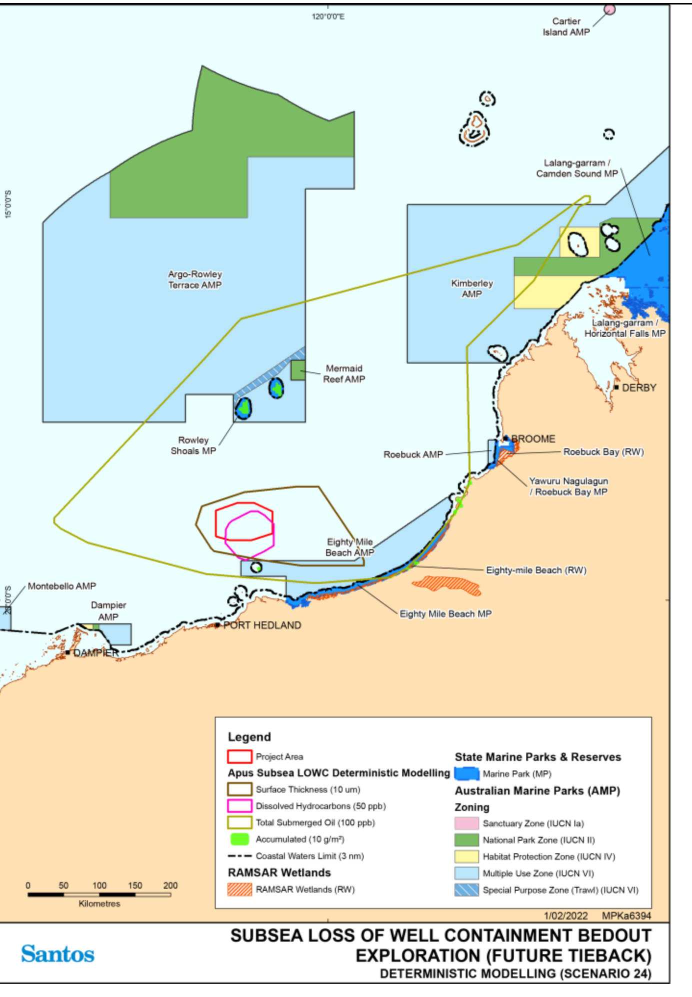


Figure 7-58: Worst-case deterministic model results based on largest volume of shoreline oil ashore.

7.3.1.5.6 Surface Loss of Well Containment from Future Tieback (based on the Bedout Exploration EP)

Results from the worst-case surface loss of well containment scenario for the Bedout Apus-1 well location as described and presented in the Bedout exploration activity (Bedout Multi-Well Drilling Environment Plan) and representing future tiebacks for Dorado Phase 1, are shown in **Figure 7-59**. A summary of the stochastic modelling results for floating oil, shoreline accumulation, dissolved and total submerged hydrocarbons for a surface loss of well containment for each season is provided in **Table 7-82**. The worst-case deterministic runs, based on the largest volume of oil onshore as shown in **Figure 7-61**.

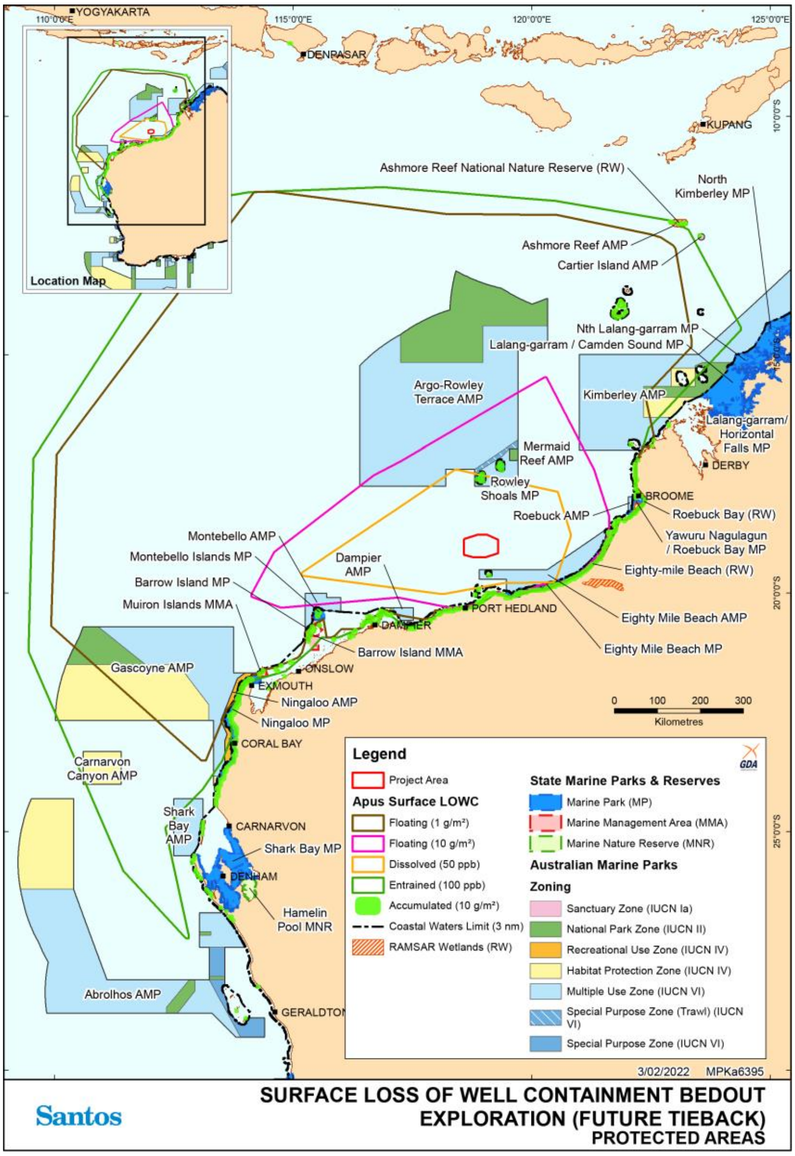


Figure 7-59: EMBA derived from stochastic modelling for floating, dissolved, total submerged oil and shoreline accumulation oil phases for a worst-case surface loss of well containment (representing future tiebacks for Dorado Phase 1) – protected areas north

Santos

Table 7-82: Worst-case surface loss of well containment scenario for Bedout exploration activity (representing future tiebacks for Dorado Development)

Impact Thresholds (NOPSEMA, 2019b)	Predicted impacts and risks based on stochastic model predictions = footprint (trajectory and fate) encompassing 150 releases (start dates for each simulation staggered approximately fortnightly across five years of hydrodynamic and wind data). A total of 150 individual 'realisations' made up the full stochastic simulation set
FLOATING OIL (SURFACE)	
Low 1 g/m^2 Visible but no biological effects. Lower than the exposure value for ecological impacts Relevant for implementing environmental monitoring in event of oil spills	**Figure 7-60** show the stochastic modelling predictions for floating oil at 1 g/m^2 (low threshold) and 10 g/m^2 (moderate threshold). Maximum extents predicted at the 1 g/m^2 threshold + Maximum extent from release location – 1,100 km, west southwest. + Based on all 150 simulations - 5 of the AMPs within the EMBA are predicted to be exposed. Probability of exposure to individual AMPs ranged from 1% to 85%, with Eighty Mile Beach and Montebello AMP being most probable (85% in minimum time of 1 and 11.3 and days after spill. The shortest time to contact predicted at Eighty Mile Beach AMP at 1 day. + 1 to 59% probability of contacting shorelines at Adele Island, King Sound, Lacepede Islands, Broome North Coast, Dampier Archipelago, Northern Island Coast, Montebello Islands, Lowendal Islands, Barrow Islands, Thevenard Islands, Southern Island Coast, Muiron Islands, Ningaloo Coast North, Ningaloo Coast South, Indonesia East, Eighty Mile Beach, Broome Roebuck, Bedout Island, with the minimum time to contact 1.1 days after spill (Bedout Island). + 1% to 58% probability of contacting reefs, shoals and banks (Mermaid Reef, Clerke Reef, Imperieuse Reef, Glomar Shoals, Scott Reef South and Rankin Bank) in minimum time of 5.8 to 38 days after spill. + KEFs at seabed or near seabed features are not contacted by floating oil.
Moderate 10 g/m^2 Environmental values and sensitivities may be at risk of impacts from floating oil.	+ Maximum extent from release location – 600 km, northeast. + Based on all the 150 simulations – Eighty Mile Beach was the only AMP to be contacted (70% probability within 1 day) + <1% probability to contact State Marine Parks. + 1 to 46% probability of contacting shorelines at Port Hedland Eighty Mile Beach, Outer Ningaloo Coast North and Bedout Island in minimum time of 1.5 to 29 days after spill. + 1 to 14% probability of contacting reefs, shoals and banks (Clerke Reef, Imperieuse Reef, Glomar Shoals) in minimum time of 2 to 12 days after spill + KEFs are seabed or near seabed features are not contacted by floating oil.

High 50 g/m^2 Potential for impact of surface oil to wildlife	+ Maximum extent from release location – 300 km, west northwest. + Eighty Mile Beach AMP is contacted >50 g/m^2 within 1.8 days (49% probability). + 29% probability of contact at Bedout island within 2 days.
SHORELINE ACCUMULATION	
Low 10 g/m^2 Represents a level of socio-economic effect	Stochastic model predictions EMBA is for the 100 simulations in **Figure 7-60**. **Figure 7-57** shows the shoreline accumulation at 10 g/m^2 (low threshold. The seasonal assessment below is based on 150 simulations annualised.

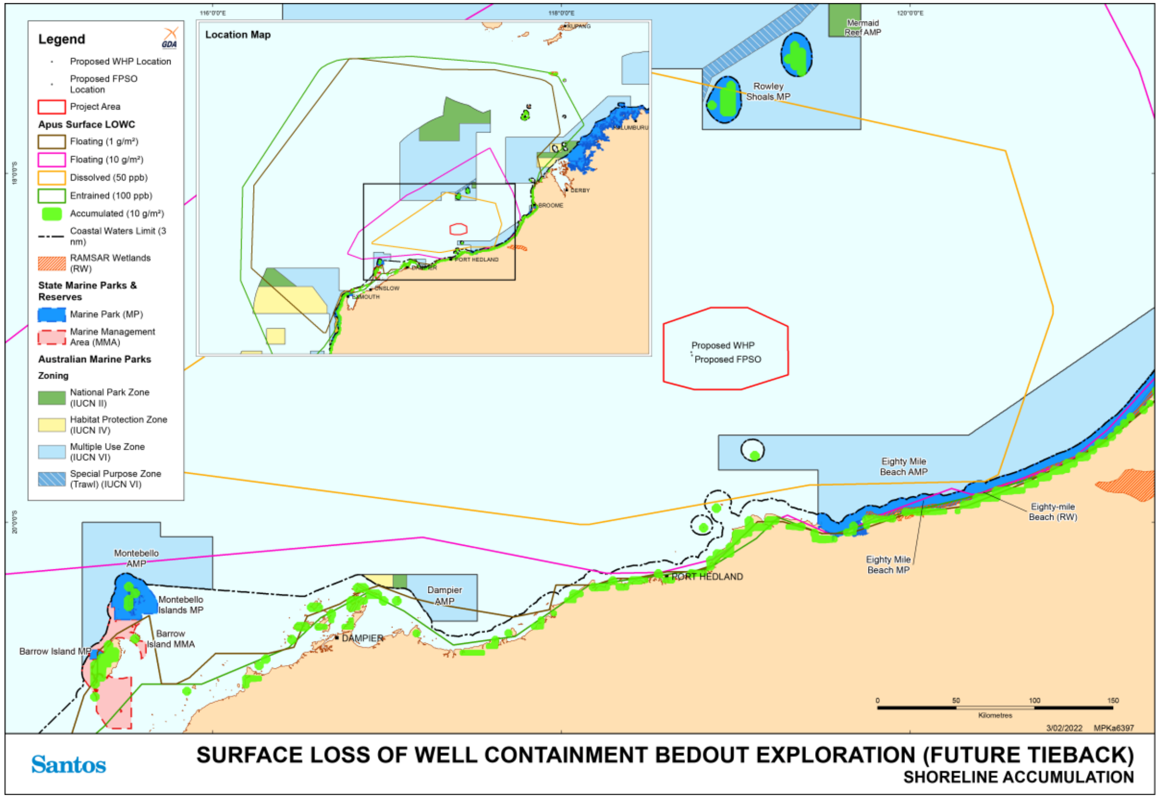


Figure 7-60: Stochastic modelling shoreline accumulation for a worst-case surface loss of well containment

	+ Maximum shoreline accumulation is 5, 127 tonnes. + 77% probability of shoreline accumulation in minimum time of 2 days + Maximum length of shoreline accumulation 233 km + Based on 150 replicate simulations combined - 27 shoreline receptors with probability of exposure to each ranging from 1 to 76%. Key receptors with highest probability of contact and minimal arrival time include: - Imperieuse MP (59% within 11 days, peak loading 29, 886 g/m^2, with a peak volume of 2, 040 tonnes, and a maximum length of shoreline loading @ 56.9 km). - Clerke Reef MP (53% within 16 days, peak loading 23, 606 g/m^2, with a peak volume of 1, 455 tonnes, and a maximum length of shoreline loading @ 51.2 km). - Dampier Archipelago (58% within 12.1 days, peak loading 21, 248 g/m^2, with a peak volume of 864 tonnes, and a maximum length of shoreline loading @ 96.6 km). - Montebello Islands (48% within 17 days, peak loading 25, 077 g/m^2, with a peak volume of 663 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (47% within 19 days, peak loading 13,827 g/m^2, with a peak volume of 628 tonnes, and a maximum length of shoreline loading @ 76.9km). - Thevenard Islands (40% within 23.9 days, peak loading 10, 264 g/m^2, with peak loading of 178 tonnes, and maximum length of shoreline loading 11.4 km). - Muiron Islands (45% within 26.6 days, peak loading 20,143 g/m^2, with peak loading of 350 tonnes, and maximum length of shoreline loading 17.1 km). - Ningaloo Coast North (41.3% contact within 31 days, peak loading 10, 938 g/m^2, with peak volume of 698 tonnes, and maximum length of shoreline loading @ 233.1 km) - Bedout Island (77% contact within 2 days, peak loading 26, 295 g/m^2, with peak volume 299 tonnes, maximum length of shoreline loading @5.7 km).
Moderate 100 g/m^2 Likely to cause adverse impacts to marine or coastal fauna and habitats	+ Maximum shoreline accumulation 5, 125 tonnes + 77% probability of shoreline accumulation in minimum time of 2 days + Maximum length of shoreline accumulation 227 km + Based on 150 replicate simulations combined- 23 shoreline receptors with probability of exposure to each ranging from 1 to 77% Key receptors with highest probability of contact and minimal arrival time include: - Imperieuse MP (58% within 11 days, peak loading 29, 886 g/m^2, with a peak volume of 2, 040tonnes, and a maximum length of shoreline loading @ 56.9 km). - Clerke Reef MP (53% within 16 days, peak loading 23, 606 g/m^2, with a peak volume of 14, 55 tonnes, and a maximum length of shoreline loading @ 51.2 km). - Dampier Archipelago (57% within 12days, peak loading 21, 248 g/m^2, with a peak volume of 864 tonnes, and a maximum length of shoreline loading @ 96. 6 km).

	- Montebello Islands (46% within 17 days, peak loading 25, 077 g/m^2, with a peak volume of 663 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (46% within 19 days, peak loading 13, 827 g/m^2, with a peak volume of 628 tonnes, and a maximum length of shoreline loading @ 68km). - Muiron Islands (43.7% within 26.6 days, peak loading 20, 143 g/m^2, with peak loading of 350 tonnes, and maximum length of shoreline loading 17.1 km). - Ningaloo Coast North (41% contact within 31 days, peak loading 10, 938 g/m^2, with peak volume of 698 tonnes, and maximum length of shoreline loading @ 227.4 km) - Bedout Island (76% contact within 2 days, peak loading 26, 295 g/m^2, with peak volume 299 tonnes, maximum length of shoreline loading @5.7 km).
High 1000 g/m^2 Impacts to shoreline receptors	+ Maximum shoreline accumulation 5, 099 tonnes + 72% probability of shoreline accumulation in minimum time of 2days + Maximum length of shoreline accumulation 96 km + Based on 150 replicate simulations combined- 23 shoreline receptors with probability of exposure to each ranging from 1 to 72% Key receptors with highest probability of contact and minimal arrival time include: - Imperieuse MP (48% within 11.4 days, peak loading 29, 886 g/m^2, with a peak volume of 2, 040 tonnes, and a maximum length of shoreline loading @ 56.9 km). - Clerke Reef MP (43% within 16 days, peak loading 23, 606 g/m^2, with a peak volume of 1, 455 tonnes, and a maximum length of shoreline loading @ 51.2 km). - Dampier Archipelago (50% within 12.1 days, peak loading 21, 248 g/m^2, with a peak volume of 844.9 tonnes, and a maximum length of shoreline loading @ 62.5km). - Montebello Islands (40% within 17 days, peak loading 25, 077 g/m^2, with a peak volume of 663 tonnes, and a maximum length of shoreline loading @ 22.7km). - Barrow Island (39% within 19 days, peak loading 13, 827 g/m^2, with a peak volume of 628 tonnes, and a maximum length of shoreline loading @ 56.9km). - Muiron Islands (45% within 28 days, peak loading 20, 143 g/m^2, with peak loading of 350 tonnes, and maximum length of shoreline loading 17.1 km). - Ningaloo Coast North (32% contact within 31 days, peak loading 10, 938 g/m^2, with peak volume of 573 tonnes, and maximum length of shoreline loading @ 96 km) - Bedout Island (72% contact within 2 days, peak loading 26, 295 g/m^2, with peak volume 299 tonnes, maximum length of shoreline loading @5.7 km).
DISSOLOVED AROMATIC HYDROCARBONS	
Low	Stochastic model predictions EMBA is based on 100 spill simulations, refer **Figure 7-59**. The figures show the dissolved hydrocarbons at 50 ppb (moderate threshold).

10 ppb Lower than the exposure value at which ecological impacts are expected to occur. Relevant for implementing environmental monitoring in event of oil spills	+ Maximum extent from release location – 500 km northeast + Based on all 150 simulations combined – contacted was limited to one AMP at the Eighty Mile Beach AMP in1 day (67% probability at 346 ppb) + Contact was predicted at Imperieuse Reef MP Glomar Shoals and Bedout Island between 2.7 and 38%, with the shortest time to contact at Bedout Island in 1.9 days.
Moderate 50 ppb Approximates potential toxic effects, particularly sublethal effects to sensitive species.	+ Maximum extent from release location – 250 km northeast + Based on all 150 simulations combined – contacted was limited to one AMP at Eighty Mile Beach AMP in 1 day (60% probability at 346 ppb) + Contact was predicted at Imperieuse Reef MP Glomar Shoals and Bedout Island between 1.3 and 28%, with the shortest time to contact at Bedout Island in 2 days.
High 400 ppb Approximates toxic effects including lethal effects to sensitive species	+ Maximum extent from release location – 150 km northeast + Based on all 150 simulations combined – contacted was limited to one AMP at Eighty Mile Beach AMP in 1 day (8.7% probability at 653 ppb) + No contact at any shorelines at this exposure value.
Total Submerged Oil	
Low 10 ppb Lower than the exposure value at which most ecological impacts are expected to occur,. Relevant for implementing environmental monitoring in event of an oil spill.	Stochastic model predictions (EMBA is for 150 spill simulations, refer **Figure 7-59**. The figure shows the total submerged hydrocarbons at 100 ppb (moderate threshold) at the water depths of 0-10m from the sea surface. + Maximum extent from release location – 1, 800 km + Based on all 150 simulations combined - 10 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1% to 98%, with Eighty Mile Beach AMP being most probable (98% in minimum time of 1 days after spill), followed Montebello AMP (75% in minimum time of 11 days after spill). The shortest time to contact predicted at Eighty Mile Beach within 1 days. Maximum concentrations of 1, 597 ppb at Kimberley AMP. + 11 Reef, shoal and bank receptors within the EMBA are predicted to be exposed. The greatest probability being 58% at Glomar Shoals within 9 days, and a maximum concentration of 9 ppb.

	+ Bedout Island (closest nearshore receptor to the south) with probability of 59% within 1.1 days and a maximum hydrocarbon concentration of 145.3 ppb.
Moderate 100 ppb Representative of sub-lethal impacts to most species and lethal impacts to sensitive species. Considered appropriate for environmental risk assessment. (NOPSEMA 2019)	+ Maximum extent from release location – 1200 km + Based on all 150 simulations combined - 5 of the AMPs within the EMBA are predicted to be exposed, probability of exposure to individual AMPs ranged from 1% to 94%, with Eighty Mile Beach AMP being most probable (94% in minimum time of 1 days after spill), followed Montebello Reef AMP (52% in minimum time of 11 days after spill). The shortest time to contact predicted at Eighty Mile Beach within 1 days. Maximum concentrations of 2, 611 ppb at Kimberley AMP. + 10 Reef, shoal and bank receptors within the EMBA are predicted to be exposed. The greatest probability being 62% at Glomar Shoals within 6.7 days, and a maximum concentration of 446 ppb. + Bedout Island (closest nearshore receptor to the south) with probability of 68% within 1.9 days and a maximum hydrocarbon concentration of 1, 292 ppb.

Predicted impacts and risks based on deterministic model predictions = footprint (trajectory and fate) of single worse-case release resulting in the largest volume of oil ashore and longest length of shoreline with oil accumulation (Figure 7-61)

+ Stochastic realisation 31 of the Apus Base Case Surface LOWC scenario resulted in the highest accumulated shoreline load (of all LOWC scenarios simulated) of 5,127 tonnes above 10 g/m2 and 5,125 tonnes above 100 g/m2 (**Figure 7-61**).
+ surface slick exceeding 10 µm thickness that extended up to 300 km from the release location (**Figure 7-61**).
+ Shoreline loading greater than 10 and 100 g/m^2 extended up to 350 km of the release site **(Figure 7-61**).
+ Total submerged oil exceeding 100 ppb extended up to 400 km, while dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within 150 km from the release location (**Figure 7-61**).

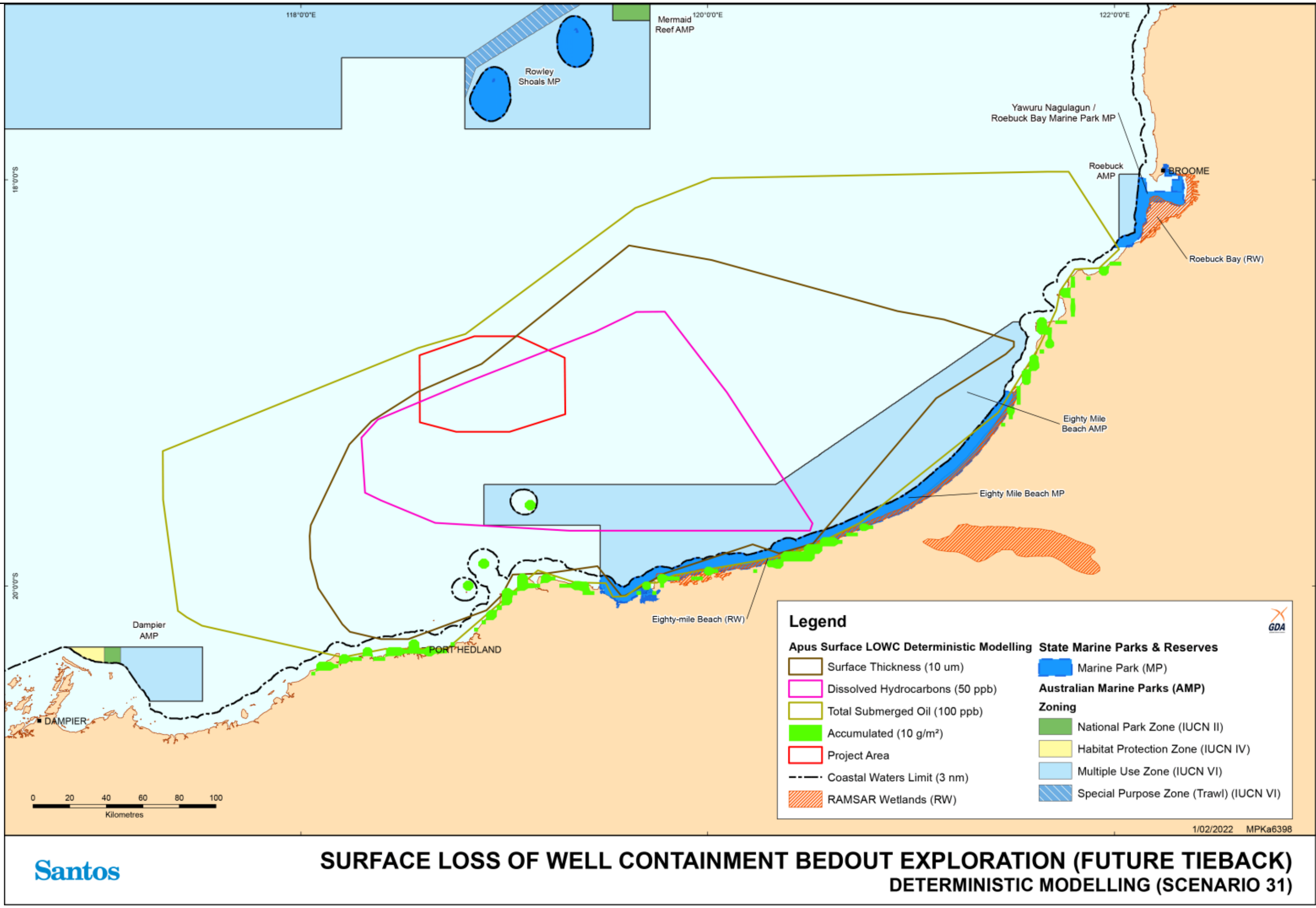


Figure 7-61: Worst-case deterministic model results based on largest volume of oil ashore

7.3.1.6 Details of Environmental Impacts and Risks

The below environmental impact assessment follows the risk assessment approach detailed in **Section 7.3.1.4**

7.3.1.6.1 Identification of hot spots for consequence assessment

As described in **Section 7.3.1.4.2**, all HEVs within the EMBA for LOWC are listed in **Table 7-83**. Further to this, **Table 7-83** filters the HEVs to identify the Hot Spots where they meet the criteria (as described in **Section 7.3.1.4**) from either the subsea or surface loss of well control scenario of any hydrocarbon phase for the tieback and Dorado LOWC scenarios. As noted in **Section 7.3.1.4**, discretion was applied during the workshop to include hotspots that didn't meet the criteria, these are marked with "x" and the rationale for their inclusion as a hotspot is included in **Table 7-83** below.

Note that the worst-case values were taken from both surface and subsea modelling scenarios across both the Dorado and subsea tieback LOWC scenarios to identify the hot spots.

Table 7-83: Receptors potentially impacted by an accidental release of hydrocarbons or chemicals

Receptor	HEV ranking	Exposure Threshold		Hot Spot *	Hotspot Selection rationale
		Low (EMBA)	Moderate/high (Impact)		
Ashmore Reef AMP	1	✓	✓	Y	HEV 1 and in the moderate exposure value.
Ningaloo - Outer Coast North	1	✓	✓	Y	HEV 1 and in the moderate exposure value.
Mermaid Reef AMP	2	✓	✓	Y	HEV 2 and in the moderate exposure value.
Muiron Islands	2	✓	✓	Y	HEV 2 and in the moderate exposure value.
Exmouth Gulf Coast	2	✓	X	N	No contact at the moderate exposure value
Ningaloo Coast North	2	✓	✓	Y	HEV 2 and in the moderate exposure value.
Carnarvon - Inner Shark Bay	2	✓	X	N	No contact at the moderate exposure value
Abrolhos Islands Wallabi, Easter and Oelsaert Group, Abrolhos West	2	✓	✓	Y	7% probability of contact at the moderate exposure value for entrained hydrocarbons (maximum concentration 585 ppb)
Geographe Bay	2	✓	✓	N	<5% probability at the moderate exposure value.
Perth Canyon AMP	2	✓	✓	Y	>5% probability of contact above the moderate exposure value for entrained hydrocarbons.
Eighty Mile Beach	2	✓	✓	Y	HEV 2 and in the moderate exposure value.
Broome - Roebuck	2	✓	✓	Y	HEV 2 and in the moderate exposure value.
Jurien AMP	2	✓	✓	N	<5% probability at the moderate exposure value.
Kimberley Coast	3	✓	X	N	No contact at the moderate exposure value
Cartier Island AMP	3	✓	✓	N	<5% probability of shoreline oil accumulations above the moderate threshold.
Scott Reef North	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Scott Reef South	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Clerke Reef MP	3	✓	✓	Y	HEV 3 and in the moderate exposure value.

Receptor	HEV ranking	Exposure Threshold		Hot Spot *	Hotspot Selection rationale
		Low (EMBA)	Moderate/high (Impact)		
Imperieuse Reef MP	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Dampier Archipelago	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Montebello Islands	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Lowendal Islands	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Barrow Island	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Barrow-Montebello Surrounds	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Ningaloo Coast South	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Shark Bay - Coast Outer	3	✓	✓	Y	HEV 3 and in the moderate exposure value for entrained hydrocarbons (maximum concentration of 1, 020 ppb).
Zuytdorp Cliffs - Kalbarri	3	✓	X	N	No contact at the moderate exposure value
Kalbarri - Geraldton	3	✓	X	N	No contact at the moderate exposure value
Geraldton - Jurien Bay	3	✓	✓	N	Entrained oil contact only but at concentrations lower than those discharged by vessels under Marine Orders in high vessel usage area
Abrolhos - Outer Island Shoals	3	✓	✓	N	HEV >3 Entrained oil contact only but at concentrations lower than those discharged by vessels under Marine Orders in high vessel usage area
Perth Southern Coast	3	✓	X	N	No contact at the moderate exposure value
Mandurah - Dawesville	3	✓	X	N	No contact at the moderate exposure value
Jurien Bay - Yanchep	3	✓	✓	N	Entrained oil contact only but at concentrations lower than those discharged by vessels under Marine Orders in high vessel usage area
Perth Northern Coast	3	✓	X	N	No contact at the moderate exposure value
Kimberley AMP	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Johnson Bank	3	✓	X	N	No contact at the moderate exposure value
Ningaloo - Outer NW	3	✓	✓	Y	HEV 3 and in the moderate exposure value.
Seringapatam Reef	4	✓	X	N	No contact at the moderate exposure value
King Sound	4	✓	✓	N	<5% probability of contact above moderate thresholds
Lacepede Islands	4	✓	✓	Y[X]	HEV> 3, Contact at the moderate exposure threshold for entrained hydrocarbons (max exposure 1, 124 ppb)
Broome North Coast	4	✓	✓	Y[X]	Shoreline loading <100 tonnes along >20km length of shoreline in area of high tourism value
Dawesville - Bunbury	4	✓	X	N	No contact at the moderate exposure value
Geographe Bay - Augusta	4	✓	X	N	No contact at the moderate exposure value
Augusta - Walpole	4	✓	X	N	No contact at the moderate exposure value
Dampier AMP	4	✓	✓	N	HEV >3, limited to entrained contact.
Montebello AMP	4	✓	✓	N	HEV > 3, limited to entrained contact.

Receptor	HEV ranking	Exposure Threshold		Hot Spot *	Hotspot Selection rationale
		Low (EMBA)	Moderate/high (Impact)		
Bremer AMP	4	✓	X	N	No contact at the moderate exposure value
Shark Bay AMP	4	✓	X	N	No contact at the moderate exposure value
Ashmore/Cartier - Outer	4	✓	✓	N	<5% probability of total submerged oil contact above moderate thresholds
Eighty Mile Beach AMP	4	✓	✓	Y[x]	>50% probability of contact of surface, total submerged and dissolved oil above moderate threshold
Rowley Shoals surrounds	4	✓	✓	Y[x]	>50% probability of total submerged oil contact above moderate threshold
South-west corner AMP	4	✓	X	N	No contact at the moderate exposure value
Ningaloo - Offshore	4	✓	✓	Y[x]	>30% probability of entrained oil contact above moderate threshold
Abrolhos	4	✓	✓	N	HEV >3 Entrained oil contact only but at concentrations lower than those discharged by vessels under Marine Orders in high vessel usage area
Christmas Island	4	✓	X	N	No contact at the moderate exposure value
Echo Shoals	5	✓	X	N	No contact at the moderate exposure value
Sahul Banks	5	✓	X	N	No contact at the moderate exposure value
Gale Bank	5	✓	X	N	No contact at the moderate exposure value
Fantome Shoals	5	✓	X	N	No contact at the moderate exposure value
Barracouta Shoals	5	✓	✓	N	<5% probability of total submerged oil contact above moderate thresholds. HEV rank 5.
Vulcan Shoals	5	✓	X	N	No contact at the moderate exposure value
Hibernia Reef	5	✓	X	N	No contact at the moderate exposure value
Woodbine Bank	5	✓	X	N	No contact at the moderate exposure value
Heywood Shoals	5	✓	X	N	No contact at the moderate exposure value
Echuca Shoals	5	✓	X	N	No contact at the moderate exposure value
Browse Island	5	✓	X	N	No contact at the moderate exposure value
Port Hedland-Eighty Mile Beach	5	✓	✓	Y[x]	2000 tonnes of shoreline oil accumulation, total submerged oil concentration >1800 ppb, short time to contact >2 days above moderate threshold
Glomar Shoals	5	✓	✓	N	Submerged feature, low HEV ranking
Karratha-Port Hedland	5	✓	✓	Y[x]	>130 tonnes of shoreline oil accumulation, time to contact >7 days above moderate threshold
Rankin Bank	5	✓	✓	N	Submerged feature, low HEV ranking
Northern Islands Coast	5	✓	✓	N	>26 days to contact above moderate threshold, low volume spread across lengths of shoreline. Low HEV ranking.
Middle Islands Coast	5	✓	✓	N	<5% probability of contact at moderate thresholds
Thevenard Islands	5	✓	✓	N	HEV = 5, >24 days to shoreline accumulation above moderate threshold

Receptor	HEV ranking	Exposure Threshold		Hot Spot *	Hotspot Selection rationale
		Low (EMBA)	Moderate/high (Impact)		
Southern Islands Coast	5	✓	✓	Y[x]	>39% probability of shoreline accumulation above moderate threshold
Rottnest Island	5	✓	X	N	No contact at the moderate exposure value
Indonesia - East	5	✓	X	N	No contact at the moderate exposure value
Indonesia - West	5	✓	X	N	No contact at the moderate exposure value
Roebuck - Eighty Mile Beach	5	✓	✓	Y[x]	>25% probability of shoreline accumulation >340 tonnes accumulated, total submerged oil contact >840 ppb above moderate threshold
Bedout Island	5	✓	✓	Y[x]	23-81% probability of contact of surface, total submerged and shoreline accumulation in short timeframes (2 days) above moderate threshold

* Greater than 5% probability of contact at the medium/high exposure value for consideration for further hotspot assessment.

[x] Discretionary hotspot.

This process identified the following hot spots:

- Outer Ningaloo Coast North
- Ashmore Reef AMP
- Eighty Mile Beach
- Mermaid Reef AMP
- Muiron Islands
- Ningaloo Coast North
- Imperieuse Reef MP
- Clerke Reef MP
- Scott Reef North
- Ningaloo Coast South
- Dampier Archipelago
- Kimberley AMP
- Eighty Mile Beach AMP
- Karratha-Port Hedland
- Roebuck – Eighty Mile Beach
- Lacepede Islands
- Broome-Roebuck
- Barrow-Montebello surrounds
- Montebello Islands
- Lowendal Islands
- Barrow Island
- Outer NW Ningaloo
- Perth Canyon AMP
- Scott Reef South
- Bedout Island
- Rowley Shoals surrounds
- Offshore Ningaloo
- Broome North Coast
- Port Hedland-Eighty Mile Beach
- Southern Islands Coast.
- Abrolhos Islands Wallabi, Easter and Pelsaert Group

Attachment 8-2 provides a simplified summary of the consequence assessment results for each of the Hot Spot areas. The consequence assessment was based on predicted contact and concentration of floating oil, accumulated oil, total submerged oil, entrained and dissolved oil**.** For each Hot Spot area, the consequence to the key values were assessed using the methodology described in **Section 7.3.1.4.**

Table 7-84 identifies the potentially impacted receptors as a result of an accidental release of hydrocarbons or chemicals within the Project Area.

Table 7-84: Receptors potentially impacted by an accidental release of hydrocarbons or chemicals

Description of the Risk	Receptor Categories
Potential widespread decrease in water quality from hydrocarbon pollution Potential localised decrease in water quality from hydrocarbon pollution Potential widespread impacts to benthic and coastal communities and habitats from hydrocarbon pollution Potential acute and chronic toxic effects Potential impacts to the natural and socio-economic values of marine and coastal protection areas Potential temporary closure of fisheries due to hydrocarbon pollution Potential loss of cultural values of heritage sites Potential impacts to tourism through loss of nature-based tourism resources due to hydrocarbon pollution.	Water Quality – **Section 7.3.1.2.1** Sediment Quality – **Section 7.3.1.2.2** Air Quality – **Section 7.3.1.2.3** Communities and Habitats – **Sections 7.3.1.2.4, 7.3.1.2.5 & 7.3.1.2.6** Mammals – **Section 7.3.1.2.7** Reptiles – **Section 7.3.1.2.8** Birds – **Section 7.3.1.2.9** Fishes – **Section 7.3.1.2.10** Protected Areas – **Section 7.3.1.2.11** Heritage – **Section 7.3.1.2.12** Fisheries – **Section 7.3.1.2.13** Tourism – **Section 7.3.1.2.14** Maritime Industry – **Section 7.3.1.2.15**

7.3.1.6.2 Physical Environment or habitat

Water Quality

The concentrations of hydrocarbons in the water column will decrease over time once the release has stopped due to processes such as dispersion, dilution, physical and biological degradation, and evaporation. For short duration release scenarios, these processes will begin to reduce the total amount of hydrocarbons in the water column shortly after the release. The worst-case subsea and surface release from the WHP will continue to release fresh hydrocarbons for the duration of the release, and the amount of hydrocarbons will increase until the release is stopped. Modelling results (**Attachment 8**) indicate that exposure to entrained hydrocarbons at the low threshold was predicted to occur up to a maximum distance of 2,878 km (west-northwest) from the spill site (winter). This distance reduced to 2,158 km (west-northwest) based on the moderate threshold in winter.

Large volume releases of Caley crude from the Dorado Development including future tiebacks have the potential to result in increased concentrations of dissolved hydrocarbons, which include BTEX and PAHs. BTEX and PAH are known to be toxic to marine biota. BTEX compounds do not persist in the marine environment due to their volatility and will diminish once released into the environment. The concentration of BTEX is expected to be highest near the release location and will decline as the spilled hydrocarbon weathers of time. PAHs are less volatile than BTEX and are expected to persist for longer in the environment. HFO typically contains relatively low concentrations of BTEX and PAH and does not readily entrain in the water column. Hence, HFO spills are expected to have a lower potential for toxic effects, although HFO may remain as a persistent floating oil for long periods of time. Modelling results (**Attachment 8-1**) indicate that exposure to entrained hydrocarbons at the low threshold was predicted to occur up to a maximum distance of 850 km (southwest) from the spill site (summer).

The decrease in water quality from worst-case hydrocarbon spills are expected to consist of short-term acute toxic effects to phytoplankton and zooplankton. Plankton utilising the sea surface layer could be impacted by floating oil. There is potential for localised mortality of plankton due to reduced water quality and toxicity. Also, through physical contact of small oil droplets, plankton mobility, feeding and/or respiration may be impaired. Plankton could include the eggs and larvae of marine invertebrates and fish and therefore entrained oil could impact on recruitment of invertebrate/fish species. The likelihood of this would be determined by the extent and timing of the spill; for example, hard coral spawning occurs primarily in March/April, so there is a heightened potential for impacts to coral eggs and larvae to occur during this period. Effects will be greatest in the upper 10 m of the water column and areas close to the spill source where hydrocarbon concentrations are likely to be highest.

Plankton could include the eggs and larvae of marine invertebrates and fish and therefore impact on recruitment of invertebrate/fish species. The Project Area has the potential to overlap with spawning of some fish species given the year round spawning of some species. In the unlikely event of a spill occurring, fish larvae may be impacted by hydrocarbons entrained in the water column. Following a hydrocarbon release a portion of the slick will rapidly evaporate and disperse in the offshore environment, reducing the concentration and toxicity of the spill. Maximum entrained oil concentrations were predicted at Argo-Rowley Terrace AMP. Plankton utilising the sea surface layer, as well as pelagic invertebrates, could be impacted from floating oil. Exposure to entrained oils and DAHs may result in lethal or sub-lethal impacts to plankton or pelagic invertebrates through a direct contact pathway. Such contact could impair the mobility, feeding and respiration of these fauna and exchange of chemicals could occur.

Planktonic communities are characterised by relatively rapid turnover rates of short-lived biota. The high turnover rate will lead to rapid recovery as the spilled hydrocarbons decay in the marine environment. Within plankton communities, there is evidence from laboratory studies that some taxonomic groups, particularly zooplankton (e.g. copepods) may be more sensitive to hydrocarbon pollution (Almeda et al. 2013; Jiang et al. 2010). Few reliable studies have shown any impacts of hydrocarbon spills on planktonic communities, with most studies concluding that impacts from hydrocarbon pollution cannot be distinguished from natural variability (Abbriano et al. 2011; Davenport et al. 1982; Varela et al. 2006).

Sediment Quality

Sediment quality in the offshore or nearshore environment is not expected to be significantly affected by any of the worst-case scenarios that release Caley oil. Hydrocarbon contaminants (e.g. PAHs) from surface releases are unlikely to reach the seabed due to the water depth and low natural sedimentation rates in the region. Hydrocarbon contaminants from the subsea releases (loss of well control) may contaminate sediments by advective transport of the plume that will be formed during the release (Romero et al. 2015). This is considered most likely to occur with the worst-case loss of well containment scenario due to the relatively long duration of the release. Any resulting contamination will be concentrated around, and down-current from, the wellhead. Due to the low density and volatile nature of the hydrocarbon and water depth weathered Caley oil is unlikely to be deposited to the seabed or accumulate on shorelines in large volumes (63m^3).

Shoreline sediments are likely to be impacted for scenarios particularly from the future tieback loss of well control scenarios described in **Section 7.3.1.1.4**. The surface release loss of well control scenario described has potential for 5,127 tonnes of accumulated hydrocarbon across 27 shorelines surrounding the release locations (**Table 7-82**). Key receptors with environment values including sandy beaches with predicted accumulation above the moderate exposure threshold include: Bedout Island, Eighty Mile Beach, Ningaloo Coast North, Middle and South, Broome Roebuck Bay and Outer Shark Bay Coast. The stranding of high volumes of accumulated oil lead to smothering of sediments and long-term contamination of these sediments. Under these circumstances hydrocarbons often continue to remobilise into the surf zone, impacting intertidal sensitivities.

The HFO release from a loss of fuel from a vessel collision scenario has a relatively low portion of volatiles, which are expected to evaporate quickly following release. The remaining HFO may sink to the seabed if sufficient sediment adheres to the surface of the residual oil. This weathered oil may subsequently become deposited in sediments. Residual HFO near shorelines may be exposed to higher sediment loads and be more likely to sink. Stranding of residual HFO on shorelines can lead to smothering of sediments and long-term contamination of sediments with high-molecular weight hydrocarbons. These compounds are typically much less toxic than low-molecular weight hydrocarbons. HFO, if released, will likely result in large amounts of weathered oil accumulating onshore with the maximum volume of 1684.5 m^3 predicted on shorelines surrounding Broome.

Air Quality

Surface releases of Caley oil will readily evaporate, resulting in an increase in volatile hydrocarbons in the air directly above the floating oil. This decrease in air quality will be temporary, with most evaporation occurring within the first day (**Figure 7-30**). Wind will disperse the volatile hydrocarbons, which will degrade naturally.

Bare Sediments

Bare sediment habitat is very widely represented in the offshore waters of northwestern Western Australia, and the associated fauna assemblages are not considered to be particularly sensitive or of high conservation value (**Section 3**).

The majority of the Project Area consists of habitat composed largely of fine sediments (typically more than 90% cover) but it also contains notable areas of hard pavement reef, which is habitat for filter feeder communities, especially whip corals, gorgonians and sponges (**Section 3**). These habitats are widely represented in the region and are not considered to be particularly sensitive. These fauna may be subject to acute and chronic toxic effects from exposure to hydrocarbons. The extent of hydrocarbons contacting shorelines (accumulated and floating hydrocarbons) and subsea sediments (entrained, and dissolved hydrocarbons) are expected across the range of scenarios described in **Section 7.3.1**.

Shoreline loading and water movement may allow hydrocarbon residue to filter down into sediments, continue to biodegrade on the surface or remobilise into the surf zone. The degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the sandy shore and continual weathering of the oil. Indirect impacts to nesting and foraging habitats for birds and turtles, with direct impacts to infauna would be expected.

Many benthic fauna species have planktonic larval phases (e.g. corals, echinoderms, sponges etc.). Organisms with planktonic larval phases typically produce very high numbers of larvae. A worst-case credible spill may result in increased mortality of planktonic larvae (which are subject to high natural mortality); however, this is not expected to result in population-scale impacts.

Filter feeding benthic communities may be vulnerable to entrained and dissolved hydrocarbons. Entrained hydrocarbons can be ingested by filter feeders, leading to increased exposure due to accumulation of ingested oil droplets (Payne and Driskell 2003). While typically less toxic than dissolved hydrocarbons, entrained oil may still cause toxic effects. Similarly, entrained oil may also result in physical impacts such as clogging of filter feeding organs, potentially resulting in reduced feeding efficiency. Filter feeder, and sessile organisms in general, may be exposed to concentrations of dissolved hydrocarbons that result in acute and chronic toxic effects.

Seagrasses and Macroalgae

Several key environmental receptors with recognised seagrass and macroalgal habitat within the EMBA for entrained and/or dissolved hydrocarbons include: Mermaid Reef AMP, Muiron Islands, Exmouth Gulf Coast, Ningaloo Coast North, Middle and South, Abrolhos Islands, Imperieuse and Clerke Reef, Eighty Mile beach, Lowendal Islands, Scott Reef, Cartier Island, Dampier Archipelago and Broome- Roebuck bay.

Most seagrasses within the EMBA of the worst-case hydrocarbon spill scenarios are subtidal, although there may be relatively small areas of intertidal seagrasses along the mainland coastline. Seagrass in the subtidal and intertidal zones have different degrees of exposure to hydrocarbon spills. Subtidal seagrass is unlikely to be exposed to spilled hydrocarbons, as most hydrocarbons in subtidal environments will be concentrated at the surface. Intertidal seagrasses are vulnerable to smothering by floating oil slicks, which can lead to mortality if it coats their flowers, leaves and stems (Dean et al. 1998; Taylor and Rasheed 2011). Long-term impacts to seagrass are unlikely unless hydrocarbon is retained within the seagrass meadow for a sustained duration (Wilson and Ralph 2011). Toxicity effects can also occur due to absorption of soluble fractions of hydrocarbons into tissues (Runcie et al. 2010). The potential for toxicity effects of entrained hydrocarbons may be reduced by weathering processes that should serve to lower the content of soluble aromatic components before contact occurs. Caley crude is expected to be highly weathered prior to reaching shallow areas where seagrasses may occur.

Like seagrasses, the potential impacts to macroalgae depend on the exposure pathway; most macroalgae in the region are subtidal, although intertidal macroalgae may be present. Studies of subtidal macroalgal assemblages exposed to fuel oil spills have shown that impacts from exposure is slight (Edgar et al. 2002; Lobón et al. 2008). Effects of exposure to oil on intertidal macroalgae are more variable; some studies reported little evidence of impacts (Díez et al. 2009), while others show significant impacts (De Vogelaere and Foster 1994). Recovery of intertidal macroalgae has been shown to occur faster in areas where oil has been left to degrade naturally compared to areas subject to intensive clean-up operations (De Vogelaere and Foster 1994).

Seagrass and macroalgae provide important habitat for ecosystem function within the region, with significant seagrass meadows known as being important for dugong feeding at Ashmore Reef, Exmouth Gulf and Lowendal Islands.

Coral Reefs, Banks and Shoals

Numerous named reefs, shoals and banks occur within the EMBA (**Section 3**). Of particular note is Ningaloo Reef, which is the largest fringing (i.e. nearshore) coral reef in Australia. Other notable reefs include those surrounding the Muiron Islands, Barrow Island, the Montebello Islands and the Rowley Shoals. The relatively shallow depth results in these reefs, banks and shoals being at risk of impacts from hydrocarbon spills. Reefs, banks and shoals have relatively high biodiversity value and are of regional importance (Bryce 2009; Wahab et al. 2018). They may also act as sources of larvae of corals and other reef fauna, and impacts to these reefs, banks and shoals may result in reduced larval supply to areas relatively far away.

Contact with dissolved and entrained hydrocarbons above moderate exposure thresholds may result in mortality of benthic biota associated with reefs, banks and shoals. The loss of habitat-forming biota such as corals, macroalgae or sponges could result in changes to habitats, with subsequent changes to fauna assemblages and composition.

The time required for recovery following disturbance will depend on the nature and scale of the impact. Shoals and banks in the region have been exposed to significant intermittent disturbance for long periods of time, such as damage from cyclones and changes in water temperature associated with the El Niño-Southern Oscillation. Hence, the communities of reefs, shoals and banks in the region will be in various states of natural succession. The intermittent nature of natural disturbance may mean the biological communities of reefs, shoals and banks in the region are adapted to recovering from disturbance. Hence, they are expected to recover over time if exposed to an oil spill, although the recovery time may take decades.

The shorelines of offshore reefs and islands (e.g. the Rowley Shoals) typically consist of intertidal reef flats and sandy beaches; shoreline types such as rocky shores, estuaries and mangroves typically occur much less frequently. Stranding of floating oil on offshore islands and reefs may result in a band of weathered oil between the low- and high-water marks on shorelines and intertidal corals. In the highly unlikely event of a subsea or surface LOWC event, hydrocarbons will likely reach both subsea and shoreline habitats of the offshore reefs (Clerke and Imperieuse Reef), islands (Bedout island, Lacepede Island) and shoals (Glomar shoals and Rankin Bank). This may result in impacts to fauna in these habitats, such as nesting turtles and wading birds. Hydrocarbons that reach nearshore environments also have the potential to impact benthic coral reefs, which may result in a long-term decrease in ecological values given toxicity impacts associated with hydrocarbon exposure.

Corals within the intertidal and shallow subtidal zone may be susceptible to impacts from hydrocarbons, ranging from potentially sublethal to lethal impacts. Impacts from physical coating of corals appears to also depend on coral morphology. Coral species more likely to retain oil coatings (e.g. due to polyp morphology, or gross morphology with high surface area to volume ratios such as branching corals) have been shown to be more susceptible to impacts (Shigenaka 2001). Exposure to dissolved and entrained hydrocarbons may result in acute and chronic toxic effects, with longer exposure durations typically leading to greater potential for mortality (Shigenaka 2001). Corals may also ingest entrained oil particles, potentially leading to update of hydrocarbons into coral tissue (Loya and Rinkevich 1980). Experimental studies and field observations indicate all coral species are sensitive to the effects of oil, although there are considerable differences in the degree of tolerance between species (e.g. NOAA 2010a). Differences in sensitivities may be due to the ease with which oil adheres to the coral structures, the degree of mucous production and self-cleaning, or simply different physiological tolerances. For example, laboratory and field studies have demonstrated that branching corals appear to have a higher susceptibility to hydrocarbon exposure than massive corals or corals with large polyps Physical oiling of coral tissue can cause a decline in metabolic rate and may cause varying degrees of tissue decomposition and death (Negri and Heyward 2000). Direct contact of coral by hydrocarbons may also impair respiration and photosynthesis by symbiotic zooxanthellae (Peters 1981; Knap et al. 1985). Chronic effects of oil exposure have been consistently noted in corals and, ultimately, can kill the entire colony. Chronic impacts include histological, biochemical, behavioural, reproductive and developmental effects.

Mangroves

Intertidal mangrove habitats occur throughout much of the Kimberley, and are highly susceptible to oil pollution. Several receptors within the EMBA have mangrove habitats predicted to be contacted by floating and accumulated hydrocarbons. These receptors include: Eighty Mile Beach, Exmouth Gulf Coast, Ningaloo Coast North Mangroves, Abrolhos Islands, Montebello/ Lowendal Islands, Barrow Island and Broome- Roebuck Bay. These receptors are vulnerable to contact with floating and accumulating hydrocarbons, such as weathered HFO, and Caley Crude (from the future tieback scenario, **Section 7.3.1.1.4**) which may coat prop roots and pneumatophores (aerial roots that support oxygen uptake) (Duke and Archibald 2016). Exposure can result in direct effects such as yellowed leaves, defoliation and mortality, and indirect effects such as reduced recruitment and increased sensitivity to other stressors (National Oceanic and Atmospheric Administration 2014). Like seagrasses, mangroves can also be impacted by entrained, dissolved aromatic and accumulated hydrocarbons either in the water or sediment.

Intertidal Sand and Mudflats

Intertidal mudflats are susceptible to potential impacts from hydrocarbons as they are typically low energy environments and therefore trap oils. The extent of oiling is influenced by the neap and spring tidal cycle and seasonal highs and lows affecting mean sea level. Potential impacts to tidal flats include heavy accumulations covering the flat at low tide. It is unlikely that oil will penetrate water-saturated sediments in intertidal sand and mudflats. However, oil can penetrate fine sediments through animal burrows and root pores.

Intertidal mudflats provide resting and feeding areas for migratory bird species. Extensive mudflats occur along Eighty Mile Beach, which seasonally hosts large aggregations of migratory birds and is recognised as a Ramsar site (**Section 7.3.1.2.11**).

Intertidal Platforms

Like intertidal sand and mudflats, the extent of oiling of intertidal platforms is influenced by the neap and spring tidal cycle and seasonal highs and lows affecting mean sea level. Unlike intertidal sand and mudflats, intertidal platforms typically have a veneer of organisms such as macroalgae and sessile invertebrates. These organisms will be vulnerable to potential toxic and smothering impacts from spilled oil, depending on the degree of weathering and the volume of oil deposited. Given the location of the Project Area, spilled oil reaching intertidal platforms is likely to be highly weathered, hence smothering effects may be the main mechanism of impact.

Sandy Beaches

Hydrocarbons at sandy shores are incorporated into fine sediments through mixing in the surface layers from wave energy, penetration down worm burrows and root pores (International Petroleum Industry Environmental Conservation Association 2000). Hydrocarbons in the intertidal zone can adhere to sand particles however high tide may remove some or most of the hydrocarbons back out of the sediments. Typically, hydrocarbons are only incorporated into the surface layers to a maximum of 10 cm (International Petroleum Industry Environmental Conservation Association 2000). It is predicted that a number of sandy shores along the coastline may have accumulation of hydrocarbons above the moderate shoreline accumulation exposure threshold, particularly as a result of a worst-case spill of HFO (**Figure 7-42** and **Figure 7-43**) and Caley Crude (**Table 7-81** and **Table 7-82)**. The persistence of the hydrocarbons will be dependent on the wave exposure but can be months to years.

Shoreline accumulation on sandy beaches may also result in oiling of fauna such as nesting female turtles and turtle hatchlings, as well as shorebirds. Impacts to fauna are considered in **Section 7.3.1.2.8.**

Rocky Shorelines

The impact of oil on rocky shores are largely dependent on the localised incline and energy environment. On steep/vertical rock faces on wave exposed coasts there is likely to be no impact from a spill event, as the oil does not typically get deposited due to wave action. However, a gradually sloping boulder shore in calm water can potentially trap large amounts of oil (International Petroleum Industry Environmental Conservation Association 2000).

Caley crude release from the drilling of future tieback wells, presented in **Table 7-81** and **Table 7-82,** present the scenarios with the greatest potential for impacts to shoreline due to the greatest tonnage of oil predicted to contact shorelines (5, 127 tonnes). Most impacts to rocky shorelines would occur as a result of physical effects, such as smothering.

Islands

Several islands are susceptible to potential impacts from hydrocarbons, particularly from the scenarios associated with the drilling of future tieback wells described in **Table 7-81** and **Table 7-82,** A very high contact probability of 88% was predicted for the proximal island receptor of Bedout Island. This receptor was predicted to receive a maximum shoreline accumulation of 299 tonnes, with a minimum arrival time of 2 days and maximum oiled shoreline length of 6 km. Bedout Island is fringed by coral reef and provides seabird and turtle foraging habitat susceptible to impact from hydrocarbons.

Key Ecological Features

KEFs by their nature are typically geomorphic features and have an inherently low likelihood of being impacted by oil spills from Dorado Phase 1. This is because spilled oil is typically closely associated with the sea surface due to the buoyancy of the oil and unlikely to penetrate to the seabed. While some features associated with the KEFs are subtidal or submerged and would not be directly contacted by a surface slick or accumulated hydrocarbons, they all may support increased productivity or abundance of marine fauna that use surface waters above the features (including plankton, pelagic invertebrates and fish, marine mammals, marine reptiles and seabirds) which may be impacted by floating oil. Impacts to these marine fauna are described in the following sections. Most KEFs within the EMBA are relatively far from the Project Area, meaning that any hydrocarbons reaching these KEFs will be highly weathered. Exceptions to this general pattern are listed below, all of which lie in relatively close proximity to the Project Area:

+ Ancient coastline at 125 m depth contour (23 km from WHP);
+ Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (138 km from WHP); and
+ Glomar Shoals (207 km from WHP).

These KEFs host benthic habitats and communities that may be impacted by hydrocarbons; refer to **Section 7.3.1.2.4** for a discussion of these potential impacts.

7.3.1.6.3 Threatened and Migratory Species

Marine Mammals

Marine mammals are at risk of direct contact with surface hydrocarbons due to chance of surfacing within slick. Effects include irritation of eyes/mouth and potential illness. Surface respiration could lead to accidental ingestion of hydrocarbons or result in the coating of sensitive epidermal surfaces. Potential impact to feeding apparatus of some species (baleen whales). Marine mammals exposed to the entrained hydrocarbons and DAHs in the water column may experience lethal or sub-lethal physical and toxic effects such as irritation of eyes/mouth and potential illness. **Table 7-76** provides further information about environmental impacts to marine mammals from hydrocarbon exposure and increased toxicity.

Cetaceans exposed to hydrocarbons may exhibit avoidance behaviour. Geraci (1988) documented apparent avoidance of floating oil by bottlenose dolphins, suggesting that cetaceans can detect and avoid surface slicks. However, observations during spills have recorded whales and dolphins traveling through and feeding in oil slicks. During the Deepwater Horizon spill in the Gulf of Mexico, cetaceans were routinely witnessed swimming in surface slicks offshore (and nearshore) (Aichinger Dias et al. 2017). Cetaceans observed during the spill response for the Montara oil spill (Timor Sea), included oceanic species such as false killer whales, bottlenose dolphins, spotted dolphins and spinner dolphins (Watson et al. 2009).

Cetaceans exposed to surface, entrained or dissolved aromatic hydrocarbons above moderate exposure thresholds may suffer external oiling, ingestion of oil and inhalation of toxic vapours (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Cetaceans in coastal waters (e.g. coastal dolphin species and humpback whales at the northern limit of their migration) are at lower risk of impacts than cetaceans in offshore water due to the oil weathering that will occur prior to the oil reaching coastal waters. Impacts from direct oiling from a spill of Caley crude are considered unlikely due to the light persistent nature of the hydrocarbon and the thick layer of skin and blubber of cetaceans. Impacts from direct exposure are expected to be irritation of eyes and mucous membranes. Entrained hydrocarbons may be ingested by cetaceans during feeding, particularly by baleen whales. Some species of baleen whale, such as humpback and blue whales, may be seasonally present during their migrations. Opportunistic feeding may occur during migration may occur, with most baleen whale feeding occurring in waters well south of the Project Area. Some whales, particularly those with coastal migration and reproduction, display strong site fidelity to specific resting, breeding and feeding habitats, as well as to their migratory paths. Migratory BIAs identified for the Pygmy Blue Whale and Humpback Whale occur within the area that may be exposed from an oil spill from the Dorado Development.

Dugongs are known to occur in coastal waters and around offshore islands within the moderate EMBA, at locations including: Dampier Archipelago, Abrolhos Islands, Lowendal Islands, Exmouth Gulf and Ashmore Reef. There is a paucity of studies examining the effects of hydrocarbon spills on dugongs, although the direct impacts of exposure to hydrocarbons may be similar to cetaceans. Like cetaceans, dugongs are expected to be resilient to direct impacts from a spill due to their thick skin and blubber. Suitable dugong habitat is associated with seagrass meadows, which are typically restricted to shallow waters around the mainland coast and islands. The distance of dugong habitat from the worst-case credible spill release locations means that oil reaching dugong habitat will be highly weathered (the distance from the WHP to the mainland coast is approximately 145 km).

Marine Reptiles

Marine turtles may be exposed to floating hydrocarbons when at the sea surface (e.g. breathing, basking etc.), and are not expected to avoid floating hydrocarbon slicks (National Oceanic and Atmospheric Administration 2010). Exposure to floating or entrained hydrocarbons may result in external oiling, which could result in physical impacts such as inflammation or infection (Gagnon and Rawson 2010; Lutcavage et al. 1995; National Oceanic and Atmospheric Administration 2010). Oiling can also irritate and injure skin which is most evident on pliable areas such as the neck and flippers (Lutcavage et al. 1995). A stress response associated with this exposure pathway includes an increase in the production of white blood cells, and even a short exposure to hydrocarbons may affect the functioning of their salt gland (Lutcavage et al. 1995).

Hydrocarbons in surface waters may also impact turtles when they surface to breathe and inhale toxic vapours. Their breathing pattern, involving large ‘tidal’ volumes and rapid inhalation before diving, results in direct exposure to petroleum vapours which are the most toxic component of the hydrocarbon spill (Milton and Lutz 2003). This can lead to lung damage and congestion, interstitial emphysema, inhalant pneumonia and neurological impairment (National Oceanic and Atmospheric Administration 2010). Contact with entrained hydrocarbons can result in hydrocarbon adherence to body surfaces causing irritation of mucous membranes in the nose, throat and eyes leading to inflammation and infection (Gagnon and Rawson 2010).

The EMBA overlaps with BIAs for five turtle species (flatback, green, hawksbill, Olive Ridley and loggerhead)**.** Sea snakes are associated with the offshore reefs and banks within the EMBA, particularly those at Ashmore, Imperieuse and Clerke Reef within the Rowley shoals, which are known for their abundance and diversity of sea snakes. The saltwater crocodile may also occur in small numbers in the EMBA, potential impacts to the crocodile are similar to those of turtles.

Important habitat including important nesting beaches for turtle species are present within the EMBA, including locations where spill modelling indicated the accumulation of hydrocarbons on shorelines such as Ashmore Reef AMP (nesting green turtles and foraging for other turtle species), Eighty Mile Beach (flatback turtle nesting) and further afield at Muiron Islands (loggerhead and green turtles) and Ningaloo Coast (loggerhead, green and hawksbill). The highest shoreline accumulations, above the 100 g/m² exposure value, were predicted at Ashmore Reef, Rowley shoals (Clerke and Imperieuse reefs) and Eighty Mile Beach. In the event of a spill, the presence of hydrocarbons on beaches would disrupt behaviour which could present a risk to turtle populations. For further detailed environmental impacts to marine reptiles from hydrocarbon exposure and increased toxicity, refer to **Table 7-75.**

HFO from the worst-case loss of containment due to vessel collision may result in shoreline accumulation above the moderate exposure threshold on nesting beaches throughout this region. Marine turtles rely on nesting beaches to reproduce, which makes them vulnerable to impacts from spilled hydrocarbon accumulations on shorelines through oiling of nesting females and emergent hatchlings (Lauritsen et al. 2017). Hydrocarbons accumulated on sandy beaches may also potentially impact nesting females, incubating eggs and emerging hatchlings through direct contact with the hydrocarbon.

Impacts to sea snakes from direct contact with hydrocarbons include potential damage to the dermis and irritation to mucous membranes of the eyes, nose and throat (International Tanker Owners Pollution Federation 2011a).

Birds

Seabirds and migratory birds are particularly vulnerable to contact with floating hydrocarbons, which may result in matted feathers leading to potential hypothermia from loss of insulation and ingestion of hydrocarbons when preening to remove hydrocarbons. These impacts combined, can lead to mortality (Hassan and Javed 2011) and sub lethal toxic effects such as irritation of eyes/ mouth. Seabirds may encounter floating oil when foraging for food or resting on the sea surface. Seabird foraging is typically concentrated around roosting locations, such as offshore and coastal islands. The EMBA contacts multiple areas where seabirds are known for breeding including Bedout Island, Eighty Mile Beach and Ashmore Reef, impacts to birds may include coating by oil when floating in open water, diving into open and coastal waters to feed on fish, wading and foraging on shallow intertidal mud/sand flats or roosting on oil affected sandy beaches. For further detailed environmental impacts to birds from hydrocarbon exposure and increased toxicity, refer to **Table 7-75.** Lethal or sub-lethal physical and toxic effects such as irritation of eyes/mouth and potential illness may occur should seabirds and shorebirds be exposed to MDO, HFO and Caley crude at moderate exposure values.

Caley crude (future tieback scenarios, **Table 7-81** and **Table 7-82** and HFO (vessel collision, **Table 7-79**) spills may result in a considerable amount of persistent floating oil. This oil is expected to remain on the sea surface, and may result in contact with seabirds that are foraging or resting within a floating oil slick. A number of BIAs for seabirds, including terns, shearwaters, boobies and frigatebirds, occur within the moderate floating HFO and Caley crude EMBA for the worst-case hydrocarbon spill scenarios described in **Section 7.3.1.1.3** and **Section 7.3.1.1.4**. The BIAs are located in the vicinity of coastal and offshore islands; these islands host large numbers of birds during the breeding seasons for these species. A spill resulting in floating oil around these islands may cause oiling of nesting birds, which may result in mortality of oiled birds. Other impacts could include behavioural impacts whereby birds avoid important nesting and migratory stop-over areas including RAMSAR wetlands or reduced food availability if important foraging areas are impacted.

Migratory shorebirds are seasonally abundant during summer months, and a spill during this period would have greater potential to impact migratory shorebirds. Migratory shorebirds are not likely to encounter floating oil at sea, but they may be affected by shoreline accumulation of oil or by oil and shallow foraging habitats, such as intertidal mudflats. Unlike seabirds, shorebird mortality due to hypothermia from matted feathers is relatively uncommon (Henkel et al. 2012). Indirect impacts, such as reduced prey availability and bioaccumulations of PAHs, may occur (Henkel et al. 2012). Impacts of an oil spill to migratory shorebird prey in important foraging areas, such as the intertidal flats off Eighty Mile Beach, could result in reduced food availability for portions of migratory shorebird populations.

There are a number of wetlands of international importance (RAMSAR sites) for migratory birds within the moderate EMBA; refer to the Protected Areas sub-section (subsection of **Section 7.3.1.2.11**) for a discussion of the potential impacts of an oil spill on these wetlands.

Fish

Fish respire through gills, which may make them more vulnerable to dissolved hydrocarbon fraction compared to fauna with less permeable skins, such as cetaceans, marine reptiles and birds. Despite this apparent vulnerability, fish mortalities are rarely observed to occur because of hydrocarbon spills (Fodrie and Heck 2011; International Tanker Owners Pollution Federation 2011c), although instances of fish mortality from spills in confined areas (e.g. bays) have been recorded. These observations are consistent with fish moving away from hydrocarbons in the water (Hjermann et al. 2007).

Exposure of fish to hydrocarbons may results in acute and chronic effects and may vary depending on a range of factors such as exposure duration and concentration, life history stage, interspecies differences and other environmental stressors (Westera and Babcock 2016). Environmental monitoring of pelagic and demersal fishes immediately following the Montara oil spill indicated that fish were exposed to hydrocarbons, although no adverse effects were detected (Gagnon and Rawson 2012, 2011). Further sampling and testing over time indicated that fish captured in close proximity to the Montara wellhead were comparable to those collected from reference sites (Gagnon and Rawson 2012, 2011).

The NWS supports a diverse assemblage of fish particularly in shallower water near the mainland and islands. Threatened species identified by the PMST include the white shark, whale shark, grey nurse shark, sawfishes (freshwater, dwarf, green, narrow and large-tooth), giant manta ray and reef manta ray, mako sharks, blind gudgeons and cave eel, porbeagle, Balston's pygmy perch, Northern river shark and oceanic white tip sharks which may be present in the EMBA. Given the absence of critical habitat for most of these species, significant numbers are not expected to be exposed to hydrocarbons in the event of a spill. These threatened and migratory fish and sharks could be present at low densities all year round within the EMBA; however, the absence of any known feeding, resting or breeding areas means significant numbers are unlikely to be impacted if an unplanned release were to occur.

Stochastic modelling results indicate that hydrocarbons are likely to be concentrated in surface waters. As a result, demersal fish are unlikely to be directly affected unless located near to a subsea release, as these are likely to be associated with seabed features (e.g. reefs, shoals, banks and KEFs). Pelagic fish are more likely to encounter dissolved and entrained hydrocarbons above adverse exposure thresholds but may move away from affected areas, particularly larger pelagic fishes such as mackerel.

Most marine fish species produce very high numbers of eggs, which then undergo a planktonic larval development phase. Early life history stages of fish (planktonic eggs and larvae) may be more vulnerable to hydrocarbon pollution than juvenile and adults, as these early life history phases cannot actively avoid water with high concentrations of hydrocarbons. Fish embryos and larvae may exhibit genetic and developmental abnormalities from long-term exposure to low concentrations of hydrocarbons (Fodrie and Heck 2011), although such long exposures may not be representative of real world conditions. PAHs have also been linked to increased mortality and stunted growth rates of early life history (pre settlement) of reef fishes, as well as behavioural impacts that may increase predation of post-settlement larvae (Johansen et al. 2017).

Given the temporal and spatial scale of the worst-case credible spill scenarios (as shown by a single deterministic run), and the typically high supply of eggs and larvae, it is unlikely that any of the worst-case credible spill scenarios will result in significantly reduced recruitment of fish due to impacts during early life history phases. This conclusion is supported by studies of fish stocks following large-scale hydrocarbon spills, which have shown relatively little evidence of reduced recruitment at the scale of fish stocks/populations (Fodrie and Heck 2011).

Transitory and resident sharks may occur within the moderate exposure threshold EMBA identified by the stochastic spill modelling. Whale sharks are expected to occur within the Project Area (e.g. traversing the Project Area during migration to and from the main aggregation location off Ningaloo Reef) and a BIA for foraging whale sharks overlaps with the Project Area. Whale sharks may be exposed to entrained and dissolved hydrocarbons by contact with their gills and ingestion during feeding, damaging their gilds and tissues and organs. The large volume filter feeding behaviour of whale sharks may result in a relatively high potential for exposure to entrained hydrocarbons compared to many other marine species (Campagna et al. 2011).

Tagging studies off Ningaloo Reef have shown that whale sharks disperse broadly (Meekan and Radford 2010; Wilson et al. 2006). Genetic studies of whale sharks have shown low genetic diversity, which suggests flow of genetic material through the movement of individual sharks over large spatial scales (Schmidt et al. 2009). On this basis, only a portion of the whale shark population would be within the moderate EMBA at any one time and impacts such as toxic effects leading to mortality would be expected to affect a small number of individual animals.

A number of threatened species of demersal sawfish were identified as potentially occurring within the Project Area and the EMBA. Impacts to these species within the Project Area are unlikely to occur as a result of an oil spill, as the oil will be concentrated in surface waters. Entrained or dissolved hydrocarbons that encroach into relatively shallow coastal waters may expose sawfish in coastal areas to hydrocarbon, potentially resulting in toxic effects which may lead to mortality. Hydrocarbons are not expected to penetrate upstream into river systems that are important pupping and juvenile habitats for these species. Any impacts from an oil spill would be restricted to adults in coastal waters. Given the wide distribution of these species, this is not expected to result in population-scale impacts.

Other oceanic (e.g. mako) and resident (e.g. reef) sharks will occur throughout the moderate exposure threshold EMBA. Potential impacts to other oceanic shark species are likely to be similar to pelagic fish. Any reduction of shark numbers may take longer to recover due to the relatively long lifespans and low reproductive output compared to finfish species.

7.3.1.6.4 Protected Areas

Australian Marine Parks, State Marine Parks, Management Areas and Reserves

The operational areas do not intercept any Australian or State Marine Parks, Management Areas or Reserves. The closest AMP is the Eighty Mile Beach AMP, with predicted contact of accumulated hydrocarbons from well LOWC. These areas are further identified and detailed in **Section 3.4.2**

The EMBA at the moderate exposure value overlaps several AMPs and state marine parks, management areas and reserves, with key protected areas including Eighty Mile Beach AMP, Imperieuse Reef MP, Clerke Reef MP, Montebello Islands, Lowendal Islands and Barrow Island. Marine protected areas (including marine parks and heritage listed places) may be vulnerable to hydrocarbon exposures from an oil spill. As the values and sensitivities of these protected places are a combination of quality, habitat, marine fauna and flora, and human use, the impact pathways are varied. Refer also to impact assessments for related receptors, including water quality, sediment quality, coastal and benthic habitats and communities and marine fauna.

Wetlands of International Importance – Ramsar Wetlands

Spill modelling identified Ramsar sites as potentially being impacted by spilled hydrocarbons (**Section 3)**, based on modelling results from the future tieback scenarios described in **Section 7.3.1.1.4.** Migratory bird species associated with Ramsar sites are most vulnerable to nearshore floating oil and oil accumulations along the shoreline. One particular RAMSAR location of high sensitivity and value is Eighty Mile Beach, displaying high predicted volumes of shoreline oil (2, 303 tonnes). Eighty Mile Beach RAMSAR wetlands provides habitat for 97 wetland bird species, 42 of which are listed under CAMBA, JAMBA and ROKAMBA. Up to 500, 000 birds use the area as a migration terminal annually, making it one of the most valuable bird rookeries globally. Broome-Roebuck is another RAMSAR wetland of significance with predicted shoreline accumulation (180 tonnes), with intertidal mudflats of the northern and eastern shores of Roebuck Bay supporting very large numbers of migratory shorebirds. Impacts to these RAMSAR wetlands include behavioural impacts, whereby birds avoid important nesting and migratory stop-over areas and reduced food availability if important foraging areas are impacted.

Potential impacts of spilled hydrocarbons on migratory shorebirds are discussed in **Section 7.3.1.2.9**.

7.3.1.6.5 Socio Economic

World Heritage Areas

The Ningaloo Coast WHA and National Heritage Area was identified by stochastic modelling as potentially being exposed to entrained, dissolved and accumulated hydrocarbons from worst-case subsea and surface loss of well containment scenarios. Stochastic modelling of the subsea loss of well containment scenario indicated the Ningaloo World and National Heritage Areas had a less than 50% probability of being contacted above the moderate entrained exposure threshold, with the shortest time to contact of 15 days and a maximum concentration of approximately 2,000 ppb.

The heritage values of these reefs are primarily their outstanding natural values, including habitats and fauna. These values are described in **Section 3**. Refer to **Section 7.3.1.2.4** for a discussion of potential impacts to these natural values.

Probability of oil contact as far south as Shark Bay WHA was predicted to be less than Ningaloo WHA and ranged from 5-29% for entrained oil and 1-6% for dissolved oil over all seasons. There was a low probability of contact of shoreline oiling predicted in Shark Bay WHA at the moderate exposure threshold (7.3%). On the basis of the nature and scale of the contact predicted by the modelling, impacts to the environmental values of the Shark Bay WHA are unlikely to occur given the low probability of contact above moderate exposure thresholds.

National Heritage

The environmental values and sensitivities of the Ningaloo Coast and Shark Bay National Heritage Areas are aligned with those of the WHAs discussed above. Refer to **Section 7.3.1.2.11** for a discussion of the potential impacts to these areas.

Stochastic modelling results indicated that the shorelines of the Dampier Archipelago and the West Kimberley National Heritage Places may be impacted by floating, accumulated, entrained and dissolved hydrocarbons above moderate exposure thresholds. These heritage places contain a range of shoreline types, including rocky shores, sandy beaches and mangroves. Many of the heritage values of the Dampier Archipelago and the West Kimberley National Heritage Place lie above the shoreline and will not be impacted by a hydrocarbon spill.

Commonwealth Heritage

Several offshore islands and reefs listed as Commonwealth Heritage Places were identified by the spill modelling results as potentially being contacted by hydrocarbons. These include:

+ Ashmore Reef National Nature Reserve Commonwealth Heritage Place;
+ Scott Reef and Surrounds Commonwealth Heritage Place;
+ Mermaid Reef – Rowley Shoals Commonwealth Heritage Place;
+ Christmas Island Natural Areas - Commonwealth Heritage Place; and
+ Ningaloo Marine Area – Commonwealth Heritage Place.

The heritage values of these reefs are primarily their outstanding natural values, including habitats and fauna. These values are described in **Section 3**. Refer to **Section 7.3.1.2.4** for a discussion of potential impacts to these natural values.

Indigenous Heritage

Hydrocarbon accumulation above the moderate exposure threshold may occur along the Pilbara and Kimberley coastlines, which could result in potential impacts to Aboriginal heritage sites. A search of the Department of Planning, Lands and Heritage's Aboriginal Heritage Inquiry System was undertaken to identify registered Aboriginal sites (Registered Sites) as outlined under Section 5 of the *Aboriginal Heritage Act 1972*. A total of 194 Registered Sites were identified to intersect the predicted areas of shoreline accumulation. Identified Registered Sites have been designated for a number of aspects including (but not limited to) artefact scatters, ceremonial, mythological, campsites, water sources, engravings and burial. In addition to Registered Sites, there are a number of other Heritage Places along the Northwest coastline of Western Australia which may also be impacted from a surface release of HFO.

The majority of the Registered Sites are located to the east of the Project Area along the coastline of Broome (both to the north and south). The deterministic model run with the greatest length of shoreline above the moderate accumulation threshold indicated up to 154 km of shore could be subject to accumulation more than 100 g/m^2. Modelling predicted the maximum length of shoreline contact was expected to be 154 km (summer conditions) for a worst-case loss of containment due to a vessel collision. Oil accumulation above the moderate exposure threshold may interfere with traditional uses of the coastal environment, such as fishing.

Fisheries

The worst-case credible hydrocarbon spill scenarios may result in a range of impacts to commercial fishing activities (International Tanker Owners Pollution Federation 2011c), such as:

+ displacement of fishing effort from areas affected by a spill or spill response activities;
+ damage to fish stocks due to mortality;
+ closure of fisheries by management agencies;
+ inability to sell catch due to perceived or actual fish tainting or contamination; and
+ oiling of fishing gear, particularly by floating oil.

A significant hydrocarbon spill would likely result in the temporary closure of areas of the fisheries within the EMBA. The spatial extent and duration of the closure would depend on the nature and scale of the pollution resulting from the hydrocarbon spill. Given the large spatial extent of managed fisheries in the area potentially contacted above moderate exposure thresholds, a spill is unlikely to result in complete closure of a fishery. Rather, the closure of areas to fishing is more likely to result in the displacement of fishing effort. Displacement from productive fishing areas may result in impacts to fishers such as increased costs and reduced catch per unit effort. The fisheries most likely to be affected by a worst-case hydrocarbon spill are those active within and around the Project Area, including:

+ Pilbara Fish Trawl (Interim) Managed Fishery;
+ Pilbara Line Fishery;
+ Pilbara Trap Managed Fishery; and
+ Mackerel Managed Fishery (Area 2 - Pilbara).

Exposure of fish to hydrocarbons may result in tainting, which may render landings unsuitable for human consumption. Tainting may occur even at low levels of hydrocarbon exposure. Monitoring of fish for taint immediately following capping of the Montara well detected differences between fish likely to have been exposed to hydrocarbons; however, these differences were not conclusively linked to oil contamination and fell within the range of "normal" fish odours (Rawson et al. 2011). Samples collected at the same monitoring locations two and four months after were not distinguishable (Rawson et al. 2011). These results are consistent with other studies of fisheries resources exposed to hydrocarbon pollution, which acknowledge the potential for impacts to fisheries resources and have shown little potential risk for consumers if suitable fisheries management actions are undertaken (Law and Hellou 1999; Law and Kelly 2004).

The actual effects of hydrocarbons on marine fisheries yield or other ecological processes are not well known. There are multiple studies on toxicological effects of exposure to hydrocarbons for fish, including lethal and sublethal effects from laboratory, modelling and field studies (e.g. Bax 1987; Marty et al. 1997), which indicate there is a potential for long-term changes in development, reproduction and growth. The Deepwater Horizon oil spill in April 2010 resulted in fisheries closures across the Gulf of Mexico (Mccrea-Strub et al. 2011). Because of concerns over food safety, in May 2010 NOAA initiated closures of waters to commercial and recreational fishing. By January 2011, 10,911 km^2 of waters around the well and coastal waters remained closed to commercial and recreational fishing (Gohlke et al. 2011). Federal agencies, in collaboration with impacted Gulf states, developed a protocol to determine when it is safe to reopen fisheries based on sensory and chemical analyses of seafood. In April 2011, NOAA reopened all remaining waters (Gohlke et al. 2011). Continued analysis of Gulf seafood was recommended to determine potential long-term health impacts and restore consumer confidence in Gulf fisheries (Oil Spill Commission 2011). The Deepwater Horizon incident may differ from other spills because of the depth at which the LOWC occurred, and the unprecedented volume of dispersants used (Gohlke et al. 2011).

Fish caught in areas affected by a worst-case hydrocarbon spill may be perceived as being of poorer quality, even if no decrease in quality is evident. This may result in lower prices at the time of sale and subsequently lead to reduced income for commercial fishers.

Tourism

There are currently no known tourism activities in the Project Area due to the remoteness of the area. A number of tourism destinations occur within the EMBA, including Ningaloo Reef (which is within a World Heritage Area, National Heritage Place and a Commonwealth Heritage Place) and offshore islands such as the Montebello Islands, Rowley Shoals and the Abrolhos Islands. A number of areas with high diversity or which have unique ecological values are protected within AMPs. These activities are expected to be exclusively nature-based tourism and potential impacts to the environmental values associated with these islands and reefs may subsequently impact upon tourism activities.

Mainland coastline and islands will typically host more nature-based tourist activities compared to offshore islands. This activity is expected to be seasonal, with increased visitation during the winter dry season months.

As well as reducing the visual amenity of these areas, a spill could impact the habitats and marine fauna of these areas thereby impacting the environmental values of these tourism areas. Depending upon the extent of impact, loss of revenue to coastal towns and communities could also occur.

Impacts to tourism activities are expected to be minor based on the likelihood and nature of contact to environmental values that support tourism activities. Impacts to these values may result in displacement of tourism activity, and potentially minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures). A large-scale oil spill is expected to attract national or international media attention. Reporting on the oil spill may lead to a perceived decrease in the environmental value of the region, which may subsequently impact upon tourism visitation numbers.

Maritime Industry

Potential impacts to ports and commercial shipping from the worst-case credible spill scenarios may result in temporary displacement of other users from areas where oil is present or from spill response activities are underway. Spill response activities would be concentrated around the release location and spill clean up activities concentrated on shoreline areas where oil had accumulated which may require access by sea.

A surface slick has the potential to disrupt production or exploration activity with associated economic impact. Exclusion zones surrounding spills will reduce access potentially resulting in delays to work schedules with possible subsequent financial implications.

7.3.1.7 Summary of Risk Evaluation

A summary of the outcomes of the risk evaluation, including, likelihood, consequence rankings, adopted control measures and EPOs is provided in **Table 7-85.** Given that the scenarios impact assessed are the worst case scenarios as described in **Section 7.3.1.3**, only these have been risk ranked.

Table 7-85: Summary of impacts, EPOs, controls and consequence evaluation for accidental spills of hydrocarbons and chemicals during Dorado Phase 1

EPOs
EPO20A Undertake Dorado Phase 1 in a manner that will prevent unplanned discharge of chemicals or hydrocarbons to the marine environment. **EPO21A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of reservoir fluids to the marine environment due to a LOWC, or failure of a flowline or FPSO cargo tank. **EPO22A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of MDO/MGO or HFO to the marine environment due to vessel collision, failure of a storage tank or release during refuelling. **EPO23A** In an event of an unplanned release of chemicals or hydrocarbons, spill response control measures will be implemented in accordance with an accepted EP/OPEP.
Control Measures (CM)
CM9 Santos Chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements. **CM52**: Accepted well operations management plans in place for all wells detailing: + blowout preventer installation and testing, + competency of the drillers engaged, + monitoring of wellbore progress and drilling fluid balance, and + well designs that consider reservoir characteristics. **CM53**: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the *Navigation Act 2012* and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM54**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM55**: All project vessels subject to Santos' marine assurance procedures. **CM56**: All offtake tankers subject to Santos' tanker vetting procedures. **CM57**: Bunkering procedures to manage the transfers of fuel that include: + weather limits on bunkering operations, + bunkering equipment specifications and inspections, + visual observations during transfers, and + emergency shutdowns.

CM58: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM59**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM60**: Should potential future tiebacks overlap within AMSA fairways Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way **CM61**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM62**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development. **CM63**: FPSO will be designed, constructed and operated to Santos' specified requirements, including: + double-hulled construction, + cyclone and adverse weather avoidance procedures, and + structural integrity inspection regime. **CM64:** Oil-spill modelling and environmental risk assessments for development of Dorado Phase 1 EPs and OPEPs will consider the full range of credible worst-case scenario LOWC consequences based on best available oil-spill modelling **CM65:** During Development Well drilling and drilling of tieback wells, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. **CM66:** Accepted EP/OPEP in place for all Dorado Development activities. **CM67**: All vessels involved in the project will have a valid Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan (as appropriate for vessel classification). **CM68**: Source control emergency response plans in place for all drilling activities. **CM69:** Emergency response capability (including equipment, personnel contracts, MOUs) will be maintained in accordance with approved SOPEPS accepted EPs and OPEPs.

Accidental release of Caley crude from a worst-case subsea or surface loss of well containment (Dorado development (Sections 7.3.1.1.3) including the future tieback drilling (Section 7.3.1.1.4))	
Likelihood	Unlikely – B The likelihood of a LOWC event occurring during Dorado Phase 1 is extremely low when applying industry statistics, Santos statistics and the standard preventive control measures in place. Wells are designed with essential engineering and safety control measures to prevent a loss of containment occurring. Blowout events during wildcat exploration drilling has been reported at a frequency of 1.5 x 10^{-4} per drilled well (IOGP, 2019; wildcat exploration drilling operations on deep, normal wells of North Sea standard). This frequency is based on two blowout incidents occurring in the UK between 1980 and 2014 during wildcat exploration drilling (IOGP, 2019) and supports the likelihood of 'has occurred elsewhere OR could occur within decades'. Although likelihood generally reduces for development drilling, a major loss of well control event has occurred as recently as 2009 offshore Australia (Montara). Wells are designed with essential engineering and safety control measures to prevent a loss of containment occurring. Management controls in place to control the flow of hydrocarbons include construction design, safety shutdown systems, regular inspection and maintenance, and competent personnel. Additional industry-standard and activity specific control measures

	to reduce the chance of a loss of containment event resulting in a release have also been implemented including (but not limited to) procedures such as the well operations management plan, safety case, crew training and awareness, and a spill response plan (OPEP) to be produced along with the environment plan (EP). These control measures are considered to reduce the risk of a loss of containment (and minimise impacts) occurring to a level that is acceptable.
Consequence	Major – IV Major long-term effect on local population, industry, or ecosystem factors.
	The detailed consequence assessment for each hot spot is provided in **Attachment 8-2**. A summary of the consequence assessment for each receptor category is presented below. *Physical environment or habitat* In the highly unlikely event of a LOWC subsea or surface, hydrocarbons will likely reach both subsea and shoreline habitats. Hydrocarbons that reach nearshore environments also have the potential to impact benthic coral reefs and mangrove areas, which may result in a long-term decrease in ecological values given toxicity impacts associated with hydrocarbon exposure. The worst case consequence assessment for physical environment at any identified hotspot was IV – Major at Imperieuse Reef MP, Clerke Reef MP and Montebello Islands. *Threatened or migratory fauna* In the highly unlikely event of a LOWC, the volume of condensate released would result in a reduction in water quality with the potential to impact marine fauna. Marine fauna present in the area may be potentially impacted by a spill through exposure to floating oil, entrained oil, or dissolved aromatic hydrocarbons. A description of impacts to marine fauna from exposure to condensate is provided in **Table 7-75** and **section 7.3.1.6.3** Impacts from a LOWC release would be greatest within several kilometres from the spill when the toxic aromatic components of the fuel will be at their highest concentration and when the hydrocarbon is at its thickest on the surface of the receiving waters. Upon release to the marine environment, the condensate will rapidly lose toxicity with time and will spread thinner at the surface as evaporation continues or will become entrained within the water column. The potential sensitive receptors in the surrounding areas of the spill will include fish, marine mammals, marine reptiles and seabirds at the sea surface, as discussed in **Table 7-75** and **section 7.3.1.6.3.** The worst case consequence assessment for threatened or migratory fauna at any identified hotspot was IV – Major at Eighty Mile Beach AMP, Imperieuse Reef MP, Clerke Reef MP, Montebello Islands, Lowendal Islands and Barrow Island. *Protected areas* The moderate exposure value EMBA intersects several protected areas including RAMSAR wetlands, AMPs and marine management areas (**Section 7.3.1.6.4**). Combined, these areas support all the habitats and faunal groups described above. Impacts to the habitat or fauna receptors described above therefore have an impact on the values of these reserves, which could have flow-on effects to tourism revenue of coastal communities that provide

	access to these marine reserves. Many of these receptors are values of protected areas, and there could be moderate-term effects to them. The worst case consequence assessment for protected areas at any identified hotspot was IV – Major at Eighty Mile Beach AMP, Imperieuse Reef MP, Clerke Reef MP, Montebello Islands, Lowendal Islands and Barrow Island. *Socio-economic receptors* There is the potential for entrained oil to temporarily disrupt fishing activities if the surface or entrained oil moves through fishing areas. Entrained oil at more than 100 ppb could reach pearl farming activities at the Montebello Islands and Eighty Mile Beach. Pearl oysters are filter feeders therefore, entrained oil droplets could create negative impacts through ingestion and accumulation of hydrocarbon compounds in oyster tissues or interference with respiratory structures. Ecotox (2009) reported that no observable effect concentration levels from weathered condensates for a comparable oyster species ranged from approximately 9,000 to 28,000 mg/l. Significant impacts on aquaculture would therefore be unlikely, as predictive modelling reported that the maximum time-averaged submerged total concentration for the worst realisation at the Montebello Islands was 3, 577 ppb and 5, 322 ppb at Eighty Mile Beach (AMP). Some loss of value to the local industry could occur in the event of a LOWC In addition, recreational fishing hot spots including the Montebello Islands, Barrow Island, Lowendal Islands, Muiron Islands and Ningaloo are of high value to recreational fishers. Tourism could be affected by spilled condensate, either from reduced water quality or shoreline oiling preventing recreational activities, reducing aesthetic appeal or from impacts to habitats and marine fauna as described in **Section 7.3.1.6.5**. Indigenous users may be impacted in the event that a land-based response is required. However, consultation will help manage activities such that potential impacts are reduced to acceptable levels. A number of oil and gas operators operate within the moderate EMBA. The worst case consequence assessment for socio-economic receptors at any identified hotspot was IV – Major at Eighty Mile Beach AMP, Imperieuse Reef MP, Clerke Reef MP and Montebello Islands. On the basis of the above assessment, a LOWC has the potential to impact an array of receptors. Given the extent and the presence of protected areas within the moderate exposure value EMBA , the worst-case consequence is considered to be Major (IV).
Residual Risk	Low
Accidental release of HFO crude from a worst-case loss of containment due to a vessel collision (Spill Scenario 5)	
Likelihood	Unlikely – B The likelihood of a rupture of the largest fuel tank of an offshore installation vessel is extremely low. Industry data shows that vessel collisions are rare, with only 37 collisions reported from 1200 marine incidents in Australian waters from 2005-2012.

	Most vessel collisions involve damage to a forward tank which are generally double-lined and smaller than other tanks; therefore, the loss of the maximum credible scenario of 1,500 m^3 of HFO is conservative and unlikely. Further given the speed at which the vessels will be undertaking activities within the Project Area it is unlikely that the larger internal fuel tanks would be breached due to a collision. Controls in place including exclusion zones for third party vessels will reduce the likelihood of this event occurring.
Consequence	Moderate – III Significant impact to local population, industry or ecosystem factors.
Residual Risk	Low
Accidental release of Caley crude from a worst-case loss of containment of FPSO cargo tank (Spill Scenario 6)	
Likelihood	Unlikely – B Significant impact to local population, industry or ecosystem factors. External impacts to the FPSO have not occurred within Santos, controls in place limiting third party vessels within a 500m radius of the DTM buoy and FPSO, standard navigational controls, double hulled FPSO reduce the likelihood of the event occurring to unlikely.
Consequence	Moderate – III
Residual Risk	Low

7.3.1.8 Demonstration of Acceptability

The acceptable levels of impact for the receptors that may credibly be impacted by accidental hydrocarbon and chemical spills as a result of Dorado Phase 1 against receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-86** and **Table 7-87.** The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case residual risk for accidental hydrocarbon and chemical spills was evaluated as low (**Table 7-85**). This consequence is considered to be acceptable when assessed against acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental risks that may result from accidental hydrocarbon and chemical releases are acceptable.

Table 7-86: Demonstration of acceptability for accidental hydrocarbon and chemical spills

Acceptability Criteria	Justification
To meet the principles of ESD	The risks and impacts from the worst-case credible spill scenarios are inherently inconsistent with some of the principles of ESD based on the following: + environmental resources may be significantly impacted in the event a worst-case credible spill occurs, and + a worst-case credible spill may prevent others exercising their right to access environmental resources.

Acceptability Criteria	Justification
	Santos will apply a range of controls to ensure that a worst-case credible spill from Dorado Phase 1 is highly unlikely to occur. These include a range of industry practices that have been developed through extensive experience, including the lessons learned from significant unplanned releases such as the Macondo and Montara well blowouts. Following successful application of these controls, Santos considers the residual risk to be consistent with the principles of ESD. This consistency is achieved by: + developing natural resources in an environmentally responsible manner, resulting in income for government, generation of Australian jobs, and developing an increased understanding of the environment (e.g. environmental surveys undertaken by Santos in the Project Area). + application of conservative inputs/assumptions and scalable response strategies to compensate for inherent uncertainties in managing oil spill risk by: + assessing the full range of worst-case credible spill scenarios (and combining where appropriate) for development activities to ensure the EMBA is sufficiently conservative for oil spill impact assessment and planning purposes. Industry statistics indicate the vast majority of unplanned spills are significantly smaller than the worst-case credible spills. + using conservative assumptions, based on field specific data where possible, to inform potential loss of well control volume + using qualified and competent oil-spill modelling providers and widely used and accepted oil-spill modelling tools + using a stochastic modelling approach for numerical modelling of the worst-case credible spill scenarios that includes a large number (300 for Dorado project, 150 for future tieback wells) of replicate runs covering a range of seasonal and metocean conditions, using environmentally conservative adverse exposure zone threshold to set a conservative EMBA to assess impact and inform response planning, + routine practices for further reducing uncertainty during the operational response phase (in the event of an actual incident) through implementation of monitor and evaluation response strategy actions such as oil spill trajectory modelling informed by real time met ocean data, and + robust oil response planning capability and capacity, with the ability to leverage significant external spill response support (personnel, equipment, expertise) to ensure scalability of Santos' response regardless of potential differences between oil spill modelling predictions and actual spill outcomes and consequences
Internal Context	The management of the risk of accidental hydrocarbon and chemical releases is aligned with Santos' policies and standards. The worst-case risk is low, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	The impact assessment, consequence levels and proposed controls for the Dorado Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Dorado Development will

Acceptability Criteria	Justification
	also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advice. The following Conservation Advice/Recovery Plans identify pollution and / or habitat degradation as a key threat which may be a consequence of accidental release of hydrocarbons: <u>Conservation advice:</u> Approved conservation advice for *Glyphis garracki* (northern river shark) (Threatened Species Scientific Committee 2014a). Approved Conservation Advice for *Pristis clavate* (Dwarf Sawfish) (Threatened Species Scientific Committee 2009) Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (Threatened Species Scientific Committee 2014b). Approved conservation advice for Green Sawfish (Threatened Species Scientific Committee 2008a) Conservation advice *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) Conservation Advice *Anous tenuirostris melanops* Australian lesser noddy (Threatened Species Scientific Committee 2015e) Conservation Advice Red Knot (*Calidris canutus*) (Threatened Species Scientific Committee 2016f) Conservation Advice Curlew Sandpiper (*Calidris ferruginea*) (Threatened Species Scientific Committee 2015f) Conservation Advice Great Knot (*Calidris tenuirostris*) (Threatened Species Scientific Committee 2016a) Approved Conservation Advice for Cereopsis novaehollandiae grisea (Cape Barren Goose (south-western)) (DEWHA 2008c) Conservation Advice Greater Sand Plover (*Charadrius leschenaultii*) (Threatened Species Scientific Committee 2016b) Conservation Advice Lesser Sand Plover (*Charadrius mongolus*) (Threatened Species Scientific Committee 2016c) Conservation Advice for the Christmas Island Frigatebird – *Fregata andrewsi* (Threatened Species Scientific Committee 2020a) Conservation Advice *Halobaena caerulea* blue petrel (Threatened Species Scientific Committee 2015g) Conservation Advice *Limosa lapponica baueri* (Bar-tailed Godwit (Western Alaskan)) (DoE 2016) Conservation Advice *Limosa lapponica menzbieri* Bar-tailed godwit (northern Siberian) (DoE 2016) Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015) Conservation Advice Fairy Prion (Threatened Species Scientific Committee 2015h) Conservation Advice *Phaethon lepturus fulvus* white-tailed tropicbird (Threatened Species Scientific Committee 2014c)) Conservation Advice *Pterodroma Mollis* soft-plumaged petrel (Threatened Species Scientific Committee 2015i)

Acceptability Criteria	Justification
	Approved Conservation Advice Australian Painted Snipe (Rostratula australis) (Threatened Species Scientific Committee 2013) Conservation Advice for *Sterna nereis nereis* (Fairy Tern) (Threatened Species Scientific Committee 2011) Approved Conservation Advice for *Aipysurus apraefrontalis* (Shortnosed Seasnake) (Threatened Species Scientific Committee 2010a) Approved conservation advice for *Aipysurus foliosquama* (leaf-scaled sea snake) (Threatened Species Scientific Committee 2010b) Conservation advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b) Conservation advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee 2015c) Approved Conservation Advice for Pezoporus wallicus flaviventris (Western Ground Parrot) (DSEWPC, 2013e) <u>Recovery plans:</u> Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPC, 2013b) Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Department of the Environment 2014) Wildlife Conservation Plan for Seabirds (DCCEEW 2022) Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australian 2015c) National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011) Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a), identified as acute chemical discharge (oil pollution)Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a) Conservation Management Plan for the Southern Right Whale. A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2011-2021 (DSEWPC 2012c) Recovery plan for the Australian sea lion (*Neophoca cinerea*) (DSEWPaC 2013a) The objectives of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The controls outlined are consistent with the objectives of the material listed above. Santos considers the impacts of hydrocarbon and chemical spills to not be inconsistent with the EPBC management plans. The Dorado Development will be managed in a manner that is consistent with management objectives and actions for all relevant WHA's, AMPs and RAMSAR wetlands further described in Section 3.4.2.
Other Relevant Requirements	Santos' management of the risk of accidental hydrocarbon and chemical releases is consistent with: + international maritime conventions, including: - International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978,

Acceptability Criteria	Justification
	- International Convention for the Safety of Life at Sea 1974, - International Regulations for Preventing Collisions at Sea 1972, and - MARPOL 73/78: Annex I: prevention of pollution by oil and oily water. + Australian legislation and requirements, including: - *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*: ○ Marine Order 21 (Safety and emergency arrangements), ○ Marine Order 27 (Safety of navigation and radio equipment), ○ Marine Order 30 (Prevention of Collisions), ○ Marine Order 71 (Masters and Deck Officers), and ○ Marine Order 91 (Marine pollution prevention – oil). - *OPGGS* (E) Regulations: ○ an accepted OPP for Dorado Phase 1, ○ accepted well operations management plans for all well activities, including drilling, operation, suspension and abandonment, and ○ accepted EPs and OPEPs for all petroleum activities associated with Dorado Phase 1. + recognised industry best practices, such as: - use of blowout preventers while drilling over-pressured formations with potential for flow, including regular function and pressure testing of the blowout preventers, and - design, construction and operation of wells, WHP and FPSO in accordance with recognised industry standards. - Using a Jack-up MODU rather than a semi-submersible MODU for developing the Dorado field with a wellhead platform and surface wellheads. Santos have a long history of successfully and safely operating jack-up MODU in Australia, including extensive experience constructing and managing platform well operations. For a semi submersible MODU to be viable, the platform would have to be many times larger than proposed to accommodate the additional equipment and dynamic loads. Direct intervention source control for wells drilled with a jack-up MODU is common (access by Well Control Specialists to target well via the platform or jack-up MODU); however, constructing the wells this way precludes the use of a subsea Capping Stack (as the well is not being constructed in open water, with wellhead/BOP equipment close to the seabed). As direct access cannot be guaranteed for a source control response, the primary source control strategy that is premised to be captured in the Development Drilling Environment Plan (EP) and Well Operations Management Plan (WOMP) is a relief well. This is the case for many existing assets, and the same for other currently accepted EPs and WOMPs. - Operations performed under various Environment Plans on the Dorado field will be assessed against commitments made in the Environment Plan prior to Operations commencing. Should any simultaneous spill risk profiles exceed the Worst-Case Credible volume, these activities will not run concurrently.

Acceptability Criteria	Justification
	This will be managed within the Matrix of Permitted Operations documented in the safety case or safety case revision.

Table 7-87: Demonstration of acceptability of accidental hydrocarbon and chemical releases against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Justification
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[44] are acceptable.	Santos considers large-scale releases of hydrocarbons during Dorado Phase 1 to be unacceptable. Such spills have potential to result in extensive, long-term environmental impacts. Santos applies a level of conservatism in all aspects of oil spill impact assessment, planning and response preparedness, to ensure the management of uncertainty associated with oil spill risk is consistent with the principles of ESD, specifically, *if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.* Examples of how this is applied in practice include the following: + assessing the full range of worst-case credible spill scenarios (and combining where appropriate) for development activities to ensure the EMBA is sufficiently conservative for oil spill impact assessment and planning purposes. Industry statistics indicate the vast majority of unplanned spills are significantly smaller than the worst-case credible spills. + Using conservative assumptions, based on field specific data where possible, to
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity[36] are acceptable.	
RSAL7: No substantial changes in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health as a result of Dorado Phase 1.	
RSAL8: No significant[45] impacts to benthic habitats and communities.	
RSAL10: No impacts to coastal habitats.	
RSAL11: No significant[47] impacts to environmental values of KEFs.	
RSAL12: No impacts to TECs.	
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of the Dorado Development must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	
RSAL17: No impacts to ecological values of Ramsar wetlands. **RSAL18**: No impacts to the values of marine parks.	

[44] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[45] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

Receptor-specific Acceptable Levels	Justification
RSAL19: No negative impacts to the economic viability of the commercial fish resources. **RSAL22**: No significant[46] impacts to World Heritage Properties, National Heritage Places, Commonwealth Heritage. Places or registered Aboriginal Heritage Sites. **RSAL23**: No impacts to nature-based tourism resources resulting in demonstrated loss of income. **RSAL24**: Short-term displacement of tourism activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL25**: Long-term (up to 20 years) exclusion of tourism activities from the gazetted PSZ during production operations is acceptable. **RSAL26**: Short-term displacement of commercial shipping within the Project Area (excluding the gazetted PSZ) during installation/drilling operations is acceptable. **RSAL28**: Short-term displacement of defence activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL29**: Long-term (up to 20 years) exclusion of defence activities from the gazetted PSZ during production operations is acceptable.	inform potential loss of well control volume + Using qualified and competent oil-spill modelling providers and widely used and accepted oil-spill modelling tools + using a stochastic modelling approach for numerical modelling of the worst-case credible spill scenarios that includes a large number (300 for Dorado project, 150 for future tieback wells) of replicate runs covering a range of seasonal and metocean conditions, using environmentally conservative adverse exposure zone threshold to set a conservative EMBA to assess impact and inform response planning, + routine practices for further reducing uncertainty during the operational response phase (in the event of an actual incident) through implementation of monitor and evaluation response strategy actions such as oil spill trajectory modelling informed by real time met ocean data, and + robust oil response planning capability and capacity, with the ability to leverage significant external spill response support (personnel, equipment, expertise), to ensure scalability of Santos' response regardless of potential differences between oil spill modelling predictions and actual spill outcomes and consequences. On the basis of the points above, while the event itself is not considered acceptable, Santos considers the likelihood of large hydrocarbon releases and the reduction in impacts should one occur from Dorado Phase 1 to be acceptable.

[46] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

7.3.2 Accidental Release – Loss of Solid Material

7.3.2.1 Description of the Event

The accidental release of solid materials, such as equipment or wastes may occur during any stage of Dorado Phase 1. Accidental release of solid materials may occur from vessels, MODU, FPSO and Dorado WHP resulting from human error, incorrect or inappropriate waste storage, mechanical failure or breakdown of equipment used to store wastes, inadequate hazardous waste management or dropped objects.

Material and waste onboard vessels, MODUs or FPSO may be hazardous or non-hazardous. Hazardous wastes are defined as an object or substance that displays toxic, explosive, poisonous or flammable characteristics, which can no longer fulfil its intended use and requires disposal. Hazardous waste that may be accidentally lost to the marine environment includes batteries, aerosol cans, empty paint cans, printer cartridges, fluorescent tubes, hydrocarbon-contaminated materials (e.g. pipe dope, oily rags, oil filters), contaminated personal protective equipment and hazardous process waste. Non-hazardous wastes are those which are not classified as hazardous (as per the characteristics described above) but which, if released into the marine environment, may pose a threat to receptors through smothering, entanglement or ingestion. Non-hazardous materials and wastes will be disposed of onshore, however they could be accidentally dropped or lost overboard due to overfull bins or crane operator error. Non-hazardous materials and wastes include paper and cardboard, wooden pallets, scrap steel, metal, aluminium, cans, etc, glass and plastics

While Santos will implement controls to prevent the unintended release of solid material to the marine environment, such releases may occur during unloading and backloading of solid materials to support vessels, lifting activities (potentially resulting in dropped objects such as drill string), failing to keep external bins covered or from inappropriate handling of solid material. Industry experience shows most solid material accidentally lost overboard are generally small in size, such as personal protective equipment (e.g. gloves and hard hats), paper and cardboard packaging, and hand-held tools.

Heavy objects could potentially be dropped on infrastructure containing hydrocarbons (e.g. topside processing equipment and subsea risers or flowlines) possibly resulting in the release of hydrocarbons (although unlikely to occur). Accidental hydrocarbon spills are assessed in **Section 7.3.1**.

7.3.2.2 Analysis of Impacts and Risks

A summary of the analysis of the environmental impact of loss of solid material as a result of Dorado Phase 1 is provided in this section. **Table 7-88** identifies the potentially impacted receptors as a result of the discharge of PW within the Project Area.

Table 7-88: Receptors potentially impacted by the loss of material

Description of the Impact	Receptor Categories
Modification of benthic habitats from accidental loss of solid material. Injury or mortality of marine fauna due to ingestion of or entanglement with lost solid material.	Water Quality – **Section 7.3.2.2.1** Benthic Habitats – **Section 7.3.2.2.2** Marine Fauna – **Section 7.3.2.2.3**

While fish may potentially be impacted by an unplanned loss of solid material, this area of influence is highly localised and of an insignificant area, and is not expected to result in a change in the viability of the population of commercially important species. Therefore, impacts to commercial fisheries from unplanned loss of solid material are not expected, and have not been evaluated further.

7.3.2.2.1 Water Quality

Unplanned discharges of hazardous waste may leach into the marine environment causing localised contamination and increased toxicity within the water column. The level of impact to water quality depends on the nature of the discharge, which are typically small volumes such as residual paint in cans or oily rags lost overboard. Due to wave action and local ocean currents minor releases of residual hazardous waste will be rapidly mixed and diluted resulting in temporary and highly localised changes to the water quality. Therefore, no long-term changes in water quality are expected. Given the small volumes, occasional nature of the events and the offshore location, potential impacts to the biodiversity, ecological integrity, social amenities and human health the loss of solid material will be minor.

7.3.2.2.2 Benthic Habitats

Impacts to benthic habitats from the loss of solid materials to the marine environment will depend on the nature of the material and the sensitivity of the benthic habitat upon which it lands. Loss of solid material is most likely to occur around the Dorado WHP and the FPSO, as these locations are where activities will be concentrated. Future tieback locations, which are yet to be determined, may also represent the location where solid material is lost to the marine environment.

The majority of the Project Area consists of habitats composed largely of fine sediments (typically more than 90% cover) but it also contains some areas of hard pavement reef, which may host filter feeder communities, especially whip corals, gorgonians and sponges (**Attachment 2**). These habitats are widely represented throughout the NWS and are not considered to be sensitive benthic habitats. The Project Area deliberately avoids overlapping the Ancient Coastline at 125 m water depth KEF, and there are no known bathymetric features (e.g. shoals, banks) or high conservation significant ecological values, habitats or communities of species identified within the Project Area.

Relatively large items that may be accidentally released to the marine environment, such as drill string and wooden pallets, are largely inert and do not represent a contamination risk to sediments or benthic habitats. Potential impacts from inert solid materials that may be released to the marine environment are expected to be limited to direct physical disturbance of the seabed (e.g. depressions in the sediment). The benthic habitats within the Project Area are not particularly sensitive to direct physical disturbance due to the absence of benthic primary producer habitat and the sparse density of epibenthic biota (RPS, 2020). If the inert material can be recovered, depressions in the seabed will recover over time through natural sedimentary processes.

Some solid materials that may be lost overboard may not be inert. Examples include plastics (e.g. hard hats), powders (e.g. drilling chemicals) and potentially hazardous wastes (e.g. used batteries). These items may result in impacts to benthic habitat from toxicity effects. Potentially hazardous materials will be handled in accordance with Santos' requirements. Santos' operational experience operating offshore facilities has demonstrated that the loss of potentially hazardous material to the marine environment is very unlikely to occur.

Impacts to the seabed from accidental releases of solid materials are expected to be restricted to a localised area in proximity to where the material may be released. Given that the benthic habitats within the Project Area are well represented throughout the region and no sensitive benthic habitats occur, potential impacts to benthic habitats from the loss of solid material will be minor.

7.3.2.2.3 Marine Fauna

Marine fauna with the potential to be impacted as a result of an unplanned discharge of solid material include:

- Fish;
- marine mammals;
- marine reptiles; and
- birds.

Marine fauna that ingest or become entangled in solid material may be subject to physical harm, which may limit feeding/foraging behaviours, resulting in death. Under the EPBC Act (2003), injury/fatality of vertebrate marine life as a result of entanglement or ingestion of marine debris was listed as a key threatening process. The Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia 2018) identifies EPBC Act listed species that have been scientifically documented as being sensitive to interactions with marine debris (Commonwealth of Australia 2018). C&R Consulting (2009) reported that between 1974 and 2008, a total of 77 individuals (variety of different species) had been subject to impacts associated with entanglement in, or ingestion of, plastic debris within Australian waters. The records were dominated by humpback whales, marine turtles, Australian pelicans and a range of cormorant species, with the sources of waste being unknown. Marine turtles and seabirds in particular may be at risk from plastics which may cause entanglement or be mistaken for food (e.g. Department of the Environment and Energy 2018, 2017) and ingested causing damage to internal tissues and potentially preventing feeding activities.

7.3.2.2.4 Fish

Plastic released to the marine environment will degrade over time. As plastic breaks down, it degrades into progressively smaller particles over time until if forms relatively persistent microplastics. Degradation of microplastic materials is primarily by physical means, as very few naturally occurring biota (e.g. bacteria) can consume plastics (Andrady 2011). Plastic and microplastic materials have the potential to impact upon marine organisms that may consume this material. Microplastics have been shown to be toxic through the concentration of persistent organic pollutants and may also cause blockage of the gastrointestinal track in fauna (Andrady 2011).

Pelagic and demersal fish may ingest microplastics. Studies show ingestion of microplastics by fish is relatively common, with over a third of all fish examined in studies in European waters having microplastics within their gastrointestinal tract (Lusher et al. 2013; Murphy et al. 2017). Ingestion of fish with a microplastics load may result in bioaccumulation within higher trophic levels, although most microplastics may pass through an animal and be expelled via faeces (Gil-Delgado et al. 2017). The consequences of microplastic ingestion by fishes has not received significant attention to date (Commonwealth of Australia 2018).

The ubiquity of microplastics on the sea and the relatively high portion of fishes observed with microplastics in their gut with little apparent consequence, suggests that significant effects of microplastics on fishes is minor.

While the recovery plan for the whale shark (Department of the Environment and Heritage 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the whale shark occurs outside Australian waters. While pollution and marine debris was listed as a future threat, at present, these do not have an impact on the numbers of whale sharks visiting Australian waters (Department of the Environment and Heritage 2005a).

While fish may potentially be impacted by an unplanned loss of solid material, the portion of fish communities that may credibly be affected is relatively small. Impacts to fish from a loss of solid material is not expected to result in a change in the viability of the population of commercially important species.

7.3.2.2.5 Marine Mammals

As presented in **Section 3.3.2** the Project Area is not recognised as an important area for marine mammals. Nonetheless, the Project Area partially overlaps a BIA migratory area for humpback whales. The recovery plan for the humpback whale (Department of the Environment and Heritage 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture and outputs from aquaculture.

Marine mammals may be impacted through ingestion or entanglement with solid material (C&R consulting 2009). Entanglement, resulting in fauna becoming trapped, is usually associated with large solids such as ropes and ghost nets. The limited use of ropes (when compared to fishing and other maritime activities) during Dorado Phase 1, and the size of the ropes used will not credibly result in the entanglement of Humpback Whales. It is nonetheless possible (even if only remotely) that other marine mammals could become entangled. Potential impacts, such as injury or mortality, would be limited to a small number of individuals.

Humpback whales, and other marine mammals, may ingest microplastic. Filter feeders, such as humpback whales, ingest microplastic directly through the water column and via prey species (Besseling et al. 2015). While ingestion of microplastic has not yet been reported for most whale species, it might be of specific concerns (Besseling et al. 2015). Dorado Phase 1 will not be a significant source of plastic or microplastic in the marine environment as plastic waste will be sent to shore for disposal at appropriately licensed facilities, and Santos' operational experience with offshore facilities shows that the loss of solid materials such as plastics to the marine environment is an uncommon event. Humpback whales are thought to only feed opportunistically during migration (Stockin and Burgess 2005), and hence are unlikely to ingest any solid material that may be lost to the sea within the Project Area. It has therefore conservatively been assessed that potential impacts, such as injury, would be limited to a small number of individuals.

The risk to marine mammals associated with the loss of solid material (through potential entanglement or degradation and ingestion of microplastic) has been assessed as a minor consequence (as it would be limited to a small number of individuals), and will not result in significant impacts to marine mammal populations.

7.3.2.2.6 Marine Reptiles

Marine reptiles, specifically turtles, may be impacted through ingestion or entanglement of solid material or through exposure to toxic chemicals. Turtles are known to be indiscriminate feeders and may mistake plastic for jellyfish (Mrosovsky et al. 2009). The Recovery plan for marine turtles in Australia 2017 – 2027 (Commonwealth of Australia 2017a) and the Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia 2018) identifies ingestion of marine debris as a threat to all species of marine turtles. Once ingested, plastics can damage internal tissues and inhibit physiological processes, which can potentially result in fatality.

Several species of turtles are common in nearshore waters of the Pilbara, with considerable nesting activity occurring throughout the region. Turtles are less common in offshore waters, such as those of the Project Area, but are still expected to occur within the Project Area in low numbers. A flatback internesting BIA partially overlaps the Project Area, but this does not overlap the WHP or FPSO locations. No habitats identified as critical for the survival of marine turtles overlap the Project Area.

Turtles foraging within the Project Area may consume plastics accidentally released into the marine environment. This may result in impacts such as injury or mortality. Turtles that forage at sea, such as juvenile turtles of all species and adult green and leatherbacks, have been identified as being at particular risk of ingesting plastic (Schuyler et al. 2014). In a review of plastic ingestion by turtles, Schuyler et al. (2014) identified plastic ingestion as a cause of death in 4% of turtles necropsied, and concludes that ingestion of small quantities of plastics by turtles is common, with a relatively small portion of turtles ingesting sufficient plastic to cause death.

Based on Santos' operational experience with offshore facilities, the loss of solid materials such as plastics to the marine environment will be an uncommon event. Given the amount of plastic released to the marine environment will be very low, the expected encounter rate between plastics accidentally released from Dorado Phase 1 and foraging turtles will be correspondingly very low. Potential impacts, such as injury or mortality, will be limited to a small number of individual turtles. This potential consequence is considered to be minor, and will not result in significant impacts to turtle populations.

7.3.2.2.7 Birds

The loss of solid material to the marine environment may impact upon marine fauna, such as seabirds. Plastics have been identified as posing a particular risk to marine fauna due to ingestion or entanglement (Commonwealth of Australia 2018).

Seabirds are common around the islands and Pilbara coast beyond the Project Area. There are two seabird breeding BIAs which intersect the Project Area:

+ lesser frigatebird (overlaps the WHP); and
+ brown booby (19 km from the WHP).

Both of these species, along with other seabird species, are expected to forage within the Project Area. Seabirds may be attracted to Dorado Phase 1 facilities, which may concentrate birds around these facilities in the Project Area.

Foraging seabirds have been shown to ingest plastics, potentially resulting in impacts such as gut obstruction or reduced stomach volume, resulting in a loss of fitness (Wilcox et al. 2015). Increased levels of plastics within seabirds has also been correlated with increased organic pollutant loads

(Wilcox et al. 2015). Once ingested, plastics can damage internal tissues and inhibit physiological processes, which can potentially result in fatality.

Seabirds foraging within the Project Area may ingest plastics accidentally released into the marine environment, causing injury and/or mortality. Based on Santos' operational experience with offshore facilities, the loss of solid materials such as plastics to the marine environment will be an uncommon event. Given the amount of plastic released to the marine environment will be very low, the expected encounter rate between plastics accidentally released from Dorado Phase 1 and foraging seabirds is unlikely. Potential impacts, such as injury or mortality, will be limited to a small number of individual birds. This potential consequence is considered to be minor, and will not result in significant impacts to seabird populations.

7.3.2.3 Risk and Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-89**.

Table 7-89: Summary of impacts, EPOs, controls and consequence evaluation of loss of solid material during Dorado Phase 1

EPOs	
EPO3G: No mortality or significant[47] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 loss of solid material. **EPO24A**: No significant[45] impacts to benthic habitats and communities. **EPO25A** Undertake Dorado Phase 1 in a manner that will prevent unplanned discharge of solid waste to the marine environment. **EPO26A** Undertake Dorado Phase 1 in a manner that will prevent unplanned seabed disturbance.	
Receptor	**Impact**
Water Quality	Localised decrease in water quality in the vicinity of the loss of solid material.
Benthic Habitat	Modification of benthic habitats from accidental loss of solid material.
Marine Fauna	Injury or mortality of marine fauna due to ingestion of or entanglement with lost solid material.
Controls	
CM10: All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification): + Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including: - Garbage management plan in place. - Garbage record book maintained onboard.	

[47] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

CM70: Crane and lifting operations will comply with the following: + Lifting equipment will be inspected and certified, + Preventative maintenance will be carried out, and + Lifting operators will be competent and qualified **CM71**: Objects dropped overboard will be recovered where practicable to mitigate the environmental consequences from objects remaining in the marine environment, unless the environmental consequences are minor or safety risks are disproportionate to the environmental consequences. **CM72**: Waste management procedures will include: + classification of wastes, including segregation of wastes into recyclable and non-recyclable materials, + appropriate storage of wastes, and + transportation and disposal of wastes by a licenced waste contractor at licenced waste management facilities in accordance with waste classifications. **CM73**: After completion of the drilling and installation stages a site clean-up activity will be undertaken to identify and remove, if safe, any dropped objects or solid materials that may have been lost.		
Likelihood	Occasional – D Control measures proposed ensure that the risk of dropped objects, lost equipment or release of solid waste to the environment has been minimised. Given the controls in place, the likelihood of releasing non-hydrocarbon solids to the environment resulting in a minor consequence is considered to occur occasionally.	
Consequence	Minor – II	
Residual Risk	Low	

7.3.2.4 Demonstration of Acceptability

The residual risks of the potential loss of solid material as a result of Dorado Phase 1 have been compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-90** and **Table 7-91**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case residual risk for the potential loss of solid material was evaluated as low (**Table 7-89**). This residual risk level is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from the unintentional loss of solid material are acceptable.

Table 7-90: Demonstration of acceptability for loss of solid materials

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	Management of accidental release of solid material from Dorado Phase 1 is consistent with the principle of ESD because: + the management in place to prevent the accidental release of solid material to the marine environment will contribute towards maintaining biological diversity and ecological integrity.

Acceptability Criteria	Demonstration of Acceptability
Internal Context	The prevention and management of loss of solid material is aligned with Santos' policies and standards. The residual risk is very low, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.
MNES	The following material published in relation to threatened and migratory species within and adjacent to the Project Area identify marine debris as a threat: **Conservation Advice** + Conservation advice *Rhincodon typus* (Whale Shark) (Threatened Species Scientific Committee 2015d) + Conservation Advice for the 'bbott's –ooby - *Papasula abbotti* (Threatened Species Scientific Committee 2020b) + Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Threatened Species Scientific Committee 2008b) **Recovery Plans** + Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia 2018). This plan identifies marine debris as a threat to marine vertebrates. There are four objectives of the plan that involve prevention, removal, mitigation and monitoring of marine debris in marine environments which are relevant to Dorado Phase 1. + Wildlife Conservation Plan for Seabirds (DCCEEW 2022). This plan identifies pollution – marine debris as a threat to seabirds. Action 2H: enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats, relates to pollution (including marine debris) and is relevant to Dorado Phase 1. + Recovery plan for Marine Turtles in Australia (Commonwealth of Australia 2017a). This recovery plan identifies marine debris as a threat to marine turtles. Action A3: reduce the impacts from marine debris, and is relevant to Dorado Phase 1. + Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia 2015a). This recovery plan identifies marine debris as a threat to Blue Whales and is considered a minor risk to the species. Given the long-term recovery objective is to minimise anthropogenic threats to allow the conservation status of the Blue Whale to improve so that it can be removed from the threatened species list under the EPBC Act, it is considered relevant to Dorado Phase 1. The objectives of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The controls outlined in **Table 7-89** are consistent with the objectives of the material listed above and Santos considers the impacts of unplanned loss of solid material to not be inconsistent with the EPBC management plans.

Acceptability Criteria	Demonstration of Acceptability
	Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify marine debris as a key threat or do not have explicit relevant objectives or management actions related to marine debris.
Other Relevant Requirements	By reducing potential marine pollution, the management to prevent the accidental loss of solid material to the marine environment is consistent with: + Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia 2018) Recovering objects dropped overboard, where practicable, to mitigate the environmental consequences from objects remaining in the marine environment is consistent with the requirements presented in the OPGGS Act (Section 572(3)).

Table 7-91: Demonstration of acceptability of potential loss of solid material against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[48] are acceptable. **RSAL4**: Substantial[49] impacts to water quality within 1 km of the Dorado WHP, FPSO and drilling activities are acceptable.	The evaluation of impacts from the loss of solid material which may leach into the marine environment shows that impacts will be localised around the vicinity of the lost. Due to the minor consequence of the potential environmental impacts, it is expected that a high level of ecological integrity will be maintained beyond 1 km of the discharge location. Given the widespread nature of the open water environment in the region, the loss of solid material which may leach into the marine environment will not result in impacts to water quality that result in a loss of ecological integrity.
RSAL8: No significant[50] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities.	Impacts to the seabed from accidental releases of solid materials are expected to be restricted to a localised area in proximity to the area where the material may be lost (if it is not retrieved). Given that the benthic habitats within the Project Area are well represented throughout the region and no sensitive benthic habitats occur, potential impacts to benthic habitats from the loss of solid material will be minor. Santos' operational experience with offshore facilities shows that the loss of solid materials to the marine environment will be an uncommon event.

[48] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[49] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

[50] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	Santos' operational experience with offshore facilities shows that the loss of solid materials to the marine environment will be an uncommon event. It is therefore expected that the likelihood of marine fauna becoming entangled or ingesting the loss material is low. Potential impacts, such as injury or mortality, has been conservatively assessed as being limited to a small number of individual marine fauna. This potential consequence is considered to be minor and will not result in significant impacts to marine fauna populations.

7.3.3 Physical Presence – Introduction of Invasive Marine Species

7.3.3.1 Description of the Event

IMS are marine organisms that are translocated from one location to another location in which they do not occur naturally, become established and result in potential environmental impacts. The major vector pathways for the introduction of marine pest species into Australia are ballast water carried in vessels and biofouling on vessels (or internal parts of the vessel that are exposed to sea water) (Department of Agriculture and Water Resources 2018). IMS are recognised as an environmental risk globally, with the IMO providing guidelines for the management of biofouling and ballast water to reduce the risk of IMS (IMO 2011, MIAL 2020).

Commonwealth, state and territory governments have also developed legislation, regulations and guidelines for managing the risk of IMS (which are considered in **Section 7.3.3.3**).

A number of factors influence the survivability of IMS during translocation and then establishment, such as the presence of natural predators, level of physical disturbance, dispersion and reproductive rates, the environment conditions (water temperature etc.), vessel speeds and vessel age. The establishment of IMS in the Project Area requires all of the following to occur:

+ the IMS to be present on a vector such as a vessel or MODU (typically as biofouling or in ballast water);
+ the IMS must be released from the vector; and
+ the IMS must become established in the receiving environment.

Interruption of any of the conditions above may prevent an IMS from becoming established. Once established in a location, IMS can be very difficult or in some instances, impossible to eradicate. Bax et al. (2003) states that rather than just blend into their new environment, many IMS will significantly change it. This can occur through increasing the predation pressure on native organisms or modifying the habitat by smothering or providing new structural habitat such as Japanese seaweeds (Bax et al. 2003). IMS introduction primarily occurs in shallow waters with high levels of slow-moving or stationary shipping traffic such as in ports. IMS colonisation also requires a suitable habitat in which to establish itself such as rocky and hard substrates or subsea infrastructure, especially with pre-existing biofouling.

7.3.3.1.1 Biofouling

Biofouling refers to the growth of marine organisms on hard surfaces immersed in the marine environment for extended periods of time. Biofouling commonly occurs on the parts of ships that are below the waterline, such as the vessel hull and water intakes. Parts of the hull that experience high water movement, such as propellers, typically have relatively low levels of biofouling. Vessels that are stationary for long periods typically develop higher levels of biofouling than vessels that are moving more frequently.

Biofouling communities typically develop as three phases:

- primary biofouling – the development of a biofilm of microscopic bacteria and algae on a previously clean surface. This layer in itself is generally considered to be of little IMS risk, however, it supports the development of secondary and tertiary biofouling, which are considered relatively higher risk;
- secondary biofouling – the growth of fouling organisms facilitated by primary biofouling, such as macroalgae growing from spores; and
- tertiary biofouling – the growth of relatively large encrusting organisms, such as ascidians and mussels. Most species identified as an IMS risk in Australian waters can be characterised as tertiary biofouling species.

All marine vessels have some degree of biofouling. Organisms attach to the vessel hull, particularly in areas where organisms can find a good surface (e.g. seams, strainers and unpainted surfaces) or where turbulence is lowest (e.g. niches, sea chests, etc.). Biofouling is usually controlled using antifouling coatings on areas of the vessel below the waterline. Seawater used on vessels (e.g. cooling water) may be dosed with biocides to prevent the growth of biofouling within piping, which may also reduce biofouling levels and associated IMS risk.

7.3.3.1.2 Ballast Water

Ballast water is required for the stability and safe operations of marine vessels at sea. Ballast water is used to maintain or increase the displacement of a vessel (e.g. when not fully loaded) and is subsequently discharged at a later time. Ballast water may include IMS from different life history phases, such as eggs, larvae and adult organisms. The discharge of ballast water containing IMS may lead to IMS becoming established in the vicinity of the discharge location. Release of unmanaged ballast water could transfer IMS into the marine environment, depending on the location that ballast water was taken onboard. A study done by Gollasch et al. (2002) on 1,508 samples identified a total of 990 different species within the ballasts of ships. The species varied in taxa from fungi, bacteria, algae and protozoans to small fish and invertebrates at varying life stages.

Ballast water has been recognised as a major pathway for introducing IMS into new environments, giving rise to adoption of the International Convention for the Control and Management of'Ships' Ballast Water and Sediments (Ballast Water Convention). The Ballast Water Convention aims to prevent the spread of IMS from one region to another, by establishing standards and procedures for the ballast water management, including phasing out the use of ballast water exchange. In Australian waters, vessels are required to demonstrate compliance to Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020), which outlines approved methods of ballast water management in line with the Ballast Water Convention, including:

- use of a Ballast Water Management System;
- ballast water exchange conducted in an acceptable area;

- use of low risk ballast water (such as fresh potable water, high seas water or fresh water from an on-board freshwater production facility);
- retention of high-risk ballast water on board the vessel; and
- discharge to an approved ballast water reception facility.

7.3.3.1.3 Sources of IMS and Dorado Development

There are several potential IMS vectors associated with different stages of Dorado Phase 1, including:

- MODU (development drilling);
- FPSO;
- offshore support vessels and equipment (installation, operations, maintenance and decommissioning); and
- Offtake tankers.

The WHP, DTM, moorings and mooring lines, umbilical and flowlines may be mobilised from within or outside Australian waters. This equipment is unlikely to host IMS as it will be new and transported dry on vessels for installation.

A jack-up MODU will be used for the initial development drilling. Future tiebacks may require either a jack-up or a moored semi-submersible MODU depending on water depth. Both types will have below the waterline external surfaces (e.g. spud cans on a jack-up and pontoons on a semi-submersible) and likely require ballast water to maintain stability. The MODU may be mobilised to the Project Area from outside Australian waters, which may present a higher risk of IMS introduction than a MODU that mobilises from within Australian waters. The MODU will only be present in the Project Area during drilling and well-related activities (e.g. well workovers).

The FPSO will not be constructed in Australia (location yet to be determined) and will enter Australian waters as part of installation activities. The FPSO will spend part of its construction time in-water at the construction location prior to arriving on station within the Project Area. Once on-station, the FPSO may occasionally leave the Project Area for cyclone avoidance and maintenance (which is likely to be carried out in a shipyard beyond Australian waters). The FPSO will be present in the Project Area for most of the duration of Dorado Phase 1, including installation, operations and some of the decommissioning.

Project vessels and equipment will be used throughout Dorado Phase 1, with the types of vessels varying depending on the specific activity and stage. The installation and decommissioning stages of Dorado Phase 1 may require specialised vessels, which are typically mobilised from beyond Australian waters. Equipment, such as mooring lines, is typically stored dry on vessels prior to installation. This equipment is unlikely to host IMS due to desiccation of biofouling when the equipment is not submerged for long periods of time. Project vessels will be present during all stages of Dorado Phase 1. Vessels required during the operational stage of Dorado Phase 1 (the longest stage) such as supply vessels are expected to be present within Australian waters for long periods of time.

Offtake tankers will be present in the Project Area during the operational stage of Dorado Phase 1. Offtake tankers are expected to be sourced from the global oil tanker fleet. Offtake tankers will discharge ballast water while loading oil from the FPSO. Each offtake is expected to take up to 48 hours.

Once installed on location structures such as the WHP and FPSO will provide hard substrate and a potential vector pathway for IMS from offtake tankers establishing on the surfaces provided by these structures.

7.3.3.2 Details of Environmental Impacts and Risks

The introduction of IMS as part of Dorado Phase 1 into the marine environment has the potential to result in impacts to the following receptors:

+ benthic habitats;
+ KEFs; and
+ fisheries.

Most potential IMS have evolved in coastal waters and are not adapted to the open ocean offshore environment (Department of Agriculture, Fisheries and Forestry 2011). The offshore environment of the Project Area is relatively deep (70 to 120 m) with water depths at the Dorado WHP and FPSO of approximately 90 m. Benthic habitats in these water depths are unsuitable for the survival of many species of IMS identified as a risk to Australia (Department of Agriculture, Fisheries and Forestry 2010). Many species of IMS require hard substrate for attachment, which is present intermittently within the Project Area, with the most common substrate being silty to coarse sands with some rubble (**Section 3**).

Table 7-92 identifies the potentially impacted receptors should IMS be introduced within the Project Area.

Table 7-92: Receptors Potentially Impacted by the introduction of IMS

Description of the Impact	Receptor Categories
Change in ecosystem dynamics Changes to the functions, interests or activities of other users Reduction in fishery resource stocks	Benthic Habitats – **Section 7.3.3.2.1** KEF – Section 7.3.3.2.2 Fisheries – Section 7.3.3.2.3

The likelihood of introducing IMS from bringing the FPSO on location is regarded as unlikely based on the Santos risk matrix (**Table 7-2**). Noting that the WHP, DTM, moorings and mooring lines, umbilical and flowlines will be new and transported dry on vessels for installation, therefore not hosting IMS. The FPSO will be constructed in a dry dock and is expected to sail away from the dry dock being flooded within a timeframe (typically 7 days) which would not allow sufficient time for IMS to settle on the FPSO hull as per Santos IMS Management Plan. Should it not be possible for the FPSO to sail away within the required timeframe, in water biofouling inspection will be undertaken to verify the absence of IMS. Upon confirmation that the FPSO is IMS free, the FPSO will then sail away within the appropriate timeframe to ensure no IMS have sufficient time to settle on the FPSO hull. The same IMS controls will be used during major FPSO maintenance campaigns which will likely require the FPSO to travel outside Australian waters and be dry docked. FPSO ballast exchange will be undertaken to comply with relevant international and national requirements (**Table 7-93**) to further reduce the risk of IMS introduction.

Following construction of the WHP and installation of the FPSO within the Project Area, it is possible that IMS may become established on the artificial habitat provided by Dorado Phase 1 facilities. The likelihood of this risk is considered unlikely in the Santos risk matrix (**Table 7-2**), as the potential vectors (e.g. offtake tankers) will typically be near these components for relatively short periods of time. Furthermore, the vessels and tankers supporting Dorado Phase 1 will comply with the IMO Guidelines for the control and management of ships biofouling to minimise the transfer of IMS, and ballast water exchanges will be undertaken as per international and national requirements (**Table 7-93**) to further reduce the risk of IMS introduction. To ensure IMS management requirements are clearly identified, a specific Dorado FPSO Biofouling Management Plan will be prepared and implemented to comply with relevant regulations and Santos' comprehensive IMS Management Plan which has been developed in consultation with the relevant authorities. Santos IMS Management Plan has been successfully implemented on the NWS where Santos has operated FPSOs and brought, on numerous occasions, FPSO from dry dock outside Australian waters without introducing IMS. The same plan has also been successfully implemented to avoid introducing IMS from support vessels. It is important to note that in the unlikely event an IMS becomes established on the WHP and/or FPSO, it is even less likely that it will spread in the marine environment due to the water depth and remoteness of the area.

Considering the remote likelihood of IMS becoming established on the WHP and FPSO, and with support vessel and tankers following biofouling and ballast water legal requirements it is expected that transmission of IMS from the facilities to vessels is even less likely. Santos is not aware of a sequence of events, such as IMS being established on an oil and gas facility then transferred to a support vessel prior to IMS establishing in a harbour, being documented anywhere in the world.

7.3.3.2.1 Benthic Habitats

The introduction of an IMS has the potential to cause impacts to benthic habitats and communities through a change in ecosystem dynamics. Changes in ecosystem dynamics can include:

- predation on native and farmed species;
- out-competing native species for space and food; and
- alter nutrient cycles and lead to a loss of diversity in local species.

Benthic communities within the Project Area are characterised by relatively sparse assemblages of filter feeding and deposit feeding organisms (RPS 2020d). No benthic primary producer habitat, such as seagrasses, macroalgae or zooxanthellate corals, were observed during benthic habitat surveys within the Project Area (RPS 2020d). These benthic habitats are not expected to occur due to insufficient photosynthetically active radiation required to sustain these habitats on the seabed as a result of the 70 to 120 m water depth.

Of the non-oceanic species identified in the Australian Marine Pest Monitoring Manual (Department of Agriculture, Fisheries and Forestry 2010), very few IMS (aside from planktonic oceanic species such as dinoflagellates) could credibly survive in the Project Area (70 to 120 m water depth); only three species (European clam, soft-shell clam and Northern Pacific sea star) were identified as potentially surviving in more than 90 m water depth. These three species are typically found in shallow, coastal waters (Department of Agriculture, Fisheries and Forestry 2011). Therefore, in the unlikely event that any IMS are introduced into the Project Area, they are unlikely to survive or become established on the seabed due to incompatibility with the water depth.

In the unlikely event that IMS were to become established within the Project Area because of Dorado Phase 1, potential impacts may include:

- reduced abundance and diversity in benthic communities due to:
  - competition with local species for resources such as food and hard substrate;
  - increased mortality of local species due to predation; and

- fouling of infrastructure on the Dorado Phase 1 FPSO and WHP.

7.3.3.2.2 KEF

The Ancient coastline at 125 m depth contour KEF located adjacent to the Project Area is shown in (**Figure 6-2**).

The KEF (defined by the depth range 115 to 135 m in the Northwest Shelf Province and Northwest Shelf Transition provincial bioregions) is beyond the depths within which most IMS can survive and therefore the likelihood of an IMS impacting upon the environmental values of the KEF is considered to be unlikely. The environmental values of the KEF are primarily a result of the geomorphic features of the KEF (e.g. provision of hard substrate and potentially enhanced vertical mixing of the water column). Potential impacts and likelihood of impacts to benthic habitats within the KEF due to IMS may be similar to those described above in **Section 7.3.3.2.1**.

7.3.3.2.3 Fisheries

The socio-economic receptor within the Project Area that may credibly be impacted by the introduction of an IMS is the commercial fishing industry (**Section 3.4.3**). The establishment of IMS may cause changes to the target prey abundance, distribution or behaviour, and in turn result in impacts to the activities of commercial fisheries.

The introduction of IMS within the Project Area may result in increased abundance of prey for fish species targeted by commercial fisheries, although this is unlikely to result in any detectable change in the abundance of targeted fish. IMS may also be taken as bycatch by these fisheries, however this is also unlikely to result in any impacts to fishing activity. It is also important to note that many IMS species require a suitable substrate on which to settle such as a hard or rock surface. As this type of substrate is lacking at the Project Area, settlement and colonisation is very unlikely and therefore likelihood of potential impacts to fisheries are considered unlikely.

7.3.3.3 Summary of Residual Risk Evaluation

A summary of the outcomes of the residual risk evaluation, including adopted control measures and EPOs is provided in **Table 7-93**.

Table 7-93: Summary of residual risks, EPOs, controls, likelihood and consequence evaluation of potential introduction of IMS during Dorado Phase 1

EPOs	
EPO27A: Undertake Dorado Phase 1 in a manner that will prevent the introduction, establishment and spread of IMS in the natural environment attributable to the development. **EPO28A**: No significant[51] impacts to benthic habitats and communities, KEF and exploited fisheries resource stocks within the Project Area.	
Receptor	**Impact**
Benthic habitats	Change in ecosystem dynamics.

[51] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

KEF	Change in ecosystem dynamics
Fisheries	Reduction in fishery resource stocks. Changes to the functions, interests or activities of other users
Control Measures (CM)	
CM74: Ballast water exchange operations will comply with the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (as appropriate to vessel class), Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020), Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 and Biosecurity Act 2015, including: + all ballast water exchanges conducted more than 12 nm from land, and + vessel Ballast Water Management Plan stipulating that ballast water exchange records will be maintained. **CM75**: Implementation of Dorado FPSO Biofouling Management Plan when the FPSO sails to the Project Area from international waters (such as when it first hooks up or comes back from dry dock) and as per the anti-fouling and in-water cleaning guidelines (Department of the Environment and New Zealand Ministry for Primary Industries 2015). **CM76**: Compliance with Santos IMS Management Plan **CM77:** Biofouling management for vessels will be in accordance with the IMO Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Marine Environment Protection Committee 2011). **CM78:** Compliance with the International Convention on the Control of Harmful Anti-fouling Systems on Ships 2001, including vessels (of appropriate class) having a valid International Anti-fouling Systems Certificate. **CM79:** Fisheries will be provided with information on the timing, nature and scale of aspects of Dorado Phase 1 through Santos' consultation activities.	
Likelihood	Unlikely (b) The pathways for IMS introduction are well known, consequently, standard preventive measures are proposed. The ability for invasive marine species to colonise a habitat is dependent on a number of environmental conditions. It has been found that highly disturbed environments (such as marinas) are more susceptible to colonisation than open water environments where the number of dilutions and the degree of dispersal are high (Paulay et al., 2002). Given the depth of the Project Area creating an unfavourable habitat for colonisation (i.e. light limiting and low habitat biodiversity with sparse epibiota) and distance from shallow coastal habitats, there is a very low likelihood that IMS would be able to survive translocation and subsequently establish and colonise. Given the dispersive open-ocean environment of the operational area, the successful translocation to surrounding shallower habitats of an IMS introduced to the operational area is unlikely. With controls in place to reduce the risk of IMS introduction, the likelihood is considered Unlikely.
Consequence	Minor – II
Residual risk	Very low

7.3.3.4 Demonstration of Acceptability

The residual risks of the potential introduction of IMS as a result of Dorado Phase 1 have been compared to receptor-specific acceptable levels of impact and other considerations are summarised **Table 7-94** and **Table 7-95**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case residual risk for the potential introduction of IMS was evaluated as very low (**Table 7-93**). This residual risk level is considered to be acceptable when assessed against the acceptable levels of risk defined in **Section 4**.

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from the unintentional introduction of IMS are acceptable.

Table 7-94: Demonstration of acceptability for potential introduction of IMS

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	The introduction of IMS resulting from Dorado Phase 1 are inherently inconsistent with some of the principles of ESD based on the following: + the introduction of an IMS poses a risk to the biological diversity and ecological integrity of benthic communities. Santos will apply controls to ensure that the risk of IMS introduction is reduced to a level that is acceptable. Following effective application of these controls, Santos considers the risk to be consistent with the principles of ESD. IMS introduced to the Project Area are unlikely to survive given the water depth and paucity of hard substrates.
Internal Context	IMS management is aligned with Santos' policies and standards. The residual risk is very low, which is acceptable. The EPOs and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	IMS introduced to the Project Area are unlikely to result in any detectable change in fish resources or the ability of fishers to target these resources. Santos' ongoing consultation program will consider stakeholders' feedback.
MNES	***Threatened and Migratory Species*** The following material published in relation to threatened and migratory species within and adjacent to the Project Area identify invasive species or as a threat: **Conservation Advice** + Conservation Advice for the 'Abbott's –Booby - *Papasula abbotti* (Threatened Species Scientific Committee 2020b **Recovery Plans** + Wildlife Conservation Plan for Seabirds (DCCEEW 2022). This plan identifies invasive species as a threat to seabirds. Action 2F: ensure seabirds are protected from the adverse effects of invasive species, is relevant to Dorado Phase 1. + Recovery plan for Marine Turtles in Australia (Commonwealth of Australia 2017a). This plan identifies diseases and pathogens as a threat to marine turtles. Given the long-term recovery objective is to minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that

Acceptability Criteria	Demonstration of Acceptability
	they can be removed from the EPBC Act threatened species list, it is considered relevant to Dorado Phase 1. The objectives of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The controls outlined in **Table 7-93** are consistent with the objectives of the material listed above and Santos considers the impacts of unplanned introduction of invasive marine species to not be inconsistent with the EPBC management plans. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify invasive species or disease as a threat or do not have explicit relevant objectives or management actions related to invasive species or disease. ***Commonwealth Marine Environment*** The Project Area does not overlap any KEFs. The water depth Ancient coastline at 125 m depth contour KEF means any IMS would be unlikely to survive. The environmental values of the KEF which could be impacted by IMS introduction are well represented in the Project Area (**Attachment 2**). Introduction of IMS as a result of Dorado Phase 1 will not credibly impact upon marine protected areas such as AMPs as AMPs are too far away (the nearest AMP is located 29 km from the Project Area) from Dorado Phase 1 and not within support vessels or tankers route.
Other Relevant Requirements	Management of the potential impacts and risks from an introduction of IMS resulting from Dorado Phase 1 are consistent with relevant legislative requirements, including: + compliance with international maritime conventions, including The International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004, The International Convention on the Control of Harmful Anti-Fouling Substances on Ships 2001, and IMO 2011 Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Marine Environment Protection Committee 2011). + compliance with Australian legislation, requirements and guidelines, including: Protection of the Sea (Harmful Anti-fouling Systems) Act 2006: Marine Order 98 – Marine Pollution prevention – anti-fouling systems *Biosecurity Act 2015*, Western Australian *Aquatic Resources Management Act 2016*, DPIRD Biofouling Biosecurity Policy, National biofouling management guidance for the petroleum production and exploration industry (Department of Agriculture, Fisheries and Forestry 2009), and Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020). Marine Biosecurity Management of Vessels servicing the Offshore Industry (MIAL 2020) Reducing marine pest biosecurity risks through good practice biofouling management (NOPSEMA 2020d)

Acceptability Criteria	Demonstration of Acceptability
	Marine Pest Plan 2018 – 2023: national Strategic Plan for Marine Pest Biosecurity (2018-2023) (Commonwealth of Australia 2018) Offshore Installations Biosecurity Guide (DAWE 2020)

Table 7-95: Demonstration of acceptability of potential introduction of IMS against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL8: No significant[52] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities.	By implementing the Dorado FPSO Biofouling Management Plan (which will comply with relevant regulations and Santos IMS Management Plan) and following international and national requirements for ballast water exchanges, the likelihood of introducing IMS is very low. In the unlikely event an IMS becomes established on the WHP and/or FPSO, it is even less likely that it will spread in the marine environment due to the water depth and remoteness of the area. The Invasive Marine Species Management Plan (IMSMP) (EA-00-RI-10172) is consistent with the Biosecurity Act 2015 and National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee 2018). The IMSMP provides guidance on assessing the risk for vessels translocating marine pest species and utilises the risk assessment, to assess the risk of marine pests entering operational areas from contracted vessel from out of State waters. Generally, vessels are sourced from local waters although out of State vessels may be used provided, they are assessed as 'low risk' in accordance with the IMSMP. The biofouling risk assessment approach adopted by Santos will ensure that the Aquatic Resources Management Act 2016 and associated regulations prohibiting the introduction of non-endemic fish species will be met. The Invasive Marine Species Management Plan (IMSMP) is consistent with the Biosecurity Act 2015 and National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee 2018). The IMSMP provides guidance on assessing the risk for vessels translocating marine pest species and utilises the risk assessment, to assess the risk of marine pests entering operational areas from contracted vessel from out of State waters.
RSAL11: No significant[56] impacts to environmental values of KEFs.	The likelihood of IMS establishing on the WHP and/or FPSO is unlikely and it is even less likely it will spread in the marine environment. Due to the depth of the Ancient coastline at 125 m

[52] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

	depth contour KEF it is not expected to offer a suitable environment for IMS colonisation.
RSAL19: No negative impacts to the economic viability of the commercial fish resources.	In the unlikely event of IMS introduction, it is expected that the potential impact on the abundance of targeted fish resources will be undetectable. The potential presence of IMS as bycatch by commercial fishers, is also unlikely to result in any impacts to fishing activity.

7.3.4 Physical Presence –Interaction with Marine Fauna

7.3.4.1 Description of the Event

There are potential opportunities for a negative interaction between the physical presence of the operation and biological receptors. These primarily fall within airborne or seaborne collision risk, as well as negative behavioural response from the physical presence of the operation.

Vessel and helicopter movements will occur within the Project Area throughout the life of Dorado Phase 1. The type, number and size of vessels and the nature and duration of their movements will change, depending on the petroleum activities that are being undertaken. Vessel presence is expected to be greatest during the installation and drilling stages (e.g. for WHP installation, flowline installation, development drilling), with the longer-term operational project stage requiring fewer vessels at any one time. Helicopter presence will occur for the duration of the project. Depending on project phase, there are expected to be up to 3 helicopter flights per week. In addition to vessels and aircraft, there is also potential for direct collision of birds with infrastructure during periods of bad weather or poor visibility. For light emissions impacts see **Section 7.2.4.**

Finally, there may be a negative behavioural impact resulting from the physical presence of any bird deterrent system on the FPSO/WHP during all project phases. Although the latter is intentional as there are operational and safety requirements that may dictate its use.

A summary of the key types and the stage at which they could be expected in the Project Area is provided in **Table 7-96.**

Table 7-96: Expected presence of key vessels and aircraft in the Project Area

Vessel and AircraftType	Project Phase					
	Development Drilling	Installation	Commissioning	Operations and Maintenance*	Future Tiebacks	Decommissioning
Helicopter	✓	✓	✓	✓	✓	✓
MODU	✓			✓	✓	✓
FPSO		✓	✓	✓	✓	
Supply vessel	✓	✓	✓	✓	✓	✓
Offshore support vessels (e.g. MODU support vessel, inspection, monitoring, maintenance	✓	✓	✓	✓	✓	✓

Vessel and AircraftType	Project Phase					
	Development Drilling	Installation	Commissioning	Operations and Maintenance*	Future Tiebacks	Decommissioning
and repair vessel, anchor handling, survey vessel, infield support vessel, ROV inspection vessel)						
Offshore installation/construction/heavy-lift vessel		✓			✓	✓
Piling barge/installation barge		✓			✓	
Construction support vessel (for flowlines/umbilicals)		✓	✓		✓	✓
Offtake tankers (third-party operated)				✓	✓	✓
* Including infill and tieback drilling						

Vessels undertaking project activities may collide with large marine fauna that occur at or near the water surface, potentially resulting in impacts to marine fauna. Vessels will transit to and from the Project Area and when undertaking petroleum activities, they will likely be holding station or moving slowly within the Project Area. In-field vessels operating within the Project Area will typically travel at speeds slower than those operating in offshore waters, and therefore exhibit a lower risk profile in terms of interactions with marine fauna.

Helicopters arriving at or departing from infrastructure run the risk of bird collision resulting in a safety risk to the helicopter, and potential bird mortality. Helicopters arriving and departing will be travelling at reduced speed during take-off and landing. Coupled with the noise level it is likely that bird collisions will be dramatically reduced in relation to infrastructure in the Project Area.

Bird deterrence measures employed are designed to disturb or disrupt roosting or potential nesting behaviours. Whilst having a negative impact on behaviour, the deterrence measures are non-lethal and cause no lasting harm to birds.

7.3.4.2 Details of Environmental Impacts and Risks

Physical interaction with marine fauna, as a result of the presence of vessels, aircraft and infrastructure required for Dorado Phase 1 has the potential to result in injury, disturbance and/or mortality to marine fauna.

The following risk evaluation and analysis of environmental impacts has focused on large marine species, such as whales, turtles, birds and whale sharks.

Table 7-97 identifies the potentially impacted receptors as a result of interactions with marine fauna within the Project Area.

Table 7-97: Receptors potentially impacted by interactions with marine fauna

Description of the Risk	Receptor Categories
Accidental interactions between project vessels, helicopters, facilities and marine fauna within the Project Area	Marine Mammals – **Section 7.3.4.2.1** Fish – **Section 7.3.4.2.2** Reptiles – **Section 7.3.4.2.3** Birds- **Section7.3.4.2.1**

7.3.4.2.1 Marine Mammals

Marine mammals must surface to breathe periodically and may spend much of their time at or near the surface. This behaviour makes marine mammals, particularly large mammals such as baleen whales, vulnerable to vessel strikes particularly due to moving vessels. The typical behavioural response of baleen whales to the presence of a vessel is to avoid the vessel, either by moving away (e.g. increasing swimming speed) or by diving (e.g. Corkeron 1995; Scheidat et al. 2004). This response reduces the likelihood of a vessel collision or strike compared to no behavioural response or an attraction response. Conservation advice for humpback whales identifies vessel disturbance and strike as a threat (Threatened Species Scientific Committee 2015a).

Despite the typical avoidance response of cetaceans, interactions between vessels and cetaceans have occurred. The probability of vessel strikes between a whale and a vessel, and the consequence of such an interaction, is influenced by vessel speed. Vanderlaan and Taggart (2007) found that the chance of lethal injury to a large whale as a result of a vessel strike increases from about 20% at 8.6 knots to 80% at 15 knots.

In general, large cetaceans tend to have wide-ranging oceanic distributions meaning that while occurrence in the Project Area is possible, the absence of aggregating behaviours overlapping with the Project Area reduces the likelihood that encounters will involve large numbers of individuals. Numbers may be increased during migration. Surveys indicate the majority of migrating humpback whales, which are seasonally present between July and October during the north- and southbound migrations, have been observed in highest densities inshore of the Project Area. Humpback whales tend to migrate close to the coastline, generally within a few tens of kilometres of shore (Double et al. 2012a, 2010, 2014). This is consistent with tagging data curated by the Australian Antarctic Division, which showed the highest concentrations of humpback whales were between the mainland coast and the Project Area (**Figure 3-13**).

While the BIA for humpback whale migration marginally overlaps the southern extent of the Project Area, it does not overlap the Dorado WHP or FPSO locations, where vessel activities will be concentrated. Other whale species, such as blue and pygmy blue whales, are not expected to occur within the Project Area in large numbers. Blue and pygmy blue whales typically migrate in deeper waters (more than 1,000 m) on the outer continental shelf (Double et al. 2014).

The likelihood of a vessel collision or strike with a large whale resulting in injury is considered unlikely given the relatively low speed (typically less than 6 knots) of vessels undertaking petroleum activities within the Project Area and the expected low numbers of whales within the Project Area. Based on reported data contained in the National Ocean and Atmospheric Administration database, there are only two known instances of vessel collisions when the vessel was travelling at less than 6 knots; both of these were from whale watching vessels that were deliberately placed among whales (Jensen and Silber 2004).

Vessel interactions with smaller marine mammals, such as dolphins and porpoises, are very infrequent due to the mobility of these species and their avoidance response to vessels. Interactions leading to harm between vessels associated with Dorado Phase 1 petroleum activities and smaller marine mammals (i.e. non-baleen whales) are not expected to occur (Commonwealth of Australia 2017b).

Dugong distribution is correlated with their preference for shallow seagrass habitats. Due to the lack of suitable habitat within the Project Area it is highly unlikely that dugongs will occur within the Project Area.

7.3.4.2.2 Fish

Whale sharks are at risk from vessel strikes when at the surface or in shallow waters, where there is limited option to dive. Studies of scarring patterns on whale sharks at several locations in the Indian Ocean, including the Ningaloo Coast, observed that scarring caused by vessel strikes was almost as commonly observed as scarring from predator attacks (Speed et al. 2008). Conservation advice for whale sharks also identifies vessel strikes as a threat (Threatened Species Scientific Committee 2015d).

Whale sharks are known to congregate around geomorphic features to feed, such as reefs and islands, with steeply sloping seabeds in close proximity to relatively deep water (Copping et al. 2018). Whales sharks are known to aggregate seasonally off the Ningaloo Coast, after which individuals disperse in a broadly northward direction (**Section 3**). While there is a broad (~125 km wide) whale shark foraging BIA overlapping the Project Area, including the Dorado WHP and FPSO locations, tagging studies indicate this is more likely to be an area through which whale sharks migrate rather than an important foraging area (Meekan and Radford 2010; Wilson et al. 2006). The Project Area does not exhibit the geomorphic or biological features associated with whale shark aggregations (**Section 3.3.1.1**). The entire whale shark BIA which overlaps the Project Area is approximately 220,000 km^2, with the Project Area comprising approximately 1.6% of the total BIA.

The *Conservation advice* Rhincodon typus *whale shark* (Threatened Species Scientific Committee 2015d) identifies the following conservation action: "Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath (as set out in the Conservation Values Atlas, DotE, 2014)." Based on the lack of features consistent with known whale shark congregations and the lack of episodic high food availability (e.g. mass spawning of invertebrates) within the Project Area, whale sharks are very unlikely to aggregate in the Project Area. Tagging studies do not show whale sharks migrating through the Project Area, or along the mid and inner continental shelf in the region, with all whale sharks tagged at Ningaloo Reef travelling away from the congregation area in water considerably deeper than the Project Area (Meekan and Radford 2010; Wilson et al. 2006). As such, Dorado Phase 1 is consistent with the conservation advice, as the Development does not occur in areas close to marine features likely to correlate with whale shark aggregations, nor does it overlap the northward migration route along the 200 m isobath, as the water depth in the deepest part of the Project Area is approximately 118 m.

Whale sharks are not expected to occur in the Project Area in large numbers, and there are no environmental constraints (e.g. shallow water, complex bathymetry) that prevent whale sharks from avoiding project vessels. As such, interactions between vessels and whale sharks are considered to be unlikely.

7.3.4.2.3 Reptiles

Several species of marine turtle are known to nest on beaches along the Pilbara coastline. These species may be present within the Project Area, although they are not expected to occur in large numbers due to the absence of foraging habitat. Benthic habitat surveys (**Attachment 2**) and habitat modelling (**Attachment 3**) did not identify areas of potential foraging habitats, such as sponges or soft corals. Turtles that forage on pelagic prey (e.g. jellyfish) may feed within the Project Area, however the Project Area has not been documented as being important foraging habitat.

Vessel disturbance is identified as a threat in the Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a). The typical response from turtles on the sea surface to the presence of vessels is to dive (a potential “startle” response), which decreases the risk of vessel collisions (Hazel et al. 2007). As with cetaceans, the risk of vessel collisions between turtles and vessels increases with vessel speed (Hazel et al. 2007). Hazel et al. (2007) noted that visual and auditory detection of vessels are important in inducing a diving behavioural response, and infer that small, fast moving vessels pose the greatest risk for turtle collisions. Given the typically low speeds of vessels, vessel interactions with turtles are considered to be unlikely.

7.3.4.2.1 Birds

The Project Area does not host a large number or diversity of bird species. As there are no emergent features for bird roosting or nesting, and the marine environment does not have high productivity or host consistently high numbers of prey for foraging seabirds. Birds within the Project Area are likely to consist of foraging seabirds and potentially migrating shorebirds (Sage 1979 cited in Ronconi et al. 2015). In addition to seabirds, the EMBA beyond the Project Area seasonally hosts large numbers of migratory shorebirds.

Seabirds and migratory seabirds may opportunistically rest on the Dorado WHP and FPSO. Santos has experienced the presence of birds resting on its other offshore WHP facilities including Reindeer and John Brookes platforms. The unmanned WHP may provide a resting point for marine birds, there has been no nesting or breeding at Santos offshore WHP.

The risk of bird collision with helicopter operations is an ongoing concern for the safety of flights to and from infrastructure. The consequence of a helicopter bird strike is related to seasonal distribution, body mass, flocking behaviour, and flight behaviour, while the probability of a strike is related to the abundances of different bird species on or near the platforms. Santos take the position that a significant bird strike of any species puts both helicopter and birds at risk. As safety is paramount, and as this automatically puts any risk in the ‘critical’ consequence, then Santos will seek to deter all species with equal effort.

Collision risk from the presence of infrastructure is well documented. Birds are often attracted to illuminated offshore structures (For further information on the impact of light emissions see Birds – Section 7.2.4.2.5.), particularly nocturnally migrating species. Poor light conditions particularly during adverse weather conditions can also increase the risk of collision. Collision is ranked as one of the highest instances of bird mortality with man made structures. Offshore, potentially disoriented, or stormbound terrestrial birds have no alternatives for landing, so increased risk of collision occurs especially during low light conditions. Although instances are rare, sometimes several thousand birds impacted in a single event (Huppop et al , 2016).

The impact of deterrent non-lethal deterrence measures that seeks to displace or disturb birds is by definition of low impact to bird mortality or population size for the species targeted. However, there may be unexpected consequences for migratory species that attempt to utilise the platform as a rest stop or to stormbound birds. Although this is hard to quantify, as with collision the impacts on terrestrial species may be more significant with limited options for sanctuary close by. The deterrence measures should also be designed to reduce secondary threats, such as forcing birds to lower levels that then scatter as helicopters land.

7.3.4.3 Summary of Environmental Impact Evaluation

A summary of the outcomes of the impact evaluation, including adopted control measures and EPOs is provided in **Table 7-98.**

Table 7-98: Summary of impacts, EPOs, controls and risk evaluation of vessel and aircraft interactions with marine fauna during Dorado Phase 1

EPOs	
EPO29A: No vessel or helicopter interactions within the Dorado Phase 1 Project operational area with EPBC Act listed threatened, migratory or cetacean species.	
Receptor	**Impact**
Marine Mammals	Injury/mortality to marine fauna from vessel or helicopter collisions, disturbance from bird deterrence measures .
Fish	
Reptiles	
Birds	
Control Measures (CM)	
CM16: Implementation of Santos' Protected Marine Fauna Interaction and Sighting Procedure **CM80**: Vessels within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans, (except in emergency conditions or when manoeuvring is not possible), which include: + Implement a caution zone of 150 m for dolphins and 300 m for whales, + Vessels will not knowingly approach closer than 50 m to a dolphin and 100 m to a whale (i.e. no approach zone), + Make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale, + Vessels will not knowingly travel more than 6 knots within the caution zone of a dolphin or whale, and + There will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone). **CM81:** Helicopters within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans (except in emergency conditions or when manoeuvring is not possible), which includes: + not operating the helicopter at a height lower than 1 650 feet or within a horizontal radius of 500 metres of a cetacean + not allowing the aircraft to approach a cetacean from head on **CM82**: If a Part 13 Permit for the disturbance of listed migratory birds is required under the EPBC Act a Santos Bird Management Plan will be developed and implemented.	
Likelihood	Unlikely – B Vessel Collision Marine fauna is expected to be present within the Project Area at various times of the year. Support vessels will be moving very slowly

	while inside the operational area, posing a low risk of collision with marine fauna. In addition, the noise generated from vessel operations will deter marine fauna from coming in close proximity to vessels. With controls in place ensuring the vessels are compliant with EPBC Regulations, the likelihood of a collision with marine fauna resulting in a very low/negligible consequence is considered to be Unlikely. Aircraft collision The primary hazard recorded on local Santos platforms is birds taking flight as helicopters approach. This causes pilot distraction and introduces the potential for bird strike, which could lead to helicopter damage / crash, potentially escalating to a multiple fatality event. Unmanned Santos platforms have recorded four and two birds strikes respectively. With the control measures and deterrence strategies in place, incidence is reduced to unlikely. targeted terrestrial bird species is predicted to be negligible.
Consequence	Minor – II
Risk	Very Low

7.3.4.4 Demonstration of Acceptability

The potential impacts and risks of vessel or helicopter collision risk with marine fauna as a result of Dorado Phase 1 have been compared to receptor-specific acceptable levels of impact and other considerations are summarised in **Table 7-99** and **Table 7-100**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 4**.

The worst-case risk of interactions with marine fauna was evaluated as very low (**Table 7-98**). This risk is considered to be acceptable when assessed against the Santos risk matrix (**Section 4**).

Based on the outcomes of the evaluation of impacts and risks, Santos considers that the potential environmental impacts that may result from vessel or helicopter interactions with marine fauna are acceptable.

Table 7-99: Demonstration of acceptability for the risk of interactions with marine fauna

Acceptability Criteria	Demonstration of Acceptability
To meet the principles of ESD	Management of interactions with marine fauna during Dorado Phase 1 is consistent with the principle of ESD because: there is no threat of serious or irreversible environmental damage as a result of vessel movements within the Project Area, and the risk of vessel or aircraft interactions with marine fauna does not pose a threat to the conservation of biological diversity or ecological integrity.
Internal Context	The management of the risk of vessel interactions with marine fauna is aligned with Santos' policies and standards. The residual risk is very low, which is acceptable. The EPO and the controls which will be implemented are consistent with Santos' internal requirements.
External Context	Santos' ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks.

Acceptability Criteria	Demonstration of Acceptability
MNES	The following material published in relation to threatened and migratory species within the Project Area identify vessel strikes or anthropogenic disturbance as a threat: <u>Conservation advice:</u> Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee 2015d), Conservation Advice *Calidris canutus* Red knot (Threatened Species Scientific Committee 2016f) (identifies bird strike with helicopters as a threat) Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Threatened Species Scientific Committee 2008b) Conservation advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee 2015b), Approved conservation advice for *Balaenoptera physalus* (fin whale) (Threatened Species Scientific Committee 2015c), and <u>Recovery plans:</u> Recovery plan for marine turtles in Australia 2017-2027 (Commonwealth of Australia 2017a). This plan identifies vessel interactions as a threat to marine turtles. Given the long-term recovery objective is to minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list, it is considered relevant to Dorado Phase 1. Conservation management plan for the blue whale: A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2015-2025 (Commonwealth of Australia 2015a). This recovery plan identifies vessel collisions as a threat to Blue Whales. Action A4: minimising vessel collisions by ensuring the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required appropriate mitigation measures are implemented; and ensure all vessel strike incidents are reported in the National Ship Strike Database. These actions are relevant to Dorado Phase 1. Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australian 2015c). This recovery plan identifies anthropogenic disturbance as a threat to migratory shorebirds. Action 3C: Investigate the significance of cumulative impacts on migratory shorebird habitat and populations in Australia; and Action 3F: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes, are relevant to Dorado Phase 1. Wildlife Conservation Plan for Seabirds (DCCEEW 2022). This recovery plan identifies anthropogenic disturbance as a threat to seabirds. Action 2D: ensure all areas of important habitat for seabirds are considered in the development assessment process; and 2E: manage the effects of anthropogenic disturbance to seabird breeding and roosting areas, are relevant to Dorado Phase 1. <u>Other material:</u> National Strategy for Reducing Vessel Strikes on Cetaceans and other Marine Megafauna (Commonwealth of Australia 2017b). The objectives of these publications were considered during the assessment of impacts and risks. The activity is not inconsistent with these objectives. The controls outlined in **Table 7-83** are consistent with the objectives of the material listed above

Acceptability Criteria	Demonstration of Acceptability
	and Santos considers the impacts of unplanned interaction with marine fauna to not be inconsistent with the EPBC management plans. Recovery Plans / Conservation Advice for other species that may occur in the project area do not identify vessel strike or anthropogenic disturbance as a key threat or do not have explicit relevant objectives or management actions related to vessel strike or anthropogenic disturbance. The controls outlined in **Table 7-83**are consistent with the objectives of the material listed above.
Other Relevant Requirements	Management of the risk of vessel interactions with marine fauna during Dorado Phase 1 are consistent with relevant legislative requirements, including: + compliance with Australian legislation and requirements, including: - adherence to the requirements of Part 8 of the EPBC Regulations (Interacting with cetaceans and whale watching). + alignment with policies, strategies, guidelines, conservation advice, and recovery plans published under the EPBC Act.

Table 7-100:Demonstration of acceptability of the risk of vessel interactions with marine fauna against receptor-specific acceptable levels of impact

Receptor-specific Acceptable Levels	Demonstration of Acceptability
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No or significant impacts[53] to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	The assessment of impacts and risks from vessel interactions with marine fauna predicts the risk is very low, with no effect on populations of these species. Management of the risk of vessel interactions with marine fauna is consistent with conservation advice and recovery plans that identify vessel strike as a threat. Significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur.

7.4 Cumulative Impacts

Cumulative impacts to environmental receptors may occur when more than one hazard impacts upon a receptor. Cumulative impacts to environmental receptors may occur as a result of:

+ more than one aspect from Dorado Phase 1 impacting upon a receptor; or
+ hazards from Dorado Phase 1 and third-party actions impacting upon the same receptor.

In order to assess cumulative impacts to environmental receptors, Santos has undertaken receptor-specific cumulative impact assessments for both multiple aspects of Dorado Phase 1 and third-party activities. The cumulative impact assessment was conducted after the aspect-specific impact

[53] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

assessments for Dorado Phase 1. The methodology used for, and the outcomes of, this assessment are described below.

Cumulative impacts may arise from causes such as (Minerals Council of Australia 2015):

- Space crowding - occurs when a system is disturbed by several similar activities, or by different activities producing a similar effect, in an area too small to assimilate the combined impacts; and
- Time crowding - occurs when impacts are so close in time that the impact of one action are not dissipated before the next occurs.

Interactive effects - interactive effects can be additive or synergistic, reflecting the interactive nature of ecosystems. Additive is the simple linear addition of one impact on another, whereas synergistic is when two or more agents combine to cause an impact greater than the sum of their individual impacts. Antagonistic effects can also occur, where the combined impact of more than one agent is less than the sum of the individual impacts.

Indirect effects - arising as a result of the direct effect, and include the impacts of activities facilitated by a project, including reasonably foreseeable impacts from downstream users.

The cumulative impact assessment only considered the impacts from planned activities during Dorado Phase 1 and third-party activities. Unplanned events, such as hydrocarbon spills, are not intended to occur at any time during Dorado Phase 1 and hence have not been assessed.

Santos has considered all third-party activities that are known to occur, or are reasonably expected to occur, in the Project Area during Dorado Phase 1 based on the information available to Santos during the preparation of this OPP. Santos has made a reasonable effort to identify credible third-party activities, but acknowledges that there is the potential for future activities to occur within the Project Area may not be considered as they are unknown or due to the inherent uncertainty of the future. The activity-specific EPs that will be prepared subsequent to this OPP will provide an opportunity to undertake additional cumulative impact assessments that consider activities known to, or reasonably expected to, occur in the future that are identified at a later date.

7.4.1 Cumulative Impact Assessment Methodology

The cumulative impact assessment methodology is aligned with Santos' method for evaluating environmental impacts and risks (**Section 7.1**). The steps for the cumulative impact assessment process are shown in **Figure 7-62** each step is described further below.

7.4.1.1 Describe the Aspects of Dorado Phase 1 and Third-party Activities

Each of the planned aspects of Dorado Phase 1 was reviewed to identify the environmental receptors that may credibly be impacted. These environmental impacts for these planned activities are assessed in **Section 7.2**.

Third-party activities that are known to occur, or are reasonably expected to occur, within the area were identified. Methods used to identify third-party activities include:

- Consultation undertaken by Santos for Dorado Phase 1 and previous petroleum activities in the Bedout Basin;
- Santos' operational experience in undertaking previous petroleum activities in the Bedout Basin;
- Reviewing of publicly available data (e.g. AMSA's craft tracking system, fisheries reports etc.);

- Review of regulatory submission websites, including for submissions under the EPBC Act and OPGGS Act; and
- Predicting future activities that may reasonably occur based on Santos' knowledge of the known resources and existing uses in the Project Area.

Third-party activities and aspects that were identified as potentially contributing to cumulative environmental impacts are summarised in **Table 7-101**.

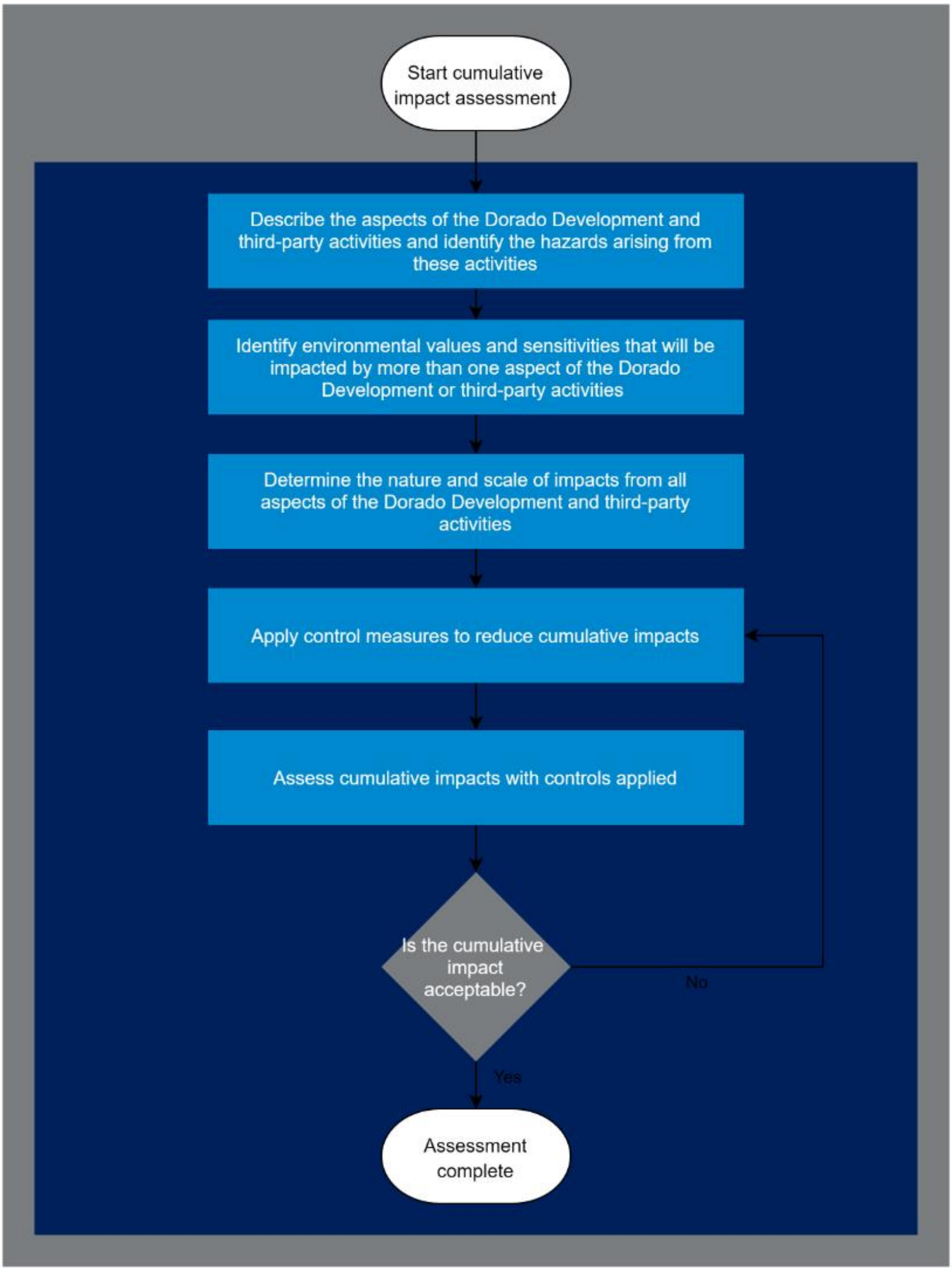


Figure 7-62: Cumulative environmental impact and risk assessment process

Table 7-101:Third-party activities and aspects that may contribute to cumulative impacts of Dorado Phase 1

Third-party Activities	Aspects
Commercial Shipping	+ wastewater discharges + light emissions + acoustic emissions + atmospheric emissions
Commercial Fishing	+ wastewater discharges + light emissions + acoustic emissions + atmospheric emissions + seabed disturbance
Oil and Gas Exploration	+ wastewater discharges + light emissions + acoustic emissions + atmospheric emissions

Activities that occur in the same location (i.e. space crowding) and at the same time (i.e. time crowding) have greater potential to cause cumulative impacts. To identify activities in the same location, the spatial extent of aspects from Dorado Phase 1 and third-party activities were compared. Aspects that were identified as occurring in the same location were further assessed to determine their relative timing.

7.4.1.2 Identify Environmental Values and Sensitivities

Environmental values and sensitivities were identified based on the nature and scale of the environmental aspects of Dorado Phase 1 and third-party activities. The methods used to identify these are described in **Section 7.1**; the environmental values and sensitivities are described in **Section 3**. The potential interactions between environmental values and sensitivities and aspects of Dorado Development and third-party activities are shown in **Table 7-102.**

7.4.1.3 Determine Nature and Scale of Impacts

The methods used to determine the nature and scale of impacts to environmental values and sensitivities is described in **Section 7.1**. The nature and scale of environmental impacts to these receptors from planned activities during Dorado Phase 1 are described in **Section7.2**. This process was also applied to aspects of third-party activities, with the nature and scale of impacts from third-party activities considered in the cumulative impact assessment (**Section 7.4.2**).

All aspects from Dorado Phase 1 and third-party activities that may impact upon a single receptor were considered together to identify the potential for:

+ space crowding;
+ time crowding;
+ interactive effects; and
+ indirect effects.

7.4.1.4 Apply Control Measures

Control measures were considered once the nature and scale of cumulative impacts had been assessed. This was done in the same manner as the assessment of impacts and risk from Dorado Phase 1. Refer to **Section 7.1** for further information.

7.4.1.5 Assess Cumulative Impacts

The cumulative impacts from aspects of Dorado Phase 1 and third-party activities were assessed using the Santos risk matrix (**Table 7-2**). As per the planned impacts from Dorado Phase 1, only consequence was assessed for cumulative impacts. The resulting consequence was then compared to Santos' acceptable levels of impact, including receptor-specific acceptable levels of impact described in **Section 4**. All cumulative impacts were deemed to be acceptable with the controls identified in the impact assessment of planned activities.

Table 7-102:Environmental values and sensitivities that may be subject to cumulative impacts

Receptor		Dorado Development Aspects										Third Party Activities		
		Drill Cuttings and Fluids	PW Discharges	Wastewater Discharges	Light Emissions	Acoustic Emissions	GHG Emissions	Atmospheric Emission	Interactions with Other Users	Seabed Disturbance	Waste Management	Commercial Shipping	Petroleum Exploration	Fishing
Physical Environment	Bathymetry													
	Climate						✓				✓	✓	✓	✓
	Oceanography													
	Water Quality	✓	✓	✓						✓		✓	✓	✓
	Sediment Quality	✓	✓	✓						✓				
	Air Quality							✓			✓	✓	✓	✓
	Acoustic Environment					✓						✓	✓	✓
Biological Environment	Communities and Habitats	✓			✓	✓				✓	✓			✓
	Fishes	✓	✓	✓	✓	✓				✓			✓	✓
	Marine Mammals	✓			✓	✓							✓	✓
	Reptiles	✓			✓	✓								✓
	Birds				✓									
Socio-economic	Regional Centres													
	Protected Areas													

Receptor		Dorado Development Aspects										Third Party Activities		
		Drill Cuttings and Fluids	PW Discharges	Wastewater Discharges	Light Emissions	Acoustic Emissions	GHG Emissions	Atmospheric Emission	Interactions with Other Users	Seabed Disturbance	Waste Management	Commercial Shipping	Petroleum Exploration	Fishing
	Fisheries					✓			✓		✓			
	Heritage													
	Tourism													
	Maritime Industry								✓					
	Defence													

7.4.2 Cumulative Impact Assessment

The following environmental values and sensitivities were identified as potentially being affected by cumulative impacts.

Physical environment:

- Climate;
- Water quality;
- Sediment quality;
- Air quality; and
- Acoustic environment.
- Biological environment:
- Communities and habitats; and
- Marine fauna (fishes, marine mammals, reptiles, and birds).

Socio-economic environment:

- Fisheries; and
- Maritime industry.

Cumulative impacts to each of these receptors are considered below.

7.4.2.1 Climate

Climate change as a result of GHG emissions is a cumulative impact resulting from anthropogenic emissions from a range of sources. A detailed cumulative impact assessment of GHG emissions from Dorado Phase 1 is provided in **Section 7.2.6.**

7.4.2.2 Water Quality

Aspects of Dorado Phase 1 that may impact water quality include:

- drill cuttings and fluids;
- PW discharge;
- wastewater discharges; and
- seabed disturbance.

Third-party activities that may impact upon water quality include wastewater discharges from commercial shipping, commercial fishing and petroleum exploration activities.

Potential impacts to water quality from the discharge of drill cuttings and fluids are predicted to be localised to the discharge location (**Section 7.2.1**). Drill cuttings and fluids during the initial development drilling stage will not occur at the same time as PW discharges, and water quality is expected to recover quickly once discharges of drill cuttings and fluids cease. Infill and tieback drilling discharges are not expected to interact with wastewater discharges or PW discharges to result in cumulative impacts to water quality, as these activities will occur away from the FPSO, where the discharges will occur. On this basis, cumulative impacts to water quality from the discharge of drilling cuttings and fluids and other aspects of Dorado Phase 1 are not expected to occur. The discharge of drill cuttings and fluids will occur at the Dorado WHP only once the jacket and the Dorado WHP foundation piles are in place and therefore no water quality cumulative impacts are expected. Then only seabed disturbance which could interact with the discharge of drill cuttings and fluids, is the installation of the flowlines and umbilicals near the Dorado WHP. These activities will generate small amounts of suspended sediments and are not expected to significantly add to or modify the drill cuttings and fluids impacts.

PW and wastewater discharges from the FPSO will occur throughout the operational stage of Dorado Phase 1 (**Sections 7.2.2** and **7.2.3**). Potential contaminants in the PW and wastewater discharge streams are unlikely to interact synergistically, as only trace amounts of chemicals are expected to be present in wastewater discharges. The main trace chemical in wastewater discharges is expected to be residual biocide (chlorine or copper), neither of which are known to interact synergistically with potential contaminants in the PW at the concentrations that will occur. As such, cumulative impacts from PW and wastewater discharges are expected to be additive in nature only.

Impacts to water quality from seabed disturbance of Dorado Phase 1 are likely to be restricted to very localised sediment plumes during deployment and recovery of MODU spud cans, project vessel and semi-submersible MODU anchors and moorings, installation of the Dorado WHP foundation piles, FPSO piles and mooring lines, and installation of the subsea system (**Section 7.2.1**).

Decommissioning activities are expected to have the same level of suspended sediments and increased turbidity levels as during installation. Sediment plumes from these activities may result in a slight and temporary decrease in water quality due to increase in suspended sediments close to the point of disturbance. Due to their location in the water column seabed disturbance (in the lower layer near the seabed) and PW and wastewater plumes (upper 15 m of the water column) are not expected to interact with each other.

Impacts to water quality from third-party activities (e.g. wastewater discharges from commercial shipping and fishing vessels) are expected to be highly localised, temporary and present a small environmental risk. (**Section 7.2.3**). Given the localised impacts to water quality from Dorado Phase 1 and third-party activities and the spatial separation of discharges due to exclusion zones and PSZ, cumulative impacts from additive and synergistic effects of impacts to water quality from Dorado Phase 1 and third-party activities are not predicted to occur.

Based on the assessment presented above, cumulative impacts to water quality are considered to be minor. An assessment of cumulative impacts against the acceptable levels of impact for water quality is provided in **Table 7-103**.

Table 7-103: Demonstration of acceptability of cumulative impacts to water quality from Dorado Phase 1 and third-party activities

Acceptable levels of Impact	Demonstration of Acceptability
RSAL3: Impacts to water quality that do not result in a loss of ecological integrity[54] are acceptable. **RSAL4**: Substantial[55] impacts to water quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	The separation of several discharge streams in space and time means the environment will assimilate these impacts before cumulative impacts will occur. PW and wastewater discharges from the FPSO are crowded in space and time, however they are not expected to interact synergistically, only additively. The additive impacts of PW and wastewater discharges will be minor and will not exceed the defined receptor-specific acceptable levels.

7.4.2.3 Sediment Quality

Aspects of Dorado Phase 1 that may impact sediment quality include:

- drill cuttings and fluids;
- PW discharges;
- wastewater discharges; and
- seabed disturbance.

Third-party activities within the Project Area could have a potential impact on sediment quality through the discharge of wastewater from commercial shipping and fishing vessels and the trawling of fishing gear on the seabed. No detectable impact is expected from the discharge of wastewater (**Section 7.2.3**). While the trawling of fishing gear may disturb and resuspend the top layer of the seabed being trawled, it is not expected to impact the quality of the sediment (no chemical changes or long-term particle size change). As such, cumulative impacts from Dorado Phase 1 and third-party activities are not expected to occur.

Impacts to sediments from the discharge of drill cuttings and fluids will be concentrated around the Dorado WHP and any future tieback locations, which could be some distance from the Dorado WHP. Hence, impacts to sediment quality from drill cuttings and fluids will be separated from impacts to sediments from PW and wastewater discharges, which will be concentrated around the FPSO. (**Sections 7.2.1**, **7.2.2** and **7.2.3**). As such, cumulative impacts from space crowding of sediment impacts is more likely to occur around the FPSO. Synergistic effects from impacts to sediment quality from PW and wastewater discharges are not expected to occur, although additive effects may occur. As impacts to sediments from PW discharges and wastewater discharges are predicted to be very minor, any additive effects are also expected to be minor.

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[54] Ecological integrity is generally referred to as the self-sustaining nature of a natural ecosystem, including ecological processes and biological communities. An ecosystem is considered to have ecological integrity if the natural ecological processes are intact and self-sustaining, the ecosystem evolves naturally and its capacity for self-renewal is maintained; and the ecosystem's biodiversity is ensured (Office of the Auditor General of British Columbia 2010).

[55] Substantial - Substantial impacts are considered to be an exceedance of the 95% species protection levels for water quality or the default guideline value (high) for sediments for contaminants in the PW derived from either Australian and New Zealand guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines.

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Impacts to sediments from the discharge of drill cuttings and fluids tend to be relatively long-term, with assimilation of impacts to sediment (e.g. reductions in concentrations of potential contaminants) expected to occur over years (**Section 7.2.1**). While this may increase the risk of cumulative impacts due to time crowding, no other aspects of Dorado Phase 1 are expected to impact upon sediments within the area impacted by drill cuttings and fluids. Therefore, cumulative impacts to sediments from drill cuttings and other aspects that may impact upon sediments are not expected to occur.

Impacts to sediments from seabed disturbance are predicted to be restricted to modification of particle size distribution **(Section 7.2.9**). This impact will not credibly result in cumulative impacts to sediment quality.

Based on the assessment presented above, cumulative impacts to sediment quality are considered to be minor. An assessment of cumulative impacts against the acceptable levels of impact for sediment quality is provided in **Table 7-104.**

Table 7-104:Demonstration of acceptability of cumulative impacts to sediment quality from Dorado Phase 1 and third-party activities

Acceptable levels of Impact	Demonstration of Acceptability
RSAL5: Impacts to sediment quality that do not result in a loss of ecological integrity are acceptable. **RSAL6**: Substantial impacts to sediment quality within 1 km of the WHP, FPSO and drilling activities are acceptable.	The greatest potential for cumulative impacts to sediment quality is expected to be around the FPSO due to PW and wastewater discharges. These impacts are expected to be very minor and result in additive cumulative impacts. Cumulative impacts to sediments from other aspects of Dorado Phase 1 or third-party activities are not expected to occur. Hence, cumulative impacts to sediment quality are predicted to be within acceptable levels.

7.4.2.4 Air Quality

Cumulative impacts to air quality may occur as a result of atmospheric emissions (excluding GHG emissions, refer to **Section 7.4.2.1** for consideration of GHG emissions) during Dorado Phase 1 and from commercial shipping, fishing vessels and petroleum activities (**Section 7.2.7**). Atmospheric emissions from Dorado Phase 1 may occur from sources such as combustion engine emissions, flaring and venting, resulting in emissions of:

+ nitrogen oxides (NO_x);
+ sulphur oxides (SO_x);
+ CO;
+ VOCs; and
+ particulate matter of differing size classes.

Third-party emissions are expected to be primarily form commercial shipping in the region, which is concentrated within the shipping fairways designated by AMSA. Commercial fishing and other petroleum activities may make minor contributions to atmospheric emissions in the Project Area. Emissions from the third-party activities are expected to be similar to those listed above for Dorado Phase 1.

The air shed in the Project Area is far offshore and is not constrained. The environment is expected to have a high capacity to assimilate the impacts to air quality from Dorado Phase 1 and third-party activities. As such, cumulative impacts to air quality from Dorado Phase 1 and third-party activities are not expected to occur. No assessment of cumulative impacts to air quality against the acceptable levels of impact to air quality is required.

7.4.2.5 Acoustic Environment

Notable sources of acoustic emissions from Dorado Phase 1, inclusive of future tiebacks, include:

- piling;
- 3-D vertical seismic profiling (3-D VSP);
- vertical seismic profiling of wells (drilling VSP);
- thruster noise from the FPSO; and
- vessel noise.

These are described in detail in **Section 7.2.5**. These noise sources are typically separated in time, with:

- piling occurring during installation activities;
- 3-D VSP occurring after installation activities, prior to start up and possibly repeated at 2-to-3-year intervals during production;
- Drilling VSP occurring during production drilling activities;
- FPSO thruster noise occurring primarily during offtakes in the operational stage; and
- vessel noise occurring throughout all stages of Dorado Phase 1, but is relatively less intense than piling, vertical seismic profiling or the FPSO thruster noise.

Third-party activities with the potential to generate acoustic emissions that may result in cumulative impacts include commercial shipping and petroleum exploration (particularly seismic surveys). Commercial fishing vessels will also generate acoustic emissions due to vessel noise; the intermittent nature and low intensity of these emissions results in a negligible potential for cumulative impacts.

Impacts from acoustic emissions, such as behavioural disturbance of marine fauna or some mortality of planktonic organisms, typically persist for the duration of the acoustic emission. Receptors impacted by acoustic emissions are expected to recover rapidly once the acoustic emissions are ceased. On this basis, the environment has a high capacity to recover from underwater noise impacts.

While acoustic emissions from Dorado Phase 1 are space crowded around the Dorado WHP and FPSO locations and potential future tieback locations, the separation of high intensity acoustic emissions in time, along with the capacity for the environment to recover between emissions, supports the ranking of minor for cumulative impacts from acoustic emissions from Dorado Phase 1.

Commercial shipping noise occurs frequently in the vicinity of the Project Area due to iron ore carrier movements to and from Port Hedland. These vessels frequently transit the shipping fairways around the Project Area and contribute to the anthropogenic underwater noise in the region. The acoustic emissions from Dorado Phase 1 after installation and production drilling will be a relatively small increase over this background noise and will be generally similar in nature.

Seismic surveys generate high intensity acoustic emissions. Seismic surveys could occur within or in close vicinity of the Project Area, which would result in acoustic emissions in and around the Project Area. Santos is aware that there are seismic surveys that overlap the Project Area, which have accepted EPs, or EPs in assessment and are intended to be acquired in the period 2021 to 2024. These surveys include:

- Keraudren Extension Survey, activity prior to December 2022;
- Rollo multi-client 3-D Survey, activity prior to October 2023; and
- Capreolus-2 3-D Survey, activity between 2020 and 2024.

The Keraudren Extension survey would be completed prior to activities commencing in the Dorado Project Area.

The Rollo multi-client 3-D Survey covers a large area across the Carnarvon Basin including overlap with the Dorado Project Area and has the potential to overlap in timing with piling activities, however, given the interference that noise emissions from piling would have on seismic interpretation it is highly unlikely that this would occur concurrently in close proximity to each other. The Capreolus-2 3-D Survey does overlap the Dorado Project Area, but does not spatially overlap with the Dorado reservoir, WHP foundation or FPSO mooring piles. There is potential for acoustic emissions from the Capreolus-2 3-D survey to occur at the same time as the installation and development drilling activities for Dorado Phase 1.

Third party seismic surveys such as the Capreolus and Rollo surveys will require authority from Santos to access WA-437-P and WA 438-P and therefore the Project Area, via an access authority agreement. Santos acknowledges that acoustic emissions from beyond the Project Area, such as seismic surveys, have the potential to result in cumulative impacts to receptors within the Project Area.

Given there is potential for the Capreolus and Rollo seismic surveys to be undertaken at the same time as installation and development drilling activities for Dorado Phase 1 some cumulative impacts may occur resulting in disturbance to marine receptors in this location. To reduce potential cumulative impacts, Santos will impose a corridor of 40 km between the Dorado WHP/FPSO locations and sources of simultaneous seismic surveys. The corridor width was established by the Bureau of Ocean Energy Management in the published environmental review of geological and geophysical survey activities in the south Atlantic Ocean (Bureau of Ocean Energy Management 2014) where, to minimise potential impacts to marine fauna, based on a worst-case scenario a 40 km geographic separation distance between sources of simultaneous seismic surveys was adopted. Adopting a 40 km width corridor is considered conservative as the ranges at which potential PTS and TTS injury to pygmy blue whales from Dorado drilling and installation activities may occur are substantially less than 40 km (**Table 7-35**). This space separation is also consistent with some seismic survey EPs on the NWS. With this control in place, it is expected that potentially affected ecological receptors would recover from the effects of concurrent seismic survey activity and Dorado Development activities within days to months of completion of the seismic survey.

The Sauropod 3D seismic survey proposed by CGG, with an operational area adjacent to Dorado Project Area in WA-527-P, was accepted by NOPSEMA in February 2022. Planned activity is scheduled to take place between January and May in 2022 so will not overlap in time with Dorado Development activities.

Santos Bedout Multi-Well Drilling EP was accepted by NOPSEMA on 20 December 2021 and allows for the drilling of up to 8 exploration wells within permits WA-437-P and WA-439-P within a 5 year window from the date of acceptance of the EP. Thus, it is possible that exploration drilling in these permits could take place during the installation of the piles for the Dorado WHP and FPSO and production drilling. The closest distance between the Dorado WHP (relevant for drilling VSP and vessel noise sources) and the Dorado FPSO (relevant for piling and vessel noise sources) is 21 km and 19.6 km respectively. Acoustic emissions from vessels associated with exploration and appraisal drilling had physiological and behavioural impacts to low frequency cetaceans predicted at 12 m for PTS onset threshold, 266 m for TTS onset threshold and within 1,200 m for the behavioural onset threshold. VSP associated with exploration and appraisal drilling, conducted over a period of up to 18 hours, results in onset thresholds for PTS and TTS of 260 m and behavioural response at 2.42 km. Given these distances, the only overlapping thresholds for exploration drilling and Dorado Phase 1 activities is TTS during PSO piling activities. However, given the short duration of VSP and the commitment to implementing controls aligned with Part A of EPBC Act Policy Statement 2.1 in the Bedout Multi-Well Drilling EP (BD-CM-018) and in the Dorado OPP (CM-18), cumulative impacts are not predicted for low frequency cetaceans such as humpback and pygmy blue whales.

Future tiebacks within the Project Area are not proposed to be developed prior to the ready for start-up date in 2027; and, at this stage, seismic surveys that may overlap or occur adjacent to the Project Area beyond December 2023 are unknown. The Bedout Basin may be subject to future seismic surveys as it is a prospective petroleum basin. However, the nature and timing of future surveys is unknown at this time and hence has not been considered in this cumulative impact assessment.

The current ambient underwater acoustic emissions near the Dorado WHP and FPSO sites for all functional cetacean hearing groups receive at least an SEL of approximately 150 dB re 1 µPa2 ·s (Lucke et al, 2022) including noise from vessel traffic in the shipping lanes. The continuous operational noises contributed by operational activities during Dorado Phase 1 are not adding significantly to ambient conditions across the Dorado Project Area.

Based on the considerations above, cumulative impacts to the acoustic environment from Dorado Phase 1 and third-party activities will be minor. An assessment of cumulative impacts against the acceptable levels of impact for the acoustic environment is provided in **Table 7-105**.

Table 7-105:Demonstration of acceptability of cumulative impacts to the acoustic environment from Dorado Phase 1 and third-party activities

Acceptable levels of Impact	Demonstration of Acceptability
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1. **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL15:** No injury to pygmy blue whales in a pygmy blue whale BIA. **RSAL16**: No significant impacts to EPBC listed threatened, migratory or cetacean species under the EPBC Act as a result of Dorado Phase 1.	The cumulative impacts of acoustic emissions from Dorado Phase 1 and third-party activities will not result in PTS or TTS injury to pygmy blue whales in a pygmy blue whale BIA or significant impacts to EPBC listed threatened, migratory or cetacean species, due to temporal and spatial distancing between activities as well as the application of temporal controls where modelling shows PTS or TTS impacts in the pygmy blue whale BIA; and piling, drilling VSP and 3-D VSP activity controls aligned with Part A of the EPBC Act Policy Statement 2.1. Nor will it result in significant behavioural impacts to noise-sensitive marine fauna. On this basis, cumulative impacts to the acoustic environment are acceptable. The objectives of relevant conservation advices and recovery plans (as presented in **Section 7.2.5**) were considered during the cumulative impacts assessment. With the addition of the above control measure, the concurrent activities are not inconsistent with these objectives.

7.4.2.6 Artificial Light

Light emissions from the project will be associated with lighting of drilling rigs, project vessels and facilities for operational and safety requirements within the Project Area. Based on the worst-case scenario (Operational flaring) the flare is no longer directly visible at 42.4 km, when the flare drops below the horizon. At this distance, the radiance is equivalent to 0.25 full moons. As the flare drops below the horizon, radiance declines rapidly and is no longer visible. To inform the cumulative impact assessment for light impacts, the distance of 42.4 km is used.

Third-party activities with the potential to generate light emissions that may result in cumulative impacts include commercial shipping and petroleum activity. Light emissions from Commercial fishing vessels within the cumulative assessment envelope for artificial light will be intermittent and low intensity resulting in a minor potential for cumulative impacts.

Maritime industry within the cumulative assessment envelope consists of commercial shipping, which is largely restricted to shipping fairways. The Dorado WHP and FPSO locations are over 10 km from the nearest shipping fairway (within the cumulative assessment envelope for artificial light). Commercial shipping and project vessels undertaking Dorado Phase 1 are all required to comply with international and Australian maritime requirements, which include requirements for safe navigation and lighting. The maritime industry addition to light emissions from vessel transit is intermittent and low intensity resulting in a minor potential for cumulative impacts.

Based on the considerations above, cumulative impacts from artificial lighting from Dorado Phase 1 and third-party activities will be minor. An assessment of cumulative impacts against the acceptable levels of impact for the light emissions is provided in **Table 7-106.** The cumulative impact assessment for light impacting marine fauna further considered in **Section 7.4.2.8.**

Table 7-106:Demonstration of acceptability of cumulative impacts from artificial light from Dorado Phase 1 and third-party activities

Receptor-specific Acceptable Levels	Justification
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	The assessment of cumulative impacts and risks from artificial light emissions predicts impacts to threatened or migratory species will be limited to minor, temporary behavioural changes (e.g. attraction, avoidance etc.) that will have no effect on populations of these species. Mortality of individual animals as a result of cumulative artificial light emissions is not expected to occur. Significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur. Areas of importance for species, such as Ramsar sites and turtle nesting beaches, will not credibly be impacted by artificial light emissions from Dorado Phase 1. The objectives of relevant conservation advices and recovery plans (as presented in **Section 7.2.4**) were considered during the cumulative impacts assessment. Concurrent activities are not inconsistent with these objectives.

7.4.2.7 Communities and Habitats

Benthic communities and habitats may be impacted by Dorado Phase 1 as a result of:

+ the discharge of drill cuttings and fluids;
+ seabed disturbance during installation; and
+ decommissioning in situ (waste management).

Third-party activities that may impact upon benthic communities and habitats consist of fishing, particular bottom trawl fishing. Trawl fishing has historically occurred, and continues to occur, within the Project Area. (**Section 3.4.3**). Trawl fishing disturbs benthic habitats by removing epibenthic biota, such as sponges, corals and gorgonians. Trawl fishing will not be permitted within the exclusion zones and PSZs that will be introduced during Dorado Phase 1. As most seabed disturbance from Dorado Phase 1 will be within these zones, impacts to benthic habitats and communities from Dorado Phase 1 and trawl fishing will not be space crowded. Hence, cumulative impacts to benthic habitats and communities will be negligible.

The seabed within the Project Area is largely bare sediment, with some areas of hard substrate. These habitats are well represented in the region and are not considered to be sensitive habitats (**Section 3.3.1**). Seabed disturbance from Dorado Phase 1 will be concentrated around the Dorado WHP and FPSO, and will be localised to these locations. The construction and potential *in situ* decommissioning of Dorado Phase 1 facilities will create an artificial reef, which may enhance biodiversity within the Project Area. Conversely, the removal of the facilities would result in small scale, temporary seabed disturbance (**Section 7.2.9**). Cumulative impacts to benthic habitats and communities from Dorado Phase 1 are not expected to be of significance.

Based on the considerations above, cumulative impacts on communities and habitats from Dorado Phase 1 and third-party activities will be minor. An assessment of cumulative impacts against the acceptable levels of impact to communities and habitats is provided in **Table 7-107**.

Table 7-107:Demonstration of acceptability of cumulative impacts to communities and habitats from Dorado Phase 1 and third-party activities

Acceptable levels of Impact	Demonstration of Acceptability
RSAL8: No significant[56] impacts to benthic habitats and communities. **RSAL9**: No direct disturbance to sensitive benthic habitats and communities.	Cumulative impacts to benthic communities from Dorado Phase 1 and third-party activities will not result in significant impacts to benthic habitats or direct disturbance to sensitive benthic habitats and communities. Benthic habitats in the Project Area are largely bare sediment and small areas of hard substrate. These habitats are broadly represented in the region and are not considered to be sensitive or unique. Hence, cumulative impacts to benthic habitats and communities are acceptable.

7.4.2.8 Marine Fauna

Marine fauna, such as fishes, marine mammals, reptiles and birds, may be impacted by aspects of Dorado Phase 1 such as:

+ drill cuttings and fluids;
+ PW discharges;
+ wastewater discharges;
+ light emissions; and
+ acoustic emissions.

Third-party activities in the Project Area are limited to commercial shipping, commercial fishing and petroleum exploration. Risks to marine fauna from these activities is low, and the aspects of these activities are not predicted to interact synergistically with aspects of Dorado Phase 1. These third-party activities will typically be separated in space from Dorado Phase 1. Hence, cumulative impacts to marine fauna as a result of Dorado Phase 1 and third-party activities is considered to be minor.

Impacts to fauna from discharges to the marine environment, such as PW, wastewater discharges and drill cuttings and fluids are predicted to be highly localised. The discharge of drill cuttings and fluids will be separated in time from PW discharges and the majority of wastewater discharges, reducing the potential for cumulative impacts. As outlined in the cumulative impact assessment for water quality (**Section 7.4.2.2**), PW and wastewater discharges are not expected to interact synergistically and any cumulative impacts are expected to be limited to within the mixing zone around the discharge location. Impacts to marine fauna are expected to be limited to behavioural disturbance, such as avoidance of discharge of the nearfield area of plumes.

Light emissions during flaring may be visible 42.4 km from the FPSO, at which point the flare drops below the horizon (**Section 7.2.4**). There are no third-party light sources within this radius aside from lighting associated with commercial shipping and commercial fishing, which are relatively low intensity and transient in nature. Hence cumulative impacts of lighting form Dorado Phase 1 and third-party activities are minor.

[56] Significant - As defined by the Commonwealth marine environment significant impact criteria in Matters of National Environmental Significance - Significant impact guidelines 1.1. *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment 2013).

Cumulative impacts from acoustic emissions to marine fauna are considered above in **Section 7.4.2.5**.

When considering all aspects of Dorado Phase 1 that may impact upon marine fauna, there is the potential for cumulative impacts to occur as many aspects are space or time crowded. However, when considering the nature and scale of the impacts that may arise from these aspects, potential impacts to fauna will be concentrated around discharge locations (i.e. the Dorado WHP and FPSO) and are expected to be limited to avoidance of the nearfield discharge plumes. These impacts are not expected to persist beyond 1 km from the discharge location. While light and acoustic emissions may extend for considerable distances form the FPSO and Dorado WHP, they are expected to impact upon fauna in different ways. Fauna considered vulnerable to impacts from artificial light emissions, such as roosting birds and nesting and hatchling turtles, are not particularly vulnerable to acoustic emissions. Likewise, fauna vulnerable to impacts from acoustic emissions, such as marine mammals, are not particularly vulnerable to artificial light emissions. Hence, cumulative impacts to marine fauna from Dorado Phase 1 are considered to be minor.

Based on the considerations above, cumulative impacts to marine fauna from Dorado Phase 1 and third-party activities, such as commercial shipping and petroleum exploration, will be minor. An assessment of cumulative impacts to marine fauna against the acceptable levels of impact is provided in **Table 7-108.**

Table 7-108: Demonstration of acceptability of cumulative impacts to marine fauna from Dorado Phase 1 and third-party activities

Acceptable levels of Impact	Demonstration of Acceptability
RSAL13: No mortality of EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 **RSAL14**: Management of aspects of Dorado Phase 1 must not be inconsistent with relevant conservation advice, recovery plans and threat abatement plans published by the DAWE. **RSAL16**: No significant impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1.	Cumulative impacts to marine fauna from Dorado Phase 1 and third-party activities will not result in mortality or significant impacts to species listed as threatened or migratory under the EPBC Act. Santos' proposed management of the aspects of Dorado Phase 1 that may impact upon marine fauna are consistent with conservation advice, recovery plans and threat abatement plans published under the EPBC Act (refer to aspect-specific assessments for further details). The cumulative impacts of acoustic emissions from Dorado Phase 1 and third-party activities will not result in PTS or TTS to sensitive marine fauna due to temporal and spatial distancing between activities as well as the application of control measures (alignment with Part A of the EPBC Act Policy Statement 2.1 for piling and VSP activities associated with Dorado and VSP activities associated with exploration drilling). Nor will it result in significant behavioural impacts to noise-sensitive marine fauna The objectives of relevant conservation advices and recovery plans (as presented in **Section7.2.5**) were considered during the cumulative impacts assessment. With the addition of the above control

	measure, the concurrent activities are not inconsistent with these objectives.

7.4.2.9 Fisheries

Aspects of Dorado Phase 1 that may impact upon fisheries and commercial fishing include:

- acoustic emissions;
- interactions with other users; and
- decommissioning *in situ* (if undertaken).

Seismic surveys presented in **Section 7.4.2.5** are the known third-party activities within the Project Area, which Santos is aware of that may have an impact on fisheries. The expected potential impacts on fish from acoustic emissions, such as behavioural disturbance, typically persist for the duration of the acoustic emission, and impacted fish are expected to recover rapidly once the acoustic emissions are ceased.

Acoustic emissions from Dorado Phase 1 are not expected to result in impacts to fish resources or commercial fishers. Impacts to fish are only expected to occur as a result of relatively high intensity noise emissions, such as piling and vertical seismic profiling. These emissions are temporary in nature, and impacts are expected to consist of short-term behavioural impacts to individual fish such as avoidance. No impacts to the fish resource as a whole, such as a reduction in the biomass, age structure or catchability of the fish resources, will occur.

Dorado Phase 1 will result in exclusion of commercial fishers from the gazetted PSZs around the Dorado WHP and FPSO as well as the necessary additional deviations area for trawl fishing to avoid the PSZs. Most commercial fisheries in the region have little or no historical fishing activity overlapping the Dorado WHP and the FPSO, with the exception for the Pilbara Fish Trawl Interim Managed Fish (**Section 3.4.3**). The areas from which commercial fishing will be excluded from is a small portion of the total area of the managed fishery (**Section 7.2.8**). Commercial fishers will have to plan trawl lines to avoid the exclusion zones and PSZs in place for Dorado Development activities. Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations, therefore trawl fishers will have prior knowledge of the activities and their proposed timings. The PSZ for the Dorado WHP and FPSO will be gazetted and the Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation activities.

The *in situ* decommissioning of Dorado Phase 1 facilities may result in an increase in the abundance and diversity of fish resources, which may result in a net increase in the fish resources available to the fishery. Conversely, the removal of the structures after decades in place may result in a net decrease in the fish resources available to the fishery. Note, decommissioning options have not been determined for Dorado Phase 1.

Based on the considerations above, cumulative impacts to fisheries from Dorado Phase 1 will be minor. An assessment of cumulative impacts to fisheries against the acceptable levels of impact is provided in **Table 7-109.**

Table 7-109: Demonstration of acceptability of cumulative impacts to fisheries from Dorado Phase 1

Acceptable levels of Impact	Demonstration of Acceptability
RSAL19: No negative impacts to the economic viability of the commercial fish resources. **RSAL20**: Short-term displacement of commercial fishing activities from exclusion zones during Project installation/drilling operations within the Project Area is acceptable. **RSAL21**: Long-term exclusion (up to 20 years) of commercial fishing activities from the gazetted PSZ during production operations is acceptable.	Cumulative impacts from Dorado Phase 1 will not result in impacts to the exploited fisheries resource stocks in the Project Area. Hence, impacts are considered to be acceptable.

7.4.2.10 Maritime Industry

Maritime industry in the Project Area consists of commercial shipping, which is largely restricted to shipping fairways. The Dorado WHP and FPSO locations are over 10 km from the nearest shipping fairway, and hence are separated in space from commercial shipping. Commercial shipping and project vessels undertaking Dorado Phase 1 are all required to comply with international and Australian maritime requirements, which include requirements for safe navigation. Compliance with these requirements will reduce the potential for impacts to commercial shipping from aspects of Dorado Phase 1. On this basis, cumulative impacts to maritime industry as a result of Dorado Phase 1 are not considered to be credible.

8 Environmental Performance Framework

The OPP has defined the activities which will be undertaken during the duration of the Dorado project (**Section 6**) and the acceptable levels of the risks and impacts which will arise from the implementation of Dorado Phase 1 (**Section 4**). The OPP also defines EPOs for the petroleum activities within the scope of the OPP. Santos will ensure environmental impacts and risks will be maintained within acceptable levels, and EPOs achieved, through its environmental performance framework as detailed below.

8.1 Santos Management System

The Santos Management System exists to support its moral, professional and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The Santos Management System is a framework of policies, standards, processes, procedures, tools and control measures that, when used together by a properly resourced and competent organisation, result in:

+ a common environmental approach is followed across the organisation;
+ environmental management is proactively managed and maintained;
+ the mandatory requirements of environmental management are implemented and auditable;
+ workforce commitments are understood and demonstrated;
+ environmental management performance is measured and corrective actions are taken; and
+ opportunities for improvement are recognised and implemented.

The Santos Management System is aligned to the requirements of the OPGGS (E) Regulations and requires:

+ environmental impacts and risks continue to be identified for the duration of the activity and reduced to ALARP;
+ control measures are effective in reducing environmental impacts and risks to ALARP and acceptable levels;
+ EPOs and environmental performance standards set out in EPs are met; and
+ stakeholder consultation is maintained throughout the activity as appropriate.

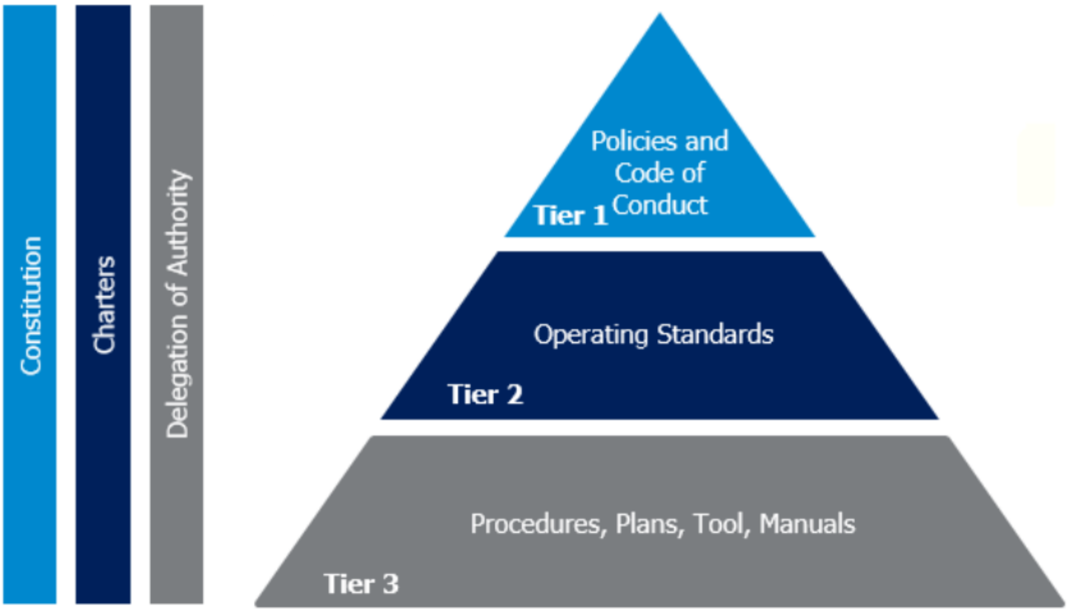

Figure 8-1: Santos management system hierarchy.

8.1.1 Santos' Environment, Health and Safety Policy

Santos' Environment, Health and Safety Management Policy (**Figure 8-2**) sets out Santos' commitment to environment, health and safety management and the responsibility to successfully implement this policy. The Dorado Development OPP has been prepared in accordance with the objectives and actions stated in this policy. By accepting employment with Santos, each employee and contractor is made aware during the recruitment process that he or she is responsible for the application of this policy.

Environment, Health & Safety

Santos

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

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Figure 8-2: Santos' environment, health and safety policy

8.1.2 Santos' Climate Change Policy

Santos also has a Climate Change policy, which was most recently reviewed and approved by the Santos' Board in December 2021. Santos' Climate Change policy is reviewed periodically and updated as required.

Santos

Climate Change

Policy

Our Commitment

Santos recognises the scientific consensus of climate change assessed by the Intergovernmental Panel on Climate Change. We support the objective of the Paris Agreement to limit global temperature rise to less than 2 degrees Celsius and pursue efforts to limit the temperature rise to 1.5 degrees Celsius.

We believe that access to reliable and affordable energy is critical to meeting sustainable development goals and improving living standards and economic prosperity in developed and developing nations. Santos is committed to being part of the solution by supporting the twin objectives of limiting greenhouse gas emissions and providing cleaner fuels to domestic and global markets.

Santos has a target of net-zero scope 1 and 2 greenhouse gas emissions by 2040. Our strategy focuses on natural gas as a reliable transition fuel source and the development of technologies such as carbon capture and storage and clean fuels, such as hydrogen, as foundations for our decarbonisation pathway.

Our Actions

We will:

+ Work with governments and stakeholders in the design of climate change regulation and policies in support of low-cost abatement and incentivising innovation and investment in emissions reduction in an equitable manner
+ Factor carbon pricing and greenhouse gas emissions into all material business decision-making
+ Set greenhouse gas emission targets consistent with the objective of limiting global temperature rise to less than 2 degrees Celsius and in pursuit of 1.5 degrees Celsius
+ Identify and pursue opportunities to reduce greenhouse gas emissions within our operations and through the supply chain
+ Work with our customers to reduce their greenhouse gas emissions and sell the products we generate only to customers from countries that have a net-zero commitment or are signatories to the Paris Agreement
+ Avoid any unnecessary flaring from our activities and reduce flaring required for the safe conduct of our operations to as low as reasonably practicable
+ Make Final Investment Decision for new offshore greenfield projects from 2025 only if they abate and/or offset reservoir CO2 emissions
+ Identify and implement cost-effective opportunities to sequester carbon, integrate new technologies and offset greenhouse gas emissions, in pursuit of our emission reduction targets
+ Identify, manage and mitigate climate change risks for our activities and in doing so, continue to adapt and develop our operational, financial and strategic resilience
+ Report annually on the company's climate change governance, strategy, risk management and targets and metrics in a transparent manner in alignment with recommendations of the Task Force on Climate-related Financial Disclosures
+ Provide our shareholders with an advisory vote, known as a 'Say on Climate' at regular intervals.

Governance

The Environment Health Safety & Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher
Managing Director & CEO

Figure 8-3: Santos' Climate Change Policy

8.2 Implementation and Review

8.2.1 Leadership, Accountability and Responsibility

To ensure the effective implementation and management of EPOs identified in this OPP, key roles and responsibilities for Santos employees and contractors will be defined within specific petroleum activity EPs.

Santos employees and contractors will be responsible for implementing the Santos Environment, Health and Safety Policy and Climate Change Policy in their areas of responsibility and ensure they are suitably trained and competent in their respective roles.

It is the responsibility of all Santos employees and contractors to implement the Santos Environment, Health and Safety Policy and Climate Change policy in their areas of responsibility and to ensure personnel are suitably trained and competent in their respective roles. Environmental responsibilities for the Dorado Development include:

- Ensure preparation and implementation of accepted EPs for all Dorado Phase 1 activities;
- Ensure systems and procedures are in place to manage Dorado Phase 1 activities so they are undertaken in accordance with the relevant standards and commitments in the OPP and EPs;
- Communicate environment performance, relevant information and environment expectations to Dorado Phase 1 Project team members and contractors;
- Undertake stakeholder consultation for Dorado Phase 1 activities; and
- Undertake relevant audits/ periodic reviews and inspections of accepted EPs, record evidence of implementation and close out corrective actions in a timely manner.

8.2.2 Environment Plans – Environmental Performance Outcomes (EPOs)

The effective application of EPOs outlined in this OPP will be demonstrated through the implementation of subsequent EPs for petroleum activities within the scope of this OPP. The OPGGS (E) Regulations require that Santos develop and implement EPs for all petroleum activities within the scope of this OPP. Each EP must be assessed and accepted by NOPSEMA prior to Santos commencing the petroleum activities. EPs for activities within the scope of this OPP may not be submitted until this OPP has been accepted by NOPSEMA.

EPs will contain EPOs (these are the EPOs that will be accepted as part of this OPP), environmental performance standards, measurement criteria and a detailed implementation strategy. The EPOs in the EPs will maintain an equivalent level of environmental performance to that stated in this OPP. **Table 8-1** provides a summary of the EPOs and key management controls relevant to each aspect of the Dorado Oil Development.

Each EP for petroleum activities within the scope of this OPP will:

- describe the petroleum activities considered by the EP and their relationship to this OPP;
- describe the environmental values and sensitivities that may be impacted by the petroleum activities;
- describe the relevant requirements that apply to the petroleum activities;
- incorporate as required updates to relevant legislation, guidelines and published scientific papers;
- detail and evaluate the environmental impacts and risks that may credibly occur as a result of the petroleum activities;
- define EPOs, controls, environmental performance standards and measurement criteria for the environmental management of the petroleum activities;
- provide an implementation strategy for the EP, which will include an OPEP; and
- describe the reporting requirements to NOPSEMA that Santos will meet, including:
  - reportable incidents – any incident relating to the activity that has caused, or has the potential to cause, moderate to significant environmental damage;

- recordable incidents – any breach of an EPO or environmental performance standard in the EP that is not a reportable incident;
- environmental performance reporting; the frequency of this reporting is typically 12 months; and
- contain activity-specific consultation outcomes.

Table 8-1: Summary of aspects, EPOs, RSALs and controls that will be implemented throughout Dorado Phase 1

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
Planned Events				
Discharges- Drilling Fluids and Cuttings Discharges (**Section 7.2.1**)	Water Quality	Localised decrease in water quality during drilling operations.	**EPO1A**: Impacts to sediment quality and water quality as a result of Dorado Phase 1 drilling fluids and cuttings discharges restricted to a 1 km radius from Dorado facilities. **EPO2A**: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area. **EPO3A**: No mortality or significant[73] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of drilling fluids and cuttings.	**CM1**: All wells to be drilled using WBM, with NAF only to be used where technical requirements preclude the use of WBM. **CM2**: Santos chemical selection process will be implemented to select drilling chemicals, muds and fluids with low environmental risk, while meeting technical requirements. **CM3**: Drilling fluids inventory will be developed and tracked to reduce discharge of excess powders, brines, and drilling fluids. **CM4**: Drill cuttings will be processed on the MODU to recover drilling fluids and reduce residual fluids content prior to overboard discharge **CM5**: An assessment of drill cuttings and fluids discharges will be undertaken prior to drilling future tieback wells to ensure impacts to environmental values and sensitivities are within acceptable levels. **CM6**: Benthic habitat surveys will be undertaken prior to drilling at future tieback locations to identify and avoid sensitive benthic habitat.
	Sediment Quality	Deposition of drill cuttings during drilling operations.		
	Benthic habitats	Localised smothering and loss of habitat.		
	Marine Fauna	Bioaccumulation of contaminants in benthic infauna.		
Discharges- Produced Water Discharge (**Section 7.2.2**)	Water Quality	Localised decrease in water quality during the operational stage of Dorado Phase 1.	**EPO3B**: No mortality or significant[73] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of PW. **EPO4A**: Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring a 99 % species protection level(based on ANZG 2018) for water quality is achieved outside of the PW mixing zone boundary[57]. **EPO5A**: Limit adverse impacts to the values and ecological integrity to the commonwealth marine area by ensuring ANZG 2018 sediment quality guideline values are not exceeded outside the PW mixing zone[55] **EPO6A:** Dorado Phase 1 is managed so that seafood caught within the project area remains safe for human consumption**.**	**CM7**: PW treatment system to meet OIW discharge standards: + less than 30 mg/L OIW during steady state operations averaged over 24 h + between 30 mg/L and 100 mg/L OIW averaged over 24 h during the initial start-up period and for commissioning of future tieback (up to 6 months after first oil) **CM8**: Adaptive PW management plan including: + PW modelling, + in-field sampling to verify modelling results are within ANZG 2018 water quality and sediment quality guidelines e.g. predicted mixing zone, sediments. + PW chemical characterisation, + PW ecotoxicity testing, + tiered management system in response to off-specification water (e.g. storage onboard and retreatment prior to discharge) + studies to verify whether bioaccumulation of toxicants in biota attributable to the discharge of PW, + adaptive management triggers and mitigative measures in response to results of bioaccumulation studies, + adopt changes in relevant legislative requirements and updates to ANZG to PW discharges. **CM9:** Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements.
	Sediment Quality	Deposition of very small quantities of precipitated solids during the operational stage of Dorado Phase 1.		
	Marine Fauna	Bioaccumulation of contaminants in marine fauna.		
Discharges- Wastewater Discharges (**Section 7.2.3**)	Water Quality	Localised decrease in water quality around wastewater discharge locations.	**EPO3C**: No mortality or significant[58] impacts to EPBC act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 discharge of wastewater. **EPO7A**: Dorado Phase 1 routine planned wastewater discharges compliant with relevant established industry standard environmental discharge limits	**CM9**: Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements. **CM10**: All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification): + Marine Order 91 (Marine Pollution Prevention – Oil), which implements Annex I of MARPOL 73/78, including (as required by vessel class):
	Sediment Quality	Minor increase in concentrations of contaminants, nutrients and organic carbon in sediments, along with a small increase in biochemical oxygen		

57 Produced water mixing zone determined to be 1000 m from the FPSO during a <30 mg/L PW discharge.

58 As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
		nutrients around wastewater discharge locations.		Machinery space bilge/oily water shall have IMO approved oil filtering equipment (oil/water separator) with an on-line monitoring device to measure OIW content to be less than 15 ppm mg/L prior to discharge. A deck drainage system capable of controlling the content of discharges for areas of high risk of fuel/oil/grease or hazardous chemical contamination. Valid International Oil Pollution Prevention Certificate. + Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including: – Garbage management plan in place. – Garbage record book maintained onboard. + Marine Order 96 (Marine Pollution Prevention – Sewage), which implements Annex IV of MARPOL 73/78, including (as required by vessel class): – a valid International Sewage Pollution Prevention Certificate, – an IMO approved sewage treatment plant, – a sewage comminuting and disinfecting system, – a sewage holding tank sized appropriately to contain all generated waste (black and grey water), and – discharge of sewage will occur at a moderate rate while vessel is proceeding (more than 4 knots).
	Marine Fauna	Potential behavioural disturbance in close proximity to the discharge and bioaccumulation of contaminants in marine fauna.		
Emissions – Artificial Light (**Section 7.2.4**)	Plankton Fish Marine Mammals Reptiles Birds	Potential changes in behaviour, such as attraction, avoidance and disorientation, of marine fauna.	**EPO3D**: No mortality or significant[59] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 artificial light emissions **EPO8A**: Artificial light emissions do not result in the displacement of marine turtles from habitat critical to their survival.	**CM11**: Align lighting design on Dorado Development facilities (e.g. WHP, FPSO) with light design described in National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2020), including: + Using minimum number and intensity of lighting to meet operational requirements (e.g. safety, navigation etc.), + Adapting lighting for colour, intensity and timing where practicable, + Use non-reflective, dark coloured surfaces where practicable (i.e. where safety is not compromised). **CM12:** Manage lighting on vessels to reduce light spill to the environment where practicable. **CM13**: Implement adaptive management (e.g. shielding, retrofitting with lower intensity lights etc.) of artificial light emissions if there is a moderate environment incident resulting from light emissions. **CM14:** Flaring limited to operation of the flare pilot during steady state operations.
Emissions- Acoustic Emissions (**Section 7.2.5**)	Marine Mammals	Potential permanent threshold shift (PTS), temporary threshold shift (TTS), behavioural impacts and masking	**EPO3E**: No mortality or significant[75] impacts to EPBC Act listed threatened, migratory or cetacean species as a result of Dorado Phase 1 acoustic emissions. **EPO9A** Undertake Dorado phase 1 in such a manner that noise in biologically important areas will be managed to prevent any displacement of threatened species as per EPBC species conservation requirements. **EPO10A** No impacts from Dorado Phase 1 acoustic emissions to pre-existing commercial fish stocks that occur within the project area that could be subject to existing or future fishing effort. **EPO11A:** No injury to pygmy blue whales in a pygmy blue whale BIA	**CM15:** Vessels movements and helicopter flights comply with Part 8 of EPBC Regulations for interacting with cetaceans. **CM16**: Implement Santos' Protected Marine Fauna Interaction and Sighting Procedure. **CM17**: Undertake acoustic emissions modelling for piling, 3D VSP and drilling VSP activities for potential future tiebacks. **CM18**: Implement mitigation measures for drilling VSP and 3-D VSP surveys and activities aligned with EPBC Act Polic– Statement 2.1 - Interaction between offshore seismic exploration and whales (Department of the Environment, Water, Heritage and the Arts 2008a), including: + development of low-power and shutdown zones, + marine fauna observers, + pre-start visual observations, + soft-start procedures, + stop work procedures, and + night-time and low visibility procedures. **CM19**: Implement mitigation measures for piling activities, including:
	Fishes	Potential mortal injury, recoverable injury, TTS and behavioural disturbance		
	Reptiles	Potential PTS, TTS and behavioural disturbance		

[59] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
			EPO12A: noise generating activities of Dorado Phase 1 are managed in such a manner to prevent PTS and reduce the risk of TTS and biologically important behavioural disturbance to all whales in the Commonwealth marine area.	+ marine fauna observers, + pre-start visual observations, + soft-start procedures, + stop work procedures, and + night-time and low visibility procedure **CM20:** Where future activity specific acoustic emissions modelling results indicate PTS, TTS envelopes overlap with a pygmy blue whale BIA, related impulsive noise generating activities will not occur during corresponding peak migration periods
Emissions- Greenhouse Gas (**Section 7.2.6**)	Australian Environment	Potential impacts as a result of climate change have been modelled by Commonwealth Scientific and Industrial Research Organisation (CSIRO). The modelling indicates that temperatures will increase across Australia, rainfall patterns will change significantly and extreme events such as droughts, floods and wildfires will become more common. These changes are likely to impact on individual species, ecosystems and ecosystem services such as food and water availability. Within decades, environments across Australia may be substantially different (CSIRO 2015).	**EPO13A**: Dorado Phase 1 Scope 1 GHG emissions managed in accordance with the Safeguard Mechanism benchmark baseline set by the Clean Energy Regulator, in support of meeting the Australian Government's Paris Agreement Nationally Determined Contribution of net zero emissions by 2050. **EPO14A**: As the Paris Agreement is the most comprehensive global agreement to seek to limit global temperature rise as specified in Article 2 of the Agreement and no significant[60] impacts to the environment globally, including in Australia, Dorado Phase 1 oil is only sold to customers from countries that have: + a net-zero emissions by 2050 (NZE) commitment; and/or + are signatories to the Paris Agreement and have Nationally Determined Contributions (NDC) in place to reduce or offset GHG emissions.	**CM14:** Flaring limited to operation of the flare pilot during steady state operations. **CM21:** Optimise facility design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable. **CM22:** The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare, and direct them to be reinjected with the produced gas. **CM23:** Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities. **CM24**: During routine operations, reinject produced gas (other than safety flare and fuel gas) to recover liquids. **CM25:** Embed fugitive emissions surveillance and management into facilities operations and maintenance. **CM26:** Undertake fuel and flare analysis, baselining and forecasting throughout Dorado Development operational life. **CM27:** Establish annual setting of energy efficiency improvements and targets throughout the life of Dorado Phase 1 facilities. **CM28:** Throughout the life of Dorado Phase 1 facilities undertake optimisation of energy efficiency through periodic opportunity identification workshops or studies, evaluation and implementation. **CM29**: Dorado Phase 1 will report on Scope 1 GHG emissions as required per the National Greenhouse and Energy Reporting (NGER) Scheme. **CM30**: Dorado Phase 1 will comply with the requirements of the Safeguard Mechanism, including purchase and/or surrender of Australian carbon credit units for any emissions above the baseline for the year, to support achievement of Australia's NDC emissions targets. **CM31**: Dorado Phase 1 will implement a GHG management plan that incorporates an adaptive management approach that facilitates a continuous cycle of monitoring, evaluating, and implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations including: + Evaluation of emissions monitoring data and ensuring the implemented controls deliver predicted emission reductions, + Seeking new and relevant data/information from external sources relevant to GHG emission management including Commonwealth legislation or policy, + Ensuring effectiveness of internal processes and procedures to reduce and manage GHG emissions, + Responding to changes from detailed engineering outcomes, and + Implementing corrective actions identified from the above.

[60] As defined by the significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
				CM32: Dorado Phase 1 will limit sales to customers from countries that have a NZE commitment or are signatories to the Paris Agreement, and will cease to supply customers in countries that withdraw from the Paris Agreement or NZE commitments. **CM33**: Regular monitoring of Dorado Phase 1 customer country compliance with NZE or NDC emissions targets (Article 4) through the Paris Agreement monitoring and assurance mechanisms: + the enhanced transparency framework 5-yearly reporting (Article 13) + the 5-yearly Global Stocktake (Article 14); and + implementation and compliance committee annual reporting (Article 15). **CM34**: If results of CM33 identify gaps in customer country compliance against NZE or NDC emissions targets, Dorado Phase 1 will take mitigation actions including ceasing to supply to those customers or offsetting their Dorado Phase 1 product emissions.
Emissions-Atmospheric Emissions (**Section 7.2.7**)	Air Quality	Change in air quality	**EPO15A**: No significant[61] impacts to air quality throughout the lifecycle of Dorado Phase 1.	**CM14**: Flaring limited to operation of the flare pilot during steady state operations. **CM21:** Optimise facility design to reduce Dorado Phase 1 Scope 1 GHG emissions to ALARP and acceptable. **CM22:** The vapour recovery system on the Dorado FPSO will be designed to capture low pressure, continuous sources of vented gas that would otherwise be sent to flare and direct them to be reinjected with the produced gas. **CM23:** Design facilities in a manner that can accommodate the adoption of economically and technically viable emission reduction technologies that may become available during the operating life of the facilities. **CM25:** Embed fugitive emissions surveillance and management into facilities operations and maintenance. **CM35**: The MODU, vessels, and FPSO will comply with MARPOL Annex VI (Prevention of Air Pollution from Ships), the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and subsequent Marine Orders, which require vessels to have a valid International Air Pollution Prevention Certificate (for vessels more than 400 tonnage) and to use low-sulphur fuel. **CM36:** Ozone-depleting substances onboard vessels and the facilities will comply with relevant MARPOL – 3/78 (Annex VI - air pollution), Navigation Act 2012, Protection of the Sea (Prevention of Pollution) Act 1983 and subsequent Marine Order requirements (as appropriate for vessel classification). **CM37**: Measure, monitor or estimate facility fuel and flare emissions (in accordance with the National Pollutant Inventory) to inform and optimise management practices and minimise environmental impact of emissions. **CM38**: National Pollutant Inventory reporting records (or contemporary requirements at the time of the activities) will be complied with during the project.

[61] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
Physical Presence-Interactions with Other Users (**Section 7.2.8**)	Commercial Fisheries Shipping	Changes to the functions, interests or activities of other users	**EPO16A**: No adverse interactions[62] between Santos' activities and other maritime users within the Project Area. **EPO17A**: The installation and drilling operations, production operations and decommissioning activities of the project will be managed in a manner that does not interfere with other marine users within the Project Area to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties of Santos under the Dorado petroleum titles. **EPO18A** Decommissioning of Dorado facilities in compliance with Section 572 (3) of the Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2009.	**CM39**: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the *Navigation Act 2012* and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM40**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM41**: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM42**: Should potential future tiebacks overlap within AMSA fairways Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way. **CM43**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM44**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM45**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development. **CM46**: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3) of the OPGGS Act. **CM47:** exclusion zones/petroleum safety zones will be limited to the minimum area necessary to exercise rights and perform duties under project specific petroleum titles. **CM48:** residual impacts to other marine users of the environment are managed to not interfere with their rights.
Physical Presence – Seabed Disturbance (**Section 7.2.9**)	Water Quality	Temporary, localised decrease in water quality during installation and removal of components on the seabed.	**EPO2B**: Direct impacts to benthic habitats from Dorado Phase 1 will be limited to less than 2% of the Project Area and less than 5% within a single ecotype within the Project Area. **EPO18B** Decommissioning of Dorado facilities in compliance with Section 572 (3) of the Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2009. **EPO3F**: No mortality or significant[63] impacts to EPBC act listed threatened and migratory species as a result of Dorado Phase 1 seabed disturbance	**CM49**: Decommissioning of Dorado Phase 1 facilities will be carried out in accordance with regulatory requirements per Section 572 (3) of the OPGGS Act. **CM50**: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints. **CM51**: Undertake benthic habitat surveys for future tieback locations and proposed subsea infrastructure corridors prior to development to identify and avoid sensitive benthic habitat where practicable within technical and safety constraints.
	Sediment Quality	Localised, minor modification of sediment characteristics, such as geological origin and particle size distribution.		
	Benthic Habitats	Localised, minor modification of benthic habitats from the introduction of artificial hard substrates.		

[63] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
	Fishes	Increased fish diversity and abundance due to modification of benthic habitats.	**EPO19A**: Impacts to sediment quality and water quality as a result of seabed disturbance from Dorado Phase 1 restricted to 1 km radius from Dorado facilities.	
	Fisheries	Potential enhanced recruitment of targeted species and increased catches.		
Unplanned Events				
Accidental Release – Hydrocarbon and Chemical Spills (**Section 7.3.1**)	Water quality	Potential widespread decrease in water quality from hydrocarbon pollution	**EPO20A** Undertake Dorado Phase 1 in a manner that will prevent unplanned discharge of chemicals or hydrocarbons to the marine environment. **EPO21A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of reservoir fluids to the marine environment due to a LOWC, or failure of a flowline or FPSO cargo tank. **EPO22A** Undertake Dorado Phase 1 in a manner that will prevent an accidental release of MDO/MGO or HFO to the marine environment due to vessel collision, failure of a storage tank or release during refuelling. **EPO23A** In an event of an unplanned release of chemicals or hydrocarbons, spill response control measures will be implemented in accordance with an accepted EP/OPEP.	**CM9**: Santos chemical selection process will be implemented to select chemicals with low environmental risk, while meeting technical requirements. **CM52**: Accepted well operations management plans in place for all wells detailing: + blowout preventer installation and testing, + competency of the drillers engaged, + monitoring of wellbore progress and drilling fluid balance, and + well designs that consider reservoir characteristics. **CM53**: All project vessels operating within the Project Area will adhere to the navigation safety requirements including: + International Regulations for Preventing Collisions at Sea 1972, + Chapter 5 of International Convention for the Safety of Life at Sea 1974, + International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, + the *Navigation Act 2012* and any subsequent Marine Orders that specify standards for crew training and competency, navigation, communication, and safety measures. **CM54**: The Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners and maintaining nautical charts prior to commencement of installation or drilling activities and operations. **CM55**: All project vessels subject to Santos' marine assurance procedures. **CM56**: All offtake tankers subject to Santos' tanker vetting procedures. **CM57**: Bunkering procedures to manage the transfers of fuel that include: + weather limits on bunkering operations, + bunkering equipment specifications and inspections, + visual observations during transfers, and + emergency shutdowns. **CM58**: Santos will undertake consultation with relevant persons for all petroleum activities within the scope of Dorado Phase 1 in accordance with the OPGGS (E) Regulations. **CM59**: The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). **CM60**: Should potential future tiebacks overlap within AMSA fairways Santos will engage with relevant authorities to facilitate the development of these tiebacks in an acceptable way. **CM61**: A 500-m exclusion zone will be established and maintained around all drilling and installation activities. **CM62**: Santos will consult with relevant commercial fishers and the Western Australian Fishing Industry Council to establish the required gazetted Petroleum Safety Zone, Exclusion Zone and Cautionary Zones for Dorado Development. **CM63**: FPSO will be designed, constructed and operated to Santos' specified requirements, including:
	Sediment quality	Potential localised decrease in water quality from hydrocarbon pollution		
	Communities and habitats	Potential widespread impacts to benthic and coastal communities and habitats from hydrocarbon pollution		
	Fishes	Potential acute and chronic toxic effects		
	Marine mammals			
	Reptiles			
	Birds			
	Protected Areas	Potential impacts to the natural and socio-economic values of marine and coastal protection areas		
	Fisheries	Potential temporary closure of fisheries due to hydrocarbon pollution		
	Heritage	Potential loss of cultural values of heritage sites		
	Tourism	Potential impacts to tourism through loss of nature-based tourism resources due to hydrocarbon pollution.		

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
				+ double hulled construction, + cyclone and adverse weather avoidance procedures, and + Structural integrity inspection regime. **CM64:** Oil-spill modelling and environmental risk assessments for the Dorado Phase 1 Eps and OPEPs will consider the full range of worst-case scenario LOWC consequences based on the best available oil-spill modelling. **CM65:** During Development Well drilling and drilling of tieback wells, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. **CM66:** Accepted Eps/OPEPs in place for all Dorado Development activities. **CM67**: All vessels involved in the project will have a valid Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan (as appropriate for vessel classification). **CM68**: Source control emergency response plans in place for all drilling activities. **CM69:** Emergency response capability (including equipment, personnel contracts, MOUs) will be maintained in accordance with approved SOPEPS accepted EPs and OPEPs.
Accidental Release – Loss of Solid Material (**Section 7.3.2**)	Benthic habitat	Modification of benthic habitats from accidental loss of solid material.	**EPO3G**: No mortality or significant[64] impacts to threatened, migratory or cetacean species as a result of Dorado Phase 1 loss of solid material. **EPO24A**: No significant[72] impacts to benthic habitats and communities. **EPO25A** Undertake Dorado Phase 1 in a manner that will prevent an unplanned discharge of solid waste to the marine environment. **EPO26A** Undertake Dorado Phase 1 in a manner that will prevent unplanned seabed disturbance.	**CM10**: All wastewater discharges will comply with relevant MARPOL 73/78, *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification): + Marine Order 95 (Marine Pollution Prevention – Garbage), which implements Annex V of MARPOL 73/78, including: – Garbage management plan in place. – Garbage record book maintained onboard. **CM70**: Crane and lifting operations will comply with the following: + Lifting equipment will be inspected and certified, + Preventative maintenance will be carried out, and + Lifting operators will be competent and qualified **CM71**: Objects dropped overboard will be recovered where practicable to mitigate the environmental consequences from objects remaining in the marine environment, unless the environmental consequences are minor or safety risks are disproportionate to the environmental consequences. **CM72**: Waste management procedures will include: + classification of wastes, including segregation of wastes into recyclable and non-recyclable materials, + appropriate storage of wastes, and + transportation and disposal of wastes by a licenced waste contractor at licenced waste management facilities in accordance with waste classifications. **CM73:** After completion of the drilling and installation stages a site clean-up activity will be undertaken to identify and remove, if safe, any dropped objects or solid materials that may have been lost.
	Marine Fauna	Injury or mortality of marine fauna due to ingestion of, or entanglement with, lost solid material.		
Physical Presence – Introduction of Invasive Marine Species (IMS)	Benthic habitats	Change in ecosystem dynamics.	**EPO27A:** Undertake Dorado Phase 1 in a manner that will prevent the introduction, establishment and spread of IMS in the natural environment attributable to the development. **EPO28A:** No significant[72] impacts to benthic habitats and communities, KEF and exploited fisheries resource stocks within the Project Area.	**CM74**: Ballast water exchange operations will comply with the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (as appropriate to vessel class), Australian Ballast Water Management Requirements (Department of Agriculture, Water and the Environment 2020), Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 and Biosecurity Act 2015, including: + All ballast water exchanges conducted more than 12 nautical miles (nm) from land, and + Vessel Ballast Water Management Plan stipulating that ballast water exchange records will be maintained.
	KEF	Changes to the functions, interests or activities of other users.		
	Fisheries	Reduction in fishery resource stocks.		

[64] As defined by the Commonwealth marine environment significant impact criteria in *Matters of National Environmental Significance - Significant impact guidelines 1.1.* Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment 2013).

Aspect	Receptor	Potential Impacts	Environmental Performance Outcome (EPO)	Control Measure (CM)
				CM75: Implementation of Dorado FPSO Biofouling Management Plan when the FPSO sails to the Project Area from overseas (such as when it first hooks up or comes back from dry dock) and as per the anti-fouling and in-water cleaning guidelines (Department of the Environment and New Zealand Ministry for Primary Industries 2015). **CM76**: Compliance with Santos IMS Management Plan. **CM77:** Biofouling management for vessels will be in accordance with the IMO Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Marine Environment Protection Committee 2011). **CM78:** Compliance with the International Convention on the Control of Harmful Anti-fouling Systems on Ships 2001, including vessels (of appropriate class) having a valid International Anti-fouling Systems Certificate. **CM79:** Fisheries will be provided with information on the timing, nature and scale of aspects of Dorado Phase 1 through Santos' consultation activities.
Physical Presence – Interactions with Marine Fauna (**Section 7.3.4**)	Marine Mammals Fish Reptiles Birds	Injury, disturbance or mortality to marine fauna	**EPO29A**: No vessel or helicopter interactions within the Dorado Phase 1 Project operational with EPBC Act listed threatened, migratory or cetacean species.	**CM16**: Implement Santos' Protected Marine Fauna Interaction and Sighting Procedure. **CM80:** Vessels within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans, (except in emergency conditions or when manoeuvring is not possible), which include: + Implement a caution zone of 150 m for dolphins and 300 m for whales, + Vessels will not knowingly approach closer than 50 m to a dolphin 100 m to a whale (i.e. no approach zone), + Make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale, + Vessels will not knowingly travel more than 6 knots within the caution zone of a dolphin or whale, and + There will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone). **CM81:** Helicopters within the designated Project operational area will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans (except in emergency conditions or when manoeuvring is not possible), which includes: + not operating the helicopter at a height lower than 1 650 feet or within a horizontal radius of 500 metres of a cetacean + not allowing the aircraft to approach a cetacean from head on **CM82**: If a Part 13 Permit for the disturbance of listed migratory birds is required under the EPBC Act a Santos Bird Management Plan will be developed and implemented.

8.2.3 Santos' Decarbonisation Program

In support of delivering on its decarbonisation aspirations, Santos has established a Climate Transition Action Plan. The Climate Transition Action Plan sets out Santos' vision for materially reducing emissions within its operational control and delivering value for shareholders through the energy transition by offering carbon solutions and partnering across the energy supply chain to produce cleaner energy and clean fuels that will reduce Santos' customers' emissions. The Action Plan focuses efforts in the following areas:

+ Operational Efficiencies - Broad range of initiatives that are designed to reduce the Scope 1 and 2 emissions of Santos operations. Operational efficiency initiatives include fuel, flare and vent reductions, electrification, renewable integration, and fugitive emissions reduction;

+ Carbon Capture and Storage - Step-change technology that will reduce emissions and pave the way for future transition initiatives;

+ Carbon Reduction Solutions - Opportunities to reduce carbon emissions and generate offsets for Santos and customers;

+ Clean Fuel Hubs - Leverage CCS hubs as pathway to generating clean fuels; and

+ Supply Chain Collaboration - Working with customers to cultivate demand for lower carbon fuels.

Santos will continue to adapt the Climate Transition Action Plan on an ongoing basis to take account of the evolving energy transition environment and apply disciplined economic and commercial criteria to inform investment decisions. Periodic reviews and associated updates (as required) by the Santos Board are published annually in Santos' annual Climate Change Report.

8.2.4 Emergency Preparedness and Response

Santos will have an Emergency Response Plan in place to address all credible operational risks and scenarios. The plan will provide procedural guidance specific to the activity to control, coordinate and respond to an emergency or incident including hydrocarbon spills.

The OPGGS (E) Regulations requires the implementation strategy in an EP to contain an OPEP. The OPEP must include adequate arrangements for responding to oil pollution that may arise from the petroleum activities considered in the EP. The arrangements must be tested at least every 12 months, as well as when they are introduced or modified.

The OPEP will detail the actions to be undertaken in response to an incident, the hierarchy for command, control and communication, and the emergency specialist response groups, statutory authorities and other relevant external bodies required for interface. Santos will be required to have OPEPs tailored to the nature and scale of the hydrocarbon spill associated with the activity being undertaken.

Unplanned releases of hydrocarbons are by their very nature unpredictable, and planning for and responding to a significant oil spill incident requires management of significant uncertainty. To manage this uncertainty, Santos employs a range of measures to counter the impact uncertainty may have on the effectiveness of spill response in the unlikely event of a major oil spill incident:

+ assessing the full range of worst-case credible spill scenarios to ensure the EMBA is sufficiently conservative for oil spill impact assessment and planning purposes;

- Using conservative assumptions to inform potential loss of well control volume;
- Using qualified and competent oil-spill modelling providers and widely used and accepted oil-spill modelling tools;
- using a stochastic modelling approach for numerical modelling of the worst-case credible spill scenarios that includes a large number of replicate runs covering a range of seasonal and metocean conditions;
- using environmentally conservative adverse exposure zone threshold to set a conservative EMBA to assess impact and inform response planning;
- further reducing uncertainty during the operational response phase through implementation of monitor and evaluation response strategy actions such as oil spill trajectory modelling informed by real time met ocean data; and
- robust oil response planning capability and capacity, with the ability to leverage significant external spill response support (personnel, equipment, expertise), to ensure scalability of Santos' response regardless of potential differences between oil spill modelling predictions and actual spill outcomes and consequences.

8.2.5 Environmental Monitoring

Santos will undertake environmental monitoring during Dorado Phase 1. This monitoring will provide a greater understanding of the environment within the Project Area and assist in verifying the outcomes achieve through mitigation and management controls.

Any future environmental monitoring requirements will be determined as the design of Dorado Phase 1 is refined. Environmental monitoring commitments will be developed and included in EPs for petroleum activities within the scope of this OPP.

The environmental monitoring will also be used to inform the ongoing environmental adaptive management of Dorado Phase 1 environmental impacts and risks.

8.2.6 Performance Reporting

Regulation 26 of the OPGGS (E) Regulations requires the reporting of environmental performance for EPs for petroleum activities within the scope of this OPP (**Table 8-2**).

Table 8-2: Routine external reporting requirements

Reporting Requirement	Description	Reporting to	Timing
Environmental Performance Report	Report includes: + Summary of activities undertaken throughout the reporting period. + Compliance with EPOs outlined in petroleum activity EPs. + Compliance with controls and standards outlined in any future EPs.	NOPSEMA	Annually
Recordable Incident Report	Report includes:	NOPSEMA	Monthly

Reporting Requirement	Description	Reporting to	Timing
	Details of recordable incidents that have occurred during the petroleum activity for the previous month (if any)		

8.2.7 Incident Reporting

A reportable incident as defined under Regulation 4 of the OPGGS (E) Regulations is an incident relating to the activity that:

"*has caused, or has the potential to cause, moderate to significant environmental damage.*"

NOPSEMA will be notified of all reportable incidents, as per the requirements of Regulations 26, 26A and 26AA of the OPGGS (E) Regulations.

8.3 Auditing and Assurance

The Santos Management System ensures a process is in place to enable conformance with applicable legal and company requirements, verify necessary safeguards are in place and functioning, and non-compliances are reported and corrective actions tracked to closure. Environmental performance of the activities defined in this OPP will be audited and reviewed. These reviews are undertaken to ensure that:

+ environmental performance standards to achieve the EPOs are being implemented, reviewed and, where necessary, amended;
+ potential non-compliances and opportunities for continuous improvement are identified; and
+ all environmental monitoring requirements are being met.

Further details including the schedule for environmental performance auditing will be provided in future EPs for petroleum activities.

9 Stakeholder Consultation

9.1 Overview

Stakeholder engagement and consultation is an integral part of Santos' impact assessment and project development process, assisting the company make informed business decisions as well as identifying important issues that may need to be addressed. Information provided by stakeholders is considered by Santos in assessing the potential impacts of its activities and determining measures to avoid or minimise those impacts to an acceptable level.

Santos has committed to building and maintaining mutually beneficial relationships with local industry, and local and Indigenous communities wherever we operate.

9.1.1 Objectives

The objective of Santos' stakeholder engagement process for the Dorado Development OPP is to:

- introduce stakeholders to Dorado Development Phase 1;
- provide easily accessible information on the development;
- provide stakeholders with the opportunity to comment on the development and raise any key concerns;
- inform stakeholders of the project timeframes and the mechanisms by which they can receive further updates or provide additional comment;
- provide key stakeholders with a point of contact for the development; and
- provide transparency to stakeholders that relevant issues raised have been addressed by Santos.

9.1.2 Approach to Stakeholder Consultation

Santos has developed a Stakeholder Management Plan for Dorado Phase 1 which has guided the stakeholder consultation process for this OPP. This plan includes the following elements:

- stakeholder identification and mapping; and
- stakeholder engagement strategy.

9.1.3 Stakeholder Identification and Mapping

Santos has been undertaking activities in the Bedout Sub-basin since 2014, and the Dorado Development is a continuation of these activities. Previous activities include drilling of nine exploration and appraisal wells over five years between 2014 and 2019, and the Keraudren 3-D marine seismic survey conducted in 2019. Santos continues to engage with stakeholders in the Bedout sub-basin on its' exploration activities.

Santos has a working history with stakeholders that may be affected by its activities in the Bedout Sub-basin and is familiar with their interests in the Project Area (**Figure 1-1**).

Santos has worked through a stakeholder identification process for this OPP to ensure all potentially interested and affected stakeholders are identified and afforded the opportunity to comment on the proposed Dorado Development. This identification process included:

- a review of Santos' stakeholder database, including stakeholders consulted for other recent activities in the area;

+ a review of legislation applicable to petroleum and marine activities to ensure relevant administrative agencies are consulted;
+ identification of marine user groups and interest groups active in the area (e.g., commercial fisheries, other oil and gas producers, merchant shipping, etc.);
+ identification of relevant stakeholders, dependant on environment risk and impacts identified;
+ a review of the Department of Primary Industry and Regional Development (DPIRD) fishery catch data;
+ utilisation of the WAFIC Oil and Gas consultation services to advise on relevant and potentially impacted State and Commonwealth managed commercial fisheries and fishers; and
+ discussions with other identified stakeholders and industry organisations to identify other potentially impacted persons.

Currently identified stakeholders for the purposes of consultation for this OPP are listed in **Table 9-1.** Santos will continue to revise and update this stakeholder list throughout the life of the project.

Table 9-1: Stakeholders identified for consultation

Stakeholder Group	Stakeholder
Australian Government Departments and Agencies	Australian Border Force (Department of Immigration and Border Protection)
	Australian Fisheries Management Authority
	Australian Marine Safety Authority
	Clean Energy Regulator
	DAWE (Fisheries)
	DAWE (Biosecurity Vessels and aircraft)
	DAWE (Marine Pests)
	Department of Defence
	Department of Foreign Affairs and Trade
	DISER
	Director of National Parks
	Australian Hydrographic Service
State Government Departments and Agencies	Department of Biodiversity, Conservation and Attractions
	Department of Jobs, Tourism, Science and Innovation
	Department of Mines, Industry Regulation and Safety (DMIRS)
	DPIRD – Fisheries Division
	Department of Transport
	Pilbara Development Commission
	Pilbara Port Authority
Local Government	Town of Port Hedland

Stakeholder Group	Stakeholder
Marine Organisations	Australian Marine Oil Spill Centre
Fisheries and Representative Organisations	Commonwealth Fisheries Association
	Australian Southern Bluefin Tuna Industry Association
	Pearl Producers Association
	Recfishwest
	Marine Tourism WA
	WAFIC
State Managed Fisheries	Pilbara Fish Trawl (Interim) Managed Fishery Pilbara Trap Managed Fishery Mackerel Managed Fishery (Area 2) Pilbara Line Fishery
Commonwealth Managed Fisheries	Consult via the Commonwealth Fisheries Association
Other Operators / Exploration Companies	3D Oil Limited
	Finder Exploration
	Inpex
	Pathfinder Energy
	PGS
Port Hedland Community	GT Diving
	Care for Hedland
	Port Hedland Chamber of Commerce and Industry
	Port Hedland Game Fishing Club
Communications	Telstra
	Vocus Communications

Santos has also conducted a stakeholder mapping exercise to identify the potential issues and opportunities for each stakeholder. This assessment has helped Santos to provide more targeted information for specific stakeholders. For example, commercial fishers whose activities may overlap the Project Area were provided additional information which included:

+ Maps relevant to a specific fishery;
+ Historical fish catch data for fisheries that may overlap the Project Area; and
+ Additional information on access to the Project Area and potential exclusion zones.

Santos will continue to revise and update the Dorado Phase 1 stakeholder list to ensure all stakeholders with an interest in the development are identified and included in future development communications.

9.1.4 Stakeholder Engagement Strategy

To complement the NOPSEMA assessment process for OPP (**Figure 1-2**), and to provide stakeholders with sufficient time to consider Dorado Phase 1, Santos will adopt a phased consultation approach for this OPP:

- Phase 1 Consultation – prior to publication of the OPP by NOPSEMA (NOPSEMA Stage 1 Assessment, **Figure 1-2**);
- Phase 2 Consultation – during formal public comment period on the OPP;
- Phase 3 Consultation – after the public comment period and prior to resubmission of the OPP to NOPSEMA (NOPSEMA Stage 2 Assessment, **Figure 1-2**); and
- Phase 4 Consultation – ongoing consultation post OPP acceptance to support preparation of EPs and operations.

Table 9-2 contains a summary of the four consultation phases and engagement approach, subject to specific stakeholder requirements identified in the mapping process.

Table 9-2: Stakeholder Consultation Phases and Engagement Overview for Dorado Phase 1

Consultation Phase	Engagement
Phase 1 Consultation Prior to publication of the OPP by NOPSEMA (NOPSEMA Stage 1 Assessment)	Dorado Development Consultation Fact Sheet sent to all identified stakeholders in **Table 9-1.** Briefings/ meetings/ phone calls to selected stakeholders in **Table 9-1** or as requested. Dorado Phase 1 Risks and Mitigations Fact Sheet, incorporating project updates and the proposed environmental management, sent to all stakeholders in **Table 9-1** prior to commencement of the public comment period.
Phase 2 Consultation During public comment period for OPP, duration determined by NOPSEMA.	Notification (via email) to all stakeholders in **Table 9-1** advising OPP is open for public comment. Public notice in national, state and Pilbara region newspapers advising Santos' Dorado Development OPP is open for public comment. Public notice on Santos' website providing access to the Dorado Development Consultation Fact Sheets and advising the Dorado Development OPP is open for public comment. Ongoing consultation as required to address stakeholder feedback.
Phase 3 Consultation After the public comment period and prior to resubmission of the OPP to NOPSEMA (NOPSEMA Stage 2 Assessment)	Assessment of public comments and follow-up consultation as required.
Phase 4 Consultation Ongoing consultation post OPP acceptance to support preparation of EPs and operations.	Relevant persons will be consulted during the preparation of the Dorado Phase 1 activity-specific EPs as per the OPGGS (E) Regulations.

9.1.4.1 Phase 1 Consultation - prior to publication of the OPP by NOPSEMA

The OPGGS (E) Regulations do not require titleholders to consult with relevant persons prior to the submission of the OPP. Santos has considered it best practice to consult with stakeholders prior to publication of the OPP for public comment, to afford them sufficient time to provide feedback on Dorado Phase 1. This initial consultation aimed to:

- Introduce Dorado Phase 1;
- Provide stakeholders with the opportunity to comment on the development and any key concerns;
- Inform stakeholders of the project timeframes and the mechanisms by which they can receive further updates or provide additional comment; and
- Provide key stakeholders with a point of contact for the development.

The Dorado Development Consultation Fact Sheet includes details such as a development summary, location map, coordinates, water depth, distance to key regional features and vessel exclusion zone details.

Commercial fishers were provided additional information which included:

- Maps and information relevant to a specific fishery;
- Information about the timing and duration of the survey; and
- Information on proposed exclusion zones and gazetted PSZs and concurrent operations.

All stakeholders identified in **Table 9-1** were provided a copy of the Dorado Development Fact Sheet via email on 15 June 2020. Stakeholders were encouraged to provide feedback on the proposed Development and where requested, Santos met directly with stakeholders to discuss the development in more detail prior to submission to NOPSEMA for Stage 1 Assessment and continue to work with stakeholders prior to commencement and during the stage 2 assessment.

A summary of the Stage 1 consultation activities undertaken to date are provided in **Table 9-3**.

Table 9-3: Summary of Stakeholder feedback received for the submission to NOPSEMA for Stage 1 Assessment

Stakeholder	Stakeholder feedback and Santos response
Australian Marine Safety Authority	15/06/2020 - Dorado Development Fact Sheet sent by email. 18/06/2020 - AMSA responded outlining notification requirements. 22/06/2020 - Santos responded advising development was still in planning stages, will keep AMSA updated and will incorporate their requirements into the relevant EPs (**Section 7.2.8**). 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. 25/08/2021 – AMSA responded acknowledging update and referred to maritime safety information sent previously. 8/11/21 – Santos responded and acknowledged information provided. *Consultation Summary: No objections were raised. Santos has addressed notification requirements in **Section 7.2.8** of the OPP. As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
Director of National Parks	15/06/2020 Dorado Development Fact Sheet sent by email. 22/06/2020 Santos and the Director of National Parks discussed development by phone. 25/06/2020 The Director of National Parks responded seeking coordinates for FPSO & DTM. 02/07/2020 The Director of National Parks responded advising the planned activities do not overlap any AMPs. Therefore, there are no authorisation requirements from the Director of National Parks. The Director of National Parks requested to be notified when the OPP was available for public comment and requested additional information on the target resource, planned and unplanned impacts and proximity to AMPs. 02/07/2020 Santos responded and addressed all questions raised by the Director of National Parks. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*

DAWE (Biosecurity)	15/06/2020 Dorado Development Fact Sheet sent by email. 11/11/2020 Department responded requesting further project information. 16/02/2021 Santos responded to the Department with the revised timing for Dorado Phase 1, and to continue to provide project updates as they become available. Santos also committed to consult with the department on all activity specific environment plans when they are in preparation and will meet the department's biosecurity requirements. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
DAWE (Fisheries)	15/06/2020 Dorado Development Fact Sheet sent by email. 24/06/2020 Department noted the information and requested + to be informed of future developments relating to this project, and + Santos communicate future developments with the Australian Fisheries Management Authority and the relevant fishing industry representation organisations in that region. 07/07/2020 Santos acknowledged response and confirmed the department's requests would be met. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. Santos has addressed feedback received regarding consulting with relevant fisheries (**Section 9.1.3**). As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
Australian Fisheries Management Authority (AFMA)	15/06/2020 Dorado Development Fact Sheet sent by email. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. 1/09/2021 – AFMA responded and advised: + it is important to consult with all fishers who have entitlements to fish within the proposed area. This can be done through the relevant fishing industry associations or directly with fishers who hold entitlements in the area. 8/11/2021 – Santos responded and advised it will continue to keep the Australian Fisheries Management Authority and relevant fishing industry representative organisations informed on the development. *Consultation Summary: No objections were raised. Santos has addressed feedback received regarding consulting with relevant fisheries (**Section 9.1.3**). As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
Department of Home Affairs (Former Department of Immigration and Border Protection)	15/06/2020 Dorado Development Fact Sheet sent by email. 25/06/2020 Department responded on requesting to discuss the development. 25/06/2020 Santos and department spoke by phone on to discuss project in more detail. Department's interest was to ensure Santos was aware of requirements for an Offshore Security Plan. 26/06/2020 Department emailed Santos guidance materials for an Offshore Security Plan. 07/07/2020 Santos acknowledged information provided.

	24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
DMIRS	15/06/2020 Dorado Development Fact Sheet sent by email. 30/06/2020 DMIRS responded and advised no further information required at this stage. DMIRS requested to be kept informed of project updates. 07/07/2020 Santos acknowledged DMIRS response and confirmed the department would be informed of project updates. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
Department of Transport	15/06/2020 Dorado Development Fact Sheet sent by email. 03/07/2020 The Department of Transport responded acknowledging notification and advising they looked forward to receiving the respective OPEPs for the activities. 07/07/2020 Santos confirmed the Department of Transport would receive copies of all related OPEP's. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
DPIRD – Fisheries	15/06/2020 Dorado Development Fact Sheet sent by email. 30/06/2020 DPIRD request briefing on Dorado Development. Meeting scheduled for 23/07/2020. 23/07/2020 Santos met and briefed DPIRD on the Dorado Development. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. Santos has addressed fisheries in* ***Section 7.2.8****. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
Department of Biodiversity, Conservation and Attractions	15/06/2020 Dorado Development Fact Sheet sent by email. 18/06/2020 The department advised that, based on the documentation provided and other readily available information, the department currently has no comments to provide in relation to its responsibilities under the *Conservation and Land Management Act 1984* and *Biodiversity Conservation Act 2016*. 08/07/2020 Santos acknowledged response. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
WAFIC	05/06/2020 Santos and WAFIC commence discussions on consultation material for relevant commercial fishers. Key issues and points of clarification raised during these discussions include:

	+ Exclusion zones; + Potential future seismic activity over Project Area; and + Potential future developments in Project Area. 15/06/2020 Dorado Development Fact Sheet sent by email. 03/07/2020 Santos provided final draft of commercial fisher consultation to WAFIC, addressing and clarifying each issue raised by WAFIC. 28/07/2020 Santos provided WAFIC final consultation information for relevant commercial fishers to issue on behalf of Santos. 10/08/2020 WAFIC provided the Santos Dorado Development Consultation material to relevant commercial fishers and fishing industry bodies, on behalf of Santos. 7/10/2020 WAFIC responded to Santos specifically regarding the extent of the gazetted Petroleum Safety Zones. 15/02/2021 WAFIC requested further information on proposed exclusion zones for Dorado Development 23/02/2021 - Santos clarified with WAFIC that the zones will be sought in accordance with OPGGS Act section 616 around the WHP and FPSO and that Santos has not finalised a proposed Petroleum Safety Zone and commits to engaging with WAFIC and fishers once the studies have been completed and the proposed extent of the Petroleum Safety Zone is understood. 25/02/2021 – WAFIC acknowledged Santos' clarification regarding proposed exclusion zones. 2/03/2021 – Santos re-iterated its commitment to engage with WAFIC to seek detailed information on potential impacts from fishing vessels (e.g the weights of anchors and traps) so that this information can be considered in the design phase. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. 31/08/2021 – Santos & WAFIC met to discuss OPP. 11/11/2021 – Santos & WAFIC met to discuss the proposed exclusion zones. *Consultation Summary: To date, Santos has received one comment from a commercial fisher seeking clarification on the proposed Dorado Development safety zones. Santos has responded and provided further information to this licence holder. Santos has addressed potential interaction with fishers in **Section 7.2.8.** As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
Recfishwest	15/06/2020 Dorado Development Fact Sheet sent by email. 15/06/2020 Advised Dorado Development is too far out to sea to impact any of their constituents. 08/07/2020 Santos acknowledged response. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. As per **Section 9.1.4** Santos will continue to provide Dorado Development updates.*
Telstra	15/06/2020 Dorado Development Fact Sheet sent by email. 15/06/2020 Advised the subsea cable JASURAUS is out of service and retired. 08/07/2020 Santos acknowledged response.

	24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. Santos has addressed infrastructure within the Project Area in* ***Section 7.2.8****. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*
Town of Port Hedland	15/06/2020 Dorado Development Fact Sheet sent by email. 15/06/2020 Santos briefed the Town of Port Hedland on the Dorado Development. 10/07/2020 The Town of Port Hedland acknowledged Santos' consultation material and noted: + The proposal provides economic and industry diversification opportunities within the Port Hedland region and the town is supportive of such projects. + The town and its residents place a high value on the natural environment and maintaining that environment for future generations. The town would expect that the highest environment safety standards and processes would be applied by Santos, with similar stringent conditions being included on any license by the relevant regulators. + The town is ideally positioned to support Santos in its venture. 13/07/2020 Santos acknowledged the town's feedback and confirmed the town would be included in all future updates on the development. 24/08/2021 – Advised by email Dorado Development Offshore Project Proposal is on the NOPSEMA website for public comment. *Consultation Summary: No objections were raised. This OPP includes Santos environment management controls. As per* ***Section 9.1.4*** *Santos will continue to provide Dorado Development updates.*

Santos will provide stakeholders identified in **Table 9-1** with the Dorado Development Risks and Mitigations Fact Sheet, incorporating project updates and the proposed environmental management prior to commencement of the OPP public comment period.

9.1.4.2 Phase 2 Consultation – During Public Comment Period on OPP

The public comment period provides all interested persons, including those not considered to be a relevant person under the OPGGS (E) Regulations, are offered an opportunity to comment on the Dorado Development OPP.

The formal public review of an OPP is undertaken for a period of between 4 – 12 weeks as determined by NOPSEMA. It was determined by NOPSEMA that an 8-week formal consultation period would apply for the Dorado OPP and the formal consultation period ran from 20th of August 2021 until 29th of October 2021.

To support the public comment period, Santos placed Notifications (as required by NOPSEMA) in the following media:

- The Australian newspaper;
- Pilbara News newspaper;
- West Australian newspaper; and
- the Santos website.

Santos continues to consult with stakeholders on specific areas of interest in the OPP.

NOPSEMA published the Dorado Development OPP on its website, along with the relevant links and information for providing public comment. All public comment is provided to NOPSEMA who provide a copy of the comments received to Santos as the Operator of Dorado for their consideration to update to the draft OPP described in the phase 3 consultation below.

9.1.4.3 Phase 3 Consultation – after public comment and prior to resubmission of the OPP to NOPSEMA

Santos is committed to considering all information provided during the public comment period and addressing all relevant comments. During this stage, the OPP may require revision to address comments received from stakeholders.

The phase 2 public consultation report is included as **Attachment 13** for NOPSEMA's stage 2 assessment and summarises the key comments (including objections and claims) and assesses the merits of these, along with Santos' response including changes made in this OPP submission in response to the comments.

The process for assessment of the OPP, including the formal public review process, is summarised in **Figure 1-3**.

9.1.4.4 Phase 4 Consultation - ongoing post OPP acceptance to support preparation of environment plans and operations

Following acceptance of the Dorado Development OPP, all the petroleum activities within the scope of the Dorado Development OPP must have a NOPSEMA accepted EP in place before Santos can commence development specific activities. The OPGGS (E) Regulations require that Santos consult with all relevant persons when preparing an EP and undertaking petroleum activities.

Santos has established processes to provide for ongoing consultation throughout the EP development and assessment process and throughout the life of the petroleum activity.

Santos

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Attachment 1 Protected Matters Search Tool and Aboriginal Heritage Search Results Reports

PMST results were compiled for the Project area (**Figure 1-2)** and the EMBA (**Figure 3-1**). The PMST results for the EMBA were obtained using shapefiles covering the scenarios informing the EMBA. The search tool only allows for a bounding area of 1 million km^2, therefore the PMST search results for each scenario informing the EMBA are made up of multiple individual PMST search results reports.

The PMST results for the Dorado Project include:

- The Project Area PMST (**Attachment 1-1)** report is based on the Dorado Project area shown in **Figure 1-2**.
- The EMBA (described in **Section 3.1.1** and presented in **Figure 3-1**) PMST report is inclusive of PMST search results for the Dorado LOWC scenario and the Future Tieback LOWC scenario (**Attachment 1-2)** . Some listed threatened species identified from the EMBA PMST results are not expected to occur in significant numbers in the marine and coastal environments due to their terrestrial distributions. Species that may occur on shorelines include shorebirds, but terrestrial mammals, reptiles (such as pythons) and bird species that do not have habitats along shorelines have been excluded from consideration. These species will not come into contact with any unplanned hydrocarbon spills and therefore are not included in the Description of Environment section (**Section 3**) of the OPP.

Attachment 1-1 PMST – Project Area

Australian Government

Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	20
Listed Migratory Species:	40

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	73
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	6
Key Ecological Features (Marine):	1
Biologically Important Areas:	10
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti		
Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
SHARK		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Migratory Marine Species		

Scientific Name	Threatened Category	Presence Text
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phoxocampus belcheri		
Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii		
Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis		
Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus		
Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus		
Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus		
Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon		
Dugong [28]		Species or species habitat may occur within area
Reptile		
Acalyptophis peronii		
Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Aipysurus duboisii		
Dubois' Seasnake [1116]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Leioselasma czeblukovi as Hydrophis czeblukovi Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Eighty Mile Beach	Multiple Use Zone (IUCN VI)

Extra Information

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Phoenix 3D Seismic Survey, Bedout Sub-Basin	2010/5360	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region

Name	Region
Ancient coastline at 125 m depth contour	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Marine Turtles		
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Attachment 1-2 PMST – EMBA

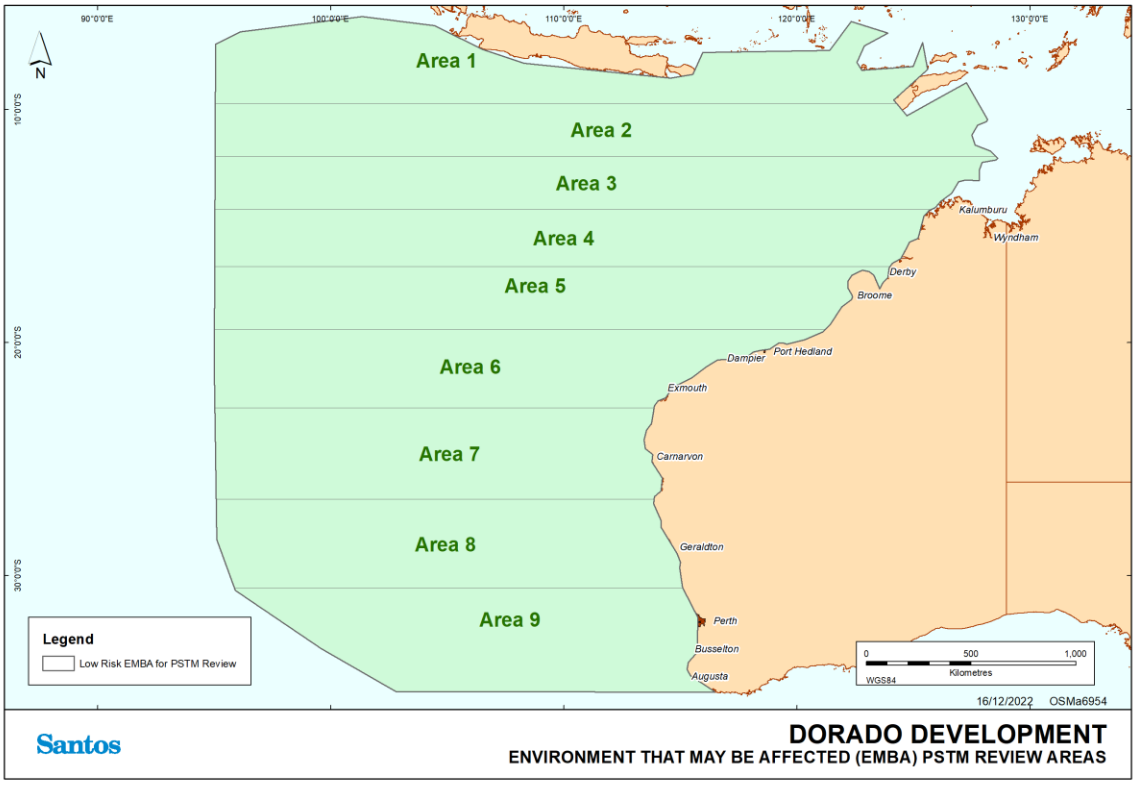

Figure A 1 PMST search areas for the EMBA, Dorado LOWC

Australian Government
Department of Climate Change, Energy, the Environment and Water

AREA 1

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	3
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	17
Listed Migratory Species:	28

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	18
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	2
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	5
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Pterodroma arminjoniana Round Island Petrel, Trinidade Petrel [89284]	Critically Endangered	Species or species habitat may occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
SHARK		

Scientific Name	Threatened Category	Presence Text
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area
Migratory Marine Species		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat may occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus		
Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat likely to occur within area
Reptile		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks	[Resource Information]
Park Name	Zone & IUCN Categories
Christmas Island	National Park Zone (IUCN II)
Cocos (Keeling) Islands	National Park Zone (IUCN II)

Extra Information

EPBC Act Referrals			[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Nava-1 Cable System	2001/510	Controlled Action	Completed
Not controlled action			
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Not controlled action (particular manner)			
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 2

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	4
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	8
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	41
Listed Migratory Species:	50

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	87
Commonwealth Heritage Places:	12
Listed Marine Species:	98
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	2
Australian Marine Parks:	6
Habitat Critical to the Survival of Marine Turtles:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	3
EPBC Act Referrals:	120
Key Ecological Features (Marine):	5
Biologically Important Areas:	19
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Ashmore reef national nature reserve	Within 10km of Ramsar site
Hosnies spring	Within Ramsar site
Pulu keeling national park	Within Ramsar site
The dales	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf
Extended Continental Shelf
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Accipiter hiogaster natalis		
Christmas Island Goshawk [82408]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Chalcophaps indica natalis Christmas Island Emerald Dove, Emerald Dove (Christmas Island) [67030]	Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Hypotaenidia philippensis andrewsi Buff-banded Rail (Cocos (Keeling) Islands), Ayam Hutan [88994]	Endangered	Species or species habitat known to occur within area
Ninox natalis Christmas Island Hawk-Owl, Christmas Boobook [66671]	Vulnerable	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Pterodroma arminjoniana Round Island Petrel, Trinidade Petrel [89284]	Critically Endangered	Breeding likely to occur within area
Turdus poliocephalus erythropleurus Christmas Island Thrush [67122]	Endangered	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Crocidura trichura Christmas Island Shrew [86568]	Critically Endangered	Species or species habitat likely to occur within area
Pteropus natalis Christmas Island Flying-fox, Christmas Island Fruit-bat [87611]	Critically Endangered	Species or species habitat known to occur within area
PLANT		
Asplenium listeri Christmas Island Spleenwort [65865]	Critically Endangered	Species or species habitat known to occur within area
Pneumatopteris truncata fern [68812]	Critically Endangered	Species or species habitat known to occur within area
Tectaria devexa [14767]	Endangered	Species or species habitat likely to occur within area
REPTILE		

Scientific Name	Threatened Category	Presence Text
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Cryptoblepharus egeriae Christmas Island Blue-tailed Skink, Blue-tailed Snake-eyed Skink [1526]	Critically Endangered	Species or species habitat likely to occur within area
Cyrtodactylus sadleiri Christmas Island Giant Gecko [86865]	Endangered	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Lepidodactylus listeri Christmas Island Gecko, Lister's Gecko [1711]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ramphotyphlops exocoeti		
Christmas Island Blind Snake, Christmas Island Pink Blind Snake [1262]	Vulnerable	Species or species habitat likely to occur within area
SHARK		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Ardenna pacifica		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata andrewsi		
Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii		
Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Sternula albifrons		
Little Tern [82849]		Congregation or aggregation known to occur within area
Sula dactylatra		
Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster		
Brown Booby [1022]		Breeding known to occur within area
Sula sula		
Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata		
Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat likely to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Environment and Heritage	
Commonwealth Land - Christmas Island National Park [94104]	CI
Commonwealth Land - Christmas Island National Park [94101]	CI
Commonwealth Land - Christmas Island National Park [94102]	CI
Commonwealth Land - Christmas Island National Park [94103]	CI
Commonwealth Land - Christmas Island National Park [94105]	CI
Commonwealth Land - Pulu Keeling National Park [95002]	CKI
Commonwealth Land - Pulu Keeling National Park [95001]	CKI
Unknown	
Commonwealth Land - [94245]	CI
Commonwealth Land - [94244]	CI
Commonwealth Land - [94249]	CI
Commonwealth Land - [94248]	CI

Commonwealth Land Name	State
Commonwealth Land - [94247]	CI
Commonwealth Land - [94246]	CI
Commonwealth Land - [94208]	CI
Commonwealth Land - [94207]	CI
Commonwealth Land - [94209]	CI
Commonwealth Land - [94204]	CI
Commonwealth Land - [94202]	CI
Commonwealth Land - [94206]	CI
Commonwealth Land - [94205]	CI
Commonwealth Land - [94201]	CI
Commonwealth Land - [94213]	CI
Commonwealth Land - [94231]	CI
Commonwealth Land - [94277]	CI
Commonwealth Land - [94274]	CI
Commonwealth Land - [94275]	CI
Commonwealth Land - [94272]	CI
Commonwealth Land - [94273]	CI
Commonwealth Land - [94270]	CI
Commonwealth Land - [94271]	CI
Commonwealth Land - [94279]	CI
Commonwealth Land - [94242]	CI
Commonwealth Land - [94243]	CI
Commonwealth Land - [94241]	CI
Commonwealth Land - [94240]	CI
Commonwealth Land - [94211]	CI
Commonwealth Land - [94210]	CI
Commonwealth Land - [94212]	CI

Commonwealth Land Name	State
Commonwealth Land - [94259]	CI
Commonwealth Land - [94278]	CI
Commonwealth Land - [94276]	CI
Commonwealth Land - [94218]	CI
Commonwealth Land - [94203]	CI
Commonwealth Land - [94219]	CI
Commonwealth Land - [94214]	CI
Commonwealth Land - [94215]	CI
Commonwealth Land - [94216]	CI
Commonwealth Land - [94217]	CI
Commonwealth Land - [94235]	CI
Commonwealth Land - [94269]	CI
Commonwealth Land - [94263]	CI
Commonwealth Land - [94260]	CI
Commonwealth Land - [94261]	CI
Commonwealth Land - [94268]	CI
Commonwealth Land - [94267]	CI
Commonwealth Land - [94264]	CI
Commonwealth Land - [94265]	CI
Commonwealth Land - [94262]	CI
Commonwealth Land - [94280]	CI
Commonwealth Land - [94233]	CI
Commonwealth Land - [94232]	CI
Commonwealth Land - [94234]	CI
Commonwealth Land - [94230]	CI
Commonwealth Land - [94239]	CI
Commonwealth Land - [94238]	CI

Commonwealth Land Name	State
Commonwealth Land - [94237]	CI
Commonwealth Land - [94236]	CI
Commonwealth Land - [94251]	CI
Commonwealth Land - [94252]	CI
Commonwealth Land - [94228]	CI
Commonwealth Land - [94250]	CI
Commonwealth Land - [94258]	CI
Commonwealth Land - [94257]	CI
Commonwealth Land - [94256]	CI
Commonwealth Land - [94255]	CI
Commonwealth Land - [94254]	CI
Commonwealth Land - [94253]	CI
Commonwealth Land - [94266]	CI
Commonwealth Land - [94225]	CI
Commonwealth Land - [94224]	CI
Commonwealth Land - [94222]	CI
Commonwealth Land - [94223]	CI
Commonwealth Land - [94229]	CI
Commonwealth Land - [94226]	CI
Commonwealth Land - [94227]	CI
Commonwealth Land - [94220]	CI
Commonwealth Land - [94221]	CI

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Historic		
Administrators House Precinct	EXT	Listed place
Bungalow 702	EXT	Listed place
Drumsite Industrial Area	EXT	Listed place

Name	State	Status
Industrial and Administrative Group	EXT	Listed place
Malay Kampong Group	EXT	Listed place
Malay Kampong Precinct	EXT	Listed place
Phosphate Hill Historic Area	EXT	Listed place
Poon Saan Group	EXT	Listed place
Settlement Christmas Island	EXT	Listed place
South Point Settlement Remains	EXT	Listed place
Natural		
Christmas Island Natural Areas	EXT	Listed place
North Keeling Island	EXT	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys sculptus Sculptured Pipefish [66197]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Cosmocampus maxweberi Maxweber's Pipefish [66209]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Doryrhamphus baldwini Redstripe Pipefish [66718]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus macrorhynchus Whiskered Pipefish, Ornate Pipefish [66222]		Species or species habitat may occur within area
Halicampus mataafae Samoan Pipefish [66223]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippichthys spicifer Belly-barred Pipefish, Banded Freshwater Pipefish [66232]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Chitulia inornata as Hydrophis inornatus Plain Seasnake [87379]		Species or species habitat may occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Commonwealth Reserves Terrestrial [Resource Information]

Name	State	Type
Christmas Island	EXT	National Park (Commonwealth)
Pulu Keeling	EXT	National Park (Commonwealth)

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Christmas Island	Habitat Protection Zone (IUCN IV)
Cocos (Keeling) Islands	Habitat Protection Zone (IUCN IV)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Christmas Island	National Park Zone (IUCN II)
Cocos (Keeling) Islands	National Park Zone (IUCN II)
Oceanic Shoals	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Extra Information

Nationally Important Wetlands [Resource Information]

Wetland Name	State
"The Dales", Christmas Island	EXT
Hosine's Spring, Christmas Island	EXT
Pulu Keeling National Park	EXT

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Northern Endeavour Phase 1 Decommissioning	2022/09327		Assessment
Controlled action			
Audacious Oil Field Standalone Development	2001/407	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Christmas Island Airport Expansion	2001/434	Controlled Action	Post-Approval
Christmas Island Port Facility	2001/435	Controlled Action	Post-Approval
Construction of mobile phone tower	2002/694	Controlled Action	Completed
Cultural Appearance Upgrade of the Chinese Literary Association Building	2007/3568	Controlled Action	Completed
Decommissioning of Buffalo Oil Field	2003/984	Controlled Action	Post-Approval
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
East Christmas Island Phosphate Mines (9 sites)	2001/487	Controlled Action	Completed
Exploration for Mineable Phosphate, Christmas Island	2000/43	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Lily Beach Recreational Facilities	2001/395	Controlled Action	Post-Approval
Lily Beach Rock Pool Development	2001/400	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
Phosphate Mining in South Point Christmas Island	2012/6653	Controlled Action	Post-Approval
Proposed exploration drilling programme for Christmas Island	2016/7779	Controlled Action	Completed
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Public Ferry Hovercraft Operation	2003/1239	Controlled Action	Post-Approval
Red-footed booby bird harvest	2002/844	Controlled Action	Referral Decision

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Road Upgrade/Construction between Lily Beach Road and Port Faci	2001/436	Controlled Action	Post-Approval
Salvage, transport and processing of phosphate resource with extended airport si	2003/1217	Controlled Action	Post-Approval
Yellow Crazy Ant Biological Control	2013/6836	Controlled Action	Post-Approval
Not controlled action			
96-108 Gaze Road - Residential upgrade	2006/2632	Not Controlled Action	Completed
Aerial Baiting, Yellow Crazy Ant Supercolonies, Christmas Island, WA	2019/8492	Not Controlled Action	Completed
Audacious-3 oil drilling well	2003/1042	Not Controlled Action	Completed
Backpacker-1 Offshore Hydrocarbon Exploration Well	2001/300	Not Controlled Action	Completed
Boat Ramp Construction	2001/237	Not Controlled Action	Completed
Buffalo In-Fill Production Wells	2001/475	Not Controlled Action	Completed
Building of a carport adjacent to residential house	2004/1538	Not Controlled Action	Completed
Christmas Island/Construction of a double storey shed/carport at MQ387 Gaze Road	2004/1561	Not Controlled Action	Completed
Christmas Island Fuel Consolidation Project, Christmas Island	2012/6454	Not Controlled Action	Completed
Community Recreation Centre	2003/1279	Not Controlled Action	Completed
Controlled Source Electromagnetic 2D Survey	2009/4980	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2010/5434	Not Controlled Action	Completed
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
courtyard shower & handbasin facilities	2006/2803	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Drilling of exploration well Audacious-1 in AC/P17	2000/5	Not Controlled Action	Completed
Dwelling demolition, maintenance and carpark/carport/storage shed works	2004/1837	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Extension of a Masonary Brick Wall adjacent to the Poon Saan Club by 500 mm	2004/1564	Not Controlled Action	Completed
Flying Fish Cove Christmas Island Boat Ramp Maintenance	2021/8924	Not Controlled Action	Completed
Flying Fish Cove Landslide Mitigation Project	2020/8616	Not Controlled Action	Completed
Garage and Office Facilities	2004/1919	Not Controlled Action	Completed
Housing and Garden Maintenance Works	2004/1487	Not Controlled Action	Completed
Hydroponics Research Program	2007/3338	Not Controlled Action	Completed
Identification of unmarked grave, exhumation/identification of remains which may belong to a sailor	2006/2992	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Internal and external modifications Lot 1014 Gaze Road	2004/1807	Not Controlled Action	Completed
Light Industrial Subdivision Development	2004/1799	Not Controlled Action	Completed
Lot 1056 Extensions and Alterations	2004/1801	Not Controlled Action	Completed
Maintenance of Tai Jin House, Smith Point	2009/4933	Not Controlled Action	Completed
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Mobile Radio Communications System Upgrade	2002/718	Not Controlled Action	Completed
Placement of bitumen/ concrete on rail sections of heritage listed incline, Christmas Island	2013/7009	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Power Station Diesel Generator Replacement	2009/4685	Not Controlled Action	Completed
Proposed sale or lease of Crown land, 11 lots, Christmas Island	2018/8220	Not Controlled Action	Completed
Realignment of Gaze Road Service Road and Gaze Road Junction	2004/1735	Not Controlled Action	Completed
Refurbishment and Extension of Seaview Lodge	2012/6353	Not Controlled Action	Completed
renovate free-standing servant's quarters	2006/2811	Not Controlled Action	Completed
Replacement of deteriorating flat roof at rear of Mosque and extending side verandahs, Christmas Is	2013/6851	Not Controlled Action	Completed
Residential upgrade, 2 Coconut Grove	2007/3295	Not Controlled Action	Completed
Stormwater Remediation Project, Christmas Island	2019/8467	Not Controlled Action	Completed
Subdivision of Lot 571 on DP 26701	2008/4230	Not Controlled Action	Completed
Subdivision of Part 7 of Lot 1014	2009/4851	Not Controlled Action	Completed
Supermarket Extensions	2006/2515	Not Controlled Action	Completed
Upgrade of Residence, Coconut Grove	2006/2728	Not Controlled Action	Completed
Verandah Extension to Existing Breezeway Unit, Gaze Road	2005/1970	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2009/5104	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D and 3D Seismic Survey WA-405-P	2008/4133	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey of Braveheart,Kurrajong,Sunshine and Crocodile	2006/2917	Not Controlled Action (Particular Manner)	Post-Approval
2D or 3D Marine Seismic Survey in Petroleum Permit Area AC/P35	2009/4864	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, petroleum exploration permit AC/P33	2006/2918	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey WA-406-P Bonaparte Basin	2007/3904	Not Controlled Action (Particular Manner)	Post-Approval
Addition of Verandah to Block of Four Units	2005/2315	Not Controlled Action (Particular Manner)	Post-Approval
Aerial Baiting of Yellow Crazy Ants	2012/6438	Not Controlled Action (Particular Manner)	Post-Approval
Asbestos Removal from Commonwealth Owned Assests including Commonwealth Heritage	2009/4873	Not Controlled Action (Particular Manner)	Post-Approval
Auralandia 3D marine seismic survey	2011/5961	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Baiting Efficacy Trial of Feral Cat Bait and PAPP Toxicant	2008/4383	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Commonwealth Marine/Flying Fish Cove Jetty Extension	2012/6675	Not Controlled Action (Particular Manner)	Post-Approval
Construction of a Power Station	2003/1177	Not Controlled Action (Particular Manner)	Post-Approval
Crazy Ant Aerial Baiting Control Program	2002/722	Not Controlled Action (Particular Manner)	Post-Approval
Dillon South-1 Exploration Well Drilling - AC/P4, Territory of Ashmore/Cartier	2013/6849	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Audacious-5 appraisal well	2008/4327	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling in Permit Areas WA-402-P & WA-403-P	2010/5297	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Helicopter baiting of exotic yellow crazy ant supercolonies, Christmas Island, Indian Ocean	2009/5016	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Malita West 3D Seismic Survey WA-402-P and WA-403-P	2007/3936	Not Controlled Action (Particular Manner)	Post-Approval
New Housing Program	2011/6056	Not Controlled Action (Particular Manner)	Post-Approval
NT/P80 2010 2D Marine Seismic Survey	2010/5487	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Searcher bathymetry & geochemical seismic survey, Brawse Basin,Timor Sea,WA	2013/6980	Not Controlled Action (Particular Manner)	Post-Approval
Sonar and Acoustic Trials	2001/345	Not Controlled Action (Particular Manner)	Post-Approval
Songa Venus Drilling and Testing Operations	2009/5122	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Songa Venus Drilling Programme, Bonaparte Basin	2009/4990	Not Controlled Action (Particular Manner)	Post-Approval
Sunshine Infill 2D and Mimosa 2D Marine Seismic Surveys	2009/4699	Not Controlled Action (Particular Manner)	Post-Approval
Swimming Pool modification	2007/3312	Not Controlled Action (Particular Manner)	Post-Approval
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Translocation of T.gigas for breeding and release	2005/1958	Not Controlled Action (Particular Manner)	Post-Approval
Trials of a bait delivery system for the control of Yellow Crazy Ants	2009/4763	Not Controlled Action (Particular Manner)	Post-Approval
Ursa 3D Marine Seismic Survey	2008/4634	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Water supply upgrade	2005/2269	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed
Alterations and Improvements to existing residence at Lot 3015 Gaze Rd, Christmas Island	2009/5039	Referral Decision	Completed
Rocky Point Dwelling Redevelopment	2005/2203	Referral Decision	Referral Decision

Key Ecological Features

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Carbonate bank and terrace system of the Sahul Shelf	North-west
Carbonate bank and terrace system of the Van Diemen Rise	North
Continental Slope Demersal Fish Communities	North-west
Pinnacles of the Bonaparte Basin	North-west
Pinnacles of the Bonaparte Basin	North

Biologically Important Areas

Scientific Name	Behaviour	Presence
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Likely to occur

Scientific Name	Behaviour	Presence
Lepidochelys olivacea Olive Ridley Turtle [1767]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur

Scientific Name	Behaviour	Presence
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government
Department of Climate Change, Energy, the Environment and Water

AREA 3

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	5
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	47
Listed Migratory Species:	65

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	23
Commonwealth Heritage Places:	21
Listed Marine Species:	112
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	12
Habitat Critical to the Survival of Marine Turtles:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	6
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	139
Key Ecological Features (Marine):	9
Biologically Important Areas:	47
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places [Resource Information]

Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Hypotaenidia philippensis andrewsi Buff-banded Rail (Cocos (Keeling) Islands), Ayam Hutan [88994]	Endangered	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pterodroma arminjoniana Round Island Petrel, Trinidade Petrel [89284]	Critically Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Mesembriomys gouldii gouldii Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat may occur within area
Petrogale concinna monastria Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		

Scientific Name	Threatened Category	Presence Text
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Unknown	
Commonwealth Land - [96005]	CKI

Commonwealth Land Name	State
Commonwealth Land - [96003]	CKI
Commonwealth Land - [96004]	CKI
Commonwealth Land - [96001]	CKI
Commonwealth Land - [96002]	CKI
Commonwealth Land - [96009]	CKI
Commonwealth Land - [52276]	ACI
Commonwealth Land - [96014]	CKI
Commonwealth Land - [96015]	CKI
Commonwealth Land - [96012]	CKI
Commonwealth Land - [96013]	CKI
Commonwealth Land - [96010]	CKI
Commonwealth Land - [96011]	CKI
Commonwealth Land - [96006]	CKI
Commonwealth Land - [96007]	CKI
Commonwealth Land - [96008]	CKI
Commonwealth Land - [52277]	ACI
Commonwealth Land - [96019]	CKI
Commonwealth Land - [96018]	CKI
Commonwealth Land - [96016]	CKI
Commonwealth Land - [52278]	ACI
Commonwealth Land - [96017]	CKI
Commonwealth Land - [96020]	CKI

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Administration Building Forecourt	EXT	Listed place
Captain Ballards Grave	EXT	Listed place
Direction Island (DI) Houses	EXT	Listed place

Name	State	Status
Early Settlers Graves	EXT	Listed place
Government House	EXT	Listed place
Home Island Cemetery	EXT	Listed place
Home Island Foreshore	EXT	Listed place
Home Island Industrial Precinct	EXT	Listed place
Oceania House and Surrounds	EXT	Listed place
Old Co-op Shop (Canteen)	EXT	Listed place
Qantas Huts (former)	EXT	Listed place
RAAF Memorial	EXT	Listed place
Six Inch Guns	EXT	Listed place
Slipway and Tank	EXT	Listed place
Type 2 Residences	EXT	Listed place
Type T Houses Precinct	EXT	Listed place
West Island Elevated Houses	EXT	Listed place
West Island Housing Precinct	EXT	Listed place
West Island Mosque	EXT	Listed place
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area overfly marine area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica		
Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans		
Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae		
Silver Gull [82326]		Breeding known to occur within area
Fregata andrewsi		
Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum		
Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area
Fish		

Scientific Name	Threatened Category	Presence Text
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys sculptus Sculptured Pipefish [66197]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia inornata as Hydrophis inornatus Plain Seasnake [87379]		Species or species habitat may occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		

Current Scientific Name	Status	Type of Presence
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Cocos (Keeling) Islands	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Christmas Island	National Park Zone (IUCN II)
Cocos (Keeling) Islands	National Park Zone (IUCN II)
Cocos (Keeling) Islands	National Park Zone (IUCN II)
Cocos (Keeling) Islands	National Park Zone (IUCN II)
Ashmore Reef	Recreational Use Zone (IUCN IV)

Park Name	Zone & IUCN Categories
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)

Habitat Critical to the Survival of Marine Turtles		
Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Extra Information

State and Territory Reserves		[Resource Information]
Protected Area Name	Reserve Type	State
Browse Island	Nature Reserve	WA
Low Rocks	Nature Reserve	WA
North Kimberley	Marine Park	WA
Scott Reef	Nature Reserve	WA
Unnamed WA41775	5(1)(h) Reserve	WA
Uunguu	Indigenous Protected Area	WA

Nationally Important Wetlands	[Resource Information]
Wetland Name	State
Ashmore Reef	EXT

EPBC Act Referrals			[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Cocos West Island Seawater Desalination Plant	2022/09409		Referral Decision
Controlled action			
2-D seismic survey Scott Reef	2000/125	Controlled Action	Post-Approval
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Bonaparte Liquified Natural Gas Project	2011/6141	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Breeding, husbandry, slaughter and sale of goats	2004/1895	Controlled Action	Completed
Browse FLNG Development, Commonwealth Waters	2013/7079	Controlled Action	Post-Approval
Conduct an exploration drilling campaign	2010/5718	Controlled Action	Completed
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
Develop Ichthys gas-condensate field permit area W	2006/2767	Controlled Action	Completed
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Eco quad tours for West Island visitors and tourists	2010/5749	Controlled Action	Completed
Home Island slipway & access channel from Home Island Port Facility to Directio	2009/4969	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Montara 4, 5, and 6 Oil Production Wells, and Montara 3 Gas Re-Injection Well	2002/755	Controlled Action	Post-Approval
Nava-1 Cable System	2001/510	Controlled Action	Completed
Prelude Floating Liquefied Natural Gas Facility and Gas Field Development	2008/4146	Controlled Action	Post-Approval
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Public Ferry Hovercraft Operation	2003/1239	Controlled Action	Post-Approval
Red-footed booby bird harvest	2002/844	Controlled Action	Referral Decision
Torosa South Initial Appraisal Drilling	2007/3500	Controlled Action	Completed
Not controlled action			
2D Seismic Survey in Permit Areas WA-318-P & WA-319-P, near Cape Londonderry	2004/1687	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
3D marine seismic survey in WA 314P and WA 315P	2004/1927	Not Controlled Action	Completed
Adele Trend TQ3D Seismic Survey	2001/252	Not Controlled Action	Completed
AEC International Hydrocarbon Well Puffin 6	2000/36	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Backpacker-1 Offshore Hydrocarbon Exploration Well	2001/300	Not Controlled Action	Completed
Buffett Close Residential Development	2004/1887	Not Controlled Action	Completed
Cocos (Keeling) Islands Maintenance Dredging Home Island Slipway Redevelopment, Cocos (Keeling) Isla	2014/7140	Not Controlled Action	Completed
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
Crux-A and Crux-B appraisal wells, Petroleum Permit Area AC/P23	2006/2748	Not Controlled Action	Completed
Crux gas-liquids development in permit AC/P23	2006/3154	Not Controlled Action	Completed
Drilling of 12 Hydrocarbon Exploration Wells, Permit Area WA-371-P	2006/3005	Not Controlled Action	Completed
Drilling of exploration wells, Permit areas WA-301-P to WA-305-P	2002/769	Not Controlled Action	Completed
Echuca Shoals-2 Exploration of Appraisal Well	2006/3020	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Exploration Well AC/P23	2001/234	Not Controlled Action	Completed
External Upgrade of House	2010/5387	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Infrasound Monitoring Station	2007/3390	Not Controlled Action	Completed
Installation of a desalination plant and associated infrastructure	2013/6833	Not Controlled Action	Completed
Kaleidoscope exploration well	2001/182	Not Controlled Action	Completed
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Montara-3 Offshore Hydrocarbon Exploration Well Permit Area AC/RL3	2001/489	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
P30 Hydrocarbon Exploration Well	2001/293	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Proposed Community Centre	2010/5306	Not Controlled Action	Completed
Puffin Oil wells 7, 8 & 9 development	2005/2336	Not Controlled Action	Completed
Saucepan 1 Exploration Well ACP23	2000/2	Not Controlled Action	Completed
Skua and Swift Oilfields	2006/3195	Not Controlled Action	Completed
Strumbo-1 Gas Exploration Well Permit Area WA-288-P	2002/884	Not Controlled Action	Completed
upgrade of House 11, William Keeling Crescent	2005/2447	Not Controlled Action	Completed
Upgrade of House 16 on William Keeling Crescent, a Cwlth owned house in Type T H	2006/2903	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2008/4133	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2009/5104	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey of Braveheart,Kurrajong,Sunshine and Crocodile	2006/2917	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey within permit area WA-318-P	2007/3879	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Marine Survey	2001/363	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey in permit areas WA-274P and WA-281P	2004/1521	Not Controlled Action (Particular Manner)	Post-Approval
2 geotechnical surveys - preliminary and final	2006/2886	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2008/4437	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey, Permit AC/P 23	2005/2364	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
3D marine seismic Survey - Maxima 3D MSS	2006/2945	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, Browse Basin, WA	2009/5048	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, near Scott Reef, Browse Basin	2005/2126	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular Manner)	Post-Approval
AC/P37 3D Seismic Survey Ashmore Cartier	2007/3774	Not Controlled Action (Particular Manner)	Post-Approval
Asbestos Removal from Various Buildings and Sites	2009/4887	Not Controlled Action (Particular Manner)	Post-Approval
Aurora MC3D Marine Seismic Survey	2010/5510	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Bassett 3D Marine Seismic Survey	2010/5538	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte Seismic and Bathymetric Survey	2012/6295	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Braveheart 2D Infill Marine Seismic Survey 100km offshore	2008/4442	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Marine Seismic Survey	2005/2322	Not Controlled Action (Particular Manner)	Post-Approval
Canis 3D Marine Seismic Survey	2008/4492	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Caswell MC3D Marine Seismic Survey	2012/6594	Not Controlled Action (Particular Manner)	Post-Approval
Conduct an exploration drilling campaign	2011/5964	Not Controlled Action (Particular Manner)	Post-Approval
Construction of a Power Station	2003/1177	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Development of a small 25 bed, tented Eco Resort	2012/6284	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Exploration & Appraisal Wells Braveheart-1 & Cornea-3	2009/5160	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Endurance 3D Marine Seismic Data Acquisition Survey	2007/3667	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Exploration Drilling Campaign	2011/6047	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Campaign, Browse Basin, WA-341-P, AC-P36 and WA-343-P	2013/6898	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling in Permit Areas WA-402-P & WA-403-P	2010/5297	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Program - Permit areas - WA-314-P, WA-315-P, WA-398-P.	2008/4064	Not Controlled Action (Particular Manner)	Post-Approval
Fishburn2D Marine Seismic Survey	2012/6659	Not Controlled Action (Particular Manner)	Post-Approval
Floyd 3D and Chisel 3D Seismic Surveys	2011/6220	Not Controlled Action (Particular Manner)	Post-Approval
Gicea 3D Marine Seismic Survey	2008/4389	Not Controlled Action (Particular Manner)	Post-Approval
Gigas 2D Pilot Ocean Bottom Cable Marine Seismic Survey	2007/3839	Not Controlled Action (Particular Manner)	Post-Approval
Gold 2D Marine Seismic Survey Permit Areas WA375P and WA376P	2009/4698	Not Controlled Action (Particular Manner)	Post-Approval
Home Island Slipway Redevelopment	2010/5511	Not Controlled Action (Particular Manner)	Post-Approval
Ichthys 3D Marine Seismic Survey	2010/5550	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Kraken, Lusca & Asperus 3D Marine Seismic Survey	2013/6730	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Malita West 3D Seismic Survey WA-402-P and WA-403-P	2007/3936	Not Controlled Action (Particular Manner)	Post-Approval
Marine Environmental Survey 2012	2012/6310	Not Controlled Action (Particular Manner)	Post-Approval
Mariner Non-Exclusive 2D Seismic Survey	2011/6172	Not Controlled Action (Particular Manner)	Post-Approval
NT/P80 2010 2D Marine Seismic Survey	2010/5487	Not Controlled Action (Particular Manner)	Post-Approval
Octantis 3D Marine Seismic Survey, Permit Area AC/P41 off northern Western Australia	2007/3369	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Gas Exploration Drilling Campaign	2012/6384	Not Controlled Action (Particular Manner)	Post-Approval
Petrel MC2D Marine Seismic Survey	2010/5368	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Pilot Appraisal Well - Torosa South 1	2008/3991	Not Controlled Action (Particular Manner)	Post-Approval
Residential Development, Lot 101 Cocos (Keeling) Island	2011/5856	Not Controlled Action (Particular Manner)	Post-Approval
Rosebud 3D Marine Seismic Survey in WA-30-R and TR/5	2012/6493	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Schild MC3D Marine Seismic Survey	2012/6373	Not Controlled Action (Particular Manner)	Post-Approval
Schild Phase 11 MC3D Marine Seismic Survey, Browse Basin	2013/6894	Not Controlled Action (Particular Manner)	Post-Approval
Scott Reef Seismic Research	2006/2647	Not Controlled Action (Particular Manner)	Post-Approval
Searcher bathymetry & geochemical seismic survey, Brawse Basin,Timor Sea,WA	2013/6980	Not Controlled Action (Particular Manner)	Post-Approval
Sonar and Acoustic Trials	2001/345	Not Controlled Action (Particular Manner)	Post-Approval
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tiffany 3D Seismic Survey	2010/5339	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Torosa-5 Apraisal Well, WA-30-R	2008/4430	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Translocation of T.gigas for breeding and release	2005/1958	Not Controlled Action (Particular Manner)	Post-Approval
Tridacna 3D Ocean Bottom Cable Marine Seismic Survey	2011/5959	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Zeppelin 3D Seismic Survey	2011/6148	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed
BRSN08 3D Marine Seismic Survey	2008/4582	Referral Decision	Completed
Cocos West Island Seawater Desalination Plant	2022/9153	Referral Decision	Referral Publication
Experimental Study of Behavioural and Physiological Impact on Fish of Seismic Ex	2006/2625	Referral Decision	Completed
Pilot Appraisal Well - Torosa South-1	2008/3985	Referral Decision	Completed
Puffin South-West Development of Oil Reserves	2007/3834	Referral Decision	Completed
Seismic Data Acquisition, Browse Basin	2010/5475	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	North-west
Canyons linking the Argo Abyssal Plain with the Scott Plateau	North-west
Carbonate bank and terrace system of the Sahul Shelf	North-west
Carbonate bank and terrace system of the Van Diemen Rise	North
Continental Slope Demersal Fish Communities	North-west
Pinnacles of the Bonaparte Basin	North-west
Pinnacles of the Bonaparte Basin	North
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Resting	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Known to occur

Scientific Name	Behaviour	Presence
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat - unknown behaviour	Likely to occur
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Chelonia mydas Green Turtle [1765]	Internesting	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Likely to occur
Chelonia mydas Green Turtle [1765]	Mating	Likely to occur
Chelonia mydas Green Turtle [1765]	Nesting	Likely to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Likely to occur
Lepidochelys olivacea Olive Ridley Turtle [1767]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 4

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	47
Listed Migratory Species:	63

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	7
Commonwealth Heritage Places:	3
Listed Marine Species:	107
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	8
Habitat Critical to the Survival of Marine Turtles:	3

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	16
Regional Forest Agreements:	None
Nationally Important Wetlands:	2
EPBC Act Referrals:	54
Key Ecological Features (Marine):	5
Biologically Important Areas:	54
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places [Resource Information]

Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Pterodroma arminjoniana Round Island Petrel, Trinidade Petrel [89284]	Critically Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Petrogale concinna monastria Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat known to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Breeding likely to occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat likely to occur within area
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis		
Oriental Reed-Warbler [59570]		Species or species habitat may occur within area
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - YAMPI SOUND TRAINING AREA [50145]	WA
Unknown	
Commonwealth Land - [52252]	WA
Commonwealth Land - [52253]	WA
Commonwealth Land - [52280]	WA
Commonwealth Land - [52254]	WA

Commonwealth Land Name	State
Commonwealth Land - [52256]	WA
Commonwealth Land - [52255]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Indigenous		
Oombalai Area	WA	Within listed place
Natural		
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place
Yampi Defence Area	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat may occur within area overfly marine area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Motacilla flava Yellow Wagtail [644]		Species or species habitat likely to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour likely to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area

Current Scientific Name	Status	Type of Presence
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Kimberley	Habitat Protection Zone (IUCN IV)
Kimberley	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)

Park Name	Zone & IUCN Categories
Cocos (Keeling) Islands	National Park Zone (IUCN II)
Kimberley	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
May - Jul		
Lepidochelys olivacea Olive Ridley Turtle [1767]	Nesting	Known to occur

Extra Information

State and Territory Reserves

[Resource Information]

Protected Area Name	Reserve Type	State
Adele Island	Nature Reserve	WA
Bardi Jawi	Indigenous Protected Area	WA
Dambimangari	Indigenous Protected Area	WA
Lalang-garram / Camden Sound	Marine Park	WA
Lalang-garram / Horizontal Falls	Marine Park	WA
Mitchell River	National Park	WA
North Kimberley	Marine Park	WA
North Lalang-garram	Marine Park	WA
Prince Regent	National Park	WA
Scott Reef	Nature Reserve	WA
Swan Island	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Tanner Island	Nature Reserve	WA
Unnamed WA28968	5(1)(h) Reserve	WA
Unnamed WA44669	5(1)(h) Reserve	WA
Unnamed WA44673	5(1)(h) Reserve	WA
Uunguu	Indigenous Protected Area	WA

Nationally Important Wetlands

[Resource Information]

Wetland Name	State
Prince Regent River System	WA
Yampi Sound Training Area	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Koolan Island Operations	2022/09392		Referral Decision
Ocean Barramundi Expansion Project	2022/09272		Assessment
Controlled action			
2-D seismic survey Scott Reef	2000/125	Controlled Action	Post-Approval
Browse FLNG Development, Commonwealth Waters	2013/7079	Controlled Action	Post-Approval
Cockatoo Island Multi-User Supply Base, WA	2017/7986	Controlled Action	Referral Decision
Develop Ichthys gas-condensate field permit area W	2006/2767	Controlled Action	Completed
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Iron ore mine	2006/2522	Controlled Action	Post-Approval
Pluton Irvine Island Iron Ore Project	2011/6064	Controlled Action	Proposed Decision

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Torosa South Initial Appraisal Drilling	2007/3500	Controlled Action	Completed
Not controlled action			
Aquaculture - Barramundi grow out, Yampi Sound	2005/2476	Not Controlled Action	Completed
Drilling of exploration wells, Permit areas WA-301-P to WA-305-P	2002/769	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
Kimberley Multi-commodity Exploration Programme, WA	2013/6839	Not Controlled Action	Completed
Koolan Island Mine - Reconstruction of seawall and capital dewatering of mine pit,130km northwest of	2016/7848	Not Controlled Action	Completed
Marine Seismic Survey in WA-239-P	2000/24	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D seismic survey in permit areas WA-274P and WA-281P	2004/1521	Not Controlled Action (Particular Manner)	Post-Approval
2 geotechnical surveys - preliminary and final	2006/2886	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic Survey - Maxima 3D MSS	2006/2945	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, near Scott Reef, Browse Basin	2005/2126	Not Controlled Action (Particular Manner)	Post-Approval
Acacia East Pit Cutback Mining Project,northern Kimberley, WA	2013/6752	Not Controlled Action (Particular Manner)	Post-Approval
Aurora MC3D Marine Seismic Survey	2010/5510	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Braveheart 2D Infill Marine Seismic Survey 100km offshore	2008/4442	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Marine Seismic Survey	2005/2322	Not Controlled Action (Particular Manner)	Post-Approval
Caswell MC3D Marine Seismic Survey	2012/6594	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Endurance 3D Marine Seismic Data Acquisition Survey	2007/3667	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Program - Permit areas - WA-314-P, WA-315-P, WA-398-P.	2008/4064	Not Controlled Action (Particular Manner)	Post-Approval
Geoscience Australia - Marine survey in Browse Basin to acquire data to assist assessment of CO2 sto	2013/6747	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Koolama 2D Seismic Survey Dampier Basin	2010/5420	Not Controlled Action (Particular Manner)	Post-Approval
Mariner Non-Exclusive 2D Seismic Survey	2011/6172	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Offshore Exploration Drilling Campaign	2011/6222	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Outer Canning exploration drilling program off NW coast of WA	2012/6618	Not Controlled Action (Particular Manner)	Post-Approval
Repsol 3d & 2D Marine Seismic Survey	2012/6658	Not Controlled Action (Particular Manner)	Post-Approval
Rosebud 3D Marine Seismic Survey in WA-30-R and TR/5	2012/6493	Not Controlled Action (Particular Manner)	Post-Approval
Schild MC3D Marine Seismic Survey	2012/6373	Not Controlled Action (Particular Manner)	Post-Approval
Scott Reef Seismic Research	2006/2647	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Veritas Voyager 2D Marine Seismic Survey	2009/5151	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Woodside Southern Browse 3D Seismic Survey, WA	2007/3534	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Zeemeermin MC3D seismic survey, Browse Basin, Offshore WA	2009/5023	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
Aurora extension MC3D Marine Seismic Survey	2011/5887	Referral Decision	Completed
Experimental Study of Behavioural and Physiological Impact on Fish of Seismic Ex	2006/2625	Referral Decision	Completed
Field efficacy trial of the Hisstory bait for feral cats, at Yampi Sound Defence Training Area, Kimb	2017/7977	Referral Decision	Completed
Kimberley Multi-commodity Exploration Program	2013/6780	Referral Decision	Completed
Seismic Data Acquisition, Browse Basin	2010/5475	Referral Decision	Completed
Tidal Power Generation Turbine	2009/5235	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Argo Abyssal Plain with the Scott Plateau	North-west
Continental Slope Demersal Fish Communities	North-west
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging likely	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Resting	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat - unknown behaviour	Likely to occur

Scientific Name	Behaviour	Presence
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Breeding	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Calving	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging likely	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Migration likely	Known to occur
Dugong		
Dugong dugon Dugong [28]	Foraging	Likely to occur
Marine Turtles		
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
River shark		
Pristis clavata Dwarf Sawfish [68447]	Foraging	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Juvenile	Known to occur

Scientific Name	Behaviour	Presence
Pristis clavata Dwarf Sawfish [68447]	Nursing	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Pupping	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Foraging	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Nursing	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Nursing	Likely to occur
Pristis zijsron Green Sawfish [68442]	Foraging	Known to occur
Pristis zijsron Green Sawfish [68442]	Pupping	Known to occur
Seabirds		
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Calving	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Nursing	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 5

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	2
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	49
Listed Migratory Species:	81

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	79
Commonwealth Heritage Places:	3
Listed Marine Species:	135
Whales and Other Cetaceans:	30
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	7
Habitat Critical to the Survival of Marine Turtles:	2

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	23
Regional Forest Agreements:	None
Nationally Important Wetlands:	5
EPBC Act Referrals:	82
Key Ecological Features (Marine):	5
Biologically Important Areas:	55
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places		[Resource Information]
Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands)	[Resource Information]
Ramsar Site Name	Proximity
Eighty-mile beach	Within Ramsar site
Roebuck bay	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Species or species habitat may occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat known to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
PLANT		
Seringia exastia Fringed Fire-bush [88920]	Critically Endangered	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding likely to occur within area
Liopholis kintorei		
Great Desert Skink, Tjakura, Warrarna, Mulyamiji [83160]	Vulnerable	Species or species habitat may occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Breeding likely to occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula birostris as Manta birostris		
Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus		
Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica		
Red-rumped Swallow [80610]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - BROOME TRAINING DEPOT [50141]	WA
Defence - NORFORCE DEPOT - DERBY [50144]	WA
Defence - RAAF BASE CURTIN [50113]	WA
Defence - YAMPI SOUND TRAINING AREA [50145]	WA
Unknown	
Commonwealth Land - [51815]	WA
Commonwealth Land - [51814]	WA
Commonwealth Land - [51086]	WA
Commonwealth Land - [51080]	WA
Commonwealth Land - [51081]	WA
Commonwealth Land - [51409]	WA
Commonwealth Land - [51831]	WA
Commonwealth Land - [51084]	WA
Commonwealth Land - [51085]	WA
Commonwealth Land - [51816]	WA
Commonwealth Land - [52280]	WA
Commonwealth Land - [51813]	WA
Commonwealth Land - [51812]	WA
Commonwealth Land - [51091]	WA
Commonwealth Land - [51809]	WA
Commonwealth Land - [51817]	WA
Commonwealth Land - [51073]	WA
Commonwealth Land - [51071]	WA

Commonwealth Land Name	State
Commonwealth Land - [51811]	WA
Commonwealth Land - [51810]	WA
Commonwealth Land - [51804]	WA
Commonwealth Land - [51818]	WA
Commonwealth Land - [51806]	WA
Commonwealth Land - [51807]	WA
Commonwealth Land - [51808]	WA
Commonwealth Land - [51803]	WA
Commonwealth Land - [51089]	WA
Commonwealth Land - [51082]	WA
Commonwealth Land - [51083]	WA
Commonwealth Land - [51079]	WA
Commonwealth Land - [51078]	WA
Commonwealth Land - [52256]	WA
Commonwealth Land - [51088]	WA
Commonwealth Land - [51070]	WA
Commonwealth Land - [51077]	WA
Commonwealth Land - [51074]	WA
Commonwealth Land - [52245]	WA
Commonwealth Land - [51067]	WA
Commonwealth Land - [52193]	WA
Commonwealth Land - [51431]	WA
Commonwealth Land - [51068]	WA
Commonwealth Land - [50340]	WA
Commonwealth Land - [51973]	WA
Commonwealth Land - [51069]	WA
Commonwealth Land - [51840]	WA

Commonwealth Land Name	State
Commonwealth Land - [51824]	WA
Commonwealth Land - [51092]	WA
Commonwealth Land - [51090]	WA
Commonwealth Land - [52194]	WA
Commonwealth Land - [51821]	WA
Commonwealth Land - [51075]	WA
Commonwealth Land - [51835]	WA
Commonwealth Land - [51072]	WA
Commonwealth Land - [51076]	WA
Commonwealth Land - [52192]	WA
Commonwealth Land - [51819]	WA
Commonwealth Land - [51966]	WA
Commonwealth Land - [51825]	WA
Commonwealth Land - [51826]	WA
Commonwealth Land - [51820]	WA
Commonwealth Land - [51822]	WA
Commonwealth Land - [51823]	WA
Commonwealth Land - [51094]	WA
Commonwealth Land - [51836]	WA
Commonwealth Land - [51837]	WA
Commonwealth Land - [51832]	WA
Commonwealth Land - [51833]	WA
Commonwealth Land - [51834]	WA
Commonwealth Land - [51087]	WA
Commonwealth Land - [50341]	WA
Commonwealth Land - [51830]	WA
Commonwealth Land - [51839]	WA

Commonwealth Land Name	State
Commonwealth Land - [51838]	WA
Commonwealth Land - [51965]	WA
Commonwealth Land - [51805]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Indigenous		
Oombalai Area	WA	Within listed place
Natural		
Mermaid Reef - Rowley Shoals	WA	Listed place
Yampi Defence Area	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Chalcites osculans as Chrysococcyx osculans		
Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius bicinctus		
Double-banded Plover [895]		Roosting known to occur within area overfly marine area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus		
Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae		
Silver Gull [82326]		Breeding known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Gallinago megala		
Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura		
Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area
Glareola maldivarum		
Oriental Pratincole [840]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Breeding known to occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area overfly marine area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		

Scientific Name	Threatened Category	Presence Text
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hydrophis macdowelli as Hydrophis mcdowelli		
Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii		
Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma czeblukovi as Hydrophis czeblukovi		
Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus		
Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera bonaerensis		
Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Breeding known to occur within area

Current Scientific Name	Status	Type of Presence
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area

Current Scientific Name	Status	Type of Presence
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Roebuck	Multiple Use Zone (IUCN VI)
Mermaid Reef	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Bardi Jawi	Indigenous Protected Area	WA
Broome Bird Observatory	5(1)(h) Reserve	WA
Broome Wildlife Centre	5(1)(h) Reserve	WA
Coulomb Point	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Eighty Mile Beach	Marine Park	WA
Jinmarnkur	Conservation Park	WA
Jinmarnkur Kulja	Nature Reserve	WA
Karajarri	Indigenous Protected Area	WA
Lacepede Islands	Nature Reserve	WA
Rowley Shoals	Marine Park	WA
Unnamed WA37168	5(1)(h) Reserve	WA
Unnamed WA51046	5(1)(h) Reserve	WA
Unnamed WA51105	5(1)(h) Reserve	WA
Unnamed WA51162	5(1)(h) Reserve	WA
Unnamed WA51497	5(1)(h) Reserve	WA
Unnamed WA51583	5(1)(h) Reserve	WA
Unnamed WA51617	5(1)(h) Reserve	WA
Unnamed WA51932	5(1)(h) Reserve	WA
Unnamed WA52354	5(1)(h) Reserve	WA
Unnamed WA53015	Nature Reserve	WA
Yawuru	Indigenous Protected Area	WA
Yawuru	Indigenous Protected Area	WA
Yawuru Nagulagun / Roebuck Bay	Marine Park	WA

Nationally Important Wetlands

[Resource Information]

Wetland Name	State
Big Springs	WA
Bunda-Bunda Mound Springs	WA
Mermaid Reef	EXT
Roebuck Bay	WA
Willie Creek Wetlands	WA

EPBC Act Referrals			[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Ocean Barramundi Expansion Project	2022/09272		Assessment
Project Highclere Cable Lay and Operation	2022/09203		Completed
Controlled action			
Broome Boating Facility	2021/9098	Controlled Action	Referral Decision
Broome International Airport Relocation Project	2000/74	Controlled Action	Post-Approval
Derby Tidal Power Project	2010/5544	Controlled Action	Final PER Or EIS
Derby Tidal Power Proposal	2001/398	Controlled Action	Completed
Development of Angel gas and condensate field, North West Shelf	2004/1805	Controlled Action	Post-Approval
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Duchess Paradise Project	2011/6033	Controlled Action	Completed
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval
Great Northern Pipeline - 630 km buried gas pipeline	2009/5257	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
Shamrock Station Irrigation Project, west Kimberley region, WA	2017/8004	Controlled Action	Post-Approval
Not controlled action			
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Broome Borefield Bushfire Mitigation Program	2020/8680	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Broome Motorplex Relocation Project, Lot 591 Broome Road	2017/8117	Not Controlled Action	Completed
Broome Road Industrial Estate	2020/8811	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033	Not Controlled Action	Completed
Establish a 4m wide trace line along the road allignment for James Price Point	2010/5682	Not Controlled Action	Completed
Huascaran-1 exploration well (WA-292-P)	2001/539	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Kimberley Marine Offloading Facility	2020/8736	Not Controlled Action	Completed
Kimberley Multi-commodity Exploration Programme, WA	2013/6839	Not Controlled Action	Completed
Maia-Gaea Exploration wells	2000/17	Not Controlled Action	Completed
Manaslu - 1 and Huascaran - 1 Offshore Exploration Wells	2001/235	Not Controlled Action	Completed
Native Orchard Development, 10km northeast of Broome WA	2019/8501	Not Controlled Action	Completed
Port of Broome Channel Optimisation Project, West Roebuck Bay, WA	2018/8162	Not Controlled Action	Completed
Power Station Upgrade	2001/357	Not Controlled Action	Completed
Power Station Upgrade (South Port Site)	2001/414	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
sub-sea tieback of Perseus field wells	2004/1326	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Telstra North Rankin Spur Fibre Optic Cable	2016/7836	Not Controlled Action	Completed
WA-295-P Kerr-McGee Exploration Wells	2001/152	Not Controlled Action	Completed
Wastewater Treatment Plant	2008/4545	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D marine seismic survey	2012/6296	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey Permit Area WA-352-P	2008/4628	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey (WA-482-P, WA-363-P), WA	2013/6761	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in WA 457-P & WA 458-P, North West Shelf, offshore WA	2013/6862	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D sesmic survey	2006/2781	Not Controlled Action (Particular Manner)	Post-Approval
Artemis-1 Drilling Program (WA-360-P)	2010/5432	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Bonaventure 3D seismic survey	2006/2514	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Construction of a 43km long sealed access road to the Browse LNG precinct	2011/5852	Not Controlled Action (Particular Manner)	Post-Approval
Cue Seismic Survey within WA-359-P, WA-361-P and WA-360-P	2007/3647	Not Controlled Action (Particular Manner)	Post-Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Effect of marine seismic sounds to demersal fish and pearl oysters, north-west WA	2018/8169	Not Controlled Action (Particular Manner)	Post-Approval
Establishment of AQIS washdown facility, logistics support base and ancillary businesses	2012/6364	Not Controlled Action (Particular Manner)	Post-Approval
Exmouth West 2D Marine Seismic Survey	2008/4132	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Exploration drilling of Zeus-1 well	2008/4351	Not Controlled Action (Particular Manner)	Post-Approval
Fletcher-Finucane Development, WA26-L and WA191-P	2011/6123	Not Controlled Action (Particular Manner)	Post-Approval
Foxhound 3D Non-Exclusive Marine Seismic Survey	2009/4703	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2008/4630	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2009/4801	Not Controlled Action (Particular Manner)	Post-Approval
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Koolama 2D Seismic Survey Dampier Basin	2010/5420	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Offshore Drilling Campaign	2011/5830	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Outer Canning exploration drilling program off NW coast of WA	2012/6618	Not Controlled Action (Particular Manner)	Post-Approval
Phoenix 3D Seismic Survey, Bedout Sub-Basin	2010/5360	Not Controlled Action (Particular Manner)	Post-Approval
Repsol 3d & 2D Marine Seismic Survey	2012/6658	Not Controlled Action (Particular Manner)	Post-Approval
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Seismic Survey	2008/4219	Referral Decision	Completed
Field efficacy trial of the Hisstory bait for feral cats, at Yampi Sound Defence Training Area, Kimb	2017/7977	Referral Decision	Completed
Kimberley Multi-commodity Exploration Program	2013/6780	Referral Decision	Completed
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging likely	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Breeding	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Calving	Known to occur

Scientific Name	Behaviour	Presence
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging likely	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Migration likely	Known to occur
Dugong		
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging	Likely to occur
Dugong dugon Dugong [28]	Migration likely	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur

Scientific Name	Behaviour	Presence
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
River shark		
Pristis clavata Dwarf Sawfish [68447]	Foraging	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Juvenile	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Nursing	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Pupping	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Foraging	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Juvenile	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Nursing	Likely to occur
Pristis pristis Freshwater Sawfish [60756]	Nursing	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Pupping	Likely to occur
Pristis pristis Freshwater Sawfish [60756]	Pupping	Known to occur
Pristis zijsron Green Sawfish [68442]	Foraging	Known to occur
Pristis zijsron Green Sawfish [68442]	Nursing	Known to occur
Pristis zijsron Green Sawfish [68442]	Pupping	Known to occur
Seabirds		

Scientific Name	Behaviour	Presence
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Resting	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Calving	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur

Scientific Name	Behaviour	Presence
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Nursing	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government

Department of Climate Change, Energy, the Environment and Water

AREA 6

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	2
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	57
Listed Migratory Species:	86

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	197
Commonwealth Heritage Places:	2
Listed Marine Species:	131
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	11
Habitat Critical to the Survival of Marine Turtles:	4

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	57
Regional Forest Agreements:	None
Nationally Important Wetlands:	7
EPBC Act Referrals:	292
Key Ecological Features (Marine):	6
Biologically Important Areas:	52
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
The Ningaloo Coast	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Natural		
The Ningaloo Coast	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Eighty-mile beach	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris		
Great Knot [862]	Critically Endangered	Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
CRUSTACEAN		
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat known to occur within area
FISH		
Milyeringa veritas Cape Range Cave Gudgeon, Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Pseudomys fieldi		
Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Minuria tridens		
Minnie Daisy [13753]	Vulnerable	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus		
Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lerista nevinae		
Nevin's Slider [85296]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Liasis olivaceus barroni		
Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Liopholis kintorei		
Great Desert Skink, Tjakura, Warrarna, Mulyamiji [83160]	Vulnerable	Species or species habitat may occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus		
Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cuculus optatus		
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50128]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50124]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50126]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50125]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50127]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50129]	WA
Defence - EXMOUTH NAVAL HF RECEIVING STATION (H/F Receiving Station, Learmonth, WA) [50130]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - KARRATHA TRAINING DEPOT [50200]	WA
Defence - KARRATHA TRAINING DEPOT [50237]	WA
Defence - KARRATHA TRAINING DEPOT [50238]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH - RAAF BASE [50099]	WA
Defence - LEARMONTH - RAAF BASE [50097]	WA
Defence - LEARMONTH - RAAF BASE [50096]	WA
Defence - LEARMONTH - RAAF BASE [50100]	WA
Defence - LEARMONTH - RAAF BASE [50098]	WA
Defence - LEARMONTH - RAAF BASE [50105]	WA
Defence - LEARMONTH - RAAF BASE [50106]	WA
Defence - LEARMONTH - RAAF BASE [50107]	WA
Defence - LEARMONTH - RAAF BASE [50103]	WA

Commonwealth Land Name	State
Defence - LEARMONTH - RAAF BASE [50102]	WA
Defence - LEARMONTH - RAAF BASE [50104]	WA
Defence - LEARMONTH - RAAF BASE [50108]	WA
Defence - LEARMONTH - RAAF BASE [50101]	WA
Defence - LEARMONTH - RAAF BASE [50109]	WA
Defence - LEARMONTH RADAR SITE - TWIN TANKS EXMOUTH [50002]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Defence - LEARMONTH TRANSMITTING STATION [50239]	WA
Unknown	
Commonwealth Land - [51450]	WA
Commonwealth Land - [51453]	WA
Commonwealth Land - [51589]	WA
Commonwealth Land - [51588]	WA
Commonwealth Land - [51586]	WA
Commonwealth Land - [51455]	WA
Commonwealth Land - [51451]	WA
Commonwealth Land - [51576]	WA
Commonwealth Land - [51704]	WA
Commonwealth Land - [52097]	WA
Commonwealth Land - [51595]	WA
Commonwealth Land - [51459]	WA
Commonwealth Land - [51702]	WA
Commonwealth Land - [50989]	WA
Commonwealth Land - [51053]	WA
Commonwealth Land - [51055]	WA
Commonwealth Land - [51054]	WA

Commonwealth Land Name	State
Commonwealth Land - [51572]	WA
Commonwealth Land - [51452]	WA
Commonwealth Land - [51671]	WA
Commonwealth Land - [51670]	WA
Commonwealth Land - [51558]	WA
Commonwealth Land - [51559]	WA
Commonwealth Land - [51554]	WA
Commonwealth Land - [51557]	WA
Commonwealth Land - [51669]	WA
Commonwealth Land - [51552]	WA
Commonwealth Land - [51475]	WA
Commonwealth Land - [51587]	WA
Commonwealth Land - [51712]	WA
Commonwealth Land - [51580]	WA
Commonwealth Land - [51703]	WA
Commonwealth Land - [51700]	WA
Commonwealth Land - [51582]	WA
Commonwealth Land - [51672]	WA
Commonwealth Land - [51709]	WA
Commonwealth Land - [51705]	WA
Commonwealth Land - [51553]	WA
Commonwealth Land - [51443]	WA
Commonwealth Land - [51442]	WA
Commonwealth Land - [51445]	WA
Commonwealth Land - [51564]	WA
Commonwealth Land - [50385]	WA
Commonwealth Land - [51567]	WA

Commonwealth Land Name	State
Commonwealth Land - [52110]	WA
Commonwealth Land - [52104]	WA
Commonwealth Land - [52101]	WA
Commonwealth Land - [51720]	WA
Commonwealth Land - [51935]	WA
Commonwealth Land - [51939]	WA
Commonwealth Land - [50977]	WA
Commonwealth Land - [52098]	WA
Commonwealth Land - [52099]	WA
Commonwealth Land - [51470]	WA
Commonwealth Land - [50349]	WA
Commonwealth Land - [51884]	WA
Commonwealth Land - [51719]	WA
Commonwealth Land - [52198]	WA
Commonwealth Land - [52096]	WA
Commonwealth Land - [51575]	WA
Commonwealth Land - [51600]	WA
Commonwealth Land - [51601]	WA
Commonwealth Land - [52108]	WA
Commonwealth Land - [51581]	WA
Commonwealth Land - [51463]	WA
Commonwealth Land - [51578]	WA
Commonwealth Land - [52109]	WA
Commonwealth Land - [52103]	WA
Commonwealth Land - [51472]	WA
Commonwealth Land - [52131]	WA
Commonwealth Land - [52195]	WA

Commonwealth Land Name	State
Commonwealth Land - [51467]	WA
Commonwealth Land - [51466]	WA
Commonwealth Land - [51464]	WA
Commonwealth Land - [51468]	WA
Commonwealth Land - [51462]	WA
Commonwealth Land - [51461]	WA
Commonwealth Land - [51460]	WA
Commonwealth Land - [51573]	WA
Commonwealth Land - [51469]	WA
Commonwealth Land - [52236]	WA
Commonwealth Land - [51555]	WA
Commonwealth Land - [51715]	WA
Commonwealth Land - [51677]	WA
Commonwealth Land - [51456]	WA
Commonwealth Land - [51465]	WA
Commonwealth Land - [51584]	WA
Commonwealth Land - [51585]	WA
Commonwealth Land - [50976]	WA
Commonwealth Land - [51583]	WA
Commonwealth Land - [51393]	WA
Commonwealth Land - [50978]	WA
Commonwealth Land - [51471]	WA
Commonwealth Land - [51473]	WA
Commonwealth Land - [51474]	WA
Commonwealth Land - [51476]	WA
Commonwealth Land - [50975]	WA
Commonwealth Land - [50974]	WA

Commonwealth Land Name	State
Commonwealth Land - [51579]	WA
Commonwealth Land - [51454]	WA
Commonwealth Land - [51686]	WA
Commonwealth Land - [51574]	WA
Commonwealth Land - [51577]	WA
Commonwealth Land - [51571]	WA
Commonwealth Land - [51570]	WA
Commonwealth Land - [51458]	WA
Commonwealth Land - [51696]	WA
Commonwealth Land - [51934]	WA
Commonwealth Land - [51104]	WA
Commonwealth Land - [52220]	WA
Commonwealth Land - [51457]	WA
Commonwealth Land - [52107]	WA
Commonwealth Land - [51947]	WA
Commonwealth Land - [52106]	WA
Commonwealth Land - [51477]	WA
Commonwealth Land - [50990]	WA
Commonwealth Land - [51692]	WA
Commonwealth Land - [52105]	WA
Commonwealth Land - [52102]	WA
Commonwealth Land - [51428]	WA
Commonwealth Land - [50324]	WA
Commonwealth Land - [51404]	WA
Commonwealth Land - [51403]	WA
Commonwealth Land - [51887]	WA
Commonwealth Land - [51667]	WA

Commonwealth Land Name	State
Commonwealth Land - [51562]	WA
Commonwealth Land - [51668]	WA
Commonwealth Land - [51666]	WA
Commonwealth Land - [51710]	WA
Commonwealth Land - [51711]	WA
Commonwealth Land - [51718]	WA
Commonwealth Land - [51713]	WA
Commonwealth Land - [51716]	WA
Commonwealth Land - [51714]	WA
Commonwealth Land - [51717]	WA
Commonwealth Land - [51566]	WA
Commonwealth Land - [51448]	WA
Commonwealth Land - [51708]	WA
Commonwealth Land - [52205]	WA
Commonwealth Land - [51556]	WA
Commonwealth Land - [51568]	WA
Commonwealth Land - [51569]	WA
Commonwealth Land - [51561]	WA
Commonwealth Land - [51444]	WA
Commonwealth Land - [51447]	WA
Commonwealth Land - [51446]	WA
Commonwealth Land - [51565]	WA
Commonwealth Land - [51560]	WA
Commonwealth Land - [51563]	WA
Commonwealth Land - [51594]	WA
Commonwealth Land - [51597]	WA
Commonwealth Land - [51596]	WA

Commonwealth Land Name	State
Commonwealth Land - [51592]	WA
Commonwealth Land - [51591]	WA
Commonwealth Land - [51593]	WA
Commonwealth Land - [51598]	WA
Commonwealth Land - [51599]	WA
Commonwealth Land - [51590]	WA
Commonwealth Land - [51698]	WA
Commonwealth Land - [51699]	WA
Commonwealth Land - [51693]	WA
Commonwealth Land - [51695]	WA
Commonwealth Land - [51449]	WA
Commonwealth Land - [51707]	WA
Commonwealth Land - [51691]	WA
Commonwealth Land - [52100]	WA
Commonwealth Land - [51706]	WA

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area overfly marine area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sternula albifrons as Sterna albifrons Little Tern [82849]		Breeding known to occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area overfly marine area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Leioselasma czeblukovi as Hydrophis czeblukovi Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Dampier	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)

Park Name	Zone & IUCN Categories
Ningaloo	Recreational Use Zone (IUCN IV)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Nov-Feb		
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Nov - May		
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur

Extra Information

State and Territory Reserves

[Resource Information]

Protected Area Name	Reserve Type	State
Airlie Island	Nature Reserve	WA
Barrow Island	Nature Reserve	WA
Barrow Island	Marine Park	WA
Barrow Island	Marine Management Area	WA
Bedout Island	Nature Reserve	WA
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Burnside And Simpson Island	Nature Reserve	WA
Cape Range	National Park	WA
Eighty Mile Beach	Marine Park	WA

Protected Area Name	Reserve Type	State
Giralia	NRS Addition - Gazettal in Progress	WA
Gnandaroo Island	Nature Reserve	WA
Great Sandy Island	Nature Reserve	WA
Jarrkunpungu	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) Reserve	WA
Kujungurru Warrarn	Nature Reserve	WA
Kujungurru Warrarn	Conservation Park	WA
Little Rocky Island	Nature Reserve	WA
Locker Island	Nature Reserve	WA
Lowendal Islands	Nature Reserve	WA
Montebello Islands	Conservation Park	WA
Montebello Islands	Marine Park	WA
Montebello Islands	Conservation Park	WA
Muiron Islands	Nature Reserve	WA
Muiron Islands	Marine Management Area	WA
Murujuga	National Park	WA
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
North Turtle Island	Nature Reserve	WA
Nyangumarta Warrarn	Indigenous Protected Area	WA
Nyangumarta Warrarn	Indigenous Protected Area	WA
Rocky Island	Nature Reserve	WA
Round Island	Nature Reserve	WA
Serrurier Island	Nature Reserve	WA
Tent Island	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Thevenard Island	Nature Reserve	WA
Unnamed WA36907	5(1)(h) Reserve	WA
Unnamed WA36909	5(1)(h) Reserve	WA
Unnamed WA36910	5(1)(h) Reserve	WA
Unnamed WA36913	Nature Reserve	WA
Unnamed WA36915	Nature Reserve	WA
Unnamed WA38287	5(1)(h) Reserve	WA
Unnamed WA40322	5(1)(h) Reserve	WA
Unnamed WA40828	5(1)(h) Reserve	WA
Unnamed WA40877	5(1)(h) Reserve	WA
Unnamed WA41080	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Unnamed WA44672	5(1)(h) Reserve	WA
Unnamed WA52366	Nature Reserve	WA
Unnamed WA53015	Nature Reserve	WA
Victor Island	Nature Reserve	WA
Weld Island	Nature Reserve	WA
Whalebone Island	Nature Reserve	WA
Whitmore,Roberts,Doole Islands And Sandalwood Landing	Nature Reserve	WA
Y Island	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
De Grey River	WA

Wetland Name	State
Eighty Mile Beach System	WA
Exmouth Gulf East	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA
Leslie (Port Hedland) Saltfields System	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Ashburton Infrastructure Project	2021/9064		Post-Approval
Balla Balla Export Facilities ? Design Variation	2022/09254		Assessment
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
North West Shelf Project Extension, Carnarvon Basin, WA	2018/8335		Approval
Optimised Mardie Solar Salt Project	2022/9169		Assessment
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Asian Renewable Energy Hub Revised Proposal, WA	2021/8891	Action Clearly Unacceptable	Completed
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	Controlled Action	Post-Approval
Additional Rail Infrastructure between Herb Elliott Port Facility and Cloudbreak Mine Site	2010/5513	Controlled Action	Post-Approval
Ammonium Nitrate Project	2010/5423	Controlled Action	Completed
Anketell Point Iron Ore Processing & Export Port	2009/5120	Controlled Action	Post-Approval
Asian Renewable Energy Hub, 220 km east of Port Hedland, Western Australia	2017/8112	Controlled Action	Post-Approval
Balmoral South Iron Ore Mine	2008/4236	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Binowee Iron Ore Project	2001/366	Controlled Action	Proposed Decision
Burrup North East Sand Mining Project	2008/4611	Controlled Action	Completed
Cape Lambert Port B Development	2008/4032	Controlled Action	Post-Approval
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Construction and operation of a Solar Salt Project, SW Onslow, WA	2016/7793	Controlled Action	Assessment Approach
Develop Jansz-Io deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Development of Angel gas and condensate field, North West Shelf	2004/1805	Controlled Action	Post-Approval
Development of an iron ore mine and associated infrastructure	2010/5630	Controlled Action	Assessment Approach
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Development of Coniston/Novara fields within the Exmouth Sub-basin	2011/5995	Controlled Action	Post-Approval
Development of Stybarrow petroleum field incl drilling and facility installation	2004/1469	Controlled Action	Post-Approval
Duplication of the Dampier Highway Stages 2 & 6	2010/5419	Controlled Action	Post-Approval
Echo-Yodel Production Wells	2000/11	Controlled Action	Post-Approval
Enfield full field development	2001/257	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Eramurra Industrial Salt Project	2021/9027	Controlled Action	Assessment Approach
Eramurra Industrial Salt Project, near Karratha, WA	2019/8448	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Gorgon Gas Development	2003/1294	Controlled Action	Post-Approval
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval
Gorgon Gas Revised Development	2008/4178	Controlled Action	Post-Approval
Greater Enfield (Vincent) Development	2005/2110	Controlled Action	Post-Approval
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	Controlled Action	Completed
Great Northern Pipeline - 630 km buried gas pipeline	2009/5257	Controlled Action	Completed
Learmonth Bundle Site and Launchway, WA	2017/8079	Controlled Action	Completed
Light Crude Oil Production	2001/365	Controlled Action	Post-Approval
Mardie Project, 80 km south west of Karratha, WA	2018/8236	Controlled Action	Post-Approval
Nava-1 Cable System	2001/510	Controlled Action	Completed
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693	Controlled Action	Assessment Approach
North Star Magnetite Project	2012/6689	Controlled Action	Post-Approval
North West Shelf Gas Venture Phase VI Expansion	2007/3436	Controlled Action	Referral Decision
Perdaman Urea Project, near Karratha, WA	2018/8383	Controlled Action	Post-Approval
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Port Hedland Outer Harbour Development and associated marine and terrestrial in	2008/4159	Controlled Action	Post-Approval
Port Hedland Spoilbank Marina, WA	2019/8520	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Proposed technical ammonium nitrate production facility	2008/4546	Controlled Action	Post-Approval
Proposed West Pilbara Iron Ore Project	2009/4706	Controlled Action	Post-Approval
Pyrenees Oil Fields Development	2005/2034	Controlled Action	Post-Approval
Simpson Development	2000/59	Controlled Action	Completed
Simpson Oil Field Development	2001/227	Controlled Action	Post-Approval
Single Jetty Deep Water Port Renewable Hub, WA	2021/8942	Controlled Action	Proposed Decision
site preparations	2005/2391	Controlled Action	Post-Approval
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
Widening and resurfacing two principal roads servicing the Dampier Port Authori	2010/5677	Controlled Action	Completed
Yannarie Solar Salt Project	2004/1679	Controlled Action	Completed
Yardie Creek Road Realignment Project	2021/8967	Controlled Action	Assessment Approach
Not controlled action			
'Goodwyn A' Low Pressure Train Project	2003/914	Not Controlled Action	Completed
'Van Gogh' Oil Appraisal Drilling Program, Exploration Permit Area WA-155-P(1)	2006/3148	Not Controlled Action	Completed
Airlie Island soil and groundwater investigations, Exmouth Gulf, offshore Pilbara coast	2014/7250	Not Controlled Action	Completed
Ammonia Plant	2001/199	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed
Barrow Island 2D Seismic survey	2006/2667	Not Controlled Action	Completed
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Bulgarene Borefield	2006/2507	Not Controlled Action	Completed
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	Not Controlled Action	Completed
Cape Lambert Port A Marine Structures Refurbishment Project	2018/8370	Not Controlled Action	Completed
Carnarvon 3D Marine Seismic Survey	2004/1890	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Construct 110km buried natural gas pipeline from Onslow, connecting to Dampier/Bunbury natural gas p	2013/7039	Not Controlled Action	Completed
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Construction of a Commodities Berth, Wharf and Associated Infrastructure	2008/4129	Not Controlled Action	Completed
Construction of Loadout Facility and Laydown Area	2002/598	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Deep Gorge Boardwalk, Murujuga National Park, WA	2018/8283	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Development of Industrial Land, Port of Dampier	2003/1293	Not Controlled Action	Completed
Development of iron ore facilities	2013/7013	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Development of iron ore resources in eastern Pilbara region, including port at P	2004/1562	Not Controlled Action	Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033	Not Controlled Action	Completed
Differential Global Positioning System (DGPS)	2001/445	Not Controlled Action	Completed
Dimethyl ether plant	2001/509	Not Controlled Action	Completed
Drilling of an exploration well Gats-1 in Permit Area WA-261-P	2004/1701	Not Controlled Action	Completed
Eagle-1 Exploration Drilling, North West Shelf, WA	2019/8578	Not Controlled Action	Completed
Echo A Development WA-23-L, WA-24-L	2005/2042	Not Controlled Action	Completed
Expansion of the Sino Iron Ore Mine and export facilities, Cape Preston, WA	2017/7862	Not Controlled Action	Completed
Expansion Proposal, Mineralogy Cape Preston Iron Ore Project, Cape Preston, WA	2009/5010	Not Controlled Action	Completed
Exploration drilling well WA-155-P(1)	2003/971	Not Controlled Action	Completed
Exploration of appraisal wells	2006/3065	Not Controlled Action	Completed
Exploration Well (Taunton-2)	2002/731	Not Controlled Action	Completed
Exploration Well in Permit Area WA-155-P(1)	2002/759	Not Controlled Action	Completed
Exploratory drilling in permit area WA-225-P	2001/490	Not Controlled Action	Completed
Extension of Simpson Oil Platforms & Wells	2002/685	Not Controlled Action	Completed
Gulf Fishing Lodge	2010/5499	Not Controlled Action	Completed
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Horizon Power South Hedland Transmission Line, WA	2012/6551	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Infill Production Well (Griffin-9)	2001/417	Not Controlled Action	Completed
Iron Bridge Port Facility, Port Hedland, WA	2015/7565	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
King Bay East Rock Quarry & Industrial Estate Development	2003/1150	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	Not Controlled Action	Completed
Learmonth Limestone Quarry	2001/392	Not Controlled Action	Completed
Mahimahi Aquaculture Facility	2002/891	Not Controlled Action	Completed
Maia-Gaea Exploration wells	2000/17	Not Controlled Action	Completed
Mermaid Marine Australia Desalination Project	2011/5916	Not Controlled Action	Completed
Methanol manufacturing	2001/528	Not Controlled Action	Completed
Methanol plant	2001/521	Not Controlled Action	Completed
Montesa-1 and Bultaco-1 Exploration Wells	2000/102	Not Controlled Action	Completed
Murujuga archaeological excavation, collection and sampling, Dampier Archipelago, WA	2014/7160	Not Controlled Action	Completed
North Rankin B gas compression facility	2005/2500	Not Controlled Action	Completed
Onslow Power Infrastructure Upgrade Project, Onslow, WA	2014/7314	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Onslow Water Supply Infrastructure Upgrade Project, Onslow, WA	2014/7329	Not Controlled Action	Completed
Pilbara Bulk Ore Transport System Project, WA	2016/7637	Not Controlled Action	Completed
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Pluto-North West Shelf Interconnector, Burrup Peninsula, WA	2018/8353	Not Controlled Action	Completed
Port Expansion and Dredging	2003/1265	Not Controlled Action	Completed
Port Hedland Channel Risk and Optimisation Project, WA	2017/7915	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Rail and Port Facilities	2001/474	Not Controlled Action	Completed
Searipple gas and condensate field development	2000/89	Not Controlled Action	Completed
Spool Base Facility	2001/263	Not Controlled Action	Completed
Stages 1 & 2 Port of Dampier Security Upgrade & Associated Works	2004/1751	Not Controlled Action	Completed
Subsea Gas Pipeline From Stybarrow Field to Griffin Venture Gas Export Pipeline	2005/2033	Not Controlled Action	Completed
sub-sea tieback of Perseus field wells	2004/1326	Not Controlled Action	Completed
Telfer Gold Mine Project - Mine and Borefield Extensions and Upgrade of Storage	2002/787	Not Controlled Action	Completed
Telstra North Rankin Spur Fibre Optic Cable	2016/7836	Not Controlled Action	Completed
Thevenard Island Retirement Project	2015/7423	Not Controlled Action	Completed
To construct and operate an offshore submarine fibre optic cable, WA	2014/7373	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Walkway Lighting Upgrade	2009/4965	Not Controlled Action	Completed
Wanda Offshore Research Project, 80 km north-east of Exmouth, WA	2018/8293	Not Controlled Action	Completed
Western Flank Gas Development	2005/2464	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Widening of MOF Road	2005/2305	Not Controlled Action	Completed
Woodside Project Facilities Increase	2006/3191	Not Controlled Action	Completed
Not controlled action (particular manner)			
'Kate' 3D marine seismic survey, exploration permits WA-320-P and WA-345-P, 60km	2005/2037	Not Controlled Action (Particular Manner)	Post-Approval
'Tourmaline' 2D marine seismic survey, permit areas WA-323-P, WA-330-P and WA-32	2005/2282	Not Controlled Action (Particular Manner)	Post-Approval
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D seismic surveys	2005/2151	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey	2012/6296	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey	2005/2146	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey Permit Area WA-352-P	2008/4628	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey	2008/4281	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in WA 457-P & WA 458-P, North West Shelf, offshore WA	2013/6862	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Surveys - Contos CT-13 & Supertubes CT-13, offshore WA	2013/6901	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey	2006/2715	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, WA	2008/4428	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778	Not Controlled Action (Particular Manner)	Post-Approval
3D sesmic survey	2006/2781	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Additional Rail Infrastructure	2012/6314	Not Controlled Action (Particular Manner)	Post-Approval
Agrippina 3D Seismic Marine Survey	2009/5212	Not Controlled Action (Particular Manner)	Post-Approval
Algae Farm and Processing Facilities	2012/6596	Not Controlled Action (Particular Manner)	Post-Approval
Ammonia Plant, Murujuga Burrup Peninsula - Renewable Hydrogen Project	2020/8739	Not Controlled Action (Particular Manner)	Post-Approval
Apache Northwest Shelf Van Gogh Field Appraisal Drilling Program	2007/3495	Not Controlled Action (Particular Manner)	Post-Approval
Aperio 3D Marine Seismic Survey, WA	2012/6648	Not Controlled Action (Particular Manner)	Post-Approval
Artemis-1 Drilling Program (WA-360-P)	2010/5432	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular Manner)	Post-Approval
Bonaventure 3D seismic survey	2006/2514	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Cable Seismic Exploration Permit areas WA-323-P and WA-330-P	2008/4227	Not Controlled Action (Particular Manner)	Post-Approval
Cape Preston East - Iron Ore Export Facilities, Pilbara, WA	2013/6844	Not Controlled Action (Particular Manner)	Post-Approval
Cerberus exploration drilling campaign, Carnarvon Basin, WA	2016/7645	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Charon 3D Marine Seismic Survey	2007/3477	Not Controlled Action (Particular Manner)	Post-Approval
Consturction & operation of the Varanus Island kitchen & mess cyclone refuge building, compression p	2013/6952	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
Cue Seismic Survey within WA-359-P, WA-361-P and WA-360-P	2007/3647	Not Controlled Action (Particular Manner)	Post-Approval
CVG 3D Marine Seismic Survey	2012/6654	Not Controlled Action (Particular Manner)	Post-Approval
Dampier Marine Services Facility including 300m Wharf and Dredging Works	2009/5108	Not Controlled Action (Particular Manner)	Post-Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092	Not Controlled Action (Particular Manner)	Post-Approval
Decommissioning of the Legendre facilities	2010/5681	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Diesel Fuel Bunker Operation	2012/6289	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	Not Controlled Action (Particular Manner)	Post-Approval
Dredging of marine sediment to enable construction of eight berths and a turnin	2010/5678	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Earthworks for kitchen/mess, cyclone refuge building & Compression Plant, Varanus Island	2013/6900	Not Controlled Action (Particular Manner)	Post-Approval
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	Not Controlled Action (Particular Manner)	Post-Approval
Effect of marine seismic sounds to demersal fish and pearl oysters, north-west WA	2018/8169	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M3 & Vincent 4D Marine Seismic Surveys	2008/3981	Not Controlled Action (Particular Manner)	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Enfield M3 4D, Vincent 4D & 4D Line Test Marine Seismic Surveys	2008/4122	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M4 4D Marine Seismic Survey	2008/4558	Not Controlled Action (Particular Manner)	Post-Approval
Enfield oilfield 3D Seismic Survey	2006/3132	Not Controlled Action (Particular Manner)	Post-Approval
Exmouth West 2D Marine Seismic Survey	2008/4132	Not Controlled Action (Particular Manner)	Post-Approval
Exploration drilling of Zeus-1 well	2008/4351	Not Controlled Action (Particular Manner)	Post-Approval
Fletcher-Finucane Development, WA26-L and WA191-P	2011/6123	Not Controlled Action (Particular Manner)	Post-Approval
Foxhound 3D Non-Exclusive Marine Seismic Survey	2009/4703	Not Controlled Action (Particular Manner)	Post-Approval
Gazelle 3D Marine Seismic Survey in WA-399-P and WA-42-L	2010/5570	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
Glencoe 3D Marine Seismic Survey WA-390-P	2007/3684	Not Controlled Action (Particular Manner)	Post-Approval
Greater Western Flank Phase 1 gas Development	2011/5980	Not Controlled Action (Particular Manner)	Post-Approval
Grimalkin 3D Seismic Survey	2008/4523	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Guacamole 2D Marine Seismic Survey	2008/4381	Not Controlled Action (Particular Manner)	Post-Approval
Harmony 3D Marine Seismic Survey	2012/6699	Not Controlled Action (Particular Manner)	Post-Approval
Harpy 1 exploration well	2001/183	Not Controlled Action (Particular Manner)	Post-Approval
Honeycombs MC3D Marine Seismic Survey	2012/6368	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas phase 2 marine seismic survey, Exmouth Plateau, Northern Carnarvon Basin, WA	2013/7093	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2009/4801	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2008/4630	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Laverda 3D Marine Seismic Survey and Vincent M1 4D Marine Seismic Survey	2010/5415	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular Manner)	Post-Approval
Lion 2D Marine Seismic Survey	2007/3777	Not Controlled Action (Particular Manner)	Post-Approval
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval
Marine Geotechnical Drilling Program	2008/4012	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Millstream 20GL Pipeline, Bungaroo, Borefield Integration	2012/6379	Not Controlled Action (Particular Manner)	Post-Approval
MOF Road Widening and Resurfacing Works	2011/5843	Not Controlled Action (Particular Manner)	Post-Approval
Moosehead 2D seismic survey within permit WA-192-P	2005/2167	Not Controlled Action (Particular Manner)	Post-Approval
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Nelson Point Dredging	2009/4920	Not Controlled Action (Particular Manner)	Post-Approval
Nickol Bay Quarry Eastern Extension Proposal, Burrup Peninsula, WA	2013/6915	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Program, WA-264-P	2007/3844	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Survey	2005/2017	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Drilling Campaign	2011/5830	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Onslow Seawater Desalination Plant Marine Geophysical Investigation	2020/8794	Not Controlled Action (Particular Manner)	Post-Approval
Orcus 3D Marine Seismic Survey in WA-450-P	2010/5723	Not Controlled Action (Particular Manner)	Post-Approval
Osprey and Dionysus Marine Seismic Survey	2011/6215	Not Controlled Action (Particular Manner)	Post-Approval
Palta-1 exploration well in Petroleum Permit Area WA-384-P	2011/5871	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	Not Controlled Action (Particular Manner)	Post-Approval
Port Headland Outer Harbour Pre-construction Pilling program	2012/6341	Not Controlled Action (Particular Manner)	Post-Approval
Port of Port Hedland channel marker replacement project, WA	2017/8010	Not Controlled Action (Particular Manner)	Post-Approval
Port Walcott upgrade, dredging & spoil disposal, & channel realignment	2006/2806	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees 4D Marine Seismic Monitor Survey, HCA12A	2012/6579	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees-Macedon 3D marine seismic survey	2005/2325	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
Realignment of the Great Northern Highway	2010/5793	Not Controlled Action (Particular Manner)	Post-Approval
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	Not Controlled Action (Particular Manner)	Post-Approval
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Rydal-1 Petroleum Exploration Well, WA	2012/6522	Not Controlled Action (Particular Manner)	Post-Approval
Salsa 3D Marine Seismic Survey	2010/5629	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Santos Winchester three dimensional seismic survey - WA-323-P & WA-330-P	2011/6107	Not Controlled Action (Particular Manner)	Post-Approval
Scarborough Development nearshore component, NWS, WA	2018/8362	Not Controlled Action (Particular Manner)	Post-Approval
Skorpion Marine Seismic Survey WA	2001/416	Not Controlled Action (Particular Manner)	Post-Approval
Sovereign 3D Marine Seismic Survey	2011/5861	Not Controlled Action (Particular Manner)	Post-Approval
Stag 4D & Reindeer MAZ Marine Seismic Surveys, WA	2013/7080	Not Controlled Action (Particular Manner)	Post-Approval
Stag Off-bottom Cable Seismic Survey	2007/3696	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow 4D Marine Seismic Survey	2011/5810	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow Baseline 4D marine seismic survey	2008/4530	Not Controlled Action (Particular Manner)	Post-Approval
Tantabiddi Boat Ramp Sand Bypassing	2015/7411	Not Controlled Action (Particular Manner)	Post-Approval
The Dampier Heavy Load Out Facility Berth and Swing Basin Expansion	2012/6271	Not Controlled Action (Particular Manner)	Post-Approval
Tidepole Maz 3D Seismic Survey Campaign	2007/3706	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Triton 3D Marine Seismic Survey, WA-2-R and WA-3-R	2006/2609	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a 3D marine seismic survey	2010/5695	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5715	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5679	Not Controlled Action (Particular Manner)	Post-Approval
upgrade of 3 community recreation sites	2005/2349	Not Controlled Action (Particular Manner)	Post-Approval
Vincent M1 and Enfield M5 4D Marine Seismic Survey	2010/5720	Not Controlled Action (Particular Manner)	Post-Approval
Warramunga Non-Inclusive 3D Seismic Survey	2008/4553	Not Controlled Action (Particular Manner)	Post-Approval
West Anchor 3D Marine Seismic Survey	2008/4507	Not Controlled Action (Particular Manner)	Post-Approval
West Panaeus 3D seismic survey	2006/3141	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone 3D MAZ Marine Seismic Survey	2011/6058	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Wheatstone Iago Appraisal Well Drilling	2008/4134	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2007/3941	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic Survey in the offshore northwest Carnarvon Basin	2011/6175	Referral Decision	Completed
3D Seismic Survey	2008/4219	Referral Decision	Completed
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	Referral Decision	Completed
construction of a new loadout facility and associated laydown area south of the	2002/579	Referral Decision	Completed
CVG 3D Marine Seismic Survey	2012/6270	Referral Decision	Completed
Enfield 4D Marine Seismic Surveys, Production Permit WA-28-L	2005/2370	Referral Decision	Completed
Mardie Salt Project, Pilbara region, WA	2018/8183	Referral Decision	Completed
Outer Harbour Development and associated marine and terrestial infrastructure	2008/4148	Referral Decision	Completed
Relocation of 2 heritage sites to National Heritage Place	2010/5709	Referral Decision	Completed
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed
Stybarrow Baseline 4D Marine Seismic Survey (Permit Areas WA-255-P, WA-32-L, WA-	2008/4165	Referral Decision	Completed
Two Dimensional Transition Zone Seismic Survey - TP/7 (R1)	2010/5507	Referral Decision	Completed
Varanus Island Compression Project	2012/6698	Referral Decision	Completed

Key Ecological Features

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Chelonia mydas Green Turtle [1765]	Aggregation	Known to occur

Scientific Name	Behaviour	Presence
Chelonia mydas Green Turtle [1765]	Basking	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Mating	Known to occur
Chelonia mydas Green Turtle [1765]	Migration corridor	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Mating	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Migration corridor	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur

Scientific Name	Behaviour	Presence
Natator depressus Flatback Turtle [59257]	Aggregation	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Mating	Known to occur
Natator depressus Flatback Turtle [59257]	Migration corridor	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
River shark		
Pristis clavata Dwarf Sawfish [68447]	Foraging	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Nursing	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Pupping	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Foraging	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Pupping	Likely to occur
Pristis zijsron Green Sawfish [68442]	Foraging	Known to occur
Pristis zijsron Green Sawfish [68442]	Nursing	Known to occur

Scientific Name	Behaviour	Presence
Pristis zijsron Green Sawfish [68442]	Pupping	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Rhincodon typus Whale Shark [66680]	Foraging (high density prey)	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Scientific Name	Behaviour	Presence
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	2
National Heritage Places:	4
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	62
Listed Migratory Species:	76

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	19
Commonwealth Heritage Places:	2
Listed Marine Species:	106
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	9
Habitat Critical to the Survival of Marine Turtles:	2

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	25
Regional Forest Agreements:	None
Nationally Important Wetlands:	4
EPBC Act Referrals:	38
Key Ecological Features (Marine):	3
Biologically Important Areas:	22
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place
Dirk Hartog Landing Site 1616 - Cape Inscription Area	WA	Listed place
Natural		
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Malurus leucopterus leucopterus White-winged Fairy-wren (Dirk Hartog Island), Dirk Hartog Black-and-White Fairy-wren [26004]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur lesueur		
Burrowing Bettong (Shark Bay), Boodie [66659]	Vulnerable	Species or species habitat known to occur within area
Bettongia penicillata ogilbyi		
Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii		
Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Lagorchestes hirsutus bernieri Rufous Hare-wallaby (Bernier Island) [66662]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus dorreae Rufous Hare-wallaby (Dorre Island) [66663]	Vulnerable	Species or species habitat known to occur within area
Lagostrophus fasciatus fasciatus Banded Hare-wallaby, Merrnine, Marnine, Munning [66664]	Vulnerable	Species or species habitat known to occur within area
Leporillus conditor Wopilkara, Greater Stick-nest Rat [137]	Vulnerable	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Translocated population known to occur within area
Perameles bougainville listed as Perameles bougainville bougainville Shark Bay Bandicoot [278]	Endangered	Species or species habitat known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat likely to occur within area
Pseudomys fieldi Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
PLANT		

Scientific Name	Threatened Category	Presence Text
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat may occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		

Scientific Name	Threatened Category	Presence Text
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Centrophorus zeehaani		
Southern Dogfish, Endeavour Dogfish, Little Gulper Shark [82679]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area
SPIDER		
Idiosoma nigrum		
Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Congregation or aggregation known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula birostris as Manta birostris		
Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus		
Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica		
Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba		
Sanderling [875]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis		
Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris		
Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - CARNARVON TRAINING DEPOT [50235]	WA
Unknown	
Commonwealth Land - [51095]	WA
Commonwealth Land - [51097]	WA
Commonwealth Land - [51882]	WA
Commonwealth Land - [50346]	WA
Commonwealth Land - [51096]	WA
Commonwealth Land - [50352]	WA
Commonwealth Land - [50266]	WA
Commonwealth Land - [51433]	WA
Commonwealth Land - [51883]	WA
Commonwealth Land - [51881]	WA
Commonwealth Land - [51885]	WA
Commonwealth Land - [50364]	WA
Commonwealth Land - [50365]	WA
Commonwealth Land - [50366]	WA

Commonwealth Land Name	State
Commonwealth Land - [50367]	WA
Commonwealth Land - [50361]	WA
Commonwealth Land - [50362]	WA
Commonwealth Land - [50363]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place
Natural		
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Stercorarius skua as Catharacta skua		
Great Skua [823]		Species or species habitat may occur within area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis		
Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bengalensis as Sterna bengalensis		
Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii		
Greater Crested Tern [83000]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Solenostomus cyanopterus		
Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus		
Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Syngnathoides biaculeatus		
Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus		
Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon		
Dugong [28]		Breeding known to occur within area
Reptile		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis		
Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum		
Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Congregation or aggregation known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Abrolhos	Habitat Protection Zone (IUCN IV)
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)

Park Name	Zone & IUCN Categories
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas		
Green Turtle [1765]	Nesting	Known to occur
Nov-Feb		
Caretta caretta		
Loggerhead Turtle [1763]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Bernier And Dorre Islands	Nature Reserve	WA
Chinamans Pool	Nature Reserve	WA
Dirk Hartog Island	National Park	WA
Faure Island	Private Nature Reserve	WA
Francois Peron	National Park	WA
Freycinet, Double Islands etc	Nature Reserve	WA
Hamelin Pool	Marine Nature Reserve	WA
Hamelin Station	Conservation Reserve	WA
Koks Island	Nature Reserve	WA
Miaboolya Beach	Fish Habitat Protection Area	WA
Monkey Mia Reserve	5(1)(h) Reserve	WA

Protected Area Name	Reserve Type	State
Nanga Station	NRS Addition - Gazettal in Progress	WA
Ningaloo	Marine Park	WA
One Tree Point	Nature Reserve	WA
Point Quobba	Fish Habitat Protection Area	WA
Sedimentary Deposits Reserve	5(1)(g) Reserve	WA
Shark Bay	Marine Park	WA
Shell Beach	Conservation Park	WA
Unnamed WA26400	5(1)(h) Reserve	WA
Unnamed WA37338	5(1)(h) Reserve	WA
Unnamed WA37383	5(1)(h) Reserve	WA
Unnamed WA37500	5(1)(g) Reserve	WA
Unnamed WA44688	5(1)(h) Reserve	WA
Unnamed WA49144	Conservation Park	WA
Yaringga	NRS Addition - Gazettal in Progress	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Hamelin Pool	WA
Lake MacLeod	WA
McNeill Claypan System	WA
Shark Bay East	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Boating Facility	2002/830	Controlled Action	Completed
Coburn Mineral Sand Project	2003/1221	Controlled Action	Post-Approval
Mauds Landing Marina	2000/98	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Nava-1 Cable System	2001/510	Controlled Action	Completed
Shark Bay Resources Dredging	2020/8717	Controlled Action	Post-Approval
Shark Bay Salt Facilities upgrade for direct ocean disposal of bitterns discharge	2011/5984	Controlled Action	Completed
Not controlled action			
Accommodation Units Sunday Island Bay, Dirk Hartog Island, WA	2015/7540	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
archaeological surveys & excavation at historic sites, Cape Inscription	2006/3027	Not Controlled Action	Completed
Boating Facility	2002/832	Not Controlled Action	Completed
Carnarvon Power Station Development Project	2010/5669	Not Controlled Action	Completed
Clearing of vegetation for borrow pit and infrastructure areas	2017/7947	Not Controlled Action	Completed
Expansion of Monkey Mia Resort	2003/1146	Not Controlled Action	Completed
Extention to the existing Blind Strait Black Lip Pearl Oyster Farm	2004/1342	Not Controlled Action	Completed
Flood Management works	2006/3127	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Realignment of Access track, Bottle Bay, Shark Bay	2004/1780	Not Controlled Action	Completed
Useless Loop Road Upgrade	2000/83	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
Guacamole 2D Marine Seismic Survey	2008/4381	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
Sampling of Stromatolites, additional sites, Mamelin Pool,WA	2013/7071	Not Controlled Action (Particular Manner)	Post-Approval
Sampling of Stromatolites and Sediments	2012/6307	Not Controlled Action (Particular Manner)	Post-Approval
search for HMAS Sydney	2006/3071	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Supply of road building material areas Shark Bay Region WA	2012/6280	Not Controlled Action (Particular Manner)	Post-Approval
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Useless Loop Port Maintenance Works and Infrastructure Upgrade	2009/4791	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
Geoscientific field-trip to Shark Bay	2012/6380	Referral Decision	Completed
Power Station Development	2009/4957	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Commonwealth waters adjacent to Ningaloo Reef	North-west
Wallaby Saddle	North-west
Western demersal slope and associated fish communities	South-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur

Scientific Name	Behaviour	Presence
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Migration	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Internesting	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 8

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	3
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	82
Listed Migratory Species:	62

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	28
Commonwealth Heritage Places:	1
Listed Marine Species:	102
Whales and Other Cetaceans:	36
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	9
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	39
Regional Forest Agreements:	None
Nationally Important Wetlands:	3
EPBC Act Referrals:	52
Key Ecological Features (Marine):	6
Biologically Important Areas:	25
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Shark Bay, Western Australia	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
Batavia Shipwreck Site and Survivor Camps Area 1629 - Houtman Abrolhos	WA	Listed place
Natural		
Lesueur National Park	WA	Listed place
Shark Bay, Western Australia	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community may occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat likely to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Turnix varius scintillans		
Painted Button-quail (Houtman Abrolhos) [82451]	Vulnerable	Species or species habitat known to occur within area
Zanda latirostris listed as Calyptorhynchus latirostris		
Carnaby's Black Cockatoo, Short-billed Black-cockatoo [87737]	Endangered	Species or species habitat known to occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia penicillata ogilbyi		
Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii		
Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
PLANT		
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat likely to occur within area
Androcalva bivillosa Straggling Androcalva [87807]	Critically Endangered	Species or species habitat likely to occur within area
Anigozanthos viridis subsp. terraspectans Dwarf Green Kangaroo Paw [3435]	Vulnerable	Species or species habitat may occur within area
Beyeria lepidopetala Small-petalled Beyeria, Short-petalled Beyeria [18362]	Endangered	Species or species habitat likely to occur within area
Caladenia barbarella Small Dragon Orchid, Common Dragon Orchid [68686]	Endangered	Species or species habitat may occur within area
Caladenia bryceana subsp. cracens Northern Dwarf Spider-orchid [64556]	Vulnerable	Species or species habitat known to occur within area
Caladenia elegans Elegant Spider-orchid [56775]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat known to occur within area
Caleana dixonii listed as Paracaleana dixonii Sandplain Duck Orchid [87944]	Endangered	Species or species habitat likely to occur within area
Chorizema humile Prostrate Flame Pea [32573]	Endangered	Species or species habitat likely to occur within area
Conostylis dielsii subsp. teres Irwin's Conostylis [3614]	Endangered	Species or species habitat may occur within area
Conostylis micrantha Small-flowered Conostylis [17635]	Endangered	Species or species habitat may occur within area
Diuris drummondii Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat may occur within area
Drakaea concolor Kneeling Hammer-orchid [56777]	Vulnerable	Species or species habitat known to occur within area
Drummondita ericoides Morseby Range Drummondita [9193]	Endangered	Species or species habitat known to occur within area
Eucalyptus argutifolia Yanchep Mallee, Wabling Hill Mallee [24263]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat may occur within area
Eucalyptus cuprea Mallee Box [56773]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Grevillea batrachioides Mt Lesueur Grevillea [21735]	Endangered	Species or species habitat may occur within area
Grevillea bracteosa subsp. howatharra [85002]	Critically Endangered	Species or species habitat likely to occur within area
Grevillea humifusa Spreading Grevillea [61182]	Endangered	Species or species habitat may occur within area
Hemiandra gardneri Red Snakebush [7945]	Endangered	Species or species habitat likely to occur within area
Hypocalymma angustifolium subsp. Hutt River (S.Patrick 2982) [85023]	Endangered	Species or species habitat known to occur within area
Hypocalymma longifolium Long-leaved Myrtle [8081]	Vulnerable	Species or species habitat likely to occur within area
Lechenaultia chlorantha Kalbarri Leschenaultia [16763]	Vulnerable	Species or species habitat known to occur within area
Leucopogon marginatus Thick-margined Leucopogon [12527]	Endangered	Species or species habitat known to occur within area
Leucopogon obtectus Hidden Beard-heath [19614]	Endangered	Species or species habitat may occur within area
Pterostylis sinuata Northampton Midget Greenhood, Western Swan Greenhood [84991]	Endangered	Species or species habitat known to occur within area
Stachystemon nematophorus Three-flowered Stachystemon [81447]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Tetratheca nephelioides [83217]	Critically Endangered	Species or species habitat may occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat likely to occur within area
Wurmbea tubulosa Long-flowered Nancy [12739]	Endangered	Species or species habitat known to occur within area
REPTILE		
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ctenotus lancelini Lancelin Island Skink [1482]	Vulnerable	Translocated population known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat may occur within area
Liopholis pulchra longicauda Jurien Bay Skink, Jurien Bay Rock-skink [83162]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Centrophorus zeehaani		
Southern Dogfish, Endeavour Dogfish, Little Gulper Shark [82679]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area
SPIDER		
Idiosoma nigrum		
Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Species or species habitat may occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Migratory Terrestrial Species

Scientific Name	Threatened Category	Presence Text
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat likely to occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat likely to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50197]	WA
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50196]	WA
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion [50195]	WA
Defence - GREENOUGH RIFLE RANGE [50234]	WA
Unknown	
Commonwealth Land - [52201]	WA
Commonwealth Land - [50379]	WA

Commonwealth Land Name	State
Commonwealth Land - [50373]	WA
Commonwealth Land - [50375]	WA
Commonwealth Land - [50376]	WA
Commonwealth Land - [50377]	WA
Commonwealth Land - [50370]	WA
Commonwealth Land - [50371]	WA
Commonwealth Land - [50372]	WA
Commonwealth Land - [51098]	WA
Commonwealth Land - [50380]	WA
Commonwealth Land - [52111]	WA
Commonwealth Land - [50381]	WA
Commonwealth Land - [50368]	WA
Commonwealth Land - [50369]	WA
Commonwealth Land - [52214]	WA
Commonwealth Land - [51099]	WA
Commonwealth Land - [50374]	WA
Commonwealth Land - [51100]	WA
Commonwealth Land - [51886]	WA
Commonwealth Land - [50378]	WA
Commonwealth Land - [51481]	WA
Commonwealth Land - [51434]	WA
Commonwealth Land - [51432]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Geraldton Drill Hall Complex	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		

Scientific Name	Threatened Category	Presence Text
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat likely to occur within area overfly marine area
Calidris ruficollis		
Red-necked Stint [860]		Species or species habitat known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans		
Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius ruficapillus		
Red-capped Plover [881]		Species or species habitat known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae		
Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis		
Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora		
Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans		
Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Breeding likely to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Puffinus huttoni Hutton's Shearwater [1025]		Foraging, feeding or related behaviour known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Species or species habitat known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Stercorarius skua as Catharacta skua Great Skua [823]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammal		

Scientific Name	Threatened Category	Presence Text
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Reptile		
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	Special Purpose Zone (IUCN VI)
Abrolhos	Special Purpose Zone (IUCN VI)

Park Name	Zone & IUCN Categories
Jurien	Special Purpose Zone (IUCN VI)

Extra Information

State and Territory Reserves		[Resource Information]
Protected Area Name	Reserve Type	State
Abrolhos Islands	Fish Habitat Protection Area	WA
Beagle Islands	Nature Reserve	WA
Beekeepers	Nature Reserve	WA
Boullanger, Whitlock, Favourite, Tern And Osprey Islands	Nature Reserve	WA
Cervantes Islands	Nature Reserve	WA
Cutubury	Nature Reserve	WA
Dongara	Nature Reserve	WA
Drovers Cave	National Park	WA
Escape Island	Nature Reserve	WA
Essex Rocks	Nature Reserve	WA
Fisherman Islands	Nature Reserve	WA
Houtman Abrolhos Islands	National Park	WA
Jurien Bay	Marine Park	WA
Kalbarri	National Park	WA
Kalbarri Blue Holes	Fish Habitat Protection Area	WA
Lesueur	National Park	WA
Lipfert, Milligan, Etc Islands	Nature Reserve	WA
Nambung	National Park	WA

Protected Area Name	Reserve Type	State
Nanga Station	NRS Addition - Gazettal in Progress	WA
Outer Rocks	Nature Reserve	WA
Part Murchison house	NRS Addition - Gazettal in Progress	WA
Port Gregory	NRS Addition - Gazettal in Progress	WA
Ronsard Rocks	Nature Reserve	WA
Sandland Island	Nature Reserve	WA
Southern Beekeepers	Nature Reserve	WA
Tamala Pastoral Lease (Part)	NRS Addition - Gazettal in Progress	WA
Unnamed WA11883	5(1)(h) Reserve	WA
Unnamed WA33287	Nature Reserve	WA
Unnamed WA33799	Nature Reserve	WA
Unnamed WA34039	5(1)(h) Reserve	WA
Unnamed WA42030	5(1)(g) Reserve	WA
Unnamed WA44682	5(1)(h) Reserve	WA
Unnamed WA46982	5(1)(h) Reserve	WA
Unnamed WA46983	5(1)(h) Reserve	WA
Unnamed WA46984	5(1)(h) Reserve	WA
Unnamed WA48205	5(1)(h) Reserve	WA
Unnamed WA48717	Conservation Park	WA
Utcha Well	Nature Reserve	WA
Zuytdorp	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Hutt Lagoon System	WA
Lake Thetis	WA

Wetland Name	State
Murchison River (Lower Reaches)	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Midwest Offshore Wind Farm	2022/09264		Assessment
Controlled action			
Coburn Mineral Sand Project	2003/1221	Controlled Action	Post-Approval
construction and operation of a unmanned platform at the Cliff Head oil field, a	2003/1300	Controlled Action	Post-Approval
Construction of the Oakajee Port and Rail Project	2011/5797	Controlled Action	Post-Approval
development of land based tourist facilities on Long Island	2006/2792	Controlled Action	Post-Approval
Hematite (iron ore) Mine and Beneficiation Plant	2001/542	Controlled Action	Completed
Jurien East Road Upgrade, 3 km NNE Jurien Bay, WA	2020/8740	Controlled Action	Proposed Decision
Karara Magnetite Project	2006/3017	Controlled Action	Post-Approval
Mount Gibson Iron Ore Pellet Project	2000/95	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
Oakajee Rail Development	2010/5500	Controlled Action	Post-Approval
open cut mine & assoc infrastructure	2005/2381	Controlled Action	Post-Approval
Port Enhancement Project	2001/266	Controlled Action	Post-Approval
Tourism Facility and Associated Infrastructure	2005/2038	Controlled Action	Post-Approval
Yogi Magnetite Project, 225km east, northeast of Geraldton, WA	2017/8124	Controlled Action	Assessment Approach
Not controlled action			
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Cliff Head 6 appraisal well	2004/1702	Not Controlled Action	Completed
Cliff Head Appraisal Wells	2003/938	Not Controlled Action	Completed
Construction of several passing lanes between Lancelin and Jurien Bay, WA	2015/7509	Not Controlled Action	Completed
Drilling between Kalbarri and Cliff Head	2005/2185	Not Controlled Action	Completed
Establishment of a 12.7 ha Gypsum Mine	2007/3398	Not Controlled Action	Completed
Exploration drilling program located in exploration permits WA-286-P and TP/15	2002/676	Not Controlled Action	Completed
Glenfield Beach Project	2012/6359	Not Controlled Action	Completed
Hadda 1,Flying Foam 1,Magnat 1 exploration drill	2004/1697	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
Indian Ocean Drive Passing Lane and Widening 52-258 SLK	2017/7884	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Maintenance Dredging in the Geraldton Port Outer Channel	2010/5488	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
Scientific Sonar Trial	2002/680	Not Controlled Action	Completed
Seismic Survey, Bremer Basin, Mentelle Basin and Zeewyck Sub-basin	2004/1700	Not Controlled Action	Completed
WA-286-P Exploration Drilling Programme	2007/3863	Not Controlled Action	Completed
Waitsia Gas Project Stage 2, Yardarino WA	2020/8633	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Yellowfin Tuna Aquaculture Trial	2003/1115	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D Marine Seismic Survey in Permit Area WA-337-P	2003/1158	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2007/3800	Not Controlled Action (Particular Manner)	Post-Approval
Australian Square Kilometre Array Pathfinder telescope & infrastructure	2009/4891	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
develop and operate a new deepwater port	2010/5760	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey for oil and gas in Commonwealth waters off the WA coast.	2004/1802	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey in Permit WA-481P	2012/6626	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
North Perth Marine Survey	2011/6067	Not Controlled Action (Particular Manner)	Post-Approval
Study of behavioural responses of Austn Humpback Whales to seismic surveys, offshore Dongara, WA	2013/6927	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3729	Referral Decision	Completed
Exploration Drilling 2014/2015 WA-481-P	2013/7043	Referral Decision	Completed
Proposed exploration drilling activities, Abrolhos Commonwealth Marine Reserve	2013/6949	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 90-120m depth	South-west
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	South-west
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Perth Canyon and adjacent shelf break, and other west coast canyons	South-west
Western demersal slope and associated fish communities	South-west
Western rock lobster	South-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Seabirds		
Anous stolidus Common Noddy [825]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Anous stolidus Common Noddy [825]	Foraging (provisioning young)	Known to occur
Anous tenuirorstris melanops Australian Lesser Noddy [26000]	Foraging (provisioning young)	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur
Pelagodroma marina White-faced Storm petrel [1016]	Foraging (in high numbers)	Known to occur
Pterodroma mollis Soft-plumaged Petrel [1036]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sterna dougallii Roseate Tern [817]	Foraging	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging (provisioning young)	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Seals		
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 9

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance (Ramsar	4
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	15
Listed Threatened Species:	130
Listed Migratory Species:	81

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	327
Commonwealth Heritage Places:	6
Listed Marine Species:	117
Whales and Other Cetaceans:	39
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	23
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	141
Regional Forest Agreements:	1
Nationally Important Wetlands:	16
EPBC Act Referrals:	316
Key Ecological Features (Marine):	8
Biologically Important Areas:	33
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Australian Convict Sites (Fremantle Prison)	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
Fremantle Prison (former)	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Becher point wetlands	Within Ramsar site
Forrestdale and thomsons lakes	Within 10km of Ramsar site
Peel-yalgorup system	Within Ramsar site
Vasse-wonnerup system	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Aquatic Root Mat Community 1 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area
Aquatic Root Mat Community 2 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area

Community Name	Threatened Category	Presence Text
Aquatic Root Mat Community 3 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area
Aquatic Root Mat Community 4 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area
Aquatic Root Mat Community in Caves of the Swan Coastal Plain	Endangered	Community known to occur within area
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community likely to occur within area
Clay Pans of the Swan Coastal Plain	Critically Endangered	Community likely to occur within area
Corymbia calophylla - Xanthorrhoea preissii woodlands and shrublands of the Swan Coastal Plain	Endangered	Community known to occur within area
Scott River Ironstone Association	Endangered	Community likely to occur within area
Sedgelands in Holocene dune swales of the southern Swan Coastal Plain	Endangered	Community known to occur within area
Shrublands on southern Swan Coastal Plain ironstones	Endangered	Community likely to occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond)	Endangered	Community known to occur within area
Thrombolite (microbialite) Community of a Coastal Brackish Lake (Lake Clifton)	Critically Endangered	Community known to occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo, Karrak [67034]	Vulnerable	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Pterodroma mollis		
Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Zanda baudinii listed as Calyptorhynchus baudinii		
Baudin's Black-Cockatoo, Long-billed Black-cockatoo [87736]	Endangered	Breeding known to occur within area
Zanda latirostris listed as Calyptorhynchus latirostris		
Carnaby's Black Cockatoo, Short-billed Black-cockatoo [87737]	Endangered	Breeding known to occur within area
CRUSTACEAN		
Cherax tenuimanus		
Hairy Marron, Margaret River Hairy Marron, Margaret River Marron [78931]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Engaewa pseudoreducta		
Margaret River Burrowing Crayfish [82674]	Critically Endangered	Species or species habitat known to occur within area
Engaewa reducta		
Dunsborough Burrowing Crayfish [82675]	Critically Endangered	Species or species habitat known to occur within area
FISH		
Galaxiella nigrostriata		
Blackstriped Dwarf Galaxias, Black-stripe Minnow [88677]	Endangered	Species or species habitat known to occur within area
Hoplostethus atlanticus		
Orange Roughy, Deep-sea Perch, Red Roughy [68455]	Conservation Dependent	Species or species habitat likely to occur within area
Nannatherina balstoni		
Balston's Pygmy Perch [66698]	Vulnerable	Species or species habitat known to occur within area
Nannoperca pygmaea		
Little Pygmy Perch [88315]	Endangered	Species or species habitat known to occur within area
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
FROG		
Anstisia alba listed as Geocrinia alba		
White-bellied Frog, Creek Frog [92544]	Critically Endangered	Species or species habitat known to occur within area
Anstisia vitellina listed as Geocrinia vitellina		
Orange-bellied Frog [92547]	Vulnerable	Species or species habitat likely to occur within area
INSECT		
Hesperocolletes douglasi		
Douglas' Broad-headed Bee, Rottnest Bee [66734]	Critically Endangered	Species or species habitat may occur within area
MAMMAL		

Scientific Name	Threatened Category	Presence Text
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat may occur within area
Pseudocheirus occidentalis Western Ringtail Possum, Ngwayir, Womp, Woder, Ngoor, Ngoolangit [25911]	Critically Endangered	Breeding known to occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat known to occur within area
OTHER		

Scientific Name	Threatened Category	Presence Text
Westralunio carteri Carter's Freshwater Mussel, Freshwater Mussel [86266]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat likely to occur within area
Anigozanthos viridis subsp. terraspectans Dwarf Green Kangaroo Paw [3435]	Vulnerable	Species or species habitat likely to occur within area
Austrostipa bronweniae listed as Austrostipa bronwenae [92773]	Endangered	Species or species habitat known to occur within area
Austrostipa jacobsiana [87809]	Critically Endangered	Species or species habitat known to occur within area
Banksia mimica Summer Honeypot [82765]	Endangered	Species or species habitat likely to occur within area
Banksia nivea subsp. uliginosa Swamp Honeypot [82766]	Endangered	Species or species habitat known to occur within area
Banksia squarrosa subsp. argillacea Whicher Range Dryandra [82769]	Vulnerable	Species or species habitat known to occur within area
Banksia verticillata Granite Banksia, Albany Banksia, River Banksia [8333]	Vulnerable	Species or species habitat likely to occur within area
Boronia exilis Scott River Boronia [64844]	Endangered	Species or species habitat known to occur within area
Brachyscias verecundus Ironstone Brachyscias [81321]	Critically Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Caladenia busselliana Bussell's Spider-orchid [24369]	Endangered	Species or species habitat known to occur within area
Caladenia caesarea subsp. maritima Cape Spider-orchid [64856]	Endangered	Species or species habitat known to occur within area
Caladenia excelsa Giant Spider-orchid [56717]	Endangered	Species or species habitat likely to occur within area
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat likely to occur within area
Caladenia huegelii King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid [7309]	Endangered	Species or species habitat known to occur within area
Caladenia lodgeana Lodge's Spider-orchid [68664]	Critically Endangered	Species or species habitat known to occur within area
Caladenia procera Carbunup King Spider Orchid [68679]	Critically Endangered	Species or species habitat known to occur within area
Caladenia viridescens Dunsborough Spider-orchid [56776]	Endangered	Species or species habitat known to occur within area
Caleana dixonii listed as Paracaleana dixonii Sandplain Duck Orchid [87944]	Endangered	Species or species habitat may occur within area
Calectasia cyanea Blue Tinsel Lily [7669]	Critically Endangered	Species or species habitat may occur within area
Chamelaucium lullfitzii listed as Chamelaucium sp. Gingin (N.G.Marchant 6) Gingin Wax [92777]	Endangered (listed as Chamelaucium sp. Gingin	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Chamelaucium sp. S coastal plain (R.D.Royce 4872)		
Royce's Waxflower [87814]	Vulnerable	Species or species habitat known to occur within area
Chorizema varium		
Limestone Pea [16981]	Endangered	Species or species habitat known to occur within area
Darwinia ferricola		
Scott River Darwinia [56706]	Endangered	Species or species habitat known to occur within area
Darwinia whicherensis		
Abba Bell [83193]	Endangered	Species or species habitat likely to occur within area
Daviesia elongata subsp. elongata		
Long-leaved Daviesia [64883]	Vulnerable	Species or species habitat known to occur within area
Diuris drummondii		
Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat known to occur within area
Diuris micrantha		
Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat known to occur within area
Diuris purdiei		
Purdie's Donkey-orchid [12950]	Endangered	Species or species habitat known to occur within area
Drakaea elastica		
Glossy-leafed Hammer Orchid, Glossy-leaved Hammer Orchid, Warty Hammer Orchid [16753]	Endangered	Species or species habitat known to occur within area
Drakaea micrantha		
Dwarf Hammer-orchid [56755]	Vulnerable	Species or species habitat known to occur within area
Eleocharis keigheryi		
Keighery's Eleocharis [64893]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Eucalyptus argutifolia Yanchep Mallee, Wabling Hill Mallee [24263]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus x phylacis Meelup Mallee [87817]	Endangered	Species or species habitat known to occur within area
Gastrolobium argyrotrichum Metricup Pea [89145]	Critically Endangered	Species or species habitat known to occur within area
Gastrolobium modestum Broad-leaved Gastrolobium [78361]	Vulnerable	Species or species habitat known to occur within area
Gastrolobium papilio Butterfly-leaved Gastrolobium [78415]	Endangered	Species or species habitat may occur within area
Grevillea brachystylis subsp. australis [55525]	Vulnerable	Species or species habitat likely to occur within area
Grevillea brachystylis subsp. grandis Large-flowered Short-styled Grevillea [85001]	Critically Endangered	Species or species habitat known to occur within area
Grevillea elongata Ironstone Grevillea [64578]	Vulnerable	Species or species habitat likely to occur within area
Grevillea maccutcheonii McCutcheon's Grevillea [64522]	Endangered	Species or species habitat known to occur within area
Hemiandra gardneri Red Snakebush [7945]	Endangered	Species or species habitat may occur within area
Kennedia glabrata Northcliffe Kennedia [16452]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Kennedia lateritia Augusta Kennedia [45985]	Endangered	Species or species habitat likely to occur within area
Lambertia echinata subsp. occidentalis Western Prickly Honeysuckle [64528]	Endangered	Species or species habitat likely to occur within area
Lambertia orbifolia Roundleaf Honeysuckle [15725]	Endangered	Species or species habitat known to occur within area
Leptomeria dielsiana Diels' Currant Bush [5146]	Vulnerable	Species or species habitat known to occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat may occur within area
Marianthus paralius [83925]	Endangered	Species or species habitat known to occur within area
Melaleuca sp. Wanneroo (G.J. Keighery 16705) [89456]	Endangered	Species or species habitat known to occur within area
Morelotia australiensis listed as Tetraria australiensis Southern Tetraria [92784]	Vulnerable	Species or species habitat known to occur within area
Petrophile latericola Laterite Petrophile [64532]	Endangered	Species or species habitat likely to occur within area
Reedia spathacea Reedia [2995]	Critically Endangered	Species or species habitat known to occur within area
Synaphea sp. Fairbridge Farm (D. Papenfus 696) Selena's Synaphea [82881]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Synaphea sp. Pinjarra Plain (A.S. George 17182) [86878]	Endangered	Species or species habitat known to occur within area
Synaphea sp. Serpentine (G.R. Brand 103) [86879]	Critically Endangered	Species or species habitat known to occur within area
Synaphea stenoloba Dwellingup Synaphea [66311]	Endangered	Species or species habitat known to occur within area
Verticordia densiflora var. pedunculata Long-stalked Featherflower [55689]	Endangered	Species or species habitat known to occur within area
Verticordia plumosa var. ananeotes Tufted Plumed Featherflower [23871]	Endangered	Species or species habitat known to occur within area
Verticordia plumosa var. vassensis Vasse Featherflower [55804]	Endangered	Species or species habitat known to occur within area
Wurmbea calcicola Naturaliste Nancy [64691]	Endangered	Species or species habitat known to occur within area
REPTILE		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ctenotus lancelini Lancelin Island Skink [1482]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia		
Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat may occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Centrophorus zeehaani		
Southern Dogfish, Endeavour Dogfish, Little Gulper Shark [82679]	Conservation Dependent	Species or species habitat likely to occur within area
Galeorhinus galeus		
School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark [68453]	Conservation Dependent	Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		

Scientific Name	Threatened Category	Presence Text
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Breeding known to occur within area
Ardenna grisea Sooty Shearwater [82651]		Species or species habitat may occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area

Migratory Marine Species

Scientific Name	Threatened Category	Presence Text
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Foraging, feeding or related behaviour known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Migratory Terrestrial Species		
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba		
Sanderling [875]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis		
Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta		
Long-toed Stint [861]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - ARTILLERY BARRACKS - FREMANTLE [50155]	WA
Defence - BUNBURY TRAINING DEPOT [50142]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50183]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50182]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50181]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50187]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50186]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50185]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50184]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50133]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50132]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50134]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50131]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50117]	WA
Defence - LANCELIN TRAINING AREA [50120]	WA
Defence - LANCELIN TRAINING AREA [50121]	WA
Defence - ROCKINGHAM - NAVY CPSO [50135]	WA
Defence - SWANBOURNE RIFLE RANGE [50188]	WA
Defence - SWANBOURNE RIFLE RANGE [50191]	WA
Unknown	
Commonwealth Land - [50423]	WA

Commonwealth Land Name	State
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Commonwealth Land - [51480]	WA
Commonwealth Land - [50500]	WA
Commonwealth Land - [51488]	WA
Commonwealth Land - [51486]	WA
Commonwealth Land - [50460]	WA
Commonwealth Land - [50462]	WA
Commonwealth Land - [50461]	WA
Commonwealth Land - [50464]	WA
Commonwealth Land - [50463]	WA
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Commonwealth Land - [50465]	WA
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Commonwealth Land - [50458]	WA
Commonwealth Land - [50459]	WA
Commonwealth Land - [51491]	WA
Commonwealth Land - [51490]	WA

Commonwealth Land Name	State
Commonwealth Land - [50451]	WA
Commonwealth Land - [50452]	WA
Commonwealth Land - [50450]	WA
Commonwealth Land - [50525]	WA
Commonwealth Land - [50522]	WA
Commonwealth Land - [50524]	WA
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Commonwealth Land - [50594]	WA
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Commonwealth Land - [50638]	WA
Commonwealth Land - [50636]	WA
Commonwealth Land - [50597]	WA
Commonwealth Land - [50596]	WA

Commonwealth Land Name	State
Commonwealth Land - [50595]	WA
Commonwealth Land - [50627]	WA
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Commonwealth Land - [50624]	WA
Commonwealth Land - [50625]	WA
Commonwealth Land - [50355]	WA
Commonwealth Land - [50356]	WA
Commonwealth Land - [50621]	WA
Commonwealth Land - [50620]	WA

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Historic		
Artillery Barracks	WA	Listed place
Cape Leeuwin Lighthouse	WA	Listed place
Cliff Point Historic Site	WA	Listed place
J Gun Battery	WA	Listed place
Natural		
Garden Island	WA	Listed place
Lancelin Defence Training Area	WA	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Breeding known to occur within area
Ardenna grisea as Puffinus griseus Sooty Shearwater [82651]		Species or species habitat may occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Eudyptula minor Little Penguin [1085]		Breeding known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area overfly marine area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Stercorarius skua as Catharacta skua Great Skua [823]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area
Leptoichthys fistularius Brushtail Pipefish [66248]		Species or species habitat may occur within area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammal		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Reptile		
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Berardius arnuxii Arnoux's Beaked Whale [70]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Foraging, feeding or related behaviour known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon hectori Hector's Beaked Whale [76]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tasmacetus shepherdi Shepherd's Beaked Whale, Tasman Beaked Whale [55]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Geographe	Habitat Protection Zone (IUCN IV)

Park Name	Zone & IUCN Categories
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
South-west Corner	Habitat Protection Zone (IUCN IV)
Geographe	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
South-west Corner	Multiple Use Zone (IUCN VI)
Two Rocks	Multiple Use Zone (IUCN VI)
Geographe	National Park Zone (IUCN II)
Jurien	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
Two Rocks	National Park Zone (IUCN II)
Jurien	Special Purpose Zone (IUCN VI)
Geographe	Special Purpose Zone (Mining Exclusion) (IUCN VI)
South-west Corner	Special Purpose Zone (Mining Exclusion) (IUCN VI)
South-west Corner	Special Purpose Zone (Mining Exclusion) (IUCN VI)

Extra Information

State and Territory Reserves		[Resource Information]
Protected Area Name	Reserve Type	State
Austin Bay	Nature Reserve	WA
Blackwood River	National Park	WA
Bold Park	Botanic Gardens	WA
Boodalan	Nature Reserve	WA
Boorara-Gardner	National Park	WA
Bramley	National Park	WA
Broadwater	Nature Reserve	WA
Buller, Whittell And Green Islands	Nature Reserve	WA
Capel	Nature Reserve	WA
Carnac Island	Nature Reserve	WA
Cervantes Islands	Nature Reserve	WA
Chester	Nature Reserve	WA
Cottesloe Reef	Fish Habitat Protection Area	WA
Crampton	Nature Reserve	WA
Creery Island	Nature Reserve	WA
D'Entrecasteaux	National Park	WA
Fish Road	Nature Reserve	WA
Flinders Bay	Nature Reserve	WA
Forest Grove	National Park	WA
Gingilup Swamps	Nature Reserve	WA
Greater Hawke	National Park	WA
Haag	Nature Reserve	WA
Hamelin Island	Nature Reserve	WA
Jurien Bay	Marine Park	WA

Protected Area Name	Reserve Type	State
Kooljerrenup	Nature Reserve	WA
Lake McLarty	Nature Reserve	WA
Lake Mealup	Nature Reserve	WA
Lancelin And Edwards Islands	Nature Reserve	WA
Lancelin Island Lagoon	Fish Habitat Protection Area	WA
Leeuwin-Naturaliste	National Park	WA
Len Howard	Conservation Park	WA
Leschenault Peninsula	Conservation Park	WA
Locke	Nature Reserve	WA
Marmion	Marine Park	WA
McLarty	Nature Reserve	WA
Mealup Point	Nature Reserve	WA
Morangarel	Nature Reserve	WA
Nambung	National Park	WA
Neerabup	National Park	WA
Neerabup	Nature Reserve	WA
Ngari Capes	Marine Park	WA
Nilgen	Nature Reserve	WA
NTWA Bushland covenant (0003)	Conservation Covenant	WA
NTWA Bushland covenant (0004)	Conservation Covenant	WA
NTWA Bushland covenant (0013)	Conservation Covenant	WA
NTWA Bushland covenant (0037)	Conservation Covenant	WA
NTWA Bushland covenant (0044A)	Conservation Covenant	WA
NTWA Bushland covenant (0044B)	Conservation Covenant	WA
NTWA Bushland covenant (0044C)	Conservation Covenant	WA
NTWA Bushland covenant (0065A)	Conservation Covenant	WA

Protected Area Name	Reserve Type	State
NTWA Bushland covenant (0065B)	Conservation Covenant	WA
NTWA Bushland covenant (0069)	Conservation Covenant	WA
NTWA Bushland covenant (0070)	Conservation Covenant	WA
NTWA Bushland covenant (0072A)	Conservation Covenant	WA
NTWA Bushland covenant (0072B)	Conservation Covenant	WA
NTWA Bushland covenant (0085A)	Conservation Covenant	WA
NTWA Bushland covenant (0085B)	Conservation Covenant	WA
NTWA Bushland covenant (0090)	Conservation Covenant	WA
NTWA Bushland covenant (0095)	Conservation Covenant	WA
NTWA Bushland covenant (0102)	Conservation Covenant	WA
NTWA Bushland covenant (0116A)	Conservation Covenant	WA
NTWA Bushland covenant (0116B)	Conservation Covenant	WA
NTWA Bushland covenant (0130)	Conservation Covenant	WA
NTWA Bushland covenant (0144)	Conservation Covenant	WA
NTWA Bushland covenant (0147)	Conservation Covenant	WA
NTWA Bushland covenant (0148)	Conservation Covenant	WA
NTWA Bushland covenant (0149)	Conservation Covenant	WA
NTWA Bushland covenant (0152)	Conservation Covenant	WA
NTWA Bushland covenant (0155)	Conservation Covenant	WA
NTWA Bushland covenant (0164)	Conservation Covenant	WA
NTWA Bushland covenant (0168)	Conservation Covenant	WA
NTWA Bushland covenant (0173)	Conservation Covenant	WA
Pagett	Nature Reserve	WA
Penguin Island	Conservation Park	WA
Port Kennedy Scientific Park	Nature Reserve	WA
Quagering	Nature Reserve	WA
Rapids	Conservation Park	WA

Protected Area Name	Reserve Type	State
Ronsard Rocks	Nature Reserve	WA
Rottnest Island	State Reserve	WA
Ruabon Townsite	Nature Reserve	WA
Sabina	Nature Reserve	WA
Scott	National Park	WA
Seal Island (WA25645)	Nature Reserve	WA
Shannon	National Park	WA
Shoalwater Bay Islands	Nature Reserve	WA
Shoalwater Islands	Marine Park	WA
Southern Beekeepers	Nature Reserve	WA
St Alouarn Island	Nature Reserve	WA
Stockdill Road	Nature Reserve	WA
Sugar Loaf Rock	Nature Reserve	WA
Sussex Location 2561	NRS Addition - Gazettal in Progress	WA
Swan River	Management Area	WA
Tuart Forest	National Park	WA
Unnamed WA01086	5(1)(h) Reserve	WA
Unnamed WA03249	Nature Reserve	WA
Unnamed WA11993	5(1)(g) Reserve	WA
Unnamed WA14567	Nature Reserve	WA
Unnamed WA15185	Nature Reserve	WA
Unnamed WA25836	Nature Reserve	WA
Unnamed WA26065	Nature Reserve	WA
Unnamed WA26620	Nature Reserve	WA
Unnamed WA40552	5(1)(h) Reserve	WA
Unnamed WA40564	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Unnamed WA41102	5(1)(h) Reserve	WA
Unnamed WA41160	5(1)(g) Reserve	WA
Unnamed WA41568	Nature Reserve	WA
Unnamed WA41597	Nature Reserve	WA
Unnamed WA42377	Nature Reserve	WA
Unnamed WA42469	Nature Reserve	WA
Unnamed WA42879	Nature Reserve	WA
Unnamed WA42942	Nature Reserve	WA
Unnamed WA43903	Nature Reserve	WA
Unnamed WA44004	Nature Reserve	WA
Unnamed WA44676	5(1)(h) Reserve	WA
Unnamed WA44705	5(1)(g) Reserve	WA
Unnamed WA44709	5(1)(h) Reserve	WA
Unnamed WA44838	Nature Reserve	WA
Unnamed WA44977	Nature Reserve	WA
Unnamed WA44978	Nature Reserve	WA
Unnamed WA45089	Nature Reserve	WA
Unnamed WA45533	Nature Reserve	WA
Unnamed WA46108	Nature Reserve	WA
Unnamed WA46400	National Park	WA
Unnamed WA46661	Nature Reserve	WA
Unnamed WA48837	Nature Reserve	WA
Unnamed WA48858	Nature Reserve	WA
Unnamed WA48968	5(1)(h) Reserve	WA
Unnamed WA49220	Conservation Park	WA
Unnamed WA49385	Nature Reserve	WA
Unnamed WA49994	Conservation Park	WA

Protected Area Name	Reserve Type	State
Unnamed WA50017	Nature Reserve	WA
Unnamed WA50190	Nature Reserve	WA
Unnamed WA50270	5(1)(h) Reserve	WA
Unnamed WA51943	5(1)(h) Reserve	WA
Unnamed WA51944	5(1)(h) Reserve	WA
Walburra	Nature Reserve	WA
Wanagarren	Nature Reserve	WA
Wedge Island	Nature Reserve	WA
Yalgorup	National Park	WA
Yanchep	National Park	WA
Yelverton	National Park	WA

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

RFA Name	State
South West WA RFA	Western Australia

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Becher Point Wetlands	WA
Blackwood River (Lower Reaches) and Tributaries System	WA
Broke Inlet System	WA
Cape Leeuwin System	WA
Doggerup Creek System	WA
Gingilup-Jasper Wetland System	WA
Lake McLarty System	WA
Lake Thetis	WA
Loch McNess System	WA
Maringup Lake	WA
McCarleys Swamp (Ludlow Swamp)	WA

Wetland Name	State
Peel-Harvey Estuary	WA
Rottnest Island Lakes	WA
Swan-Canning Estuary	WA
Vasse-Wonnerup Wetland System	WA
Yalgorup Lakes System	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Fremantle District Police Complex Project	2022/09345		Completed
Gnarabup Tourism Development: Resort and Beach Village	2022/09224		Assessment
Gravel Extraction Project	2022/09278		Referral Decision
Production horticulture in Lot 6 and Lot 8 Old Coast Road, Myalup	2020/8827		Assessment
Runnymede Road Sand Quarry	2022/09262		Completed
Runnymede Road Sand Quarry	2022/09332		Assessment
Samphire Offshore Wind Farm	2022/09306		Assessment
Sand Extraction on 150 Runnymede Road Binningup	2022/09364		Referral Decision
Controlled action			
313-316 Mimminup Road, Dalyellup	2012/6274	Controlled Action	Post-Approval
Aerial Application of Lavicide to Vasse-Wonnerup Wetlands	2010/5593	Controlled Action	Post-Approval
Airborne sonar trials	2001/540	Controlled Action	Completed
Albemarle Lithium hydroxide manufacturing plant, Kemerton, WA	2017/8099	Controlled Action	Post-Approval
Alkimos city centre and central development, WA	2015/7561	Controlled Action	Post-Approval
Alkimos Coastal Node	2020/8861	Controlled Action	Further Information

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
			Request
Alkimos Seawater Desalination	2019/8453	Controlled Action	Assessment Approach
All weather access track road between Windy Harbour and Nelson Location 7965	2011/6121	Controlled Action	Post-Approval
Bagieau Road Limestone Quarry	2019/8533	Controlled Action	Further Information Request
Binningup Beach Residential Development, Lots 195, 304, 9003 Lakes Parade, Binningup WA	2009/5046	Controlled Action	Post-Approval
Bluewaters Power Station Expansion Phases 3 & 4	2008/4113	Controlled Action	Proposed Decision
Bunbury Outer Ring Road Northern and Central Section Project, WA	2019/8471	Controlled Action	Post-Approval
Bunbury Outer Ring Road Southern Section	2012/6652	Controlled Action	Completed
Bunbury Outer Ring Road Southern Section project, WA	2019/8543	Controlled Action	Final PD
Bunbury Port Berth 14A Expansion & Coal Storage & Loading Facility, WA	2014/7200	Controlled Action	Post-Approval
Bussell Highway - Capel to Hutton Section, WA	2015/7626	Controlled Action	Post-Approval
Bussell Highway Duplication Hutton to Sabina	2020/8800	Controlled Action	Post-Approval
Busselton Foreshore Redevelopment from West Street to Ford Road	2013/6830	Controlled Action	Post-Approval
Butler North District Open Space playing fields development, Wanneroo, WA	2017/8053	Controlled Action	Post-Approval
Capecare, urban and commercial new development, Aged Care - Naturaliste Terrace, Dunsborough, WA	2006/2834	Controlled Action	Post-Approval
Cape View Resort at Lot 190 Little Colin Street	2006/3070	Controlled Action	Post-Approval
Catalina Residential Development	2010/5785	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Clear 2.86 ha of native vegetation for the purpose of horticulture	2010/5655	Controlled Action	Post-Approval
Clearing for Bunbury Airport Expansion, WA	2013/6872	Controlled Action	Post-Approval
Construction of a Deepwater, General Container Port	2009/5178	Controlled Action	Proposed Decision
Construction of New Perth Bunbury Highway project	2005/2193	Controlled Action	Post-Approval
Construction of new sporting field	2007/3333	Controlled Action	Post-Approval
Dalyellup Beach Estate - Residential Development	2007/3361	Controlled Action	Post-Approval
Dawson Beach Estate Stage 2	2005/2153	Controlled Action	Post-Approval
Development Guide Plan for 46 ha Residential Subdivision	2008/4102	Controlled Action	Post-Approval
Development of Busselton Health Campus	2011/6011	Controlled Action	Post-Approval
Development of Kwinana Quay port facility	2008/4387	Controlled Action	Completed
Development of Lot 9018 Martingale Road and Lot 377 Clinker Drive, Dunsborough, WA	2018/8278	Controlled Action	Further Information Request
Develop Trails and a Wetlands Demonstration Site and Centre	2008/4439	Controlled Action	Post-Approval
Eastern Link Project, Busselton WA	2018/8155	Controlled Action	Post-Approval
Eglinton/South Yanchep Residential Development	2011/6021	Controlled Action	Post-Approval
Eglinton Estates - Clearing of native vegetation from Lot 1007 & part Lot 1008	2010/5777	Controlled Action	Post-Approval
Excavate sand and limestone resources	2010/5621	Controlled Action	Completed
Extension of Lots 4 & 5 Ludlow Road Limestone Extraction, Myalup, WA	2019/8388	Controlled Action	Post-Approval
Flat Rock boating facility	2008/4506	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Halls Head Shopping Centre stages 2 & 3 expansion	2010/5636	Controlled Action	Post-Approval
Industry Zone	2010/5337	Controlled Action	Post-Approval
Jindee Residential Development	2012/6631	Controlled Action	Post-Approval
Leeuwin Offshore Wind Farm	2022/9160	Controlled Action	Assessment Approach
Lennox Weir Removal, 12kms west Busselton	2021/8915	Controlled Action	Assessment Approach
Lot 32 Tom Cullity Drive, Wilyabrup	2020/8866	Controlled Action	Post-Approval
Lot 4 Runnymede Road, Wellesley - Proposed Sand Extraction	2020/8862	Controlled Action	Assessment Approach
Lot 505 Hungerford Avenue, Halls Head, WA Residential Development	2009/4789	Controlled Action	Post-Approval
Lower Vasse River Sediment Removal	2021/9051	Controlled Action	Post-Approval
Mandurah Junction Commercial and Residential Development	2010/5410	Controlled Action	Completed
Mangles Bay Marina Based Tourist Precinct	2010/5659	Controlled Action	Post-Approval
Milyeannup Wind Farm	2009/4911	Controlled Action	Post-Approval
Mitchell Freeway Extension and Wanneroo Road Upgrade, WA	2018/8367	Controlled Action	Post-Approval
Mitchell Freeway Extension between Burns Beach Rd and Hester Av, Neerabup, WA	2013/7091	Controlled Action	Post-Approval
Mixed Use Residential and Commercial Development	2009/4919	Controlled Action	Post-Approval
Nava-1 Cable System	2001/510	Controlled Action	Completed
Neerabup Industrial Estate, Lot 701 Flynn Drive Neerabup WA	2012/6424	Controlled Action	Post-Approval
Neighbourhood Shopping Centre and Mixed Business Centre, Ocean Road, Dawesville	2006/3155	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Ocean Reef Marina Development	2009/4937	Controlled Action	Completed
Old Broadwater Farm Estate Subdivision - Stage 3	2009/5231	Controlled Action	Post-Approval
Parklands West Estate Development	2010/5693	Controlled Action	Post-Approval
Peel's Retreat Estate - Residential development	2006/3063	Controlled Action	Post-Approval
Peppermint Park Residential Subdivision - Stage 5	2008/4028	Controlled Action	Post-Approval
Point Grey Marina Project	2010/5515	Controlled Action	Post-Approval
Point Grey Residential Development - Terrestrial Component	2011/5825	Controlled Action	Post-Approval
Preston Industrial Park	2012/6312	Controlled Action	Completed
Proposed excavation and earthworks at existing quarry, prior to subdivision	2008/4562	Controlled Action	Completed
Proposed Sand Extraction at Lot 601 Stanley Road, Wellesley, WA	2020/8635	Controlled Action	Further Information Request
Proposed Urban Development	2008/3984	Controlled Action	Post-Approval
Proposed Urban Development of Lots 1005 & 1006	2008/4638	Controlled Action	Post-Approval
Remove 1.87ha of degraded parkland cleared vegetation to utilising the area for	2010/5661	Controlled Action	Post-Approval
Residential/Industrial subdivision, Lot 18, Vasse Highway, Shire of Busselton	2006/3208	Controlled Action	Post-Approval
Residential Development	2007/3463	Controlled Action	Post-Approval
Residential development, College Grove, WA	2015/7579	Controlled Action	Completed
Residential Development, Lot 3 & 4 Dorsett Street	2006/2774	Controlled Action	Completed
Residential Development, Lot 522 Ditchingham Place Australind, WA	2019/8432	Controlled Action	Assessment Approach

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Residential development,Lot 609, Yanchep Beach Road, Yanchep, WA	2014/7146	Controlled Action	Post-Approval
Residential development, Lots 21 and 100 Southern Estuary Road, Herron, WA	2017/8135	Controlled Action	Completed
Residential development Lot 1004 Alkimos WA	2011/5902	Controlled Action	Post-Approval
Residential development Lot 3, 500 Bussell Highway, WA	2013/7098	Controlled Action	Post-Approval
Residential development Lot 71 Spurr St, Capel, WA	2019/8441	Controlled Action	Assessment Approach
Residential development Lots 8 & 9 King Street	2006/2787	Controlled Action	Completed
Residential subdivision, Lot 501 Vasse Hwy, Yalyalup, WA	2018/8244	Controlled Action	Post-Approval
retirement units & aged care facility development	2007/3533	Controlled Action	Post-Approval
Rural Subdivision of a 975.2ha property	2004/1635	Controlled Action	Completed
Sand and Limestone Excavation Quarry	2008/4229	Controlled Action	Post-Approval
Sand and limestone extraction	2003/1284	Controlled Action	Completed
Sand and Limestone Extraction on Lots 313 and 314, Harewoods Road	2005/2291	Controlled Action	Completed
Sand Extraction Project Lot 5 Wellesley Road, Wellesley Shire of Harvey	2021/9034	Controlled Action	Assessment Approach
Sand mine	2008/4114	Controlled Action	Completed
Sand Mine, Lot 122 Old Coast Road, Parkfield, Binningup, WA	2014/7164	Controlled Action	Post-Approval
Sand Mining on Lot 7 Runnymede Road	2011/5996	Controlled Action	Post-Approval
Shark Hazard Mitigation Drum Line Program, WA	2014/7174	Controlled Action	Completed
Shenton Park Subdivision	2004/1479	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Smiths Beach Project, Yallingup - Coastal Tourism Village	2021/9141	Controlled Action	Referral Publication
Somerville Drive Extension	2011/6153	Controlled Action	Post-Approval
South Capel Remediation Project, WA	2018/8250	Controlled Action	Post-Approval
Southern Seawater Desalination Project	2008/4173	Controlled Action	Post-Approval
Stage 2 of the Bunbury Port Access Project	2010/5768	Controlled Action	Post-Approval
Subdivision Lot 1 Dawesville Rd	2005/2394	Controlled Action	Post-Approval
Three Turning Pockets West of Busselton Townsite	2002/846	Controlled Action	Post-Approval
Tourism Villa Facility Development	2008/4025	Controlled Action	Post-Approval
tourist and residential development	2007/3483	Controlled Action	Post-Approval
Upgrade of Ford Road	2005/2113	Controlled Action	Completed
Urban and Residential Development at Lot 9 Brighton	2011/6137	Controlled Action	Post-Approval
Urban development, multiple lots Northerly Street, Vasse, WA	2019/8494	Controlled Action	Assessment Approach
Urban development in accordance with the Local Structure Plan	2008/4601	Controlled Action	Post-Approval
Urban Development Ravendale Drive, Coodanup Drive & Wanjeep Street	2011/5928	Controlled Action	Post-Approval
Urban development subdivision	2013/6955	Controlled Action	Post-Approval
Urban Residential Development at Lot 9049 Marmoin Avenue	2009/5155	Controlled Action	Post-Approval
Vasse Diversion Drain Upgrade	2017/7932	Controlled Action	Post-Approval
Vegetation Clearing, Wannaroo Rd and Nowergup Rd	2011/5955	Controlled Action	Completed
Vlam Road Gravel Pit, Vlam Road, Karridale, WA	2014/7141	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
WA Offshore Windfarm	2021/8961	Controlled Action	Assessment Approach
Warders Hotel, Block 1 Warders Cottages, Fremantle, WA	2018/8144	Controlled Action	Post-Approval
Wonnerup North Mineral Sands Project, Busselton, WA	2014/7205	Controlled Action	Post-Approval
Wonnerup South Mineral Sands Project, Yalyalup, WA	2014/7135	Controlled Action	Post-Approval
Wonnerup Titanium Mineral Mining Project	2010/5403	Controlled Action	Post-Approval
Yanchep Rail Extension, WA	2018/8262	Controlled Action	Post-Approval
Yarragadee Water Supply Development	2005/2073	Controlled Action	Completed
Yoongarillup Mineral Sands Project, WA	2012/6521	Controlled Action	Post-Approval
Not controlled action			
'Looping 10' gas transmission pipeline from Kwinana to Hopelands	2005/2212	Not Controlled Action	Completed
25 Lot Residential Subdivision	2009/4830	Not Controlled Action	Completed
Aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, WA	2016/7780	Not Controlled Action	Completed
Alkimos seawater desalination plant, offshore investigations, WA	2018/8224	Not Controlled Action	Completed
Amberton West urban development - Part lot 9005 Eglington WA	2013/7068	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Bunbury Water Resources Recovery Scheme-Recycled Water Treatment Plant	2021/8986	Not Controlled Action	Completed
Bushfire Mitigation Works - City of Mandurah	2020/8674	Not Controlled Action	Completed
Bussell Highway (Bramley Section) SLK Upgrade	2012/6511	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Busselton-Margaret River Regional Airport Development Project, WA	2016/7675	Not Controlled Action	Completed
Busselton to Flinders Bay Rails to Trails Project, WA	2013/6835	Not Controlled Action	Completed
Busselton to Margaret River Transmission Line	2008/3964	Not Controlled Action	Completed
Butler Railway Extension Project - Nowergup Depot Eastern Alignment	2011/5989	Not Controlled Action	Completed
Cape Naturaliste Road Shared Pathway, Dunsborough, WA	2018/8282	Not Controlled Action	Completed
Causeway Bridge Duplication, Busselton, WA	2018/8309	Not Controlled Action	Completed
Caves Road and Cape Naturaliste Road Intersection Upgrade	2012/6395	Not Controlled Action	Completed
Caves Road widening project between Dunsborough and Yallingup(20.3 -24.6 SLK), WA	2015/7475	Not Controlled Action	Completed
Clearing 5.4ha of native vegetation for sand extraction	2012/6592	Not Controlled Action	Completed
Clear Lot 503, 54 Ocean Road Dawesville, WA	2014/7375	Not Controlled Action	Completed
Construction and operation of an 8 turbine wind farm at Rous Head Harbour, Frema	2003/933	Not Controlled Action	Completed
Construction of Secret Harbour High School	2004/1489	Not Controlled Action	Completed
Construction of several passing lanes between Lancelin and Jurien Bay, WA	2015/7509	Not Controlled Action	Completed
Construction of the Margaret River bypass road	2012/6677	Not Controlled Action	Completed
Container Deposit Scheme Project	2019/8517	Not Controlled Action	Completed
CTBT - Cape Leeuwin Hydroacoustic Station Proposal	2000/27	Not Controlled Action	Completed
Demolish and replace Old Mandurah Traffic Bridge, Mandurah, WA	2015/7415	Not Controlled Action	Completed
Development of 5ha limestone quarry at Lot 2 Ludlow Rd	2006/2568	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Development of new Alkimos Wastwater Treatment Plant	2007/3259	Not Controlled Action	Completed
Disposal of residential properties, Fremantle, WA	2019/8593	Not Controlled Action	Completed
Earthworks and Excavation of Lots 2, 13 & 22 Old Coast Road	2009/5101	Not Controlled Action	Completed
Eastport canal estate development stage 5	2007/3737	Not Controlled Action	Completed
Eradication of the European House Borer, Perth metropolitan area, WA	2009/5027	Not Controlled Action	Completed
Establishment of a National Lifestyle Village	2011/6081	Not Controlled Action	Completed
Expansion of berthing facilities at Kwinana Bulk Terminal	2006/2509	Not Controlled Action	Completed
Expansion of existing Ammonium Nitrate Production Facility	2005/1941	Not Controlled Action	Completed
Expedition 369-Australian Cretaceous Climate and Tectonics, Australian EEZ waters	2017/7891	Not Controlled Action	Completed
Extension of 7.5km of the Joondalup Line electrified passenger railway from Cla	2010/5632	Not Controlled Action	Completed
Extension of Brittain Road to connect with the South Western Hwy/Robertson Drive intersection	2007/3707	Not Controlled Action	Completed
Extension of commercial sand extraction operation, Shire of Capel WA	2003/1250	Not Controlled Action	Completed
Extension of Existing Limestone Quarry at Lot 5 Old Coast Road	2006/2831	Not Controlled Action	Completed
Florida Estate Residential Subdivision Development Stage 13	2011/6045	Not Controlled Action	Completed
Florida North residential development, Lot 9008, Ocean Road, Dawesville, WA	2015/7462	Not Controlled Action	Completed
Fremantle Ports Inner Harbour Capital Dredging Proposal	2005/2477	Not Controlled Action	Completed
Gas-fired Power Station	2005/2213	Not Controlled Action	Completed
Geo-science Investigations	2005/2069	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Gloucester Park Precinct-expansion of ovals and community facilities, Margaret River, WA	2017/7985	Not Controlled Action	Completed
Horizontal drilling from Lot 35 Ballarat Rd under Wonnerup Inlet	2004/1354	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
Indian Ocean Drive Passing Lane and Widening 52-258 SLK	2017/7884	Not Controlled Action	Completed
Indian Ocean Drive Widening, Gingin Shire, WA	2018/8346	Not Controlled Action	Completed
INDIGO Central Submarine Telecommunicats Cable	2017/8127	Not Controlled Action	Completed
INDIGO West Submarine Telecommunicats Cable, WA	2017/8126	Not Controlled Action	Completed
Industrial development, Lot 561 Paris Road, Australind, WA	2016/7712	Not Controlled Action	Completed
Installation of stock proof fencing and a stock crossing 8 km from Karridale WA	2012/6427	Not Controlled Action	Completed
Kemerton Lateral Gas Pipeline Project	2005/2388	Not Controlled Action	Completed
Kennedy Bay urban development, Port Kennedy, WA	2014/7122	Not Controlled Action	Completed
Kennedy Park Estate Residential Development	2003/1044	Not Controlled Action	Completed
Kwinana Gas-Fired Power Station	2005/2101	Not Controlled Action	Completed
Lancelin Caravan Park Project, Hopkins Dve & Casserley Way, Lancelin	2015/7546	Not Controlled Action	Completed
larvaciding of potential mosquito breeding wetlands	2006/2601	Not Controlled Action	Completed
Limestone quarry expansion	2005/2268	Not Controlled Action	Completed
Limestone Quarry Expansion, Lots 3618 and 1794, Finn Road	2005/2332	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Limestone quarry mining	2006/2942	Not Controlled Action	Completed
Lot 101 Mandurah Road, Madora Bay, WA	2012/6466	Not Controlled Action	Completed
Lot 200 Caves Road Tourist Accommodation	2020/8775	Not Controlled Action	Completed
Mandurah Quay Residential Development	2010/5754	Not Controlled Action	Completed
New automotive centre at the Southwest Institute of Technology, Bunbury, WA	2010/5766	Not Controlled Action	Completed
Nowergup Strawberry Farm McLennan Drive, Nowergup, WA	2017/8042	Not Controlled Action	Completed
Nuttman Road, Busselton Gravel Extraction, WA	2017/8086	Not Controlled Action	Completed
Ocean Reef Marina Development, City of Joondalup, WA	2014/7237	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
Palm Beach Caravan Park Redevelopment, Rockingham, WA	2013/6853	Not Controlled Action	Completed
Point Grey Entrance Road	2011/5807	Not Controlled Action	Completed
Proposal to widen Harris Road within the Shire of Dardanup, WA	2013/6934	Not Controlled Action	Completed
Proposed Expansion of Existing Gracetown Townsite & Upgrade of Existing Associa	2010/5358	Not Controlled Action	Completed
Proposed Fuel Reduction Burn, Loughton Park, Bunbury, WA	2014/7148	Not Controlled Action	Completed
Quinns Main sewer extension, Clarkson - Neerabup, WA	2018/8215	Not Controlled Action	Completed
Redevelopment of Lots 3 & 4, Kent Street	2007/3243	Not Controlled Action	Completed
Reinstating of Firebreaks at McLeod Creek, South West WA	2012/6402	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Replacement Floodgates	2003/1010	Not Controlled Action	Completed
Residential & Light Industrial Development, Vasse WA	2013/6932	Not Controlled Action	Completed
Residential development, Lot 42, Farmhouse Court, Bovell, WA	2014/7195	Not Controlled Action	Completed
Residential development, Lot 54 Vittoria Road, Glen Iris, WA	2018/8308	Not Controlled Action	Completed
Residential development, Lots 120-121 Minninup Road, Dalyellup WA	2018/8254	Not Controlled Action	Completed
Residential development, Lots 9010 and 9031, Yanchep Beach Rd, Yanchep	2016/7642	Not Controlled Action	Completed
Residential Development - Assorted Lots Parade Rd, Washington Av & Bussell Hwy, Usher WA	2013/6935	Not Controlled Action	Completed
Residential Development Eglinton West, Lot 5000 & part Lot 5001, Pipidinny Road, Eglinton	2014/7137	Not Controlled Action	Completed
Residential Development Riverslea Estate Stage 8, Margaret River, WA	2014/7227	Not Controlled Action	Completed
Residential-Rural Subdivision, Lot 1 Kudardup Rd, Kudardup, WA	2012/6471	Not Controlled Action	Completed
residential subdivision	2005/1965	Not Controlled Action	Completed
Residential Subdivision, Lot 90 Leisure Way, Halls Head, WA	2018/8175	Not Controlled Action	Completed
Re-zoning of Land for Future Residential Development Purposes	2009/4908	Not Controlled Action	Completed
Rezoning of Lot 31, 80-lot Residential Subdivision	2008/4680	Not Controlled Action	Completed
Rottnest Lodge Redevelopment	2019/8565	Not Controlled Action	Completed
Rural Residential Development Lot 7 Dunkeld Drive, Herron, WA	2014/7340	Not Controlled Action	Completed
Sand Extraction, Lot 265 Ducane Road, Gelorup, WA	2012/6616	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Scientific Sonar Trial	2002/680	Not Controlled Action	Completed
Secondary School Campus Development at Lot 150 Leisure Drive, Australind	2013/6744	Not Controlled Action	Completed
Seismic Survey, Bremer Basin, Mentelle Basin and Zeewyck Sub-basin	2004/1700	Not Controlled Action	Completed
Sepia Depression Ocean Outlet Landline Duplication	2012/6248	Not Controlled Action	Completed
South Western Highway Reconstruction between Waterloo and Hynes Roads, Waterloo	2010/5617	Not Controlled Action	Completed
Stanley Road waste management facility, Wellesley, WA	2014/7131	Not Controlled Action	Completed
Titanium Mining	2001/340	Not Controlled Action	Completed
Twin Rivers Residential Subdivision	2005/2168	Not Controlled Action	Completed
urban residential development	2006/2924	Not Controlled Action	Completed
Vasse Hotel and Supermarket Redevelopment	2001/288	Not Controlled Action	Completed
Vegetation Clearance for Horticulture Operation Expansion, Lot 2, Springfield Rd, Parkfield, WA	2014/7196	Not Controlled Action	Completed
Vegetation clearing for industrial development	2013/6960	Not Controlled Action	Completed
Vegetation clearing for sand extraction, Lot 268 Leeuwin Road, Augusta	2013/6860	Not Controlled Action	Completed
Warders' Cottages Block 2 'W2'	2022/9148	Not Controlled Action	Completed
Warders' Cottages W2 minor works, Fremantle, WA	2018/8185	Not Controlled Action	Completed
West's gravel pit development, Cowaramup, WA	2015/7586	Not Controlled Action	Completed
Woodcrest Rise Estate Residential Development	2007/3794	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Yngling-1 exploration well for WA-368-P	2007/3523	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey Within WA-382-P	2007/3799	Not Controlled Action (Particular Manner)	Post-Approval
Aerial Application of Larvicide	2010/5490	Not Controlled Action (Particular Manner)	Post-Approval
Aerial Mosquito Spraying Vasse-Wonnerup System	2005/1952	Not Controlled Action (Particular Manner)	Post-Approval
Ambergate North Residential Development	2009/4802	Not Controlled Action (Particular Manner)	Post-Approval
Australian Underwater Discovery Centre	2021/9019	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Australind Piggery expansion	2014/7117	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Garden Island Project, offshore WA	2016/7635	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Geophysical and Geotechnical Surveys	2014/7408	Not Controlled Action (Particular Manner)	Post-Approval
City of Cockburn Sporting Facilties	2005/2139	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Clearing of understorey vegetation for fire management purposes	2010/5788	Not Controlled Action (Particular Manner)	Post-Approval
Construct and operate a 132kV transmission line and upgrade Kemerton Terminal Si	2008/4484	Not Controlled Action (Particular Manner)	Post-Approval
Construction of Mandurah Entrance Road	2009/4692	Not Controlled Action (Particular Manner)	Post-Approval
Construction of new bridge (Bridge 5370) across the Collie River, Eaton, WA	2016/7657	Not Controlled Action (Particular Manner)	Post-Approval
Construction of urea production plant and supporting infrastructure	2009/5067	Not Controlled Action (Particular Manner)	Post-Approval
Coodanup residential development	2006/3073	Not Controlled Action (Particular Manner)	Post-Approval
Country Road Estate - Final Stage Development	2006/3095	Not Controlled Action (Particular Manner)	Post-Approval
Dalyellup Beach Estate Stages 12 and 14, near Bunbury	2004/1726	Not Controlled Action (Particular Manner)	Post-Approval
Dalyellup Beach Estate - Stages 13 and 16	2006/3075	Not Controlled Action (Particular Manner)	Post-Approval
Development of Limestone and Sand Extraction Sites on Lots 1498 and 1504, and Upgrade of Finn and Ha	2009/5200	Not Controlled Action (Particular Manner)	Post-Approval
Diversion of Surface Water into Lake Mealup	2010/5467	Not Controlled Action (Particular Manner)	Post-Approval
Dredging of the Yunderup Approach Channel	2007/3415	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Extension and Renewal of Existing Sand Quarry	2008/4326	Not Controlled Action (Particular Manner)	Post-Approval
Extension of existing mains water supply pipeline	2009/4686	Not Controlled Action (Particular Manner)	Post-Approval
Grand Southern Margin 2D Marine Seismic Survey	2008/4599	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Lake Richmond Boardwalk installation, Rockingham, WA	2013/6977	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Limestone Excavation - Ludlow Road, Myalup	2008/3956	Not Controlled Action (Particular Manner)	Post-Approval
Limestone Extraction on Lot 5 Old Coast Road, Myalup, WA	2012/6468	Not Controlled Action (Particular Manner)	Post-Approval
Locations 2629, 2699 & 2991 - Jamisons Road	2002/771	Not Controlled Action (Particular Manner)	Post-Approval
Lots 123,124& Pt Loc 170 Geographe Bay Road	2005/2317	Not Controlled Action (Particular Manner)	Post-Approval
Maintenance Channel Dredging	2010/5528	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Marine Environmental Survey	2012/6275	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
McCourt Hills Estate Stage 3	2006/2760	Not Controlled Action (Particular Manner)	Post-Approval
Monaghan's Roundabout Project - Intersection of Bussell Highway and Caves Road, Shire of Busselton	2007/3515	Not Controlled Action (Particular Manner)	Post-Approval
Multipurpose development stage 1 within 340ha	2004/1913	Not Controlled Action (Particular Manner)	Post-Approval
Nexus Energy Seismic survey WA	2006/2569	Not Controlled Action (Particular Manner)	Post-Approval
Novacare Lifestyle Village	2001/311	Not Controlled Action (Particular Manner)	Post-Approval
Rezoning and Residential Development, Lot 2942, Old Bunbury Road	2007/3768	Not Controlled Action (Particular Manner)	Post-Approval
Sand and Limestone Extraction on Lots 313 and 314, Harewoods Road	2005/2346	Not Controlled Action (Particular Manner)	Post-Approval
South Busselton Primary School	2001/290	Not Controlled Action (Particular Manner)	Post-Approval
South West Metropolitan Railway Project	2003/1175	Not Controlled Action (Particular Manner)	Post-Approval
Stratham Park Estate Subdivision - Lots 70, 11 and 12	2008/4068	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Subdivision and development of residential dwelling on part Lot 1, Bussell Highw	2006/3023	Not Controlled Action (Particular Manner)	Post-Approval
Waterloo to Busselton 132kV Transmission Line	2002/816	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Widening of Ludlow North Road Between Peppermint Grove Road and Mallokup Road	2009/5242	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3725	Referral Decision	Completed
3D Seismic Survey	2012/6245	Referral Decision	Completed
Ambergate North Residential Community (4896 lots)	2008/4617	Referral Decision	Completed
Bunbury Port Berth 14 Development, Bunbury Port Inner Harbour	2011/6023	Referral Decision	Completed
Bunbury Water Resource Recovery Scheme - Stage 2 Pipeline	2022/9145	Referral Decision	Referral Publication
Bunbury WRRS - Stage 2 Pipeline	2021/9092	Referral Decision	Completed
CO2 3D Seismic Survey Vlaming Sub-Basin	2012/6343	Referral Decision	Completed
Construction of 14.5km 132kV transmission line	2009/4995	Referral Decision	Completed
Grand Southern Margin 2D Marine Seismic Survey	2008/4573	Referral Decision	Completed
Harvesting of Pinus Radiata Plantation	2010/5414	Referral Decision	Completed
Kennedy Bay Urban Development,PortKennedy,Rockingh	2013/7022	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Lots 1-5 Bluerise Cove & Lots 801 & 124 Pleasant Grove Rezoning and Subdivision	2008/4295	Referral Decision	Completed
Narelle 3D Marine Seismic Survey	2008/4575	Referral Decision	Completed
Nirimba Rural Residential Development	2020/8690	Referral Decision	Completed
Residential development, Lot 71 Spurr Street, Capel, WA	2017/8128	Referral Decision	Completed
Residential Subdivision, Location 871 Goodwood Rd and Lot 1181 Hawley Rd, Capel	2008/4090	Referral Decision	Completed
Residential subdivision and development	2007/3711	Referral Decision	Completed
Residential Subdivision Lot 801 Pleasant Grove Circle, Falcon, WA	2012/6507	Referral Decision	Referral Publication
Residential Subdivision of 60ha, Swan Location 2424	2004/1928	Referral Decision	Completed
Riverbank and Country Road Estates Lot 43 Bussell Highway	2005/2367	Referral Decision	Completed
Sonar Trials and Acoustic Trials	2001/538	Referral Decision	Completed
Water quality improvement trial, Lower Vasse River, Busselton, WA	2013/6975	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 90-120m depth	South-west
Cape Mentelle upwelling	South-west
Commonwealth marine environment within and adjacent to Geographe Bay	South-west
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Naturaliste Plateau	South-west
Perth Canyon and adjacent shelf break, and other west coast canyons	South-west

Name	Region
Western demersal slope and associated fish communities	South-west
Western rock lobster	South-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Seabirds		
Anous stolidus Common Noddy [825]	Foraging	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Aggregation	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Foraging (in high numbers)	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Eudyptula minor Little Penguin [1085]	Foraging (provisioning young)	Known to occur
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Former Range
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Pelagodroma marina White-faced Storm petrel [1016]	Foraging (in high numbers)	Known to occur
Pterodroma macroptera macroptera Great-winged Petrel (macroptera race) [1035]	Foraging (provisioning young)	Known to occur
Pterodroma mollis Soft-plumaged Petrel [1036]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Thalassarche chlororhynchos bassi Indian Yellow-nosed Albatross [85249]	Foraging (in high numbers)	Known to occur
Seals		
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur
Whales		
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (abundant food source)	Known to occur
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (high density)	Known to occur

Scientific Name	Behaviour	Presence
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (on migration)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging Area (annual high use area)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Eubalaena australis Southern Right Whale [40]	Calving buffer	Known to occur
Eubalaena australis Southern Right Whale [40]	Seasonal calving habitat	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (south)	Known to occur
Physeter macrocephalus Sperm Whale [59]	Foraging (abundant food source)	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

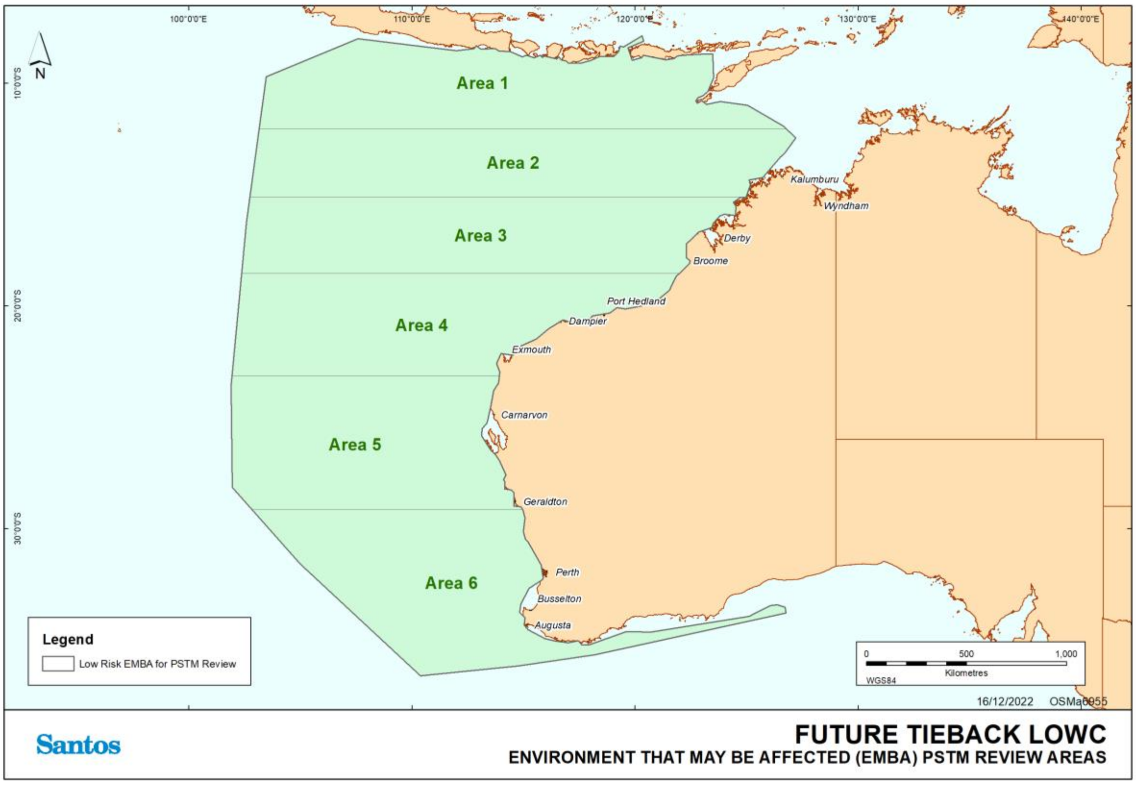

Figure A 2 PMST search areas for the EMBA, Future Tieback LOWC

AREA 1

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	3
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	5
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	38
Listed Migratory Species:	46

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	85
Commonwealth Heritage Places:	11
Listed Marine Species:	92
Whales and Other Cetaceans:	28
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	1
Australian Marine Parks:	3
Habitat Critical to the Survival of Marine Turtles:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	2
EPBC Act Referrals:	102
Key Ecological Features (Marine):	2
Biologically Important Areas:	19
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Ashmore reef national nature reserve	Within 10km of Ramsar site
Hosnies spring	Within Ramsar site
The dales	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Accipiter hiogaster natalis		
Christmas Island Goshawk [82408]	Endangered	Species or species habitat known to occur within area
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Chalcophaps indica natalis		
Christmas Island Emerald Dove, Emerald Dove (Christmas Island) [67030]	Endangered	Species or species habitat known to occur within area
Fregata andrewsi		
Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Ninox natalis		
Christmas Island Hawk-Owl, Christmas Boobook [66671]	Vulnerable	Species or species habitat known to occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti		
Abbott's Booby [59297]	Endangered	Species or species habitat known to occur within area
Phaethon lepturus fulvus		
Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat known to occur within area
Turdus poliocephalus erythropleurus		
Christmas Island Thrush [67122]	Endangered	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Crocidura trichura Christmas Island Shrew [86568]	Critically Endangered	Species or species habitat likely to occur within area
Pteropus natalis Christmas Island Flying-fox, Christmas Island Fruit-bat [87611]	Critically Endangered	Species or species habitat known to occur within area
PLANT		
Asplenium listeri Christmas Island Spleenwort [65865]	Critically Endangered	Species or species habitat known to occur within area
Pneumatopteris truncata fern [68812]	Critically Endangered	Species or species habitat known to occur within area
Tectaria devexa [14767]	Endangered	Species or species habitat likely to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Cryptoblepharus egeriae Christmas Island Blue-tailed Skink, Blue-tailed Snake-eyed Skink [1526]	Critically Endangered	Species or species habitat likely to occur within area
Cyrtodactylus sadleiri Christmas Island Giant Gecko [86865]	Endangered	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Lepidodactylus listeri Christmas Island Gecko, Lister's Gecko [1711]	Critically Endangered	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ramphotyphlops exocoeti Christmas Island Blind Snake, Christmas Island Pink Blind Snake [1262]	Vulnerable	Species or species habitat likely to occur within area
SHARK		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata andrewsi		
Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Environment and Heritage	
Commonwealth Land - Christmas Island National Park [94105]	CI
Commonwealth Land - Christmas Island National Park [94103]	CI

Commonwealth Land Name	State
Commonwealth Land - Christmas Island National Park [94102]	CI
Commonwealth Land - Christmas Island National Park [94101]	CI
Commonwealth Land - Christmas Island National Park [94104]	CI
Unknown	
Commonwealth Land - [94202]	CI
Commonwealth Land - [94201]	CI
Commonwealth Land - [94231]	CI
Commonwealth Land - [94276]	CI
Commonwealth Land - [94205]	CI
Commonwealth Land - [94204]	CI
Commonwealth Land - [94277]	CI
Commonwealth Land - [94274]	CI
Commonwealth Land - [94275]	CI
Commonwealth Land - [94272]	CI
Commonwealth Land - [94270]	CI
Commonwealth Land - [94271]	CI
Commonwealth Land - [94273]	CI
Commonwealth Land - [94232]	CI
Commonwealth Land - [94233]	CI
Commonwealth Land - [94279]	CI
Commonwealth Land - [94280]	CI
Commonwealth Land - [94238]	CI
Commonwealth Land - [94230]	CI
Commonwealth Land - [94234]	CI
Commonwealth Land - [94239]	CI
Commonwealth Land - [94236]	CI
Commonwealth Land - [94237]	CI

Commonwealth Land Name	State
Commonwealth Land - [94269]	CI
Commonwealth Land - [94268]	CI
Commonwealth Land - [94261]	CI
Commonwealth Land - [94260]	CI
Commonwealth Land - [94263]	CI
Commonwealth Land - [94245]	CI
Commonwealth Land - [94262]	CI
Commonwealth Land - [94246]	CI
Commonwealth Land - [94244]	CI
Commonwealth Land - [94243]	CI
Commonwealth Land - [94242]	CI
Commonwealth Land - [94241]	CI
Commonwealth Land - [94240]	CI
Commonwealth Land - [94247]	CI
Commonwealth Land - [94223]	CI
Commonwealth Land - [94222]	CI
Commonwealth Land - [94208]	CI
Commonwealth Land - [94209]	CI
Commonwealth Land - [94248]	CI
Commonwealth Land - [94249]	CI
Commonwealth Land - [94207]	CI
Commonwealth Land - [94206]	CI
Commonwealth Land - [94251]	CI
Commonwealth Land - [94250]	CI
Commonwealth Land - [94228]	CI
Commonwealth Land - [94229]	CI
Commonwealth Land - [94255]	CI

Commonwealth Land Name	State
Commonwealth Land - [94254]	CI
Commonwealth Land - [94253]	CI
Commonwealth Land - [94252]	CI
Commonwealth Land - [94265]	CI
Commonwealth Land - [94220]	CI
Commonwealth Land - [94267]	CI
Commonwealth Land - [94264]	CI
Commonwealth Land - [94225]	CI
Commonwealth Land - [94266]	CI
Commonwealth Land - [94227]	CI
Commonwealth Land - [94224]	CI
Commonwealth Land - [94221]	CI
Commonwealth Land - [94226]	CI
Commonwealth Land - [94210]	CI
Commonwealth Land - [94211]	CI
Commonwealth Land - [94216]	CI
Commonwealth Land - [94217]	CI
Commonwealth Land - [94235]	CI
Commonwealth Land - [94213]	CI
Commonwealth Land - [94212]	CI
Commonwealth Land - [94256]	CI
Commonwealth Land - [94257]	CI
Commonwealth Land - [94258]	CI
Commonwealth Land - [94214]	CI
Commonwealth Land - [94219]	CI
Commonwealth Land - [94215]	CI
Commonwealth Land - [94278]	CI

Commonwealth Land Name	State
Commonwealth Land - [94259]	CI
Commonwealth Land - [94218]	CI
Commonwealth Land - [94203]	CI

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Historic		
Administrators House Precinct	EXT	Listed place
Bungalow 702	EXT	Listed place
Drumsite Industrial Area	EXT	Listed place
Industrial and Administrative Group	EXT	Listed place
Malay Kampong Group	EXT	Listed place
Malay Kampong Precinct	EXT	Listed place
Phosphate Hill Historic Area	EXT	Listed place
Poon Saan Group	EXT	Listed place
Settlement Christmas Island	EXT	Listed place
South Point Settlement Remains	EXT	Listed place
Natural		
Christmas Island Natural Areas	EXT	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area overfly marine area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys sculptus Sculptured Pipefish [66197]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Cosmocampus maxweberi Maxweber's Pipefish [66209]		Species or species habitat may occur within area
Doryrhamphus baldwini Redstripe Pipefish [66718]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus macrorhynchus Whiskered Pipefish, Ornate Pipefish [66222]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus mataafae Samoan Pipefish [66223]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippichthys spicifer Belly-barred Pipefish, Banded Freshwater Pipefish [66232]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat likely to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Commonwealth Reserves Terrestrial [Resource Information]

Name	State	Type
Christmas Island	EXT	National Park (Commonwealth)

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Christmas Island	Habitat Protection Zone (IUCN IV)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Christmas Island	National Park Zone (IUCN II)

Habitat Critical to the Survival of Marine Turtles		
Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Extra Information

Nationally Important Wetlands	[Resource Information]
Wetland Name	State
"The Dales", Christmas Island	EXT
Hosine's Spring, Christmas Island	EXT

EPBC Act Referrals			[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Audacious Oil Field Standalone Development	2001/407	Controlled Action	Completed
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Christmas Island Airport Expansion	2001/434	Controlled Action	Post-Approval
Christmas Island Port Facility	2001/435	Controlled Action	Post-Approval
Construction of mobile phone tower	2002/694	Controlled Action	Completed
Cultural Appearance Upgrade of the Chinese Literary Association Building	2007/3568	Controlled Action	Completed
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
East Christmas Island Phosphate Mines (9 sites)	2001/487	Controlled Action	Completed
Exploration for Mineable Phosphate, Christmas Island	2000/43	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Lily Beach Recreational Facilities	2001/395	Controlled Action	Post-Approval
Lily Beach Rock Pool Development	2001/400	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
Phosphate Mining in South Point Christmas Island	2012/6653	Controlled Action	Post-Approval
Proposed exploration drilling programme for Christmas Island	2016/7779	Controlled Action	Completed
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Road Upgrade/Construction between Lily Beach Road and Port Faci	2001/436	Controlled Action	Post-Approval
Salvage, transport and processing of phosphate resource with extended airport si	2003/1217	Controlled Action	Post-Approval
Yellow Crazy Ant Biological Control	2013/6836	Controlled Action	Post-Approval
Not controlled action			
96-108 Gaze Road - Residential upgrade	2006/2632	Not Controlled Action	Completed
Aerial Baiting, Yellow Crazy Ant Supercolonies, Christmas Island, WA	2019/8492	Not Controlled Action	Completed
Audacious-3 oil drilling well	2003/1042	Not Controlled Action	Completed
Backpacker-1 Offshore Hydrocarbon Exploration Well	2001/300	Not Controlled Action	Completed
Boat Ramp Construction	2001/237	Not Controlled Action	Completed
Building of a carport adjacent to residential house	2004/1538	Not Controlled Action	Completed
Christmas Island/Construction of a double storey shed/carport at MQ387 Gaze Road	2004/1561	Not Controlled Action	Completed
Christmas Island Fuel Consolidation Project, Christmas Island	2012/6454	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Community Recreation Centre	2003/1279	Not Controlled Action	Completed
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
courtyard shower & handbasin facilities	2006/2803	Not Controlled Action	Completed
Drilling of exploration well Audacious-1 in AC/P17	2000/5	Not Controlled Action	Completed
Dwelling demolition, maintenance and carpark/carport/storage shed works	2004/1837	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Extension of a Masonary Brick Wall adjacent to the Poon Saan Club by 500 mm	2004/1564	Not Controlled Action	Completed
Flying Fish Cove Christmas Island Boat Ramp Maintenance	2021/8924	Not Controlled Action	Completed
Flying Fish Cove Landslide Mitigation Project	2020/8616	Not Controlled Action	Completed
Garage and Office Facilities	2004/1919	Not Controlled Action	Completed
Housing and Garden Maintenance Works	2004/1487	Not Controlled Action	Completed
Hydroponics Research Program	2007/3338	Not Controlled Action	Completed
Identification of unmarked grave, exhumation/identification of remains which may belong to a sailor	2006/2992	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Internal and external modifications Lot 1014 Gaze Road	2004/1807	Not Controlled Action	Completed
Light Industrial Subdivision Development	2004/1799	Not Controlled Action	Completed
Lot 1056 Extensions and Alterations	2004/1801	Not Controlled Action	Completed
Maintenance of Tai Jin House, Smith Point	2009/4933	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Mobile Radio Communications System Upgrade	2002/718	Not Controlled Action	Completed
Placement of bitumen/ concrete on rail sections of heritage listed incline, Christmas Island	2013/7009	Not Controlled Action	Completed
Power Station Diesel Generator Replacement	2009/4685	Not Controlled Action	Completed
Proposed sale or lease of Crown land, 11 lots, Christmas Island	2018/8220	Not Controlled Action	Completed
Realignment of Gaze Road Service Road and Gaze Road Junction	2004/1735	Not Controlled Action	Completed
Refurbishment and Extension of Seaview Lodge	2012/6353	Not Controlled Action	Completed
renovate free-standing servant's quarters	2006/2811	Not Controlled Action	Completed
Replacement of deteriorating flat roof at rear of Mosque and extending side verandahs, Christmas Is	2013/6851	Not Controlled Action	Completed
Residential upgrade, 2 Coconut Grove	2007/3295	Not Controlled Action	Completed
Stormwater Remediation Project, Christmas Island	2019/8467	Not Controlled Action	Completed
Subdivision of Lot 571 on DP 26701	2008/4230	Not Controlled Action	Completed
Subdivision of Part 7 of Lot 1014	2009/4851	Not Controlled Action	Completed
Supermarket Extensions	2006/2515	Not Controlled Action	Completed
Upgrade of Residence, Coconut Grove	2006/2728	Not Controlled Action	Completed
Verandah Extension to Existing Breezeway Unit, Gaze Road	2005/1970	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D or 3D Marine Seismic Survey in Petroleum Permit Area AC/P35	2009/4864	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, petroleum exploration permit AC/P33	2006/2918	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular Manner)	Post-Approval
Addition of Verandah to Block of Four Units	2005/2315	Not Controlled Action (Particular Manner)	Post-Approval
Aerial Baiting of Yellow Crazy Ants	2012/6438	Not Controlled Action (Particular Manner)	Post-Approval
Asbestos Removal from Commonwealth Owned Assests including Commonwealth Heritage	2009/4873	Not Controlled Action (Particular Manner)	Post-Approval
Auralandia 3D marine seismic survey	2011/5961	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Baiting Efficacy Trial of Feral Cat Bait and PAPP Toxicant	2008/4383	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Commonwealth Marine/Flying Fish Cove Jetty Extension	2012/6675	Not Controlled Action (Particular Manner)	Post-Approval
Crazy Ant Aerial Baiting Control Program	2002/722	Not Controlled Action (Particular Manner)	Post-Approval
Dillon South-1 Exploration Well Drilling - AC/P4, Territory of Ashmore/Cartier	2013/6849	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Audacious-5 appraisal well	2008/4327	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling in Permit Areas WA-402-P & WA-403-P	2010/5297	Not Controlled Action (Particular Manner)	Post-Approval
Helicopter baiting of exotic yellow crazy ant supercolonies, Christmas Island, Indian Ocean	2009/5016	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
New Housing Program	2011/6056	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Searcher bathymetry & geochemical seismic survey, Brawse Basin,Timor Sea,WA	2013/6980	Not Controlled Action (Particular Manner)	Post-Approval
Songa Venus Drilling and Testing Operations	2009/5122	Not Controlled Action (Particular Manner)	Post-Approval
Swimming Pool modification	2007/3312	Not Controlled Action (Particular Manner)	Post-Approval
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Trials of a bait delivery system for the control of Yellow Crazy Ants	2009/4763	Not Controlled Action (Particular Manner)	Post-Approval
Ursa 3D Marine Seismic Survey	2008/4634	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Water supply upgrade	2005/2269	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed
Alterations and Improvements to existing residence at Lot 3015 Gaze Rd, Christmas Island	2009/5039	Referral Decision	Completed
Rocky Point Dwelling Redevelopment	2005/2203	Referral Decision	Referral Decision

Key Ecological Features

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Carbonate bank and terrace system of the Sahul Shelf	North-west
Continental Slope Demersal Fish Communities	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur

Scientific Name	Behaviour	Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Likely to occur
Lepidochelys olivacea Olive Ridley Turtle [1767]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		

Scientific Name	Behaviour	Presence
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	45
Listed Migratory Species:	66

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	3
Commonwealth Heritage Places:	2
Listed Marine Species:	108
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	10
Habitat Critical to the Survival of Marine Turtles:	2

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	10
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	113
Key Ecological Features (Marine):	6
Biologically Important Areas:	51
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places		[Resource Information]
Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands)	[Resource Information]
Ramsar Site Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
EEZ and Territorial Sea
Extended Continental Shelf
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Mesembriomys gouldii gouldii		
Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat may occur within area
Petrogale concinna monastria		
Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis		
Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus		
Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis		
Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides		
Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
REPTILE		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		

Scientific Name	Threatened Category	Presence Text
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica		
Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis		
Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Unknown	
Commonwealth Land - [52278]	ACI
Commonwealth Land - [52277]	ACI
Commonwealth Land - [52276]	ACI

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area overfly marine area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus		
Bridled Tern [82845]		Breeding known to occur within area
Pandion haliaetus		
Osprey [952]		Breeding known to occur within area
Papasula abbotti		
Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus		
Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding known to occur within area
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area overfly marine area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Breeding known to occur within area
Sula dactylatra		
Masked Booby [1021]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Trachyrhamphus bicoarctatus		
Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon		
Dugong [28]		Breeding known to occur within area
Reptile		
Acalyptophis peronii		
Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii		
Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii		
Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area
Aipysurus fuscus		
Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis		
Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis		
Brown-lined Seasnake [1121]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma coggeri as Hydrophis coggeri Black-headed Sea Snake, Slender-necked Seasnake [87373]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		

Current Scientific Name	Status	Type of Presence
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Kimberley	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Christmas Island	National Park Zone (IUCN II)
Kimberley	National Park Zone (IUCN II)
Ashmore Reef	Recreational Use Zone (IUCN IV)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
May - Jul		
Lepidochelys olivacea Olive Ridley Turtle [1767]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Browse Island	Nature Reserve	WA
Dambimangari	Indigenous Protected Area	WA
Lalang-garram / Camden Sound	Marine Park	WA
Low Rocks	Nature Reserve	WA
North Kimberley	Marine Park	WA
North Lalang-garram	Marine Park	WA
Prince Regent	National Park	WA
Scott Reef	Nature Reserve	WA
Unnamed WA41775	5(1)(h) Reserve	WA
Uunguu	Indigenous Protected Area	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Ashmore Reef	EXT

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Controlled action			
2-D seismic survey Scott Reef	2000/125	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Australia-ASEAN Power Link	2020/8818	Controlled Action	Proposed Decision
Browse FLNG Development, Commonwealth Waters	2013/7079	Controlled Action	Post-Approval
Conduct an exploration drilling campaign	2010/5718	Controlled Action	Completed
Decommissioning of Challis Oilfield	2003/942	Controlled Action	Post-Approval
Develop Ichthys gas-condensate field permit area W	2006/2767	Controlled Action	Completed
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Ichthys Gas Field, Offshore and onshore processing facilities and subsea pipeline	2008/4208	Controlled Action	Post-Approval
Montara 4, 5, and 6 Oil Production Wells, and Montara 3 Gas Re-Injection Well	2002/755	Controlled Action	Post-Approval
Nava-1 Cable System	2001/510	Controlled Action	Completed
Prelude Floating Liquefied Natural Gas Facility and Gas Field Development	2008/4146	Controlled Action	Post-Approval
PTTEP AA Floating LNG Facility	2011/6025	Controlled Action	Completed
Torosa South Initial Appraisal Drilling	2007/3500	Controlled Action	Completed
Not controlled action			
3D marine seismic survey in WA 314P and WA 315P	2004/1927	Not Controlled Action	Completed
Adele Trend TQ3D Seismic Survey	2001/252	Not Controlled Action	Completed
AEC International Hydrocarbon Well Puffin 6	2000/36	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Backpacker-1 Offshore Hydrocarbon Exploration Well	2001/300	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Coot-1 hydrocarbon exploration well, Permit Area AC/L2 or AC/L3	2001/296	Not Controlled Action	Completed
Crux-A and Crux-B appraisal wells, Petroleum Permit Area AC/P23	2006/2748	Not Controlled Action	Completed
Crux gas-liquids development in permit AC/P23	2006/3154	Not Controlled Action	Completed
Drilling of 12 Hydrocarbon Exploration Wells, Permit Area WA-371-P	2006/3005	Not Controlled Action	Completed
Drilling of exploration wells, Permit areas WA-301-P to WA-305-P	2002/769	Not Controlled Action	Completed
Echuca Shoals-2 Exploration of Appraisal Well	2006/3020	Not Controlled Action	Completed
Exploration Drilling in AC/P17, AC/P18 and AC/P24	2001/359	Not Controlled Action	Completed
Exploration Well AC/P23	2001/234	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Kaleidoscope exploration well	2001/182	Not Controlled Action	Completed
Marine Seismic Survey in WA-239-P	2000/24	Not Controlled Action	Completed
Marine Survey for the Australia-ASEAN Power Link AAPL	2020/8714	Not Controlled Action	Completed
Montara-3 Offshore Hydrocarbon Exploration Well Permit Area AC/RL3	2001/489	Not Controlled Action	Completed
P30 Hydrocarbon Exploration Well	2001/293	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Puffin Oil wells 7, 8 & 9 development	2005/2336	Not Controlled Action	Completed
Saucepan 1 Exploration Well ACP23	2000/2	Not Controlled Action	Completed
Skua and Swift Oilfields	2006/3195	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Strumbo-1 Gas Exploration Well Permit Area WA-288-P	2002/884	Not Controlled Action	Completed
Not controlled action (particular manner)			
2 (3D) Marine Seismic Surveys	2009/4994	Not Controlled Action (Particular Manner)	Completed
2D and 3D Seismic Survey	2011/6197	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2008/4133	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D Seismic Survey WA-405-P	2009/5104	Not Controlled Action (Particular Manner)	Post-Approval
2D Marine Seismic Survey	2009/4728	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey of Braveheart,Kurrajong,Sunshine and Crocodile	2006/2917	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Marine Survey	2001/363	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic survey	2009/5076	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey in permit areas WA-274P and WA-281P	2004/1521	Not Controlled Action (Particular Manner)	Post-Approval
2 geotechnical surveys - preliminary and final	2006/2886	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2008/4437	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
3D Marine Seismic Survey, Permit AC/P 23	2005/2364	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic Survey - Maxima 3D MSS	2006/2945	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, Browse Basin, WA	2009/5048	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, near Scott Reef, Browse Basin	2005/2126	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey of AC/P4, AC/P17 and AC/P24	2006/2857	Not Controlled Action (Particular Manner)	Post-Approval
AC/P37 3D Seismic Survey Ashmore Cartier	2007/3774	Not Controlled Action (Particular Manner)	Post-Approval
Aurora MC3D Marine Seismic Survey	2010/5510	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Bassett 3D Marine Seismic Survey	2010/5538	Not Controlled Action (Particular Manner)	Post-Approval
Bonaparte 2D & 3D marine seismic survey	2011/5962	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Infill Marine Seismic Survey 100km offshore	2008/4442	Not Controlled Action (Particular Manner)	Post-Approval
Braveheart 2D Marine Seismic Survey	2005/2322	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Canis 3D Marine Seismic Survey	2008/4492	Not Controlled Action (Particular Manner)	Post-Approval
Cartier East and Cartier West 3D Marine Seismic Surveys	2009/5230	Not Controlled Action (Particular Manner)	Post-Approval
Caswell MC3D Marine Seismic Survey	2012/6594	Not Controlled Action (Particular Manner)	Post-Approval
Conduct an exploration drilling campaign	2011/5964	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of Exploration & Appraisal Wells Braveheart-1 & Cornea-3	2009/5160	Not Controlled Action (Particular Manner)	Post-Approval
Drilling of two appraisal wells	2011/5840	Not Controlled Action (Particular Manner)	Post-Approval
Endurance 3D Marine Seismic Data Acquisition Survey	2007/3667	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Campaign	2011/6047	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling Campaign, Browse Basin, WA-341-P, AC-P36 and WA-343-P	2013/6898	Not Controlled Action (Particular Manner)	Post-Approval
Exploration Drilling in Permit Areas WA-402-P & WA-403-P	2010/5297	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Exploration Drilling Program - Permit areas - WA-314-P, WA-315-P, WA-398-P.	2008/4064	Not Controlled Action (Particular Manner)	Post-Approval
Geoscience Australia - Marine survey in Browse Basin to acquire data to assist assessment of CO2 sto	2013/6747	Not Controlled Action (Particular Manner)	Post-Approval
Gicea 3D Marine Seismic Survey	2008/4389	Not Controlled Action (Particular Manner)	Post-Approval
Gigas 2D Pilot Ocean Bottom Cable Marine Seismic Survey	2007/3839	Not Controlled Action (Particular Manner)	Post-Approval
Gold 2D Marine Seismic Survey Permit Areas WA375P and WA376P	2009/4698	Not Controlled Action (Particular Manner)	Post-Approval
Ichthys 3D Marine Seismic Survey	2010/5550	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval
Kraken, Lusca & Asperus 3D Marine Seismic Survey	2013/6730	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Mariner Non-Exclusive 2D Seismic Survey	2011/6172	Not Controlled Action (Particular Manner)	Post-Approval
Octantis 3D Marine Seismic Survey, Permit Area AC/P41 off northern Western Australia	2007/3369	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Offshore Exploration Drilling Campaign	2011/6222	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Gas Exploration Drilling Campaign	2012/6384	Not Controlled Action (Particular Manner)	Post-Approval
Petrel MC2D Marine Seismic Survey	2010/5368	Not Controlled Action (Particular Manner)	Post-Approval
Pilot Appraisal Well - Torosa South 1	2008/3991	Not Controlled Action (Particular Manner)	Post-Approval
Rosebud 3D Marine Seismic Survey in WA-30-R and TR/5	2012/6493	Not Controlled Action (Particular Manner)	Post-Approval
Sandalford 3D Seismic Survey	2012/6261	Not Controlled Action (Particular Manner)	Post-Approval
Schild MC3D Marine Seismic Survey	2012/6373	Not Controlled Action (Particular Manner)	Post-Approval
Schild Phase 11 MC3D Marine Seismic Survey, Browse Basin	2013/6894	Not Controlled Action (Particular Manner)	Post-Approval
Scott Reef Seismic Research	2006/2647	Not Controlled Action (Particular Manner)	Post-Approval
Searcher bathymetry & geochemical seismic survey, Brawse Basin,Timor Sea,WA	2013/6980	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Thoar 3D Marine Seismic Survey	2010/5668	Not Controlled Action (Particular Manner)	Post-Approval
Tiffany 3D Seismic Survey	2010/5339	Not Controlled Action (Particular Manner)	Post-Approval
Torosa-5 Apraisal Well, WA-30-R	2008/4430	Not Controlled Action (Particular Manner)	Post-Approval
Tow West Atlas wreck from present location to boundary of EEZ	2010/5652	Not Controlled Action (Particular Manner)	Post-Approval
Tridacna 3D Ocean Bottom Cable Marine Seismic Survey	2011/5959	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Veritas Voyager 2D Marine Seismic Survey	2009/5151	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Woodside Southern Browse 3D Seismic Survey, WA	2007/3534	Not Controlled Action (Particular Manner)	Post-Approval
Zeemeermin MC3D seismic survey, Browse Basin, Offshore WA	2009/5023	Not Controlled Action (Particular Manner)	Post-Approval
Zeppelin 3D Seismic Survey	2011/6148	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
2D Marine Seismic Survey	2008/4623	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Aurora extension MC3D Marine Seismic Survey	2011/5887	Referral Decision	Completed
BRSN08 3D Marine Seismic Survey	2008/4582	Referral Decision	Completed
Experimental Study of Behavioural and Physiological Impact on Fish of Seismic Ex	2006/2625	Referral Decision	Completed
Pilot Appraisal Well - Torosa South-1	2008/3985	Referral Decision	Completed
Puffin South-West Development of Oil Reserves	2007/3834	Referral Decision	Completed
Seismic Data Acquisition, Browse Basin	2010/5475	Referral Decision	Completed

Key Ecological Features

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	North-west
Canyons linking the Argo Abyssal Plain with the Scott Plateau	North-west
Carbonate bank and terrace system of the Sahul Shelf	North-west
Continental Slope Demersal Fish Communities	North-west
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur

Scientific Name	Behaviour	Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Resting	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Significant habitat - unknown behaviour	Likely to occur
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging (high density	Known to occur

Scientific Name	Behaviour	Presence
	seagrass beds)	
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Likely to occur
Chelonia mydas Green Turtle [1765]	Mating	Likely to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Likely to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Likely to occur

Scientific Name	Behaviour	Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Lepidochelys olivacea Olive Ridley Turtle [1767]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Calving	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Nursing	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 3

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	50
Listed Migratory Species:	83

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	47
Commonwealth Heritage Places:	2
Listed Marine Species:	132
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	10
Habitat Critical to the Survival of Marine Turtles:	3

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	32
Regional Forest Agreements:	None
Nationally Important Wetlands:	5
EPBC Act Referrals:	61
Key Ecological Features (Marine):	4
Biologically Important Areas:	57
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places [Resource Information]

Name	State	Legal Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Roebuck bay	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pezoporus occidentalis		
Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus		
Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae		
Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Tyto novaehollandiae kimberli		
Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Conilurus penicillatus		
Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus		
Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Petrogale concinna monastria Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Trichosurus vulpecula arnhemensis Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
PLANT		
Seringia exastia Fringed Fire-bush [88920]	Critically Endangered	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Liopholis kintorei Great Desert Skink, Tjakura, Warrarna, Mulyamiji [83160]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Breeding likely to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat may occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - BROOME TRAINING DEPOT [50141]	WA
Defence - YAMPI SOUND TRAINING AREA [50145]	WA
Unknown	
Commonwealth Land - [51809]	WA
Commonwealth Land - [51813]	WA
Commonwealth Land - [51812]	WA
Commonwealth Land - [51814]	WA
Commonwealth Land - [51817]	WA
Commonwealth Land - [51074]	WA
Commonwealth Land - [51078]	WA
Commonwealth Land - [51079]	WA
Commonwealth Land - [51082]	WA
Commonwealth Land - [51088]	WA
Commonwealth Land - [51080]	WA
Commonwealth Land - [51083]	WA
Commonwealth Land - [51081]	WA
Commonwealth Land - [51815]	WA
Commonwealth Land - [51067]	WA
Commonwealth Land - [51075]	WA
Commonwealth Land - [51824]	WA
Commonwealth Land - [51069]	WA
Commonwealth Land - [51431]	WA
Commonwealth Land - [51068]	WA

Commonwealth Land Name	State
Commonwealth Land - [51806]	WA
Commonwealth Land - [51807]	WA
Commonwealth Land - [51808]	WA
Commonwealth Land - [51803]	WA
Commonwealth Land - [51966]	WA
Commonwealth Land - [51825]	WA
Commonwealth Land - [51819]	WA
Commonwealth Land - [51820]	WA
Commonwealth Land - [51826]	WA
Commonwealth Land - [51822]	WA
Commonwealth Land - [51823]	WA
Commonwealth Land - [51821]	WA
Commonwealth Land - [51072]	WA
Commonwealth Land - [51810]	WA
Commonwealth Land - [51811]	WA
Commonwealth Land - [51071]	WA
Commonwealth Land - [51073]	WA
Commonwealth Land - [51804]	WA
Commonwealth Land - [51816]	WA
Commonwealth Land - [51818]	WA
Commonwealth Land - [51070]	WA
Commonwealth Land - [51077]	WA
Commonwealth Land - [51076]	WA
Commonwealth Land - [51965]	WA
Commonwealth Land - [51805]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		

Name	State	Status
Mermaid Reef - Rowley Shoals	WA	Listed place
Yampi Defence Area	WA	Listed place

Listed Marine Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat may occur within area overfly marine area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Breeding known to occur within area
Sternula nereis as Sterna nereis		
Fairy Tern [82949]		Breeding known to occur within area
Stiltia isabella		
Australian Pratincole [818]		Species or species habitat known to occur within area overfly marine area
Sula dactylatra		
Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster		
Brown Booby [1022]		Breeding known to occur within area
Sula sula		
Red-footed Booby [1023]		Breeding known to occur within area
Thalasseus bengalensis as Sterna bengalensis		
Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii		
Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes as Heteroscelus brevipes		
Grey-tailed Tattler [851]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus laevis		
Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis		
Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii		
Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia ornata as Hydrophis ornatus		
Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Crocodylus johnstoni		
Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii		
Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major		
Olive-headed Seasnake [1124]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma czeblukovi as Hydrophis czeblukovi Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Pelamis platurus		
Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis		
Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata		
Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus		
Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus		
Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus		
Longman's Beaked Whale [72]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Breeding known to occur within area

Current Scientific Name	Status	Type of Presence
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Kimberley	Habitat Protection Zone (IUCN IV)
Kimberley	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)

Park Name	Zone & IUCN Categories
Roebuck	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Kimberley	National Park Zone (IUCN II)
Mermaid Reef	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles		
Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
May - Jul		
Lepidochelys olivacea Olive Ridley Turtle [1767]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Adele Island	Nature Reserve	WA
Bardi Jawi	Indigenous Protected Area	WA
Broome Bird Observatory	5(1)(h) Reserve	WA
Broome Wildlife Centre	5(1)(h) Reserve	WA
Coulomb Point	Nature Reserve	WA
Dambimangari	Indigenous Protected Area	WA
Karajarri	Indigenous Protected Area	WA
Lacepede Islands	Nature Reserve	WA
Lalang-garram / Camden Sound	Marine Park	WA

Protected Area Name	Reserve Type	State
Lalang-garram / Horizontal Falls	Marine Park	WA
North Kimberley	Marine Park	WA
North Lalang-garram	Marine Park	WA
Prince Regent	National Park	WA
Rowley Shoals	Marine Park	WA
Swan Island	Nature Reserve	WA
Tanner Island	Nature Reserve	WA
Unnamed WA28968	5(1)(h) Reserve	WA
Unnamed WA37168	5(1)(h) Reserve	WA
Unnamed WA44669	5(1)(h) Reserve	WA
Unnamed WA44673	5(1)(h) Reserve	WA
Unnamed WA51046	5(1)(h) Reserve	WA
Unnamed WA51105	5(1)(h) Reserve	WA
Unnamed WA51162	5(1)(h) Reserve	WA
Unnamed WA51497	5(1)(h) Reserve	WA
Unnamed WA51583	5(1)(h) Reserve	WA
Unnamed WA51617	5(1)(h) Reserve	WA
Unnamed WA51932	5(1)(h) Reserve	WA
Unnamed WA52354	5(1)(h) Reserve	WA
Uunguu	Indigenous Protected Area	WA
Yawuru	Indigenous Protected Area	WA
Yawuru	Indigenous Protected Area	WA
Yawuru Nagulagun / Roebuck Bay	Marine Park	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Bunda-Bunda Mound Springs	WA

Wetland Name	State
Mermaid Reef	EXT
Roebuck Bay	WA
Willie Creek Wetlands	WA
Yampi Sound Training Area	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Koolan Island Operations	2022/09392		Referral Decision
Ocean Barramundi Expansion Project	2022/09272		Assessment
Controlled action			
2-D seismic survey Scott Reef	2000/125	Controlled Action	Post-Approval
Broome Boating Facility	2021/9098	Controlled Action	Referral Decision
Broome International Airport Relocation Project	2000/74	Controlled Action	Post-Approval
Cape Leveque Road upgrade, Stage 3, Shire of Broome, WA	2013/6984	Controlled Action	Post-Approval
Cockatoo Island Multi-User Supply Base, WA	2017/7986	Controlled Action	Referral Decision
Derby Tidal Power Project	2010/5544	Controlled Action	Final PER Or EIS
Develop Ichthys gas-condensate field permit area W	2006/2767	Controlled Action	Completed
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Great Northern Pipeline - 630 km buried gas pipeline	2009/5257	Controlled Action	Completed
Iron ore mine	2006/2522	Controlled Action	Post-Approval
Pluton Irvine Island Iron Ore Project	2011/6064	Controlled Action	Proposed Decision
Shamrock Station Irrigation Project, west Kimberley region, WA	2017/8004	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Not controlled action			
Aquaculture - Barramundi grow out, Yampi Sound	2005/2476	Not Controlled Action	Completed
Broome Borefield Bushfire Mitigation Program	2020/8680	Not Controlled Action	Completed
Broome Motorplex Relocation Project, Lot 591 Broome Road	2017/8117	Not Controlled Action	Completed
Broome Road Industrial Estate	2020/8811	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Drilling of exploration wells, Permit areas WA-301-P to WA-305-P	2002/769	Not Controlled Action	Completed
Establish a 4m wide trace line along the road allignment for James Price Point	2010/5682	Not Controlled Action	Completed
Kimberley Marine Offloading Facility	2020/8736	Not Controlled Action	Completed
Koolan Island Mine - Reconstruction of seawall and capital dewatering of mine pit,130km northwest of	2016/7848	Not Controlled Action	Completed
Manaslu - 1 and Huascaran - 1 Offshore Exploration Wells	2001/235	Not Controlled Action	Completed
Marine Seismic Survey in WA-239-P	2000/24	Not Controlled Action	Completed
Native Orchard Development, 10km northeast of Broome WA	2019/8501	Not Controlled Action	Completed
Port of Broome Channel Optimisation Project, West Roebuck Bay, WA	2018/8162	Not Controlled Action	Completed
Power Station Upgrade	2001/357	Not Controlled Action	Completed
Power Station Upgrade (South Port Site)	2001/414	Not Controlled Action	Completed
WA-295-P Kerr-McGee Exploration Wells	2001/152	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Wastewater Treatment Plant	2008/4545	Not Controlled Action	Completed
Not controlled action (particular manner)			
3D Marine Seismic Survey (WA-482-P, WA-363-P), WA	2013/6761	Not Controlled Action (Particular Manner)	Post-Approval
Acacia East Pit Cutback Mining Project,northern Kimberley, WA	2013/6752	Not Controlled Action (Particular Manner)	Post-Approval
Aurora MC3D Marine Seismic Survey	2010/5510	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Construction of a 43km long sealed access road to the Browse LNG precinct	2011/5852	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Effect of marine seismic sounds to demersal fish and pearl oysters, north-west WA	2018/8169	Not Controlled Action (Particular Manner)	Post-Approval
Establishment of AQIS washdown facility, logistics support base and ancillary businesses	2012/6364	Not Controlled Action (Particular Manner)	Post-Approval
Geoscience Australia - Marine survey in Browse Basin to acquire data to assist assessment of CO2 sto	2013/6747	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Kingtree & Ironstone-1 Exploration Wells	2011/5935	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Koolama 2D Seismic Survey Dampier Basin	2010/5420	Not Controlled Action (Particular Manner)	Post-Approval
Mariner Non-Exclusive 2D Seismic Survey	2011/6172	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Outer Canning exploration drilling program off NW coast of WA	2012/6618	Not Controlled Action (Particular Manner)	Post-Approval
Repsol 3d & 2D Marine Seismic Survey	2012/6658	Not Controlled Action (Particular Manner)	Post-Approval
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Vampire 2D Non Exclusive Seismic Survey, WA	2010/5543	Not Controlled Action (Particular Manner)	Post-Approval
Veritas Voyager 2D Marine Seismic Survey	2009/5151	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Woodside Southern Browse 3D Seismic Survey, WA	2007/3534	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Zeemeermin MC3D seismic survey, Browse Basin, Offshore WA	2009/5023	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Seismic Survey	2008/4219	Referral Decision	Completed
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed
Seismic Data Acquisition, Browse Basin	2010/5475	Referral Decision	Completed
Tidal Power Generation Turbine	2009/5235	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dolphins		
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Breeding	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Calving	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging (high density prey)	Known to occur

Scientific Name	Behaviour	Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Foraging likely	Known to occur
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Resting	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Breeding	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Calving	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging	Likely to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Known to occur
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Foraging (high density prey)	Likely to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Breeding	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Calving	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Foraging likely	Known to occur
Tursiops aduncus Indo-Pacific/Spotted Bottlenose Dolphin [68418]	Migration likely	Known to occur
Dugong		

Scientific Name	Behaviour	Presence
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging	Likely to occur
Dugong dugon Dugong [28]	Migration likely	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
River shark		
Pristis clavata Dwarf Sawfish [68447]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Pristis clavata Dwarf Sawfish [68447]	Juvenile	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Nursing	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Pupping	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Foraging	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Juvenile	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Nursing	Likely to occur
Pristis pristis Freshwater Sawfish [60756]	Pupping	Known to occur
Pristis zijsron Green Sawfish [68442]	Foraging	Known to occur
Pristis zijsron Green Sawfish [68442]	Pupping	Known to occur
Seabirds		
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Fregata minor Greater Frigatebird [1013]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Sula sula Red-footed Booby [1023]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Calving	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Nursing	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

AREA 4

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	3
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	59
Listed Migratory Species:	86

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	110
Commonwealth Heritage Places:	2
Listed Marine Species:	132
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	12
Habitat Critical to the Survival of Marine Turtles:	4

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	58
Regional Forest Agreements:	None
Nationally Important Wetlands:	7
EPBC Act Referrals:	298
Key Ecological Features (Marine):	6
Biologically Important Areas:	55
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
The Ningaloo Coast	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Natural		
The Ningaloo Coast	WA	Listed place
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Eighty-mile beach	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Polytelis alexandrae		
Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Pterodroma mollis		
Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
CRUSTACEAN		
Kumonga exleyi		
Cape Range Remipede [86875]	Vulnerable	Species or species habitat known to occur within area
FISH		
Milyeringa veritas		
Cape Range Cave Gudgeon, Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum		
Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Petrogale lateralis lateralis		
Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Saccolaimus saccolaimus nudicluniatus		
Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat may occur within area
Trichosurus vulpecula arnhemensis		
Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat may occur within area
PLANT		
Minuria tridens		
Minnie Daisy [13753]	Vulnerable	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus		
Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lerista nevinae Nevin's Slider [85296]	Endangered	Species or species habitat known to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Liopholis kintorei Great Desert Skink, Tjakura, Warrarna, Mulyamiji [83160]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species		[Resource Information]
Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Migratory Terrestrial Species		
Cuculus optatus		
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundo rustica		
Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba		
Sanderling [875]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis		
Red-necked Stint [860]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50126]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50124]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50125]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50128]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50127]	WA
Defence - EXMOUTH ADMIN & HF TRANSMITTING [50129]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH RADAR SITE - TWIN TANKS EXMOUTH [50002]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Unknown	
Commonwealth Land - [51719]	WA
Commonwealth Land - [51720]	WA
Commonwealth Land - [51462]	WA
Commonwealth Land - [50325]	WA
Commonwealth Land - [51460]	WA

Commonwealth Land Name	State
Commonwealth Land - [51461]	WA
Commonwealth Land - [50349]	WA
Commonwealth Land - [51463]	WA
Commonwealth Land - [51884]	WA
Commonwealth Land - [51939]	WA
Commonwealth Land - [50975]	WA
Commonwealth Land - [51669]	WA
Commonwealth Land - [50974]	WA
Commonwealth Land - [51677]	WA
Commonwealth Land - [52245]	WA
Commonwealth Land - [51469]	WA
Commonwealth Land - [52236]	WA
Commonwealth Land - [51055]	WA
Commonwealth Land - [51054]	WA
Commonwealth Land - [50989]	WA
Commonwealth Land - [51053]	WA
Commonwealth Land - [51702]	WA
Commonwealth Land - [51671]	WA
Commonwealth Land - [51464]	WA
Commonwealth Land - [51466]	WA
Commonwealth Land - [51467]	WA
Commonwealth Land - [51472]	WA
Commonwealth Land - [51470]	WA
Commonwealth Land - [52131]	WA
Commonwealth Land - [51468]	WA
Commonwealth Land - [51715]	WA
Commonwealth Land - [51477]	WA

Commonwealth Land Name	State
Commonwealth Land - [51456]	WA
Commonwealth Land - [51703]	WA
Commonwealth Land - [50977]	WA
Commonwealth Land - [50978]	WA
Commonwealth Land - [51455]	WA
Commonwealth Land - [50976]	WA
Commonwealth Land - [51450]	WA
Commonwealth Land - [51451]	WA
Commonwealth Land - [51452]	WA
Commonwealth Land - [51453]	WA
Commonwealth Land - [51459]	WA
Commonwealth Land - [51717]	WA
Commonwealth Land - [51714]	WA
Commonwealth Land - [51711]	WA
Commonwealth Land - [51716]	WA
Commonwealth Land - [51710]	WA
Commonwealth Land - [52205]	WA
Commonwealth Land - [51708]	WA
Commonwealth Land - [51691]	WA
Commonwealth Land - [51404]	WA
Commonwealth Land - [51403]	WA
Commonwealth Land - [51713]	WA
Commonwealth Land - [51718]	WA
Commonwealth Land - [51668]	WA
Commonwealth Land - [51887]	WA
Commonwealth Land - [51667]	WA
Commonwealth Land - [51666]	WA

Commonwealth Land Name	State
Commonwealth Land - [51104]	WA
Commonwealth Land - [52220]	WA
Commonwealth Land - [51457]	WA
Commonwealth Land - [50324]	WA
Commonwealth Land - [51947]	WA
Commonwealth Land - [51696]	WA
Commonwealth Land - [51458]	WA
Commonwealth Land - [51692]	WA
Commonwealth Land - [50990]	WA
Commonwealth Land - [50326]	WA
Commonwealth Land - [51476]	WA
Commonwealth Land - [51473]	WA
Commonwealth Land - [51474]	WA
Commonwealth Land - [51465]	WA
Commonwealth Land - [51471]	WA
Commonwealth Land - [51454]	WA
Commonwealth Land - [51686]	WA
Commonwealth Land - [51444]	WA
Commonwealth Land - [51447]	WA
Commonwealth Land - [51449]	WA
Commonwealth Land - [51707]	WA
Commonwealth Land - [51704]	WA
Commonwealth Land - [51448]	WA
Commonwealth Land - [51695]	WA
Commonwealth Land - [51693]	WA
Commonwealth Land - [51699]	WA
Commonwealth Land - [51698]	WA

Commonwealth Land Name	State
Commonwealth Land - [51442]	WA
Commonwealth Land - [51443]	WA
Commonwealth Land - [51446]	WA
Commonwealth Land - [51670]	WA
Commonwealth Land - [51475]	WA
Commonwealth Land - [51709]	WA
Commonwealth Land - [51672]	WA
Commonwealth Land - [51706]	WA
Commonwealth Land - [50385]	WA
Commonwealth Land - [51445]	WA
Commonwealth Land - [51705]	WA
Commonwealth Land - [51700]	WA
Commonwealth Land - [51712]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area overfly marine area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Breeding known to occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area

Fish

Scientific Name	Threatened Category	Presence Text
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptile		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli Small-headed Seasnake [75601]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lapemis curtus as Lapemis hardwickii Spine-bellied Seasnake [83554]		Species or species habitat may occur within area
Leioselasma czeblukovi as Hydrophis czeblukovi Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Current Scientific Name	Status	Type of Presence
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Dampier	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Ningaloo	Recreational Use Zone (IUCN IV)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus		
Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas		
Green Turtle [1765]	Nesting	Known to occur
Nov-Feb		
Caretta caretta		
Loggerhead Turtle [1763]	Nesting	Known to occur
Nov - May		
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Airlie Island	Nature Reserve	WA
Barrow Island	Nature Reserve	WA
Barrow Island	Marine Management Area	WA
Barrow Island	Marine Park	WA
Bedout Island	Nature Reserve	WA
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Burnside And Simpson Island	Nature Reserve	WA
Cape Range	National Park	WA
Eighty Mile Beach	Marine Park	WA
Gnandaroo Island	Nature Reserve	WA
Great Sandy Island	Nature Reserve	WA
Jarrkunpungu	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Jinmarnkur	Conservation Park	WA
Jinmarnkur Kulja	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) Reserve	WA
Karajarri	Indigenous Protected Area	WA
Kujungurru Warrarn	Conservation Park	WA
Kujungurru Warrarn	Nature Reserve	WA
Little Rocky Island	Nature Reserve	WA
Locker Island	Nature Reserve	WA
Lowendal Islands	Nature Reserve	WA
Montebello Islands	Conservation Park	WA
Montebello Islands	Marine Park	WA
Montebello Islands	Conservation Park	WA
Muiron Islands	Nature Reserve	WA
Muiron Islands	Marine Management Area	WA
Murujuga	National Park	WA
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
North Turtle Island	Nature Reserve	WA
Nyangumarta Warrarn	Indigenous Protected Area	WA
Nyangumarta Warrarn	Indigenous Protected Area	WA
Rocky Island	Nature Reserve	WA
Round Island	Nature Reserve	WA
Serrurier Island	Nature Reserve	WA
Tent Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Unnamed WA36907	5(1)(h) Reserve	WA
Unnamed WA36909	5(1)(h) Reserve	WA
Unnamed WA36910	5(1)(h) Reserve	WA
Unnamed WA36913	Nature Reserve	WA
Unnamed WA36915	Nature Reserve	WA
Unnamed WA37500	5(1)(g) Reserve	WA
Unnamed WA40322	5(1)(h) Reserve	WA
Unnamed WA40828	5(1)(h) Reserve	WA
Unnamed WA40877	5(1)(h) Reserve	WA
Unnamed WA41080	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Unnamed WA44672	5(1)(h) Reserve	WA
Unnamed WA52366	Nature Reserve	WA
Unnamed WA53015	Nature Reserve	WA
Victor Island	Nature Reserve	WA
Weld Island	Nature Reserve	WA
Whalebone Island	Nature Reserve	WA
Y Island	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
De Grey River	WA
Eighty Mile Beach System	WA
Exmouth Gulf East	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA

Wetland Name	State
Leslie (Port Hedland) Saltfields System	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Ashburton Infrastructure Project	2021/9064		Post-Approval
Balla Balla Export Facilities ? Design Variation	2022/09254		Assessment
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
North West Shelf Project Extension, Carnarvon Basin, WA	2018/8335		Approval
Optimised Mardie Solar Salt Project	2022/9169		Assessment
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Asian Renewable Energy Hub Revised Proposal, WA	2021/8891	Action Clearly Unacceptable	Completed
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	Controlled Action	Post-Approval
Additional Rail Infrastructure between Herb Elliott Port Facility and Cloudbreak Mine Site	2010/5513	Controlled Action	Post-Approval
Ammonium Nitrate Project	2010/5423	Controlled Action	Completed
Anketell Point Iron Ore Processing & Export Port	2009/5120	Controlled Action	Post-Approval
Asian Renewable Energy Hub, 220 km east of Port Hedland, Western Australia	2017/8112	Controlled Action	Post-Approval
Balmoral South Iron Ore Mine	2008/4236	Controlled Action	Post-Approval
Binowee Iron Ore Project	2001/366	Controlled Action	Proposed Decision
Boating Facility	2002/830	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Burrup North East Sand Mining Project	2008/4611	Controlled Action	Completed
Cape Lambert Port B Development	2008/4032	Controlled Action	Post-Approval
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Construction and operation of a Solar Salt Project, SW Onslow, WA	2016/7793	Controlled Action	Assessment Approach
Develop Jansz-Io deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Development of Angel gas and condensate field, North West Shelf	2004/1805	Controlled Action	Post-Approval
Development of an iron ore mine and associated infrastructure	2010/5630	Controlled Action	Assessment Approach
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Development of Coniston/Novara fields within the Exmouth Sub-basin	2011/5995	Controlled Action	Post-Approval
Development of Stybarrow petroleum field incl drilling and facility installation	2004/1469	Controlled Action	Post-Approval
Duplication of the Dampier Highway Stages 2 & 6	2010/5419	Controlled Action	Post-Approval
Echo-Yodel Production Wells	2000/11	Controlled Action	Post-Approval
Enfield full field development	2001/257	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Eramurra Industrial Salt Project	2021/9027	Controlled Action	Assessment Approach
Eramurra Industrial Salt Project, near Karratha, WA	2019/8448	Controlled Action	Completed
Gorgon Gas Development	2003/1294	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval
Gorgon Gas Revised Development	2008/4178	Controlled Action	Post-Approval
Greater Enfield (Vincent) Development	2005/2110	Controlled Action	Post-Approval
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	Controlled Action	Completed
Great Northern Pipeline - 630 km buried gas pipeline	2009/5257	Controlled Action	Completed
Light Crude Oil Production	2001/365	Controlled Action	Post-Approval
Mardie Project, 80 km south west of Karratha, WA	2018/8236	Controlled Action	Post-Approval
Mauds Landing Marina	2000/98	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693	Controlled Action	Assessment Approach
North Star Magnetite Project	2012/6689	Controlled Action	Post-Approval
North West Shelf Gas Venture Phase VI Expansion	2007/3436	Controlled Action	Referral Decision
Perdaman Urea Project, near Karratha, WA	2018/8383	Controlled Action	Post-Approval
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Port Hedland Outer Harbour Development and associated marine and terrestrial in	2008/4159	Controlled Action	Post-Approval
Port Hedland Spoilbank Marina, WA	2019/8520	Controlled Action	Post-Approval
Proposed technical ammonium nitrate production facility	2008/4546	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Proposed West Pilbara Iron Ore Project	2009/4706	Controlled Action	Post-Approval
Pyrenees Oil Fields Development	2005/2034	Controlled Action	Post-Approval
Simpson Development	2000/59	Controlled Action	Completed
Simpson Oil Field Development	2001/227	Controlled Action	Post-Approval
Single Jetty Deep Water Port Renewable Hub, WA	2021/8942	Controlled Action	Proposed Decision
site preparations	2005/2391	Controlled Action	Post-Approval
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
Widening and resurfacing two principal roads servicing the Dampier Port Authori	2010/5677	Controlled Action	Completed
Yardie Creek Road Realignment Project	2021/8967	Controlled Action	Assessment Approach
Not controlled action			
'Goodwyn A' Low Pressure Train Project	2003/914	Not Controlled Action	Completed
'Van Gogh' Oil Appraisal Drilling Program, Exploration Permit Area WA-155-P(1)	2006/3148	Not Controlled Action	Completed
Airlie Island soil and groundwater investigations, Exmouth Gulf, offshore Pilbara coast	2014/7250	Not Controlled Action	Completed
Ammonia Plant	2001/199	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed
Barrow Island 2D Seismic survey	2006/2667	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Boating Facility	2002/832	Not Controlled Action	Completed
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Bulgarene Borefield	2006/2507	Not Controlled Action	Completed
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	Not Controlled Action	Completed
Cape Lambert Port A Marine Structures Refurbishment Project	2018/8370	Not Controlled Action	Completed
Carnarvon 3D Marine Seismic Survey	2004/1890	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Construct 110km buried natural gas pipeline from Onslow, connecting to Dampier/Bunbury natural gas p	2013/7039	Not Controlled Action	Completed
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Construction of a Commodities Berth, Wharf and Associated Infrastructure	2008/4129	Not Controlled Action	Completed
Construction of Loadout Facility and Laydown Area	2002/598	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Deep Gorge Boardwalk, Murujuga National Park, WA	2018/8283	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Development of Industrial Land, Port of Dampier	2003/1293	Not Controlled Action	Completed
Development of iron ore facilities	2013/7013	Not Controlled Action	Completed
Development of iron ore resources in eastern Pilbara region, including port at P	2004/1562	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033	Not Controlled Action	Completed
Differential Global Positioning System (DGPS)	2001/445	Not Controlled Action	Completed
Dimethyl ether plant	2001/509	Not Controlled Action	Completed
Drilling of an exploration well Gats-1 in Permit Area WA-261-P	2004/1701	Not Controlled Action	Completed
Eagle-1 Exploration Drilling, North West Shelf, WA	2019/8578	Not Controlled Action	Completed
Echo A Development WA-23-L, WA-24-L	2005/2042	Not Controlled Action	Completed
Expansion of the Sino Iron Ore Mine and export facilities, Cape Preston, WA	2017/7862	Not Controlled Action	Completed
Expansion Proposal, Mineralogy Cape Preston Iron Ore Project, Cape Preston, WA	2009/5010	Not Controlled Action	Completed
Exploration drilling well WA-155-P(1)	2003/971	Not Controlled Action	Completed
Exploration of appraisal wells	2006/3065	Not Controlled Action	Completed
Exploration Well (Taunton-2)	2002/731	Not Controlled Action	Completed
Exploration Well in Permit Area WA-155-P(1)	2002/759	Not Controlled Action	Completed
Exploratory drilling in permit area WA-225-P	2001/490	Not Controlled Action	Completed
Extension of Simpson Oil Platforms & Wells	2002/685	Not Controlled Action	Completed
Gulf Fishing Lodge	2010/5499	Not Controlled Action	Completed
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
Horizon Power South Hedland Transmission Line, WA	2012/6551	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Huascaran-1 exploration well (WA-292-P)	2001/539	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Infill Production Well (Griffin-9)	2001/417	Not Controlled Action	Completed
Iron Bridge Port Facility, Port Hedland, WA	2015/7565	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
King Bay East Rock Quarry & Industrial Estate Development	2003/1150	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	Not Controlled Action	Completed
Mahimahi Aquaculture Facility	2002/891	Not Controlled Action	Completed
Maia-Gaea Exploration wells	2000/17	Not Controlled Action	Completed
Manaslu - 1 and Huascaran - 1 Offshore Exploration Wells	2001/235	Not Controlled Action	Completed
Mermaid Marine Australia Desalination Project	2011/5916	Not Controlled Action	Completed
Methanol manufacturing	2001/528	Not Controlled Action	Completed
Methanol plant	2001/521	Not Controlled Action	Completed
Montesa-1 and Bultaco-1 Exploration Wells	2000/102	Not Controlled Action	Completed
Murujuga archaeological excavation, collection and sampling, Dampier Archipelago, WA	2014/7160	Not Controlled Action	Completed
North Rankin B gas compression facility	2005/2500	Not Controlled Action	Completed
Onslow Power Infrastructure Upgrade Project, Onslow, WA	2014/7314	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Onslow Water Supply Infrastructure Upgrade Project, Onslow, WA	2014/7329	Not Controlled Action	Completed
Pilbara Bulk Ore Transport System Project, WA	2016/7637	Not Controlled Action	Completed
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Pluto-North West Shelf Interconnector, Burrup Peninsula, WA	2018/8353	Not Controlled Action	Completed
Port Expansion and Dredging	2003/1265	Not Controlled Action	Completed
Port Hedland Channel Risk and Optimisation Project, WA	2017/7915	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Rail and Port Facilities	2001/474	Not Controlled Action	Completed
Searipple gas and condensate field development	2000/89	Not Controlled Action	Completed
Spool Base Facility	2001/263	Not Controlled Action	Completed
Stages 1 & 2 Port of Dampier Security Upgrade & Associated Works	2004/1751	Not Controlled Action	Completed
Subsea Gas Pipeline From Stybarrow Field to Griffin Venture Gas Export Pipeline	2005/2033	Not Controlled Action	Completed
sub-sea tieback of Perseus field wells	2004/1326	Not Controlled Action	Completed
Telfer Gold Mine Project - Mine and Borefield Extensions and Upgrade of Storage	2002/787	Not Controlled Action	Completed
Telfer Gold Mine Project - Power Supply and Infrastructure Corridor	2002/786	Not Controlled Action	Completed
Telstra North Rankin Spur Fibre Optic Cable	2016/7836	Not Controlled Action	Completed
Thevenard Island Retirement Project	2015/7423	Not Controlled Action	Completed
To construct and operate an offshore submarine fibre optic	2014/7373	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
cable, WA			
WA-295-P Kerr-McGee Exploration Wells	2001/152	Not Controlled Action	Completed
Walkway Lighting Upgrade	2009/4965	Not Controlled Action	Completed
Wanda Offshore Research Project, 80 km north-east of Exmouth, WA	2018/8293	Not Controlled Action	Completed
Western Flank Gas Development	2005/2464	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Widening of MOF Road	2005/2305	Not Controlled Action	Completed
Woodside Project Facilities Increase	2006/3191	Not Controlled Action	Completed
Not controlled action (particular manner)			
'Kate' 3D marine seismic survey, exploration permits WA-320-P and WA-345-P, 60km	2005/2037	Not Controlled Action (Particular Manner)	Post-Approval
'Tourmaline' 2D marine seismic survey, permit areas WA-323-P, WA-330-P and WA-32	2005/2282	Not Controlled Action (Particular Manner)	Post-Approval
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D seismic surveys	2005/2151	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey	2012/6296	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey	2005/2146	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
2D Seismic Survey Permit Area WA-352-P	2008/4628	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey	2008/4281	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey (WA-482-P, WA-363-P), WA	2013/6761	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in WA 457-P & WA 458-P, North West Shelf, offshore WA	2013/6862	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Surveys - Contos CT-13 & Supertubes CT-13, offshore WA	2013/6901	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey	2006/2715	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey, WA	2008/4428	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778	Not Controlled Action (Particular Manner)	Post-Approval
3D sesmic survey	2006/2781	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Additional Rail Infrastructure	2012/6314	Not Controlled Action (Particular Manner)	Post-Approval
Agrippina 3D Seismic Marine Survey	2009/5212	Not Controlled Action (Particular Manner)	Post-Approval
Algae Farm and Processing Facilities	2012/6596	Not Controlled Action (Particular Manner)	Post-Approval
Ammonia Plant, Murujuga Burrup Peninsula - Renewable Hydrogen Project	2020/8739	Not Controlled Action (Particular Manner)	Post-Approval
Apache Northwest Shelf Van Gogh Field Appraisal Drilling Program	2007/3495	Not Controlled Action (Particular Manner)	Post-Approval
Aperio 3D Marine Seismic Survey, WA	2012/6648	Not Controlled Action (Particular Manner)	Post-Approval
Artemis-1 Drilling Program (WA-360-P)	2010/5432	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular Manner)	Post-Approval
Bonaventure 3D seismic survey	2006/2514	Not Controlled Action (Particular Manner)	Post-Approval
Cable Seismic Exploration Permit areas WA-323-P and WA-330-P	2008/4227	Not Controlled Action (Particular Manner)	Post-Approval
Cape Preston East - Iron Ore Export Facilities, Pilbara, WA	2013/6844	Not Controlled Action (Particular Manner)	Post-Approval
Cerberus exploration drilling campaign, Carnarvon Basin, WA	2016/7645	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Charon 3D Marine Seismic Survey	2007/3477	Not Controlled Action (Particular Manner)	Post-Approval
Consturction & operation of the Varanus Island kitchen & mess cyclone refuge building, compression p	2013/6952	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
Cue Seismic Survey within WA-359-P, WA-361-P and WA-360-P	2007/3647	Not Controlled Action (Particular Manner)	Post-Approval
CVG 3D Marine Seismic Survey	2012/6654	Not Controlled Action (Particular Manner)	Post-Approval
Dampier Marine Services Facility including 300m Wharf and Dredging Works	2009/5108	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092	Not Controlled Action (Particular Manner)	Post-Approval
Decommissioning of the Legendre facilities	2010/5681	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Diesel Fuel Bunker Operation	2012/6289	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	Not Controlled Action (Particular Manner)	Post-Approval
Dredging of marine sediment to enable construction of eight berths and a turnin	2010/5678	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Earthworks for kitchen/mess, cyclone refuge building & Compression Plant, Varanus Island	2013/6900	Not Controlled Action (Particular Manner)	Post-Approval
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Effect of marine seismic sounds to demersal fish and pearl oysters, north-west WA	2018/8169	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M3 & Vincent 4D Marine Seismic Surveys	2008/3981	Not Controlled Action (Particular Manner)	Completed
Enfield M3 4D, Vincent 4D & 4D Line Test Marine Seismic Surveys	2008/4122	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M4 4D Marine Seismic Survey	2008/4558	Not Controlled Action (Particular Manner)	Post-Approval
Enfield oilfield 3D Seismic Survey	2006/3132	Not Controlled Action (Particular Manner)	Post-Approval
Exmouth West 2D Marine Seismic Survey	2008/4132	Not Controlled Action (Particular Manner)	Post-Approval
Exploration drilling of Zeus-1 well	2008/4351	Not Controlled Action (Particular Manner)	Post-Approval
Fletcher-Finucane Development, WA26-L and WA191-P	2011/6123	Not Controlled Action (Particular Manner)	Post-Approval
Foxhound 3D Non-Exclusive Marine Seismic Survey	2009/4703	Not Controlled Action (Particular Manner)	Post-Approval
Gazelle 3D Marine Seismic Survey in WA-399-P and WA-42-L	2010/5570	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
Glencoe 3D Marine Seismic Survey WA-390-P	2007/3684	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Greater Western Flank Phase 1 gas Development	2011/5980	Not Controlled Action (Particular Manner)	Post-Approval
Grimalkin 3D Seismic Survey	2008/4523	Not Controlled Action (Particular Manner)	Post-Approval
Guacamole 2D Marine Seismic Survey	2008/4381	Not Controlled Action (Particular Manner)	Post-Approval
Harmony 3D Marine Seismic Survey	2012/6699	Not Controlled Action (Particular Manner)	Post-Approval
Harpy 1 exploration well	2001/183	Not Controlled Action (Particular Manner)	Post-Approval
Honeycombs MC3D Marine Seismic Survey	2012/6368	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas phase 2 marine seismic survey, Exmouth Plateau, Northern Carnarvon Basin, WA	2013/7093	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2008/4630	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2009/4801	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular Manner)	Post-Approval
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Laverda 3D Marine Seismic Survey and Vincent M1 4D Marine Seismic Survey	2010/5415	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular Manner)	Post-Approval
Lion 2D Marine Seismic Survey	2007/3777	Not Controlled Action (Particular Manner)	Post-Approval
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval
Marine Geotechnical Drilling Program	2008/4012	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Millstream 20GL Pipeline, Bungaroo, Borefield Integration	2012/6379	Not Controlled Action (Particular Manner)	Post-Approval
MOF Road Widening and Resurfacing Works	2011/5843	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Moosehead 2D seismic survey within permit WA-192-P	2005/2167	Not Controlled Action (Particular Manner)	Post-Approval
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular Manner)	Post-Approval
Nelson Point Dredging	2009/4920	Not Controlled Action (Particular Manner)	Post-Approval
Nickol Bay Quarry Eastern Extension Proposal, Burrup Peninsula, WA	2013/6915	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Program, WA-264-P	2007/3844	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Survey	2005/2017	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Drilling Campaign	2011/5830	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Onslow Seawater Desalination Plant Marine Geophysical Investigation	2020/8794	Not Controlled Action (Particular Manner)	Post-Approval
Orcus 3D Marine Seismic Survey in WA-450-P	2010/5723	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Osprey and Dionysus Marine Seismic Survey	2011/6215	Not Controlled Action (Particular Manner)	Post-Approval
Palta-1 exploration well in Petroleum Permit Area WA-384-P	2011/5871	Not Controlled Action (Particular Manner)	Post-Approval
Phoenix 3D Seismic Survey, Bedout Sub-Basin	2010/5360	Not Controlled Action (Particular Manner)	Post-Approval
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	Not Controlled Action (Particular Manner)	Post-Approval
Port Headland Outer Harbour Pre-construction Pilling program	2012/6341	Not Controlled Action (Particular Manner)	Post-Approval
Port of Port Hedland channel marker replacement project, WA	2017/8010	Not Controlled Action (Particular Manner)	Post-Approval
Port Walcott upgrade, dredging & spoil disposal, & channel realignment	2006/2806	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees 4D Marine Seismic Monitor Survey, HCA12A	2012/6579	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees-Macedon 3D marine seismic survey	2005/2325	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
Realignment of the Great Northern Highway	2010/5793	Not Controlled Action (Particular Manner)	Post-Approval
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Rydal-1 Petroleum Exploration Well, WA	2012/6522	Not Controlled Action (Particular Manner)	Post-Approval
Salsa 3D Marine Seismic Survey	2010/5629	Not Controlled Action (Particular Manner)	Post-Approval
Santos Winchester three dimensional seismic survey - WA-323-P & WA-330-P	2011/6107	Not Controlled Action (Particular Manner)	Post-Approval
Scarborough Development nearshore component, NWS, WA	2018/8362	Not Controlled Action (Particular Manner)	Post-Approval
Skorpion Marine Seismic Survey WA	2001/416	Not Controlled Action (Particular Manner)	Post-Approval
Sovereign 3D Marine Seismic Survey	2011/5861	Not Controlled Action (Particular Manner)	Post-Approval
Stag 4D & Reindeer MAZ Marine Seismic Surveys, WA	2013/7080	Not Controlled Action (Particular Manner)	Post-Approval
Stag Off-bottom Cable Seismic Survey	2007/3696	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow 4D Marine Seismic Survey	2011/5810	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow Baseline 4D marine seismic survey	2008/4530	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Tantabiddi Boat Ramp Sand Bypassing	2015/7411	Not Controlled Action (Particular Manner)	Post-Approval
The Dampier Heavy Load Out Facility Berth and Swing Basin Expansion	2012/6271	Not Controlled Action (Particular Manner)	Post-Approval
Tidepole Maz 3D Seismic Survey Campaign	2007/3706	Not Controlled Action (Particular Manner)	Post-Approval
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Triton 3D Marine Seismic Survey, WA-2-R and WA-3-R	2006/2609	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a 3D marine seismic survey	2010/5695	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5679	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5715	Not Controlled Action (Particular Manner)	Post-Approval
upgrade of 3 community recreation sites	2005/2349	Not Controlled Action (Particular Manner)	Post-Approval
Vincent M1 and Enfield M5 4D Marine Seismic Survey	2010/5720	Not Controlled Action (Particular Manner)	Post-Approval
Warramunga Non-Inclusive 3D Seismic Survey	2008/4553	Not Controlled Action (Particular Manner)	Post-Approval
West Anchor 3D Marine Seismic Survey	2008/4507	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
West Panaeus 3D seismic survey	2006/3141	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone 3D MAZ Marine Seismic Survey	2011/6058	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2007/3941	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2008/4134	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic Survey in the offshore northwest Carnarvon Basin	2011/6175	Referral Decision	Completed
3D Seismic Survey	2008/4219	Referral Decision	Completed
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	Referral Decision	Completed
construction of a new loadout facility and associated laydown area south of the	2002/579	Referral Decision	Completed
CVG 3D Marine Seismic Survey	2012/6270	Referral Decision	Completed
Enfield 4D Marine Seismic Surveys, Production Permit WA-28-L	2005/2370	Referral Decision	Completed
Mardie Salt Project, Pilbara region, WA	2018/8183	Referral Decision	Completed
Outer Harbour Development and associated marine and terrestial infrastructure	2008/4148	Referral Decision	Completed
Relocation of 2 heritage sites to National Heritage Place	2010/5709	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed
Stybarrow Baseline 4D Marine Seismic Survey (Permit Areas WA-255-P, WA-32-L, WA-	2008/4165	Referral Decision	Completed
Two Dimensional Transition Zone Seismic Survey - TP/7 (R1)	2010/5507	Referral Decision	Completed
Varanus Island Compression Project	2012/6698	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging	Likely to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur

Scientific Name	Behaviour	Presence
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Foraging	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Chelonia mydas Green Turtle [1765]	Aggregation	Known to occur
Chelonia mydas Green Turtle [1765]	Basking	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Likely to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Mating	Known to occur
Chelonia mydas Green Turtle [1765]	Migration corridor	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Likely to occur

Scientific Name	Behaviour	Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Mating	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Migration corridor	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Natator depressus Flatback Turtle [59257]	Aggregation	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Mating	Known to occur
Natator depressus Flatback Turtle [59257]	Migration corridor	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
River shark		
Pristis clavata Dwarf Sawfish [68447]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Pristis clavata Dwarf Sawfish [68447]	Nursing	Known to occur
Pristis clavata Dwarf Sawfish [68447]	Pupping	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Foraging	Known to occur
Pristis pristis Freshwater Sawfish [60756]	Pupping	Likely to occur
Pristis zijsron Green Sawfish [68442]	Foraging	Known to occur
Pristis zijsron Green Sawfish [68442]	Nursing	Known to occur
Pristis zijsron Green Sawfish [68442]	Pupping	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Resting	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Breeding	Known to occur
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sula leucogaster Brown Booby [1022]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Rhincodon typus Whale Shark [66680]	Foraging (high density prey)	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government
Department of Climate Change, Energy, the Environment and Water

AREA 5

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	2
National Heritage Places:	5
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	86
Listed Migratory Species:	80

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	6
Commonwealth Heritage Places:	2
Listed Marine Species:	128
Whales and Other Cetaceans:	37
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	14
Habitat Critical to the Survival of Marine Turtles:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	22
Regional Forest Agreements:	None
Nationally Important Wetlands:	4
EPBC Act Referrals:	51
Key Ecological Features (Marine):	8
Biologically Important Areas:	35
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place
Batavia Shipwreck Site and Survivor Camps Area 1629 - Houtman Abrolhos	WA	Listed place
Dirk Hartog Landing Site 1616 - Cape Inscription Area	WA	Listed place
Natural		
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Malurus leucopterus leucopterus White-winged Fairy-wren (Dirk Hartog Island), Dirk Hartog Black-and-White Fairy-wren [26004]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Turnix varius scintillans		
Painted Button-quail (Houtman Abrolhos) [82451]	Vulnerable	Species or species habitat known to occur within area
Zanda latirostris listed as Calyptorhynchus latirostris		
Carnaby's Black Cockatoo, Short-billed Black-cockatoo [87737]	Endangered	Species or species habitat known to occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Bettongia lesueur lesueur Burrowing Bettong (Shark Bay), Boodie [66659]	Vulnerable	Species or species habitat known to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Translocated population known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Lagorchestes hirsutus bernieri Rufous Hare-wallaby (Bernier Island) [66662]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus dorreae Rufous Hare-wallaby (Dorre Island) [66663]	Vulnerable	Species or species habitat known to occur within area
Lagostrophus fasciatus fasciatus Banded Hare-wallaby, Merrnine, Marnine, Munning [66664]	Vulnerable	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat may occur within area
Perameles bougainville listed as Perameles bougainville bougainville Shark Bay Bandicoot [278]	Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Petrogale lateralis lateralis		
Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Pseudomys fieldi		
Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
PLANT		
Androcalva bivillosa		
Straggling Androcalva [87807]	Critically Endangered	Species or species habitat known to occur within area
Beyeria lepidopetala		
Small-petalled Beyeria, Short-petalled Beyeria [18362]	Endangered	Species or species habitat likely to occur within area
Caladenia barbarella		
Small Dragon Orchid, Common Dragon Orchid [68686]	Endangered	Species or species habitat may occur within area
Caladenia bryceana subsp. cracens		
Northern Dwarf Spider-orchid [64556]	Vulnerable	Species or species habitat known to occur within area
Caladenia elegans		
Elegant Spider-orchid [56775]	Endangered	Species or species habitat known to occur within area
Caladenia hoffmanii		
Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat known to occur within area
Caleana dixonii listed as Paracaleana dixonii		
Sandplain Duck Orchid [87944]	Endangered	Species or species habitat likely to occur within area
Chorizema humile		
Prostrate Flame Pea [32573]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Conostylis dielsii subsp. teres Irwin's Conostylis [3614]	Endangered	Species or species habitat likely to occur within area
Conostylis micrantha Small-flowered Conostylis [17635]	Endangered	Species or species habitat likely to occur within area
Diuris drummondii Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat may occur within area
Drakaea concolor Kneeling Hammer-orchid [56777]	Vulnerable	Species or species habitat known to occur within area
Drummondita ericoides Morseby Range Drummondita [9193]	Endangered	Species or species habitat known to occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat may occur within area
Eucalyptus cuprea Mallee Box [56773]	Endangered	Species or species habitat likely to occur within area
Grevillea bracteosa subsp. howatharra [85002]	Critically Endangered	Species or species habitat likely to occur within area
Hypocalymma angustifolium subsp. Hutt River (S.Patrick 2982) [85023]	Endangered	Species or species habitat known to occur within area
Hypocalymma longifolium Long-leaved Myrtle [8081]	Vulnerable	Species or species habitat likely to occur within area
Lechenaultia chlorantha Kalbarri Leschenaultia [16763]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Leucopogon marginatus Thick-margined Leucopogon [12527]	Endangered	Species or species habitat known to occur within area
Pterostylis sinuata Northampton Midget Greenhood, Western Swan Greenhood [84991]	Endangered	Species or species habitat known to occur within area
Stachystemon nematophorus Three-flowered Stachystemon [81447]	Vulnerable	Species or species habitat known to occur within area
Wurmbea tubulosa Long-flowered Nancy [12739]	Endangered	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Centrophorus zeehaani		
Southern Dogfish, Endeavour Dogfish, Little Gulper Shark [82679]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area
SPIDER		
Idiosoma nigrum		
Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons		
Little Tern [82849]		Species or species habitat may occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis		
Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Congregation or aggregation known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica		
Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba		
Sanderling [875]		Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Species or species habitat known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - GREENOUGH RIFLE RANGE [50234]	WA
Unknown	
Commonwealth Land - [52214]	WA
Commonwealth Land - [51101]	WA
Commonwealth Land - [52111]	WA
Commonwealth Land - [52201]	WA
Commonwealth Land - [51102]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place
Natural		
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Species or species habitat known to occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Species or species habitat known to occur within area overfly marine area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Breeding likely to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat known to occur within area overfly marine area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Puffinus huttoni Hutton's Shearwater [1025]		Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Recurvirostra novaehollandiae Red-necked Avocet [871]		Species or species habitat known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Stercorarius skua as Catharacta skua Great Skua [823]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Thalasseus bengalensis as Sterna bengalensis Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Species or species habitat known to occur within area
Tringa glareola Wood Sandpiper [829]		Species or species habitat known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Species or species habitat known to occur within area overfly marine area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammal		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Dugong dugon Dugong [28]		Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Reptile		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Congregation or aggregation known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis as Sousa chinensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Abrolhos	Habitat Protection Zone (IUCN IV)

Park Name	Zone & IUCN Categories
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Abrolhos	Special Purpose Zone (IUCN VI)
Abrolhos	Special Purpose Zone (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Nov-Feb		
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Abrolhos Islands	Fish Habitat Protection Area	WA
Bernier And Dorre Islands	Nature Reserve	WA
Dirk Hartog Island	National Park	WA
Freycinet, Double Islands etc	Nature Reserve	WA
Houtman Abrolhos Islands	National Park	WA

Protected Area Name	Reserve Type	State
Kalbarri	National Park	WA
Kalbarri Blue Holes	Fish Habitat Protection Area	WA
Koks Island	Nature Reserve	WA
Nanga Station	NRS Addition - Gazettal in Progress	WA
Ningaloo	Marine Park	WA
Oakabella	Nature Reserve	WA
Part Murchison house	NRS Addition - Gazettal in Progress	WA
Point Quobba	Fish Habitat Protection Area	WA
Port Gregory	NRS Addition - Gazettal in Progress	WA
Shark Bay	Marine Park	WA
Tamala Pastoral Lease (Part)	NRS Addition - Gazettal in Progress	WA
Unnamed WA26400	5(1)(h) Reserve	WA
Unnamed WA37338	5(1)(h) Reserve	WA
Unnamed WA37383	5(1)(h) Reserve	WA
Unnamed WA37500	5(1)(g) Reserve	WA
Unnamed WA44688	5(1)(h) Reserve	WA
Zuytdorp	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Hutt Lagoon System	WA
Lake MacLeod	WA
Murchison River (Lower Reaches)	WA
Shark Bay East	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status

Title of referral	Reference	Referral Outcome	Assessment Status
Midwest Offshore Wind Farm	2022/09264		Assessment
Controlled action			
Boating Facility	2002/830	Controlled Action	Completed
Construction of the Oakajee Port and Rail Project	2011/5797	Controlled Action	Post-Approval
development of land based tourist facilities on Long Island	2006/2792	Controlled Action	Post-Approval
Karara Magnetite Project	2006/3017	Controlled Action	Post-Approval
Mauds Landing Marina	2000/98	Controlled Action	Completed
Mount Gibson Iron Ore Pellet Project	2000/95	Controlled Action	Completed
Nava-1 Cable System	2001/510	Controlled Action	Completed
open cut mine & assoc infrastructure	2005/2381	Controlled Action	Post-Approval
Port Enhancement Project	2001/266	Controlled Action	Post-Approval
Tourism Facility and Associated Infrastructure	2005/2038	Controlled Action	Post-Approval
Yogi Magnetite Project, 225km east, northeast of Geraldton, WA	2017/8124	Controlled Action	Assessment Approach
Not controlled action			
Accommodation Units Sunday Island Bay, Dirk Hartog Island, WA	2015/7540	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
archaeological surveys & excavation at historic sites, Cape Inscription	2006/3027	Not Controlled Action	Completed
Boating Facility	2002/832	Not Controlled Action	Completed
Drilling between Kalbarri and Cliff Head	2005/2185	Not Controlled Action	Completed
Extention to the existing Blind Strait Black Lip Pearl Oyster Farm	2004/1342	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Hadda 1,Flying Foam 1,Magnat 1 exploration drill	2004/1697	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Mumbida Wind Farm	2002/650	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
Seismic Survey, Bremer Basin, Mentelle Basin and Zeewyck Sub-basin	2004/1700	Not Controlled Action	Completed
Useless Loop Road Upgrade	2000/83	Not Controlled Action	Completed
WA-286-P Exploration Drilling Programme	2007/3863	Not Controlled Action	Completed
Yellowfin Tuna Aquaculture Trial	2003/1115	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D Marine Seismic Survey in Permit Area WA-337-P	2003/1158	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2007/3800	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
develop and operate a new deepwater port	2010/5760	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey for oil and gas in Commonwealth waters off the WA coast.	2004/1802	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey in Permit WA-481P	2012/6626	Not Controlled Action (Particular Manner)	Post-Approval
North Perth Marine Survey	2011/6067	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
search for HMAS Sydney	2006/3071	Not Controlled Action (Particular Manner)	Post-Approval
Study of behavioural responses of Austn Humpback Whales to seismic surveys, offshore	2013/6927	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Dongara, WA		Manner)	
Supply of road building material areas Shark Bay Region WA	2012/6280	Not Controlled Action (Particular Manner)	Post-Approval
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3729	Referral Decision	Completed
Exploration Drilling 2014/2015 WA-481-P	2013/7043	Referral Decision	Completed
Proposed exploration drilling activities, Abrolhos Commonwealth Marine Reserve	2013/6949	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 90-120m depth	South-west
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	South-west
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Perth Canyon and adjacent shelf break, and other west coast canyons	South-west
Wallaby Saddle	North-west
Western demersal slope and associated fish communities	South-west
Western rock lobster	South-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Internesting	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Seabirds		
Anous stolidus Common Noddy [825]	Foraging (provisioning young)	Known to occur
Anous tenuirorstris melanops Australian Lesser Noddy [26000]	Foraging (provisioning young)	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur

Scientific Name	Behaviour	Presence
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur
Pelagodroma marina White-faced Storm petrel [1016]	Foraging (in high numbers)	Known to occur
Pterodroma mollis Soft-plumaged Petrel [1036]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging (provisioning young)	Known to occur
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Seals		

Scientific Name	Behaviour	Presence
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government
Department of Climate Change, Energy, the Environment and Water

AREA 6

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 16-Dec-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	2
Wetlands of International Importance (Ramsar	3
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	14
Listed Threatened Species:	130
Listed Migratory Species:	86

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	494
Commonwealth Heritage Places:	7
Listed Marine Species:	123
Whales and Other Cetaceans:	40
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	33
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	119
Regional Forest Agreements:	1
Nationally Important Wetlands:	13
EPBC Act Referrals:	309
Key Ecological Features (Marine):	11
Biologically Important Areas:	39
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Australian Convict Sites (Fremantle Prison)	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Historic		
Fremantle Prison (former)	WA	Listed place
Natural		
Lesueur National Park	WA	Listed place

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity
Becher point wetlands	Within Ramsar site
Forrestdale and thomsons lakes	Within Ramsar site
Peel-yalgorup system	10 - 20km upstream from Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
EEZ and Territorial Sea
Extended Continental Shelf

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Aquatic Root Mat Community 2 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area
Aquatic Root Mat Community 3 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area

Community Name	Threatened Category	Presence Text
Aquatic Root Mat Community 4 in Caves of the Leeuwin Naturaliste Ridge	Endangered	Community known to occur within area
Aquatic Root Mat Community in Caves of the Swan Coastal Plain	Endangered	Community known to occur within area
Assemblages of plants and invertebrate animals of tumulus (organic mound) springs of the Swan Coastal Plain	Endangered	Community known to occur within area
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community likely to occur within area
Clay Pans of the Swan Coastal Plain	Critically Endangered	Community likely to occur within area
Corymbia calophylla - Kingia australis woodlands on heavy soils of the Swan Coastal Plain	Endangered	Community known to occur within area
Corymbia calophylla - Xanthorrhoea preissii woodlands and shrublands of the Swan Coastal Plain	Endangered	Community known to occur within area
Proteaceae Dominated Kwongkan Shrublands of the Southeast Coastal Floristic Province of Western Australia	Endangered	Community may occur within area
Sedgelands in Holocene dune swales of the southern Swan Coastal Plain	Endangered	Community known to occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond)	Endangered	Community known to occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community likely to occur within area

Listed Threatened Species

[Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo, Karrak [67034]	Vulnerable	Species or species habitat known to occur within area
Cereopsis novaehollandiae grisea Cape Barren Goose (south-western), Recherche Cape Barren Goose [25978]	Vulnerable	Breeding known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Dasyornis longirostris Western Bristlebird [515]	Endangered	Species or species habitat likely to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Pezoporus flaviventris Western Ground Parrot, Kyloring [84650]	Critically Endangered	Species or species habitat likely to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Zanda baudinii listed as Calyptorhynchus baudinii		
Baudin's Black-Cockatoo, Long-billed Black-cockatoo [87736]	Endangered	Breeding known to occur within area
Zanda latirostris listed as Calyptorhynchus latirostris		
Carnaby's Black Cockatoo, Short-billed Black-cockatoo [87737]	Endangered	Breeding known to occur within area
CRUSTACEAN		
Cherax tenuimanus		
Hairy Marron, Margaret River Hairy Marron, Margaret River Marron [78931]	Critically Endangered	Species or species habitat may occur within area
Engaewa pseudoreducta		
Margaret River Burrowing Crayfish [82674]	Critically Endangered	Species or species habitat known to occur within area
FISH		
Galaxiella nigrostriata		
Blackstriped Dwarf Galaxias, Black-stripe Minnow [88677]	Endangered	Species or species habitat likely to occur within area
Hoplostethus atlanticus		
Orange Roughy, Deep-sea Perch, Red Roughy [68455]	Conservation Dependent	Species or species habitat likely to occur within area
Nannatherina balstoni		
Balston's Pygmy Perch [66698]	Vulnerable	Species or species habitat likely to occur within area
Seriolella brama		
Blue Warehou [69374]	Conservation Dependent	Species or species habitat known to occur within area
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area
FROG		
Anstisia alba listed as Geocrinia alba		
White-bellied Frog, Creek Frog [92544]	Critically Endangered	Species or species habitat known to occur within area
INSECT		

Scientific Name	Threatened Category	Presence Text
Hesperocolletes douglasi Douglas' Broad-headed Bee, Rottnest Bee [66734]	Critically Endangered	Species or species habitat known to occur within area
Leioproctus douglasiellus a short-tongued bee [66756]	Critically Endangered	Species or species habitat may occur within area
Neopasiphae simplicior A native bee [66821]	Critically Endangered	Species or species habitat likely to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Pseudocheirus occidentalis Western Ringtail Possum, Ngwayir, Womp, Woder, Ngoor, Ngoolangit [25911]	Critically Endangered	Species or species habitat known to occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat known to occur within area
OTHER		
Westralunio carteri Carter's Freshwater Mussel, Freshwater Mussel [86266]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat known to occur within area
Anigozanthos viridis subsp. terraspectans Dwarf Green Kangaroo Paw [3435]	Vulnerable	Species or species habitat known to occur within area
Banksia brownii Brown's Banksia, Feather-leaved Banksia [8277]	Endangered	Species or species habitat likely to occur within area
Banksia goodii Good's Banksia [16727]	Vulnerable	Species or species habitat may occur within area
Banksia nivea subsp. uliginosa Swamp Honeypot [82766]	Endangered	Species or species habitat may occur within area
Banksia squarrosa subsp. argillacea Whicher Range Dryandra [82769]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Banksia verticillata Granite Banksia, Albany Banksia, River Banksia [8333]	Vulnerable	Species or species habitat likely to occur within area
Caladenia excelsa Giant Spider-orchid [56717]	Endangered	Species or species habitat likely to occur within area
Caladenia granitora [65292]	Endangered	Species or species habitat may occur within area
Caladenia harringtoniae Harrington's Spider-orchid, Pink Spider-orchid [56786]	Vulnerable	Species or species habitat may occur within area
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat may occur within area
Caladenia huegelii King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid [7309]	Endangered	Species or species habitat known to occur within area
Caladenia lodgeana Lodge's Spider-orchid [68664]	Critically Endangered	Species or species habitat known to occur within area
Caleana dixonii listed as Paracaleana dixonii Sandplain Duck Orchid [87944]	Endangered	Species or species habitat likely to occur within area
Calectasia cyanea Blue Tinsel Lily [7669]	Critically Endangered	Species or species habitat likely to occur within area
Calytrix breviseta subsp. breviseta Swamp Starflower [23879]	Endangered	Species or species habitat likely to occur within area
Chamelaucium lullfitzii listed as Chamelaucium sp. Gingin (N.G.Marchant 6) Gingin Wax [92777]	Endangered (listed as Chamelaucium sp. Gingin	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Chorizema varium Limestone Pea [16981]	Endangered	Species or species habitat known to occur within area
Conospermum undulatum Wavy-leaved Smokebush [24435]	Vulnerable	Species or species habitat may occur within area
Conostylis dielsii subsp. teres Irwin's Conostylis [3614]	Endangered	Species or species habitat likely to occur within area
Conostylis micrantha Small-flowered Conostylis [17635]	Endangered	Species or species habitat likely to occur within area
Conostylis misera Grass Conostylis [21320]	Endangered	Species or species habitat may occur within area
Diuris drummondii Tall Donkey Orchid [4365]	Vulnerable	Species or species habitat known to occur within area
Diuris micrantha Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat known to occur within area
Diuris purdiei Purdie's Donkey-orchid [12950]	Endangered	Species or species habitat known to occur within area
Drakaea elastica Glossy-leafed Hammer Orchid, Glossy-leaved Hammer Orchid, Warty Hammer Orchid [16753]	Endangered	Species or species habitat known to occur within area
Drakaea micrantha Dwarf Hammer-orchid [56755]	Vulnerable	Species or species habitat known to occur within area
Eleocharis keigheryi Keighery's Eleocharis [64893]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Eremophila glabra subsp. chlorella [84927]	Endangered	Species or species habitat likely to occur within area
Eucalyptus argutifolia Yanchep Mallee, Wabling Hill Mallee [24263]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus x balanites Cadda Road Mallee, Cadda Mallee [87816]	Endangered	Species or species habitat may occur within area
Gastrolobium papilio Butterfly-leaved Gastrolobium [78415]	Endangered	Species or species habitat may occur within area
Grevillea batrachioides Mt Lesueur Grevillea [21735]	Endangered	Species or species habitat may occur within area
Grevillea curviloba subsp. incurva Narrow curved-leaf Grevillea [64909]	Endangered	Species or species habitat may occur within area
Grevillea humifusa Spreading Grevillea [61182]	Endangered	Species or species habitat may occur within area
Hemiandra gardneri Red Snakebush [7945]	Endangered	Species or species habitat likely to occur within area
Isopogon uncinatus Albany Cone Bush, Hook-leaf Isopogon [20871]	Endangered	Species or species habitat likely to occur within area
Kennedia glabrata Northcliffe Kennedia [16452]	Vulnerable	Species or species habitat may occur within area
Lambertia echinata subsp. occidentalis Western Prickly Honeysuckle [64528]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lepidosperma rostratum Beaked Lepidosperma [14152]	Endangered	Species or species habitat may occur within area
Leucopogon marginatus Thick-margined Leucopogon [12527]	Endangered	Species or species habitat may occur within area
Leucopogon obtectus Hidden Beard-heath [19614]	Endangered	Species or species habitat likely to occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat known to occur within area
Marianthus paralius [83925]	Endangered	Species or species habitat known to occur within area
Melaleuca sp. Wanneroo (G.J. Keighery 16705) [89456]	Endangered	Species or species habitat known to occur within area
Morelotia australiensis listed as Tetraria australiensis Southern Tetraria [92784]	Vulnerable	Species or species habitat likely to occur within area
Reedia spathacea Reedia [2995]	Critically Endangered	Species or species habitat likely to occur within area
Sphenotoma drummondii Mountain Paper-heath [21160]	Endangered	Species or species habitat may occur within area
Synaphea sp. Fairbridge Farm (D. Papenfus 696) Selena's Synaphea [82881]	Critically Endangered	Species or species habitat likely to occur within area
Synaphea sp. Pinjarra Plain (A.S. George 17182) [86878]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Synaphea sp. Serpentine (G.R. Brand 103) [86879]	Critically Endangered	Species or species habitat known to occur within area
Tetratheca nephelioides [83217]	Critically Endangered	Species or species habitat may occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat likely to occur within area
Verticordia apecta Hay River Featherflower, Scruffy Verticordia [65545]	Critically Endangered	Species or species habitat may occur within area
Wurmbea tubulosa Long-flowered Nancy [12739]	Endangered	Species or species habitat likely to occur within area
REPTILE		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Ctenotus lancelini Lancelin Island Skink [1482]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Liopholis pulchra longicauda		
Jurien Bay Skink, Jurien Bay Rock-skink [83162]	Vulnerable	Species or species habitat known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pseudemydura umbrina		
Western Swamp Tortoise [1760]	Critically Endangered	Species or species habitat may occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Centrophorus zeehaani		
Southern Dogfish, Endeavour Dogfish, Little Gulper Shark [82679]	Conservation Dependent	Species or species habitat likely to occur within area
Galeorhinus galeus		
School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark [68453]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		

Scientific Name	Threatened Category	Presence Text
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Breeding known to occur within area
Ardenna grisea Sooty Shearwater [82651]		Species or species habitat may occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Ardenna tenuirostris Short-tailed Shearwater [82652]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Migratory Terrestrial Species		
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius dubius Little Ringed Plover [896]		Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting known to occur within area

Scientific Name	Threatened Category	Presence Text
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - ARTILLERY BARRACKS - FREMANTLE [50155]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50183]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50182]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50181]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50187]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50186]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50185]	WA
Defence - CAMPBELL BARRACKS - SWANBOURNE [50184]	WA
Defence - EAST FREMANTLE SMALL CRAFT BASE [50118]	WA

Commonwealth Land Name	State
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50134]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50133]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50132]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50117]	WA
Defence - HMAS STIRLING-ROCKINGHAM ;HMAS STIRLING - GARDEN ISLAND [50131]	WA
Defence - IRWIN BARRACKS - KARRAKATTA [50175]	WA
Defence - LANCELIN - AIR SAFETY MARKER [50236]	WA
Defence - LANCELIN TRAINING AREA [50120]	WA
Defence - LANCELIN TRAINING AREA [50121]	WA
Defence - LANCELIN TRAINING AREA [50119]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50148]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50153]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50154]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50151]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50152]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50150]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50149]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50147]	WA
Defence - LEEUWIN BARRACKS - EAST FREMANTLE [50146]	WA
Defence - MUCHEA ARMAMENT RANGE [50057]	WA
Defence - MUCHEA ARMAMENT RANGE [50058]	WA
Defence - MUCHEA ARMAMENT RANGE [50059]	WA
Defence - MUCHEA ARMAMENT RANGE [50095]	WA
Defence - MUCHEA ARMAMENT RANGE [50094]	WA
Defence - MUCHEA ARMAMENT RANGE [50092]	WA

Commonwealth Land Name	State
Defence - MUCHEA ARMAMENT RANGE [50077]	WA
Defence - MUCHEA ARMAMENT RANGE [50072]	WA
Defence - MUCHEA ARMAMENT RANGE [50076]	WA
Defence - MUCHEA ARMAMENT RANGE [50078]	WA
Defence - PRESTON POINT TRAINING DEPOT [50174]	WA
Defence - PRESTON POINT TRAINING DEPOT [50173]	WA
Defence - PRESTON POINT TRAINING DEPOT [50172]	WA
Defence - ROCKINGHAM - NAVY CPSO [50135]	WA
Defence - SWANBOURNE RIFLE RANGE [50188]	WA
Defence - SWANBOURNE RIFLE RANGE [50189]	WA
Defence - SWANBOURNE RIFLE RANGE [50190]	WA
Defence - SWANBOURNE RIFLE RANGE [50191]	WA
Unknown	
Commonwealth Land - [50596]	WA
Commonwealth Land - [50590]	WA
Commonwealth Land - [51425]	WA
Commonwealth Land - [51421]	WA
Commonwealth Land - [50594]	WA
Commonwealth Land - [50595]	WA
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Commonwealth Land - [51426]	WA
Commonwealth Land - [50745]	WA
Commonwealth Land - [50504]	WA
Commonwealth Land - [50503]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50624]	WA
Commonwealth Land - [50751]	WA
Commonwealth Land - [50457]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50598]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50712]	WA

Commonwealth Land Name	State
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Commonwealth Land - [50467]	WA

Commonwealth Land Name	State
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Commonwealth Land - [51899]	WA
Commonwealth Land - [50696]	WA

Commonwealth Land Name	State
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Commonwealth Land Name	State
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Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Army Magazine Buildings Irwin Barracks	WA	Listed place
Artillery Barracks	WA	Listed place
Claremont Post Office	WA	Listed place
Cliff Point Historic Site	WA	Listed place
J Gun Battery	WA	Listed place
Natural		
Garden Island	WA	Listed place
Lancelin Defence Training Area	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna grisea as Puffinus griseus Sooty Shearwater [82651]		Species or species habitat may occur within area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Ardenna tenuirostris as Puffinus tenuirostris Short-tailed Shearwater [82652]		Breeding known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area overfly marine area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area overfly marine area
Cereopsis novaehollandiae grisea Cape Barren Goose (south-western), Recherche Cape Barren Goose [25978]	Vulnerable	Breeding known to occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area overfly marine area
Charadrius dubius Little Ringed Plover [896]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Eudyptula minor Little Penguin [1085]		Breeding known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area
Gallinago stenura Pin-tailed Snipe [841]		Roosting known to occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area overfly marine area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area overfly marine area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area overfly marine area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Foraging, feeding or related behaviour likely to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Species or species habitat known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area overfly marine area
Pterodroma macroptera Great-winged Petrel [1035]		Breeding known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area
Stercorarius skua as Catharacta skua Great Skua [823]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area
Tringa brevipes as Heteroscelus brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area overfly marine area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area overfly marine area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area overfly marine area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area overfly marine area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus subelongatus West Australian Seahorse [66722]		Species or species habitat may occur within area
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Leptoichthys fistularius Brushtail Pipefish [66248]		Species or species habitat may occur within area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammal		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Endangered	Breeding known to occur within area
Reptile		
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Berardius arnuxii Arnoux's Beaked Whale [70]		Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Hyperoodon planifrons Southern Bottlenose Whale [71]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Foraging, feeding or related behaviour known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Mesoplodon hectori Hector's Beaked Whale [76]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Tasmacetus shepherdi Shepherd's Beaked Whale, Tasman Beaked Whale [55]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
South-west Corner	Habitat Protection Zone (IUCN IV)
Abrolhos	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
Perth Canyon	Multiple Use Zone (IUCN VI)
South-west Corner	Multiple Use Zone (IUCN VI)
South-west Corner	Multiple Use Zone (IUCN VI)
South-west Corner	Multiple Use Zone (IUCN VI)
Two Rocks	Multiple Use Zone (IUCN VI)
Bremer	National Park Zone (IUCN II)
Eastern Recherche	National Park Zone (IUCN II)

Park Name	Zone & IUCN Categories
Eastern Recherche	National Park Zone (IUCN II)
Jurien	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
Perth Canyon	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
South-west Corner	National Park Zone (IUCN II)
Two Rocks	National Park Zone (IUCN II)
Abrolhos	Special Purpose Zone (IUCN VI)
Eastern Recherche	Special Purpose Zone (IUCN VI)
Jurien	Special Purpose Zone (IUCN VI)
South-west Corner	Special Purpose Zone (IUCN VI)
South-west Corner	Special Purpose Zone (IUCN VI)
Bremer	Special Purpose Zone (Mining Exclusion) (IUCN VI)
Bremer	Special Purpose Zone (Mining Exclusion) (IUCN VI)
South-west Corner	Special Purpose Zone (Mining Exclusion) (IUCN VI)
South-west Corner	Special Purpose Zone (Mining Exclusion) (IUCN VI)

Extra Information

State and Territory Reserves		[Resource Information]
Protected Area Name	Reserve Type	State
Alfred Cove	Nature Reserve	WA
Banksia	Nature Reserve	WA
Bashford	Nature Reserve	WA
Beagle Islands	Nature Reserve	WA
Beekeepers	Nature Reserve	WA
Bold Park	Botanic Gardens	WA
Boullanger, Whitlock, Favourite, Tern And Osprey Islands	Nature Reserve	WA
Bramley	National Park	WA
Buller, Whittell And Green Islands	Nature Reserve	WA
Canning River	Management Area	WA
Carnac Island	Nature Reserve	WA
Cervantes Islands	Nature Reserve	WA
Cottesloe Reef	Fish Habitat Protection Area	WA
D'Entrecasteaux	National Park	WA
Dongara	Nature Reserve	WA
Drovers Cave	National Park	WA
Escape Island	Nature Reserve	WA
Essex Rocks	Nature Reserve	WA
Fisherman Islands	Nature Reserve	WA
Forest Grove	National Park	WA
Gibbs Road	Nature Reserve	WA
Gingin Stock Route	Nature Reserve	WA
Hamelin Island	Nature Reserve	WA
Harry Waring Marsupial Reserve	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Jandabup	Nature Reserve	WA
Jurien Bay	Marine Park	WA
Keanes Point Reserve	5(1)(g) Reserve	WA
Kings Park	Botanic Gardens	WA
Lake Joondalup	Nature Reserve	WA
Lancelin And Edwards Islands	Nature Reserve	WA
Lancelin Island Lagoon	Fish Habitat Protection Area	WA
Leda	Nature Reserve	WA
Leeuwin-Naturaliste	National Park	WA
Lesueur	National Park	WA
Lipfert, Milligan, Etc Islands	Nature Reserve	WA
Marmion	Marine Park	WA
Matilda Bay Reserve	5(1)(g) Reserve	WA
Modong	Nature Reserve	WA
Nambung	National Park	WA
Neerabup	Nature Reserve	WA
Neerabup	National Park	WA
Ngari Capes	Marine Park	WA
Nilgen	Nature Reserve	WA
NTWA Bushland covenant (0003)	Conservation Covenant	WA
NTWA Bushland covenant (0084)	Conservation Covenant	WA
NTWA Bushland covenant (0137)	Conservation Covenant	WA
NTWA Bushland covenant (0144)	Conservation Covenant	WA
NTWA Bushland covenant (0147)	Conservation Covenant	WA
NTWA Bushland covenant (0155)	Conservation Covenant	WA
Outer Rocks	Nature Reserve	WA

Protected Area Name	Reserve Type	State
Penguin Island	Conservation Park	WA
Piara	Nature Reserve	WA
Port Kennedy Scientific Park	Nature Reserve	WA
Quarram	Nature Reserve	WA
Recherche Archipelago	Nature Reserve	WA
Ronsard Rocks	Nature Reserve	WA
Rottnest Island	State Reserve	WA
Rudyard Beach	Nature Reserve	WA
Sandland Island	Nature Reserve	WA
Shoalwater Bay Islands	Nature Reserve	WA
Shoalwater Islands	Marine Park	WA
Southern Beekeepers	Nature Reserve	WA
South Mimegarra	Nature Reserve	WA
St Alouarn Island	Nature Reserve	WA
Swan Estuary	Marine Park	WA
Swan Estuary - Alfred Cove	Marine Park	WA
Swan Estuary - Milyu	Marine Park	WA
Swan Estuary - Pelican Point	Marine Park	WA
Swan River	Management Area	WA
Tennessee North	Nature Reserve	WA
Thomsons Lake	Nature Reserve	WA
Torndirrup	National Park	WA
Unnamed WA11883	5(1)(h) Reserve	WA
Unnamed WA21176	5(1)(h) Reserve	WA
Unnamed WA31906	Nature Reserve	WA
Unnamed WA33287	Nature Reserve	WA
Unnamed WA34039	5(1)(h) Reserve	WA

Protected Area Name	Reserve Type	State
Unnamed WA39584	Conservation Park	WA
Unnamed WA39752	Conservation Park	WA
Unnamed WA42030	5(1)(g) Reserve	WA
Unnamed WA42469	Nature Reserve	WA
Unnamed WA43290	Conservation Park	WA
Unnamed WA43903	Nature Reserve	WA
Unnamed WA44004	Nature Reserve	WA
Unnamed WA44414	5(1)(g) Reserve	WA
Unnamed WA44676	5(1)(h) Reserve	WA
Unnamed WA44682	5(1)(h) Reserve	WA
Unnamed WA45772	5(1)(h) Reserve	WA
Unnamed WA45773	5(1)(h) Reserve	WA
Unnamed WA46756	Conservation Park	WA
Unnamed WA46926	5(1)(h) Reserve	WA
Unnamed WA46982	5(1)(h) Reserve	WA
Unnamed WA46983	5(1)(h) Reserve	WA
Unnamed WA46984	5(1)(h) Reserve	WA
Unnamed WA48205	5(1)(h) Reserve	WA
Unnamed WA48291	Conservation Park	WA
Unnamed WA48717	Conservation Park	WA
Unnamed WA48858	Nature Reserve	WA
Unnamed WA48968	5(1)(h) Reserve	WA
Unnamed WA49220	Conservation Park	WA
Unnamed WA49362	Nature Reserve	WA
Unnamed WA49363	Conservation Park	WA
Unnamed WA49561	Conservation Park	WA
Unnamed WA49994	Conservation Park	WA

Protected Area Name	Reserve Type	State
Unnamed WA50067	5(1)(h) Reserve	WA
Unnamed WA50514	5(1)(h) Reserve	WA
Unnamed WA51658	5(1)(h) Reserve	WA
Unnamed WA51784	Nature Reserve	WA
Unnamed WA52237	5(1)(h) Reserve	WA
Unnamed WA53313	Conservation Park	WA
Unnamed WA53632	Conservation Park	WA
Walpole-Nornalup	National Park	WA
Wanagarren	Nature Reserve	WA
Wandi	Nature Reserve	WA
Wedge Island	Nature Reserve	WA
West Cape Howe	National Park	WA
Woodvale	5(1)(h) Reserve	WA
Yanchep	National Park	WA
Yardanogo	Nature Reserve	WA

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

RFA Name	State
South West WA RFA	Western Australia

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Becher Point Wetlands	WA
Booragoon Swamp	WA
Gibbs Road Swamp System	WA
Herdsman Lake	WA
Joondalup Lake	WA
Karakin Lakes	WA
Lake Thetis	WA

Wetland Name	State
Loch McNess System	WA
Palmer Barracks, Guildford	WA
Rottnest Island Lakes	WA
Spectacles Swamp	WA
Swan-Canning Estuary	WA
Thomsons Lake	WA

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Beale Park Redevelopment	2022/09297		Referral Decision
BEHARRA SILICA SAND PROJECT	2022/09308		Assessment
Cockburn Surf Park	2022/09267		Completed
Expansion of Limestone Extraction	2022/09324		Assessment
Fremantle District Police Complex Project	2022/09345		Completed
Gnarabup Tourism Development: Resort and Beach Village	2022/09224		Assessment
Hale School Development	2022/09273		Referral Decision
Jandakot Horse Agistment	2022/09280		Assessment
Land clearing for timber storage	2022/09367		Assessment
Lot 1401 Fifty Road, Baldivis	2020/8620		Approval
Residential Development, Wattleup Road, Hammond Park, WA	2021/8933		Post-Approval
Samphire Offshore Wind Farm	2022/09306		Assessment
Controlled action			
Airborne sonar trials	2001/540	Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Albany Port Authority dredging project	2006/2540	Controlled Action	Post-Approval
Alcoa Bauxite Residue Storage Area Extension	2011/5878	Controlled Action	Further Information Request
Alkimos city centre and central development, WA	2015/7561	Controlled Action	Post-Approval
Alkimos Coastal Node	2020/8861	Controlled Action	Further Information Request
Alkimos Seawater Desalination	2019/8453	Controlled Action	Assessment Approach
Arrowsmith North Silica Sand Project	2020/8788	Controlled Action	Proposed Decision
Atlas Mineral Sands Mine	2020/8813	Controlled Action	Completed
Atlas Mineral Sands Project	2021/9056	Controlled Action	Assessment Approach
Baldivis Residential development on lots 98, 323,529 and 530	2010/5733	Controlled Action	Post-Approval
Butler North District Open Space playing fields development, Wanneroo, WA	2017/8053	Controlled Action	Post-Approval
Catalina Residential Development	2010/5785	Controlled Action	Post-Approval
Clearing of 12.8ha of native vegetation on Lots 19 and 20, Sixty Eight Road, Baldivis, WA	2016/7661	Controlled Action	Post-Approval
Clearing of 18.80 ha of vegatation ahead of quarrying operations	2010/5650	Controlled Action	Completed
Clearing of 22 ha vegatation to allow for the continuation of quarrying	2010/5649	Controlled Action	Post-Approval
Clearing of Lots 2 and 10 Rowley Road, Mandogalup WA	2018/8182	Controlled Action	Assessment Approach
Commercial Development of Lots 12 and 13 Lodge Drive, East Rockingham, WA	2021/9069	Controlled Action	Further Information Request
construction and operation of a unmanned platform at the Cliff Head oil field, a	2003/1300	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Construction of a Deepwater, General Container Port	2009/5178	Controlled Action	Proposed Decision
Construction of Fiona Stanley Hospital	2008/3970	Controlled Action	Post-Approval
Construction of New Perth Bunbury Highway project	2005/2193	Controlled Action	Post-Approval
Development of Kwinana Quay port facility	2008/4387	Controlled Action	Completed
Develop three sites into residential housing and mixed use developments, Western Australia	2013/6916	Controlled Action	Post-Approval
Eglinton/South Yanchep Residential Development	2011/6021	Controlled Action	Post-Approval
Eglinton Estates - Clearing of native vegetation from Lot 1007 & part Lot 1008	2010/5777	Controlled Action	Post-Approval
Erindale Road Development, Hamersley, WA	2018/8324	Controlled Action	Further Information Request
Excavate sand and limestone resources	2010/5621	Controlled Action	Completed
Extend a section of Mundijong Road	2011/5971	Controlled Action	Post-Approval
Extension of Beeliar Drive between the junction of Mayor and Fawcett Roads an...	2003/1029	Controlled Action	Completed
Extraction of sand from Lot 6 Banksia Road & lots 300 & 301 Boomerang Road, WA	2010/5622	Controlled Action	Post-Approval
Hammond Park Secondary School development, WA	2016/7741	Controlled Action	Post-Approval
Honeywood Estate Development	2010/5476	Controlled Action	Post-Approval
Industry Zone	2010/5337	Controlled Action	Post-Approval
Jandakot Airport Expansion, Commercial Development and Clearing of Vegetation	2009/4796	Controlled Action	Post-Approval
Jindee Residential Development	2012/6631	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Jurien East Road Upgrade, 3 km NNE Jurien Bay, WA	2020/8740	Controlled Action	Proposed Decision
Land Development, James Street and Well Street, East Wanneroo, Elberton Property	2021/9106	Controlled Action	Assessment Approach
Latitude 32-industrial development of various lots, Ashley and Sayer Roads, Hope Valley, WA	2016/7695	Controlled Action	Post-Approval
Leeuwin Offshore Wind Farm	2022/9160	Controlled Action	Assessment Approach
Limestone extraction on Lot 8 Wattle Avenue, Nowergup	2013/6767	Controlled Action	Post-Approval
Lot 1665 Wanneroo Road, Sinagra.	2017/7921	Controlled Action	Post-Approval
Lot 2 Corner Durrant Avenue and Sicklemore Road - Residential Development	2011/5882	Controlled Action	Completed
Lot 9000 Wanneroo Road Sinagra Mixed Use Development, Western Australia	2020/8798	Controlled Action	Proposed Decision
Lots 13, 14 & 18 Barfield Rd & Lots 48-51 Rowley Rd, Hammond Park	2012/6524	Controlled Action	Post-Approval
Mandogalup Urban Development, Mandogalup, WA	2014/7308	Controlled Action	Post-Approval
Mangles Bay Marina Based Tourist Precinct	2010/5659	Controlled Action	Post-Approval
Meridian Business Park Industrial Development	2007/3479	Controlled Action	Post-Approval
Mitchell Freeway Extension and Wanneroo Road Upgrade, WA	2018/8367	Controlled Action	Post-Approval
Mitchell Freeway Extension between Burns Beach Rd and Hester Av, Neerabup, WA	2013/7091	Controlled Action	Post-Approval
Mitchell Freeway Principal Shared Path Gaps Project Ocean Reef Road to Hepburn Avenue	2020/8833	Controlled Action	Post-Approval
National Lifestyle Villages Development	2011/6020	Controlled Action	Post-Approval
Natural Gas Pipeline Expansion	2006/2813	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Nava-1 Cable System	2001/510	Controlled Action	Completed
Neerabup Industrial Area, WA	2021/8917	Controlled Action	Assessment Approach
Neerabup Industrial Estate, Lot 701 Flynn Drive Neerabup WA	2012/6424	Controlled Action	Post-Approval
Ocean Reef Marina Development	2009/4937	Controlled Action	Completed
Proposed Urban Development of Lots 1005 & 1006	2008/4638	Controlled Action	Post-Approval
Ranford Road Residential Development	2002/549	Controlled Action	Post-Approval
Residential and commercial development on part 19 (Lot 6) Taronga Place, Eglinton, WA	2017/7872	Controlled Action	Post-Approval
Residential development, Bertram, WA	2017/7887	Controlled Action	Further Information Request
Residential Development, Lot 123 Mortimer Road, Casuarina, WA	2018/8379	Controlled Action	Assessment Approach
Residential development,Lot 609, Yanchep Beach Road, Yanchep, WA	2014/7146	Controlled Action	Post-Approval
Residential development, Village of Wellard, City of Kwinana, WA	2013/6986	Controlled Action	Post-Approval
Residential Development at Shenton Park	2007/3386	Controlled Action	Completed
Residential development Lot 1004 Alkimos WA	2011/5902	Controlled Action	Post-Approval
Residential Development Lot 131 Jandakot Road, Treeby WA	2018/8205	Controlled Action	Further Information Request
Residential development of Lots 635, 739 and 740 on Deposited Plan 202751, Baldivis Road, Baldivis,	2018/8361	Controlled Action	Post-Approval
Residential development of various lots	2019/8500	Controlled Action	Proposed Decision
Residential developmnt, Lots 11 and 74 Beenyup Road, Banjup, WA	2017/7923	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Residential Estate Development, Lot 682 Rowley Road, Mandogalup, Western Australia	2014/7126	Controlled Action	Post-Approval
Roe Highway extension, Kwinana Freeway to Stock Road, WA	2009/5031	Controlled Action	Post-Approval
Roe Hwy Extension	2003/972	Controlled Action	Post-Approval
Sand Mining	2010/5522	Controlled Action	Completed
Sand Mining 70/915 Banksia Road, Wellard, WA	2015/7438	Controlled Action	Post-Approval
Shark Hazard Mitigation Drum Line Program, WA	2014/7174	Controlled Action	Completed
Shenton Park Subdivision	2004/1479	Controlled Action	Completed
Spatial Property Group Ltd - Residential Development	2021/9006	Controlled Action	Assessment Approach
Subdivision of Lot 902 Flynn Drive Neerabup for Industrial Development	2021/8977	Controlled Action	Assessment Approach
Thornlie-Cockburn Link Project, WA	2018/8188	Controlled Action	Post-Approval
Tiwest Dongara Project, mineral sands mining and concentrating operation, 25km	2009/5032	Controlled Action	Post-Approval
Undertake seismic survey to assess shale resources	2013/7088	Controlled Action	Post-Approval
Urban and Residential Development at Lot 9 Brighton	2011/6137	Controlled Action	Post-Approval
Urban development in accordance with the Local Structure Plan	2008/4601	Controlled Action	Post-Approval
Urban Residential Development at Lot 9049 Marmoin Avenue	2009/5155	Controlled Action	Post-Approval
Vegetation Clearing, Wannaroo Rd and Nowergup Rd	2011/5955	Controlled Action	Completed
Vegetation clearing (Cwlth land), Jandakot Airport, Cockburn, WA	2013/7032	Controlled Action	Post-Approval
Vlam Road Gravel Pit, Vlam Road, Karridale, WA	2014/7141	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Warders Hotel, Block 1 Warders Cottages, Fremantle, WA	2018/8144	Controlled Action	Post-Approval
Wellard Village Primary School development, part Lot 9074 Lambeth Circle, Wellard	2020/8732	Controlled Action	Post-Approval
Yanchep Rail Extension, WA	2018/8262	Controlled Action	Post-Approval
Not controlled action			
'Looping 10' gas transmission pipeline from Kwinana to Hopelands	2005/2212	Not Controlled Action	Completed
Alkimos seawater desalination plant, offshore investigations, WA	2018/8224	Not Controlled Action	Completed
Amberton West urban development - Part lot 9005 Eglington WA	2013/7068	Not Controlled Action	Completed
APX-West Fibre-optic telecommunications cable system, WA to Singapore	2013/7102	Not Controlled Action	Completed
Armadale Road Duplication - Tapper to Anstey Road	2017/7972	Not Controlled Action	Completed
Armadale Road to North Lake Road Bridge development, Jandakot, WA	2018/8284	Not Controlled Action	Completed
Baldivis District Sporting Complex, Baldivis, WA	2018/8323	Not Controlled Action	Completed
Bibra Lake Aboriginal Cultural Centre Development	2020/8642	Not Controlled Action	Completed
Bight Basin Geological Survey	2006/3137	Not Controlled Action	Completed
Bogdanich Farms Proposed Removal of 9.75ha of Native Vegetation	2010/5390	Not Controlled Action	Completed
Bold Park St John's Wood Mt Claremont residential development,Claremont WA	2014/7248	Not Controlled Action	Completed
Bushfire hazard reduction, Lot 37 Barfield Road, Hammond Park, WA	2018/8204	Not Controlled Action	Completed
Busselton to Flinders Bay Rails to Trails Project, WA	2013/6835	Not Controlled Action	Completed
Busselton to Margaret River Transmission Line	2008/3964	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Butler Railway Extension Project - Nowergup Depot Eastern Alignment	2011/5989	Not Controlled Action	Completed
Calleya Residential Development, Banjup, WA	2016/7708	Not Controlled Action	Completed
Clearing and development of 220 and 234 Wattleup Rd, Wattleup, WA	2016/7738	Not Controlled Action	Completed
Clearing of Native Vegetation, Hammond Park, WA	2011/6041	Not Controlled Action	Completed
Clear native vegetation to undertake a residential development, Baldivis, Wa	2013/6779	Not Controlled Action	Completed
Cliff Head 6 appraisal well	2004/1702	Not Controlled Action	Completed
Cliff Head Appraisal Wells	2003/938	Not Controlled Action	Completed
Commercial development of Lot 106 Wright Road, Forrestdale WA	2003/1255	Not Controlled Action	Completed
Commercial development of Lot 9004 Hodges Drive, Joondalup, WA	2016/7844	Not Controlled Action	Completed
Connect Joondalup - Lot 9000 McLarty Ave and Lot 999 Piccadilly Circus, Joondalup, WA	2016/7758	Not Controlled Action	Completed
Construction and operation of an 8 turbine wind farm at Rous Head Harbour, Frema	2003/933	Not Controlled Action	Completed
Construction of Hammond Road Primary School, Hammond Park, WA	2012/6619	Not Controlled Action	Completed
Construction of international rowing course and commercial/residential areas	2003/1034	Not Controlled Action	Completed
Construction of Secret Harbour High School	2004/1489	Not Controlled Action	Completed
Construction of several passing lanes between Lancelin and Jurien Bay, WA	2015/7509	Not Controlled Action	Completed
Construction of the Margaret River bypass road	2012/6677	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Container Deposit Scheme Project	2019/8517	Not Controlled Action	Completed
Continuation of quarrying sand and limestone, Lot 800 Kerosene Lane, Baldivis, WA	2013/6832	Not Controlled Action	Completed
Cottesloe Golf Course safety improvements, Swanbourne, WA	2019/8423	Not Controlled Action	Completed
CTBT - Cape Leeuwin Hydroacoustic Station Proposal	2000/27	Not Controlled Action	Completed
Curtin Main Street Project - Transformation of Bentley Campus to a major urban centre WA	2013/7044	Not Controlled Action	Completed
Development Application 20 Kenhelm St Balcatta WA	2021/9037	Not Controlled Action	Completed
Development of a Diagnostic Laboratory	2011/6089	Not Controlled Action	Completed
Development of ECU Engineering Annex, Joondalup Campus, WA	2017/7995	Not Controlled Action	Completed
Development of Existing Lots 9970 & 10754, Bedbrook Pl, Shenton Park, WA	2013/7033	Not Controlled Action	Completed
Development of Lots 100-101 Sayer Road, Hope Valley, WA	2019/8399	Not Controlled Action	Completed
Development of new Alkimos Wastwater Treatment Plant	2007/3259	Not Controlled Action	Completed
Disposal of residential properties, Fremantle, WA	2019/8593	Not Controlled Action	Completed
Drilling between Kalbarri and Cliff Head	2005/2185	Not Controlled Action	Completed
Eradication of the European House Borer, Perth metropolitan area, WA	2009/5027	Not Controlled Action	Completed
Establishment of a 12.7 ha Gypsum Mine	2007/3398	Not Controlled Action	Completed
Expansion of berthing facilities at Kwinana Bulk Terminal	2006/2509	Not Controlled Action	Completed
Expansion of existing Ammonium Nitrate Production Facility	2005/1941	Not Controlled Action	Completed
Expansion of Lifestyle Village development, Lots 1, 3, 700 and 703 Mandurah Rd, Baldivis, WA	2016/7850	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Expedition 369-Australian Cretaceous Climate and Tectonics, Australian EEZ waters	2017/7891	Not Controlled Action	Completed
Exploration drilling program located in exploration permits WA-286-P and TP/15	2002/676	Not Controlled Action	Completed
Extension of 7.5km of the Joondalup Line electrified passenger railway from Cla	2010/5632	Not Controlled Action	Completed
Extension of horticulture Farming	2012/6318	Not Controlled Action	Completed
extensions to minerals laboratory	2005/2285	Not Controlled Action	Completed
Flynn Drive / Pinjar Road Intersection Works, Lot 9000 Flynn Drive, Neerabup, WA	2017/7983	Not Controlled Action	Completed
Frankland Parks Oval project, Hammond Park, WA	2018/8369	Not Controlled Action	Completed
Fremantle Ports Inner Harbour Capital Dredging Proposal	2005/2477	Not Controlled Action	Completed
Gas-fired Power Station	2005/2213	Not Controlled Action	Completed
Geo-science Investigations	2005/2069	Not Controlled Action	Completed
Gloucester Park Precinct-expansion of ovals and community facilities, Margaret River, WA	2017/7985	Not Controlled Action	Completed
Groundwater Replenishment Scheme (GWRS) Stage 2	2016/7786	Not Controlled Action	Completed
Hammond West Urban Development, Hammond Park, WA	2017/7917	Not Controlled Action	Completed
Hazard reduction and site access, Lot 682 Rowley Road, Mandogalup, WA	2018/8186	Not Controlled Action	Completed
Highschool and Primary development, Wellard, WA	2016/7639	Not Controlled Action	Completed
High Street Upgrade, Fremantle, WA	2018/8315	Not Controlled Action	Completed
Hope Valley-Wattleup Redevelopment Project	2020/8644	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
Indian Ocean Drive Passing Lane and Widening 52-258 SLK	2017/7884	Not Controlled Action	Completed
Indian Ocean Drive Widening, Gingin Shire, WA	2018/8346	Not Controlled Action	Completed
INDIGO Central Submarine Telecommunications Cable	2017/8127	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Industrial development 105 Sayer Road, Hope Valley, WA	2014/7261	Not Controlled Action	Completed
Industrial Development Lot 64 Ashley Road, Hope Valley, WA	2014/7238	Not Controlled Action	Completed
Installation of stock proof fencing and a stock crossing 8 km from Karridale WA	2012/6427	Not Controlled Action	Completed
Jandakot Road Widening, Solomon Road to Berrigan Drive, Jandakot, WA	2020/8728	Not Controlled Action	Completed
Karnup Sand Mining Project, Stakehill Road, Baldivis, WA	2015/7533	Not Controlled Action	Completed
Kennedy Bay urban development, Port Kennedy, WA	2014/7122	Not Controlled Action	Completed
Kennedy Park Estate Residential Development	2003/1044	Not Controlled Action	Completed
Kwinana Depot Upgrade	2011/6035	Not Controlled Action	Completed
Kwinana Fwy southbound widening Roe Hwy to Armadale Rd and construction of farrington Rd off-ramp	2013/7062	Not Controlled Action	Completed
Kwinana Gas-Fired Power Station	2005/2101	Not Controlled Action	Completed
Lancelin Caravan Park Project, Hopkins Dve & Casserley Way, Lancelin	2015/7546	Not Controlled Action	Completed
Latitude 32 industrial development 6A, Cockburn, WA	2018/8193	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Lot 170 Hope Valley Road, Hope Valley	2020/8830	Not Controlled Action	Completed
Lot 28 157 Barfield Road, Hammond Park - Proposed Residential Development	2021/9063	Not Controlled Action	Completed
Lot 29 Barfield Road, Hammond Park	2017/7948	Not Controlled Action	Completed
Lot 2 Nicholson Road, Forrestdale	2012/6561	Not Controlled Action	Completed
Lot 594 Wanneroo Road development, Hocking	2020/8621	Not Controlled Action	Completed
Lots 12, 13 and 18 Hammond Road, Lot 80 Beeliar Drive and Lot 500 Hird Road	2012/6576	Not Controlled Action	Completed
Lots 569 & 1263, Baldivis Road and Lot 21, Sixty Eight Road, Baldivis, WA	2012/6526	Not Controlled Action	Completed
Montessori School Lot 11 and 700 Karnup Rd, Karnup, WA	2017/8034	Not Controlled Action	Completed
Murdoch University Sports Precinct, Melville, WA	2016/7823	Not Controlled Action	Completed
Nilgen Wind Farm	2009/4694	Not Controlled Action	Completed
Nowergup Strawberry Farm McLennan Drive, Nowergup, WA	2017/8042	Not Controlled Action	Completed
Oakford Village development, Shire of Serpentine-Jarrahdale, WA	2018/8157	Not Controlled Action	Completed
Ocean Reef Marina Development, City of Joondalup, WA	2014/7237	Not Controlled Action	Completed
Oman Australia Cable Installation, WA	2021/8922	Not Controlled Action	Completed
Oman Australia Cable - Marine Route Survey	2020/8731	Not Controlled Action	Completed
Palm Beach Caravan Park Redevelopment, Rockingham, WA	2013/6853	Not Controlled Action	Completed
Pearsall Primary School, Lots 62, 269, 1008, 1009 & Part Lot 23, Pearsall, WA	2012/6405	Not Controlled Action	Completed
Perth Desalination Plant 2	2019/8454	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Perth Seawater Desalination Project: Thomsons Lake to Kogolup Pipeline	2005/1971	Not Controlled Action	Completed
Pinjar Motorcycle Park Raceway Development	2012/6419	Not Controlled Action	Completed
Proposed Expansion of Existing Gracetown Townsite & Upgrade of Existing Associa	2010/5358	Not Controlled Action	Completed
Quinns Main sewer extension, Clarkson - Neerabup, WA	2018/8215	Not Controlled Action	Completed
Realignment of Flynn Drive	2011/6170	Not Controlled Action	Completed
Redevelopment of Purvis Street school site, Hamilton Hill, WA	2018/8255	Not Controlled Action	Completed
Reid Highway duplication project(Erindale Rd - Duffy Rd)WA	2013/7073	Not Controlled Action	Completed
Residential Development, Lot 12 Lyon Road, Aubin Grove, WA	2013/6852	Not Controlled Action	Completed
Residential development, Lot 13 Lyon Road, Aubin Grove, WA	2014/7151	Not Controlled Action	Completed
Residential development, Lot 33 Barfield Road, Hammond Park, WA	2015/7548	Not Controlled Action	Completed
Residential Development, Lot 4 Coogee Road, Mariginiup, WA	2019/8452	Not Controlled Action	Completed
Residential development, Lot 74 Wattleup Road, Hammond Park, WA	2018/8273	Not Controlled Action	Completed
Residential Development, Lots 10 Dundebar Road and 28 and 29 Belgrade Road, East Wanneroo, WA	2019/8521	Not Controlled Action	Completed
Residential development, Lots 124 and 125, Wattleup Road, Hammond Park, WA	2015/7519	Not Controlled Action	Completed
Residential development, Lots 1 and 7-11 Lyon Rd and Lot 88 De Haer Rd, Wandi, WA	2017/7908	Not Controlled Action	Completed
Residential development, Lots 9010 and 9031, Yanchep Beach Rd, Yanchep	2016/7642	Not Controlled Action	Completed
Residential development, part of Lot 601, Mandurah Road, West	2013/6871	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Baldivis, WA			
Residential Development, Serpentine and Baldivis Roads	2020/8700	Not Controlled Action	Completed
Residential Development Eglinton West, Lot 5000 & part Lot 5001, Pipidinny Road, Eglinton	2014/7137	Not Controlled Action	Completed
Residential Development Lot 4225 North Lake Road, Kardinya, WA	2015/7505	Not Controlled Action	Completed
Residential development of 118 Coogee Road, Mariginiup, WA	2017/8011	Not Controlled Action	Completed
Residential development of Lot 7 Anketell Rd, Anketell, WA	2018/8281	Not Controlled Action	Completed
Residential development of Lot 9501 Muzzlewood Street, Baldivis, WA	2016/7775	Not Controlled Action	Completed
Residential Development of Lots 76 and 107 Wattleup Road, Hamond Park	2020/8865	Not Controlled Action	Completed
Residential development on part of Lot 2 Fanstone Avenue, Beeliar, WA	2016/7726	Not Controlled Action	Completed
Residential Development Riverslea Estate Stage 8, Margaret River, WA	2014/7227	Not Controlled Action	Completed
Residential estate, multiple lots, Mandogalup, WA	2018/8264	Not Controlled Action	Completed
residential subdivision	2005/1965	Not Controlled Action	Completed
Residential Subdivision - Lots 12, 36 & 38 Capron St, Wanneroo	2012/6409	Not Controlled Action	Completed
Residential Subdivision on Baldivis Road, Sabrina Road & Zig Zag Road	2012/6613	Not Controlled Action	Completed
Residential Subdivision on Lots 921 & 922 Baldivis Road and Lot 3 Key Close, Baldivis, WA	2012/6601	Not Controlled Action	Completed
Roe Highway - Karel Avenue to Hope Road Bridge Project	2005/2061	Not Controlled Action	Completed
Rottnest Lodge Redevelopment	2019/8565	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Sand extraction operation, Lot 1 Thomas Road, Oakford, WA	2017/8136	Not Controlled Action	Completed
Sand quarry, Lot 102 King Road, Oldbury, WA	2015/7439	Not Controlled Action	Completed
Scientific Sonar Trial	2002/680	Not Controlled Action	Completed
Seismic Survey, Bremer Basin, Mentelle Basin and Zeewyck Sub-basin	2004/1700	Not Controlled Action	Completed
Sepia Depression Ocean Outlet Landline Duplication	2012/6248	Not Controlled Action	Completed
Shenton Park Rehabilitation Hospital Redevelopment, Shenton Park, WA	2015/7622	Not Controlled Action	Completed
Shenton Park Zone Substation Conversion and Expansion	2012/6354	Not Controlled Action	Completed
South Metropolitan Crop Research Hub, Murdoch WA	2018/8201	Not Controlled Action	Completed
Stages 2-5 of primary school and assoc facilities development, Hammond Park, WA	2015/7407	Not Controlled Action	Completed
Subdivision, Lot 4 Anketell Road, Anketell, WA	2018/8145	Not Controlled Action	Completed
Subdivision development on Fifty Rd & Eighty Rd Baldivis	2011/6195	Not Controlled Action	Completed
Translocation of orchids (Caladenia huegelii) from Roe Hway Reserve	2002/781	Not Controlled Action	Completed
Urban development, Lot 109 Wattleup Road, Hammond Park, WA	2015/7425	Not Controlled Action	Completed
Urban development Lots 3, 1199 and 650 Thomas Road, Casuarina, WA	2016/7659	Not Controlled Action	Completed
Urban development of Lot 107 Wattleup Road, Hammond Park, WA	2017/7890	Not Controlled Action	Completed
Urban developmnet & associated infrastructure, Lot 4 Armadale Road, Banjup WA	2013/7049	Not Controlled Action	Completed
WA-286-P Exploration Drilling Programme	2007/3863	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Waitsia Gas Project Stage 2, Yardarino WA	2020/8633	Not Controlled Action	Completed
Wandi South residential development Kenby Close & Lyon Rd, Wandi, WA	2014/7198	Not Controlled Action	Completed
Wanneroo Road/Ocean Reef Road Grade Separation, Pearsall, WA	2017/8110	Not Controlled Action	Completed
Wanneroo Road Duplication, WA	2015/7632	Not Controlled Action	Completed
Warders' Cottages Block 2 'W2'	2022/9148	Not Controlled Action	Completed
Warders' Cottages W2 minor works, Fremantle, WA	2018/8185	Not Controlled Action	Completed
Wellard Farms Urban Development, Baldivis WA	2020/8634	Not Controlled Action	Completed
Wentworth West residential development, Bartram Road, Success, WA	2014/7245	Not Controlled Action	Completed
Wind Farm development	2005/2105	Not Controlled Action	Completed
Yngling-1 exploration well for WA-368-P	2007/3523	Not Controlled Action	Completed
Not controlled action (particular manner)			
2D Marine Seismic Survey in Permit Area WA-337-P	2003/1158	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2007/3273	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey	2007/3800	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey Within WA-382-P	2007/3799	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Arcadia Petroleum - BR12 3D Marine Seismic Survey	2012/6476	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Bremer Basin 2D Marine Seismic Survey, WA	2009/5013	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Garden Island Project, offshore WA	2016/7635	Not Controlled Action (Particular Manner)	Post-Approval
CETO 6 Geophysical and Geotechnical Surveys	2014/7408	Not Controlled Action (Particular Manner)	Post-Approval
City of Cockburn Sporting Facilties	2005/2139	Not Controlled Action (Particular Manner)	Post-Approval
Clearing of understorey vegetation for fire management purposes	2010/5788	Not Controlled Action (Particular Manner)	Post-Approval
Extension of Spearwood Ave, from Barrington Rd to Miguel Rd	2009/5140	Not Controlled Action (Particular Manner)	Post-Approval
Grand Southern Margin 2D Marine Seismic Survey	2008/4599	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
Lake Richmond Boardwalk installation, Rockingham, WA	2013/6977	Not Controlled Action (Particular Manner)	Post-Approval
Laying a submarine optical fibre telecommunications cable, Perth to Singapore and Jakarta	2014/7332	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Marine Environmental Survey	2012/6275	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey for oil and gas in Commonwealth waters off the WA coast.	2004/1802	Not Controlled Action (Particular Manner)	Post-Approval
Marine Seismic Survey in Permit WA-481P	2012/6626	Not Controlled Action (Particular Manner)	Post-Approval
Multipurpose development stage 1 within 340ha	2004/1913	Not Controlled Action (Particular Manner)	Post-Approval
Nexus Energy Seismic survey WA	2006/2569	Not Controlled Action (Particular Manner)	Post-Approval
Road realignment and widening	2009/4926	Not Controlled Action (Particular Manner)	Post-Approval
South West Metropolitan Railway Project	2003/1175	Not Controlled Action (Particular Manner)	Post-Approval
Study of behavioural responses of Austn Humpback Whales to seismic surveys, offshore Dongara, WA	2013/6927	Not Controlled Action (Particular Manner)	Post-Approval
Subdivision Lot 4 Flynn Drive and earthworks for industrial development, 240 Fl	2009/5028	Not Controlled Action (Particular Manner)	Post-Approval
Transmission Line Rebuild and Extension	2009/5105	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Wastewater Treatment Plant	2009/4970	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic survey	2007/3725	Referral Decision	Completed
3D Marine Seismic survey	2007/3729	Referral Decision	Completed
3D Seismic Survey	2012/6245	Referral Decision	Completed
CO2 3D Seismic Survey Vlaming Sub-Basin	2012/6343	Referral Decision	Completed
Eldrad MC3D Seismic Survey, Bight Basin	2014/7128	Referral Decision	Completed
Exploration Drilling 2014/2015 WA-481-P	2013/7043	Referral Decision	Completed
Grand Southern Margin 2D Marine Seismic Survey	2008/4573	Referral Decision	Completed
Kennedy Bay Urban Development,PortKennedy,Rockingh	2013/7022	Referral Decision	Completed
Lot 877 Stakehill Road, Karnup	2021/8887	Referral Decision	Completed
Lots 569 & 1263, Baldivis Road and Lot 21, Sixty Eight Road, Baldivis, WA	2012/6491	Referral Decision	Completed
Mundijong Road Ext Realignment Project Baldivis WA	2011/5864	Referral Decision	Completed
Narelle 3D Marine Seismic Survey	2008/4575	Referral Decision	Completed
Raven 2D Seismic Acquisition Survey	2020/8659	Referral Decision	Referral Publication
Residential Subdivision of 60ha, Swan Location 2424	2004/1928	Referral Decision	Completed
Rezoning of Crown Reserve 39181 to facilitate future residential development	2005/2096	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Sonar Trials and Acoustic Trials	2001/538	Referral Decision	Completed
Transmission Line Rebuild and Extension	2009/4972	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Albany Canyons group and adjacent shelf break	South-west
Ancient coastline at 90-120m depth	South-west
Cape Mentelle upwelling	South-west
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	South-west
Commonwealth marine environment surrounding the Recherche Archipelago	South-west
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	South-west
Diamantina Fracture Zone	South-west
Naturaliste Plateau	South-west
Perth Canyon and adjacent shelf break, and other west coast canyons	South-west
Western demersal slope and associated fish communities	South-west
Western rock lobster	South-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Seabirds		
Anous stolidus Common Noddy [825]	Foraging	Known to occur
Anous stolidus Common Noddy [825]	Foraging (provisioning young)	Known to occur

Scientific Name	Behaviour	Presence
Anous tenuirorstris melanops Australian Lesser Noddy [26000]	Foraging (provisioning young)	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Aggregation	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Foraging	Known to occur
Ardenna carneipes Flesh-footed Shearwater [82404]	Foraging (in high numbers)	Known to occur
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging (in high numbers)	Known to occur
Ardenna tenuirostris Short-tailed Shearwater [82652]	Foraging (in high numbers)	Known to occur
Eudyptula minor Little Penguin [1085]	Foraging (provisioning young)	Known to occur
Hydroprogne caspia Caspian Tern [808]	Foraging (provisioning young)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Known to occur
Larus pacificus Pacific Gull [811]	Foraging (in high numbers)	Former Range
Onychoprion anaethetus Bridled Tern [82845]	Foraging (in high numbers)	Known to occur
Onychoprion fuscata Sooty Tern [82847]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Pelagodroma marina White-faced Storm petrel [1016]	Foraging (in high numbers)	Known to occur
Phalacrocorax fuscescens Black-faced Cormorant [59660]	Foraging	Known to occur
Pterodroma macroptera macroptera Great-winged Petrel (macroptera race) [1035]	Foraging (provisioning young)	Known to occur
Pterodroma mollis Soft-plumaged Petrel [1036]	Foraging (in high numbers)	Known to occur
Puffinus assimilis tunneyi Little Shearwater [59363]	Foraging (in high numbers)	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging	Known to occur
Sterna dougallii Roseate Tern [817]	Foraging (provisioning young)	Known to occur
Sternula nereis Fairy Tern [82949]	Foraging (in high numbers)	Known to occur
Thalassarche chlororhynchos bassi Indian Yellow-nosed Albatross [85249]	Foraging (in high numbers)	Known to occur
Seals		
Neophoca cinerea Australian Sea Lion [22]	Foraging (male)	Likely to occur
Neophoca cinerea Australian Sea Lion [22]	Foraging (male and female)	Known to occur
Sharks		
Carcharodon carcharias White Shark [64470]	Foraging	Known to occur

Scientific Name	Behaviour	Presence
Carcharodon carcharias White Shark [64470]	Known distribution	Known to occur
Whales		
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (abundant food source)	Known to occur
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (high density)	Known to occur
Balaenoptera musculus Blue and Pygmy Blue Whale [36]	Foraging (on migration)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging Area (annual high use area)	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Eubalaena australis Southern Right Whale [40]	Calving buffer	Known to occur
Eubalaena australis Southern Right Whale [40]	Seasonal calving habitat	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Physeter macrocephalus Sperm Whale [59]	Foraging (abundant food source)	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Santos

Attachment 1-3 Aboriginal Heritage Search

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

Search Criteria

194 Registered Aboriginal Sites in Shapefile - Shoreline_100gm2_combined

Disclaimer

The *Aboriginal Heritage Act 1972* preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

Coordinate Accuracy

Coordinates (Easting/Northing metres) are based on the GDA 94 Datum. Accuracy is shown as a code in brackets following the coordinates.

Terminology (NB that some terminology has varied over the life of the legislation)

Place ID/Site ID: This a unique ID assigned by the Department of Planning, Lands and Heritage to the place.

Status:

- **Registered Site**: The place has been assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972.*
- **Other Heritage Place which includes:**
  - **Stored Data / Not a Site:** The place has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972.*
  - **Lodged:** Information has been received in relation to the place, but an assessment has not been completed at this *stage* to determine if it meets Section 5 of the *Aboriginal Heritage Act 1972.*

Access and Restrictions:

- **File Restricted = No:** Availability of information that the Department of Planning, Lands and Heritage holds in relation to the place is not restricted in any way.
- **File Restricted = Yes:** Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- **Boundary Restricted = No:** Place location is shown as accurately as the information lodged with the Registrar allows.
- **Boundary Restricted = Yes:** To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the place is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- **Restrictions:**
  - **No Restrictions:** *Anyone* can view the information.
  - **Male Access Only:** Only *males* can view restricted information.
  - **Female Access Only:** *Only* females can view restricted information.

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
348	ROCKY RIDGE	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Skeletal Material / Burial, Shell	*Registered Knowledge Holder names available from DPL	513207mE 7715560mN Zone 50 [Reliable]	P07582
368	ROCKY CREEK 1.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Quarry, Shell	*Registered Knowledge Holder names available from DPL	504661mE 7714274mN Zone 50 [Reliable]	P07545
369	ROCKY CREEK 2.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Grinding Patches / Grooves, Midden / Scatter	*Registered Knowledge Holder names available from DPL	504452mE 7712661mN Zone 50 [Reliable]	P07546
394	ROCKY CREEK MIDDEN	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Grinding Patches / Grooves, Midden / Scatter	*Registered Knowledge Holder names available from DPL	504289mE 7714405mN Zone 50 [Reliable]	P07571
565	WICKHAM 12	Yes	Yes	Male Access Only	Registered Site	Artefacts / Scatter, Engraving	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P07454
567	WICKHAM 14.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Historical, Midden / Scatter	*Registered Knowledge Holder names available from DPL	505463mE 7715498mN Zone 50 [Reliable]	P07456
580	WICKHAM 27	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	505907mE 7715660mN Zone 50 [Reliable]	P07469
621	WICKHAM 11.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Historical, Midden / Scatter	*Registered Knowledge Holder names available from DPL	510547mE 7715818mN Zone 50 [Reliable]	P07453
680	LOCK HOSPITAL.	No	No	No Gender Restrictions	Registered Site	Historical, Man-Made Structure, Midden / Scatter, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	667239mE 7753438mN Zone 50 [Reliable]	P07393
681	EAST CREEK	No	No	No Gender Restrictions	Registered Site	Engraving	*Registered Knowledge Holder names available from DPL	666450mE 7753125mN Zone 50 [Unreliable]	P07394
731	FOUR MILE ENGRAVINGS	No	No	No Gender Restrictions	Registered Site	Engraving, Midden / Scatter	*Registered Knowledge Holder names available from DPL	672715mE 7751763mN Zone 50 [Reliable]	P07389
753	PORT HEDLAND HOTEL	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	668140mE 7753526mN Zone 50 [Reliable]	P07357

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791	FINUCANE IS. EAST 1	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	662126mE 7752123mN Zone 50 [Reliable]	P07303
938	CLEAVERVILLE WEST 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Quarry	*Registered Knowledge Holder names available from DPL	498139mE 7713155mN Zone 50 [Unreliable]	P07244
939	CLEAVERVILLE WEST 2	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Quarry	*Registered Knowledge Holder names available from DPL	498339mE 7713355mN Zone 50 [Unreliable]	P07245
945	SHELL POINT	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	506493mE 7715662mN Zone 50 [Reliable]	P07251
1023	WANGALNGURRU.	No	No	No Gender Restrictions	Registered Site	Historical, Midden / Scatter, Water Source	*Registered Knowledge Holder names available from DPL	356666mE 7930195mN Zone 51 [Reliable]	K02895
6021	PORT HEDLAND TOWNSITE	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter	*Registered Knowledge Holder names available from DPL	671074mE 7753855mN Zone 50 [Reliable]	P07119
6247	MT ANKETEL 1	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	505639mE 7715655mN Zone 50 [Reliable]	P06717
6321	ANDERSON ST, PORT HEDLAND.	No	No	No Gender Restrictions	Registered Site	Engraving, Camp	*Registered Knowledge Holder names available from DPL	666765mE 7753296mN Zone 50 [Reliable]	P06638
7787	WEST HILL NORTH	Yes	Yes	Male Access Only	Registered Site	Engraving, Man-Made Structure, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P05060
7859	CAPE LAMBERT BURIAL	No	No	No Gender Restrictions	Registered Site	Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	518689mE 7722305mN Zone 50 [Unreliable]	P05009
7906	DELAMBRE ISLAND SOUTH.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Water Source	*Registered Knowledge Holder names available from DPL	508039mE 7737955mN Zone 50 [Unreliable]	P04954
8014	CAPE LAMBERT MIDDEN 07	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Quarry	*Registered Knowledge Holder names available from DPL	517939mE 7722255mN Zone 50 [Reliable]	P04665

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
10056	CAPE LAMBERT.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	517739mE 7721155mN Zone 50 [Unreliable]	P02120
11649	DEBBY'S DUNE (DIXON ISLAND 4)	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	505639mE 7718655mN Zone 50 [Unreliable]	P00513
11650	GAYLEEN BAY (DIXON IS. 6).	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Arch Deposit	*Registered Knowledge Holder names available from DPL	505639mE 7719655mN Zone 50 [Unreliable]	P00514
11653	BOBBY'S FLAT E(DIXON IS.2)	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	508639mE 7720655mN Zone 50 [Unreliable]	P00517
11654	BOBBY'S FLAT (DIXON IS. 3)	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	508639mE 7720655mN Zone 50 [Unreliable]	P00518
11656	SUSAN BAY (DIXON ISLAND 7)	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	506227mE 7718934mN Zone 50 [Unreliable]	P00520
11866	POVERTY WINDMLL,MT WELCOME.	No	No	No Gender Restrictions	Registered Site	Camp	*Registered Knowledge Holder names available from DPL	511000mE 7716236mN Zone 50 [Unreliable]	P00303
11943	TWO MILE RIDGE, NELSON POINT	Yes	Yes	No Gender Restrictions	Registered Site	Engraving, Other: PA 02	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P00219
12069	SOUTH WEST CREEK 1,2,3.	Yes	Yes	No Gender Restrictions	Registered Site	Engraving, Midden / Scatter, Mythological, Camp, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P00088
12071	SOUTH WEST CREEK 4.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Engraving, Man-Made Structure, Midden / Scatter, Arch Deposit, Camp, Other: PA 25	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P00090
12072	SOUTH WEST CREEK 5:BOODARI.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Midden / Scatter, Camp, Hunting Place	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	P00091
12165	KUNGULUMA, YAMPI SOUND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	568571mE 8212325mN Zone 51 [Reliable]	K00045

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12167	MARILI-MA, MYRIDI BAY.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	568637mE 8210661mN Zone 51 [Unreliable]	K00047
12172	KARALU, YAMPI SOUND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Midden / Scatter, Rockshelter	*Registered Knowledge Holder names available from DPL	563710mE 8212444mN Zone 51 [Reliable]	K00052
12230	BARINBAR, SWAN POINT	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00005
12387	BOONGINJ-GOON	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02850
12389	SWAN POINT ULLULONG GROUND	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02852
12410	LINTAPITJIN/LOT 2065PORT DR	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02819
12468	GALYUNGA	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Fish Trap, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02772
12469	GUNJI CEREMONIAL GROUND	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02773
12470	GULGUDUNG	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02774
12471	MARUNGUDA	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02775
12552	CLEMENTSON ST. SITE COMPLEX	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02700
12590	RED BANK.	No	No	No Gender Restrictions	Registered Site	Fish Trap, Midden / Scatter, Mythological, Camp	*Registered Knowledge Holder names available from DPL	419087mE 8012861mN Zone 51 [Unreliable]	K02636

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12677	HEYWOOD ISLAND	No	No	No Gender Restrictions	Registered Site	Man-Made Structure	*Registered Knowledge Holder names available from DPL	642691mE 8304486mN Zone 51 [Unreliable]	K02566
12685	BUNGARUGUN.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Fish Trap, Midden / Scatter, Skeletal Material / Burial, Camp, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02521
12793	UNDANDA.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Grinding Patches / Grooves, Midden / Scatter, Mythological, Camp	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02417
12835	LAMBINJINMAN.	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Named Place	*Registered Knowledge Holder names available from DPL	417365mE 8026042mN Zone 51 [Unreliable]	K02405
12838	JILBANUNG.	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	417389mE 8022550mN Zone 51 [Reliable]	K02408
12839	BILLINGURRU.	Yes	Yes	Male Access Only	Registered Site	Ceremonial, Mythological, Camp	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02409
12842	INBALMARRA.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological, Quarry, Camp	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02412
12873	ENTRANCE POINT/YINARA.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02332
12875	BARRED CREEK	Yes	Yes	Male Access Only	Registered Site	Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02334
12888	BALJARKURUKUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Quarry, Named Place	*Registered Knowledge Holder names available from DPL	416336mE 8029372mN Zone 51 [Reliable]	K02347
12902	KUNDANDU.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp, Water Source, Other: Part of failed PA 139. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02308

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12903	MURRJAL.	Yes	Yes	Female Access Only	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp, Water Source, Other: Part of failed PA 139. ACMC Res11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02309
12904	RURRJAMAN.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp, Plant Resource, Water Source, Other: Part of failed PA 139. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02310
12905	NORTH BARRED CREEK.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Water Source	*Registered Knowledge Holder names available from DPL	414237mE 8047061mN Zone 51 [Unreliable]	K02311
12906	WILLIES CREEK COMPLEX.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological, Skeletal Material / Burial, Camp, Hunting Place, Named Place, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02312
12907	COCONUT WELL 2	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	416037mE 8030361mN Zone 51 [Reliable]	K02313
12908	COCONUT WELL 1.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02314
12909	COCONUT WELL ISLAND	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02315
12910	NORTH CABLE BEACH 6	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	417137mE 8023861mN Zone 51 [Reliable]	K02316
12911	NORTH CABLE BEACH 5	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	417237mE 8023261mN Zone 51 [Reliable]	K02317
12912	JURLIRR.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological, Water Source, Other: Failed PA 142. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02318
12913	NORTH CABLE BEACH 4	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	417637mE 8022261mN Zone 51 [Reliable]	K02319

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12914	NORTH CABLE BEACH 3	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	417637mE 8021961mN Zone 51 [Reliable]	K02320
12917	CABLE BEACH 6.	Yes	Yes	No Gender Restrictions	Registered Site	Midden / Scatter, Camp, Meeting Place, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02323
12918	CABLE BEACH 4.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	416087mE 8016161mN Zone 51 [Unreliable]	K02324
12919	CABLE BEACH 2	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	414737mE 8013361mN Zone 51 [Reliable]	K02325
12920	CABLE BEACH 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	413737mE 8012661mN Zone 51 [Reliable]	K02326
12921	MINYIRR.	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Water Source, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02327
12922	JUNGKURR	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02328
12923	NGAKALYALYA	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Other: Part of Failed PA 143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02329
12924	GANTHEAUME POINT 1	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Other: Part of Failed PA143. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02330
12944	KURAKARAMUNJUNO 1.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	410237mE 8079761mN Zone 51 [Reliable]	K02298
12945	KURAKARAMUNJUNO 2.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	410137mE 8079361mN Zone 51 [Reliable]	K02299
12946	KURAKARAMUNJUNO 3.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	410287mE 8078761mN Zone 51 [Reliable]	K02300

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12947	KURAKARAMUNJUNO 4.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	410237mE 8077161mN Zone 51 [Unreliable]	K02301
12948	FLAT ROCK 1.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	410037mE 8076461mN Zone 51 [Reliable]	K02302
12950	KULMUKARAKUN JUNO 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	409887mE 8073161mN Zone 51 [Reliable]	K02304
13014	BARGAJOC SOAK.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Water Source	*Registered Knowledge Holder names available from DPL	444911mE 8129056mN Zone 51 [Reliable]	K02206
13015	BARGAJOC DUNES.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	444534mE 8129425mN Zone 51 [Reliable]	K02207
13016	BARGAJOC BURIAL	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	444447mE 8129851mN Zone 51 [Reliable]	K02208
13017	BARGAJOC FISHTRAPS	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	444302mE 8130134mN Zone 51 [Reliable]	K02209
13052	HUNTERS BEACH CEMETERY	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	496824mE 8186329mN Zone 51 [Reliable]	K02193
13075	MANGALAGUN+IWALANG ANJDANJ.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, BP Dating: 3640, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K02163
13076	WALMADAN (James Price Point)	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Fish Trap, Midden / Scatter, Skeletal Material / Burial, BP Dating: 1,300, Camp, Hunting Place, Water Source, Other: Part of Failed PA 139. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	409429mE 8065351mN Zone 51 [Reliable]	K02164
13320	WUNDORDA	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01927

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13321	BULGURGUN.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01928
13350	FRAZIER DOWNS BEACH	No	No	No Gender Restrictions	Registered Site	Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	357192mE 7924475mN Zone 51 [Reliable]	K01902
13351	NGILIRIRRBANJIN	Yes	Yes	Male Access Only	Registered Site	Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01903
13384	KOOLAN ISLAND.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Painting, Skeletal Material / Burial, Arch Deposit	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01773
13385	KOOLAN ISLAND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, Arch Deposit	*Registered Knowledge Holder names available from DPL	573382mE 8218658mN Zone 51 [Reliable]	K01774
13386	KOOLAN ISLAND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, Arch Deposit	*Registered Knowledge Holder names available from DPL	573382mE 8218658mN Zone 51 [Reliable]	K01775
13387	KOOLAN ISLAND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, Arch Deposit, BP Dating: 26, 500+/-1050BP, Camp	*Registered Knowledge Holder names available from DPL	573382mE 8218658mN Zone 51 [Reliable]	K01776
13388	YAMPI SOUND.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, Arch Deposit, Other: ?	*Registered Knowledge Holder names available from DPL	566248mE 8212466mN Zone 51 [Reliable]	K01777
13391	YAMPI SOUND	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Quarry	*Registered Knowledge Holder names available from DPL	564705mE 8212952mN Zone 51 [Reliable]	K01780
13398	TOOKER POINT DUNES 1.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	447858mE 8128636mN Zone 51 [Reliable]	K01787
13465	WIRGANJU GROUND	Yes	Yes	No Gender Restrictions	Registered Site		*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01694

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13466	WONGANIN/BATHURST & IRVINE.	Yes	Yes	Male Access Only	Registered Site	Man-Made Structure, Mythological, Skeletal Material / Burial, Hunting Place, Named Place, Plant Resource, Other: LOCAL GP. Failed PA 133	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01695
13490	KAN/BADBA A & B.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Rockshelter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	598917mE 8205287mN Zone 51 [Reliable]	K01664
13493	ARAIRMA.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	503337mE 8190161mN Zone 51 [Unreliable]	K01667
13497	MALAGUN	No	No	No Gender Restrictions	Registered Site	Fish Trap, Mythological	*Registered Knowledge Holder names available from DPL	502637mE 8189661mN Zone 51 [Unreliable]	K01671
13503	WIRRAR.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Skeletal Material / Burial, Camp, Water Source	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01677
13504	KARDILAKAN - JAJAL.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Fish Trap, Midden / Scatter, Mythological, Camp, Water Source, Other: Part of Failed PA 139. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01678
13561	BOWUD.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Hunting Place, Water Source	*Registered Knowledge Holder names available from DPL	503537mE 8190161mN Zone 51 [Reliable]	K01626
13729	RESERVE 21801 BROOME	Yes	Yes	Male Access Only	Registered Site	Artefacts / Scatter, Ceremonial, Man-Made Structure, Mythological, Other: Proposed PA 087. ACMC Res 23/77	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K01380
13916	NIMLARUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Skeletal Material / Burial, Arch Deposit, Camp, Other: ?	*Registered Knowledge Holder names available from DPL	490737mE 8183361mN Zone 51 [Unreliable]	K01177
13917	GURRUDUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	490637mE 8183161mN Zone 51 [Reliable]	K01178

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
13918	DJEBUNDUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	490637mE 8183461mN Zone 51 [Reliable]	K01179
13919	DJILUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	490637mE 8183161mN Zone 51 [Reliable]	K01180
13920	GNAMAGUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	490370mE 8183102mN Zone 51 [Reliable]	K01181
13921	GARRADARRADUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	490537mE 8182961mN Zone 51 [Reliable]	K01182
13925	ILAN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	489837mE 8181961mN Zone 51 [Reliable]	K01186
13927	ANBARMAN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	489537mE 8182161mN Zone 51 [Reliable]	K01188
13929	LARBUNDUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	485237mE 8174861mN Zone 51 [Reliable]	K01190
13930	GUNBUDARUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	490137mE 8178261mN Zone 51 [Reliable]	K01191
13931	DJUNDJUNBULGUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Arch Deposit, Camp, Other: ?	*Registered Knowledge Holder names available from DPL	490437mE 8178161mN Zone 51 [Reliable]	K01192
13932	MIDALUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Skeletal Material / Burial, Camp	*Registered Knowledge Holder names available from DPL	495337mE 8186161mN Zone 51 [Reliable]	K01193
13961	MILBANAN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	492137mE 8187461mN Zone 51 [Reliable]	K01167
13962	KAYERUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	492637mE 8187461mN Zone 51 [Reliable]	K01168

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
13964	LAYUD.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	492572mE 8187440mN Zone 51 [Unreliable]	K01170
13967	MALINGUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	493137mE 8187161mN Zone 51 [Reliable]	K01173
13968	GULDJIMAN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source, Other: LOCAL GROUP	*Registered Knowledge Holder names available from DPL	493438mE 8186968mN Zone 51 [Reliable]	K01174
13969	GULAMANGUN.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	492737mE 8187161mN Zone 51 [Unreliable]	K01175
14240	FISHERMENS BEND 2	No	No		Registered Site	Ceremonial, Skeletal Material / Burial, Other: Part of proposed PA 117	*Registered Knowledge Holder names available from DPL	421987mE 8014661mN Zone 51 [Unreliable]	K00850
14241	FISHERMENS BEND 3	Yes	Yes	Male Access Only	Registered Site	Ceremonial, Mythological, Repository / Cache, Other: Part of proposed PA 117	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00851
14242	FISHERMENS BEND 4	Yes	Yes	Male Access Only	Registered Site	Mythological, Other: Part of proposed PA 117	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00852
14243	FISHERMENS BEND 5	Yes	Yes	Male Access Only	Registered Site	Mythological, Other: Part of proposed PA 117	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00853
14274	EMERIAU POINT 2	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	454737mE 8146161mN Zone 51 [Unreliable]	K00832
14275	EMERIAU POINT 3	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	454937mE 8145261mN Zone 51 [Unreliable]	K00833
14279	WAPET GRAVITY LINE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Water Source	*Registered Knowledge Holder names available from DPL	463937mE 8143061mN Zone 51 [Unreliable]	K00837
14283	WEEDONG LAGOON MIDDEN 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	471036mE 8144960mN Zone 51 [Unreliable]	K00841

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14286	TAPPERS INLET - COAST	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Grinding Patches / Grooves	*Registered Knowledge Holder names available from DPL	454437mE 8140061mN Zone 51 [Unreliable]	K00844
14287	FISHING HUTS MIDDEN 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	454836mE 8144560mN Zone 51 [Unreliable]	K00845
14288	FISHING HUTS MIDDEN 2	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	454836mE 8144860mN Zone 51 [Unreliable]	K00846
14291	FISHERMENS BEND 1.	Yes	Yes	Male Access Only	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp, Water Source, Other: Part of proposed PA 117	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00849
14312	CAPE VILLARET	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00817
14432	CAPE JAUBERT	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	348472mE 7903559mN Zone 51 [Reliable]	K00650
14433	PORT SMITH.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Camp	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00651
14434	ADMIRAL BAY	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Fish Trap, Midden / Scatter	*Registered Knowledge Holder names available from DPL	357548mE 7925925mN Zone 51 [Reliable]	K00652
14439	BIDIR-NGA:BA	Yes	Yes	No Gender Restrictions	Registered Site	Fish Trap, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00657
14440	BLACKROCK POINT 1.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	369637mE 7934661mN Zone 51 [Unreliable]	K00658
14441	POST OFFICE, LAGRANGE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	370637mE 7933661mN Zone 51 [Unreliable]	K00659
14442	LAGRANGE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DPL	371637mE 7936661mN Zone 51 [Unreliable]	K00660

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14445	CAPE VILLARET BURIAL	No	No	No Gender Restrictions	Registered Site	Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	401657mE 7973326mN Zone 51 [Unreliable]	K00663
14560	TITIRRKUN/KENNEDY HILL.	Yes	Yes	Male Access Only	Registered Site	Artefacts / Scatter, Ceremonial, Grinding Patches / Grooves, Midden / Scatter, Mythological, Hunting Place, Water Source, Other: Failed PA 140. ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00500
14561	SACRED STORES/ BROOME	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Repository / Cache	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00501
14609	CABLE BEACH 3.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp, Other: Part of Failed PA 143.ACMC Res 11/89	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00496
14665	LOMBADINA MISSION	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00396
14696	BEAGLE BAY 1	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	449386mE 8126301mN Zone 51 [Reliable]	K00374
14698	TAPPERS POINT.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Camp	*Registered Knowledge Holder names available from DPL	452936mE 8138860mN Zone 51 [Unreliable]	K00376
14699	MURPHY CREEK	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	453436mE 8132060mN Zone 51 [Unreliable]	K00377
14700	IMBALGUN, TAPPERS INLET.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Fish Trap, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DPL	459486mE 8143461mN Zone 51 [Reliable]	K00378
14701	MIDHREGUN	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	454637mE 8144661mN Zone 51 [Unreliable]	K00379
14891	SWAN POINT.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Midden / Scatter, Mythological, Camp, Hunting Place	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00091

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14893	LINBINGUN.	Yes	Yes	No Gender Restrictions	Registered Site	Engraving, Mythological, Named Place	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00093
14976	MONTGOMERY ISLANDS	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Man-Made Structure, Mythological, Painting, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	K00178
14977	CHAMPAGNY ISLANDS	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Painting	*Registered Knowledge Holder names available from DPL	634435mE 8307609mN Zone 51 [Unreliable]	K00179
14980	DECEPTION BAY	No	No	No Gender Restrictions	Registered Site	Painting	*Registered Knowledge Holder names available from DPL	645138mE 8265161mN Zone 51 [Unreliable]	K00182
17043	Limbingoon	Yes	Yes	Male Access Only	Registered Site	Engraving, Named Place	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	
17568	CAPE VILLARET AREA 03 / HOMESTEAD SITE	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, BP Dating: 3100+/-60, Other: Baler shell	*Registered Knowledge Holder names available from DPL	409437mE 7975711mN Zone 51 [Reliable]	
17569	CAPE VILLARET AREA 04	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Camp, Other: Baler shell	*Registered Knowledge Holder names available from DPL	401637mE 7973311mN Zone 51 [Reliable]	
17570	CAPE VILLARET AREA 05	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, BP Dating: 1390+/-70, Other: Baler shell	*Registered Knowledge Holder names available from DPL	401337mE 7973411mN Zone 51 [Reliable]	
17571	CAPE VILLARET AREA 06	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Rockshelter, Other: Archaeological Deposit?	*Registered Knowledge Holder names available from DPL	401187mE 7972961mN Zone 51 [Reliable]	
17572	CAPE VILLARET AREA 07 / BARNES BEACH MIDDEN	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Other: Baler shell	*Registered Knowledge Holder names available from DPL	398437mE 7969011mN Zone 51 [Reliable]	
17573	CAPE VILLARET AREA 08	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Arch Deposit, BP Dating: 1800+/-70, Ochre	*Registered Knowledge Holder names available from DPL	391987mE 7963761mN Zone 51 [Reliable]	
17574	CAPE VILLARET AREA 09	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DPL	389337mE 7961161mN Zone 51 [Reliable]	

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
17575	CAPE VILLARET AREA 10	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	388087mE 7960511mN Zone 51 [Reliable]	
17576	CAPE VILLARET AREA 11 / GUMALIINGA	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	386937mE 7959761mN Zone 51 [Reliable]	
17851	BALDWIN CREEK	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DPL	434308mE 8119459mN Zone 51 [Unreliable]	
17918	Yardoogarra Reburial	No	No	No Gender Restrictions	Registered Site	Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	403048mE 7973160mN Zone 51 [Reliable]	
20288	Sunday Island Mission Cemeteries	No	No	No Gender Restrictions	Registered Site	Historical, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	519737mE 8185661mN Zone 51 [Unreliable]	
21398	Wickham 37	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving	*Registered Knowledge Holder names available from DPL	506313mE 7715781mN Zone 50 [Unreliable]	
21512	Railway 4	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	662797mE 7754831mN Zone 50 [Reliable]	
21515	Finucane Island Burial & Midden Site	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Skeletal Material / Burial	*Registered Knowledge Holder names available from DPL	663550mE 7754397mN Zone 50 [Reliable]	
22796	PHPF57 (FMGP04-002)	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DPL	663920mE 7751015mN Zone 50 [Reliable]	
22874	Marapikurrinya Yintha Site	No	No	No Gender Restrictions	Registered Site	Mythological, Named Place	*Registered Knowledge Holder names available from DPL	664961mE 7751743mN Zone 50 [Reliable]	
23297	DS05-07	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	674535mE 7749718mN Zone 50 [Reliable]	
23298	DS05-08	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	673830mE 7750197mN Zone 50 [Reliable]	

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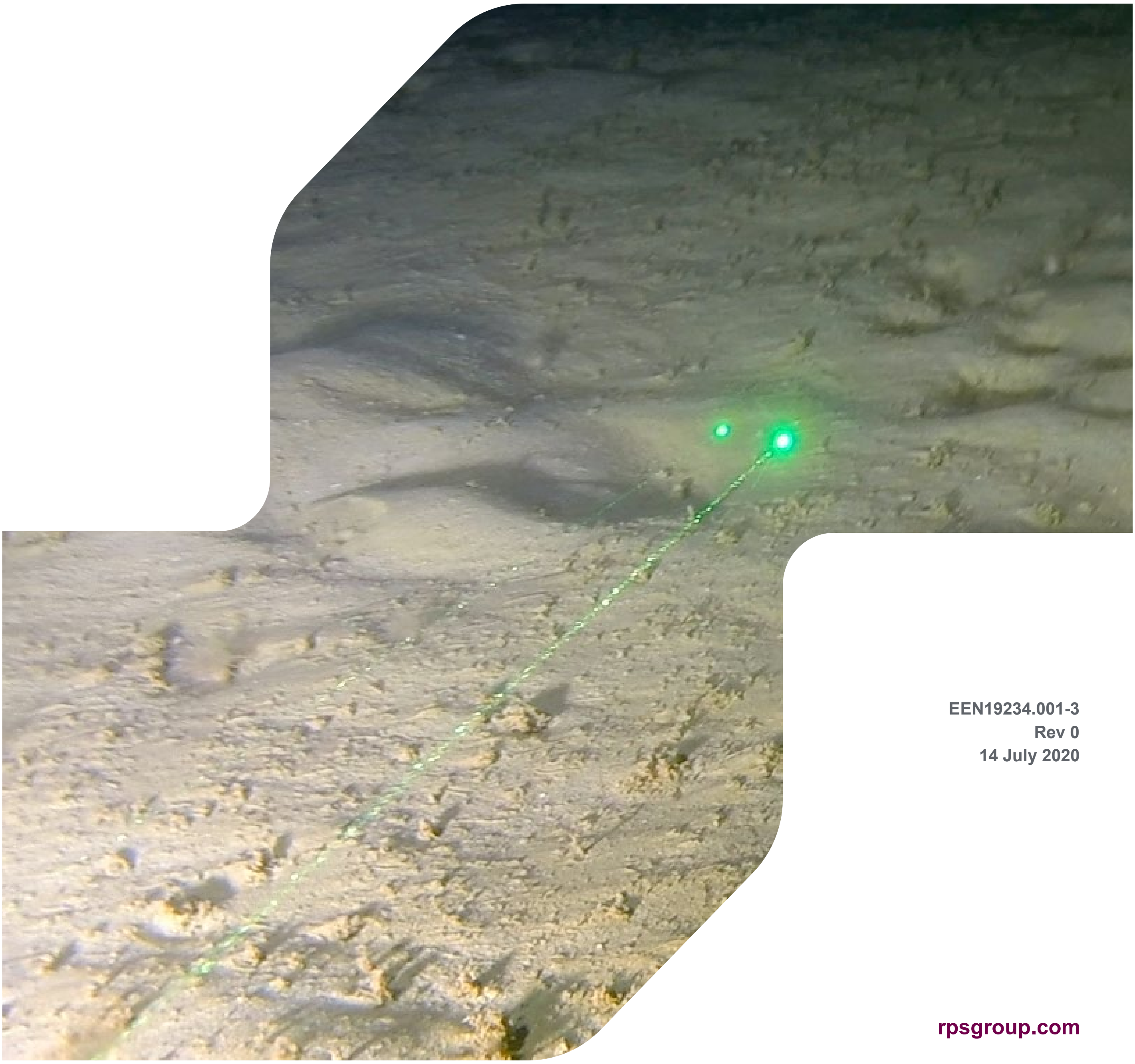
ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
24396	Nelson Point Fuel Facility 07-01	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Midden / Scatter	*Registered Knowledge Holder names available from DPL	665718mE 7752984mN Zone 50 [Reliable]	
25665	FI 08-01	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	662501mE 7754667mN Zone 50 [Reliable]	
25666	FI 08-02	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	662312mE 7754039mN Zone 50 [Reliable]	
25667	FI 08-03	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	662410mE 7754195mN Zone 50 [Reliable]	
25669	Insert B/EA01	No	No	No Gender Restrictions	Registered Site	Engraving	*Registered Knowledge Holder names available from DPL	665816mE 7753006mN Zone 50 [Reliable]	
28249	Pretty Pool	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Mythological, Camp	*Registered Knowledge Holder names available from DPL	671070mE 7753036mN Zone 50 [Reliable]	
32041	PIL3381	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Shell	*Registered Knowledge Holder names available from DPL	662125mE 7754659mN Zone 50 [Reliable]	
32447	Gardalargun South	No	No	No Gender Restrictions	Registered Site		*Registered Knowledge Holder names available from DPL	409737mE 8060936mN Zone 51 [Reliable]	
36532	Djarindjin Law Ground	Yes	Yes	Male Access Only	Registered Site	Ceremonial, Mythological	*Registered Knowledge Holder names available from DPL	Not available when location is restricted	

Attachment 2 Benthic Habitat Survey

BENTHIC HABITAT SURVEY REPORT

Dorado development ROV survey, December 2019



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Approval for issue

J. Fitzpatrick	[signature]	14 July 2020

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Prepared by:

RPS

Garnet Hooper PhD
Principal Marine Scientist

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
E garnet.hooper@rpsgroup.com.au

Prepared for:

Santos WA Energy Ltd

Sonja Mavrick
HSE Team Lead Dorado Development

Level 7, 100 St Georges Terrace
Perth WA 6000

T +61 8 6218 7100
E sonja.mavrick@santos.com

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ABBREVIATIONS AND TERMS

Abbreviation/term	Definition
Ancient coastline KEF	Ancient coastline at 125 m depth contour Key Ecological Feature
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FPSO	Floating production storage and offloading vessel
ROV	Remotely operated vehicle
Tappity	Habitat characterisation software and hardware designed by CSIRO
USBL	Ultra-short baseline positioning system
WHP	Wellhead platform

EXECUTIVE SUMMARY

Santos is planning the Dorado development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 130 km north of Port Hedland. The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority.

The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project and this assessment requires an understanding of the status of the receiving environment. Santos identified uncertainty in the status of the marine environment in the vicinity of the development and commissioned ecological studies to provide environmental data to support appropriate assessment. A key component of the marine environmental characterisation studies was a benthic habitat survey.

RPS was commissioned to conduct a benthic habitat survey at the Dorado Project location between 18 and 22 December 2019. The objective of the study was to characterise existing benthic habitats and communities in the area.

Remotely operated vehicle (ROV) surveys were conducted to characterise benthic communities and habitats, and sediment grab sampling was conducted to describe infauna across the Survey Area. The survey revealed predominantly soft sediment habitats, with low sand waves and scattered rocky reef. The sediment habitats support low abundance of infauna and epifauna, and the rocky substrates support low to medium density filter-feeder communities and other fauna including fish at low densities. Infaunal taxa were characteristic of the sediments recorded at the sample sites (RPS 2020), and indicated where epibiota (e.g. hydroids, bryozoans and sponges) and consolidated/hard substrate may also be present. No high conservation significant ecological values, habitats, communities or species were identified. The benthic communities and habitats within the Dorado Survey Area are considered to be well represented in the local area and region.

1 INTRODUCTION

1.1 Background

Santos is planning the Dorado Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia, approximately 130 km north of Port Hedland. The Dorado Project will target the Dorado field, with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading (FPSO) facility. There is also potential for future development of surrounding fields within the Dorado Survey Area (Survey Area). Given some uncertainty in the precise location of seabed disturbing activities within the Survey Area, Santos has taken the approach of describing broad habitat types and associated communities such that development in any part of other Survey Area can be assessed accordingly when the locations are better defined.

The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority. The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk. The purpose of this study is to characterise existing benthic habitats within the survey area to assess potential impacts to benthic communities and habitats under the NOPSEMA regulatory requirements.

CSIRO has been assisting Santos in characterising regional-scale ecotypes (habitat types) that occur in the Survey Area, based on extensive data from the region over decades of offshore research (Keesing et al. 2020). From this work, Santos identified the need for a survey of benthic habitats, and macrofaunal and infaunal communities within the Survey Area. RPS was engaged to conduct benthic habitat surveys to feed into re-analysis of CSIRO's ecotype model for the area and to inform the OPP. The field survey was conducted in December 2019 and the outcomes of the survey and subsequent analyses are described herein.

1.2 Rationale

Seabed infrastructure will include elements of the WHP, FPSO, flowlines, drilling and cuttings discharges etc; however, facility and field layout are not finalised. Information on the benthic habitats and communities within the Dorado Survey Area is required to inform the assessment of environmental impacts and risks in the Dorado Development OPP. The benthic habitat survey reported herein was designed to characterise survey benthic habitats and communities to fulfill this requirement. The spatial extent of the survey extends well beyond the areas of the seabed that may be directly disturbed by Dorado Project activities and includes environmental features of interest, such as the Ancient Coastline at 125 m depth contour Key Ecological Feature ('Ancient coastline KEF'). The information collected was also used to inform revision of modelling of 'ecotypes' within the Dorado Survey Area (Keesing et al 2020).

The benthic habitat survey was designed by CSIRO, RPS and Santos to target the likely development locations (area encompassing nominal WHP and FPSO locations) and to representatively survey the range of habitat and community types in the Survey Area. Survey design focussed on representative ROV deployments within the five ecotypes identified by CSIRO in preliminary modelling, which lie within the Survey Area.

1.3 Objectives

- To characterise the benthic habitats, macrofaunal communities and infauna communities within the Survey Area, with a focus on sites and habitats that may be impacted by the Dorado Project.
- Describe the distribution of benthic habitats and communities in the Survey Area to support subsequent impact assessment.
- Assess the ecological value of the benthic habitats and communities and the likely representation in the broader region.

2 METHODS

2.1 Survey team

2.1.1 Marine ecology

The field team was led by suitably qualified and experienced RPS marine scientists who ensured that the remotely operated vehicle (ROV) transects were flown according to the survey plan, while recording live habitat and community data using CSIRO's Tappity benthic characterisation system (further detail on this system is described below).

A separate RPS team of marine scientists undertaking sediment and water quality sampling for the Dorado Project (covered in separate reports) conducted the benthic infauna sampling presented herein.

2.1.2 CSIRO collaboration

Santos engaged CSIRO directly to provide the habitat and community characterisation and assemblages described in Keesing (2020). CSIRO researchers provided the ecotype model outputs and used computer algorithms to generate representative survey sites, from which the final transect locations were selected (Figure 2-1). The site selection process aimed to representatively sample the environmental variability in the region, according to the importance of each environmental variable in the analyses undertaken to date. The CSIRO analyses included ecotype modelling based on historic datasets from the region comprising data on a variety of biotic and abiotic parameters.

CSIRO has reported on the re-analysis of the ecotype data incorporating the findings from the current study in a separate report (Keesing et al. 2020).

2.1.3 ROV operation

The ROV was operated by Intervention Engineering, under the direction of the RPS party chief. The ROV position was recorded throughout each deployment, using an ultra-short baseline (USBL) acoustic positioning system. The USBL transceiver was mounted and deployed via the survey vessel's moon pool.

A clump weight was attached to the end of the winch cable. The ROV tether was attached above the clump weight, leaving around 50 m of tether between the ROV and the clump weight. This configuration allows the ROV free range of movement around the clump weight, but also takes the drag of the cable between the clump weight and the surface off the ROV, mitigating impact to speed and manoeuvrability. This approach has the added benefit of removing vertical drag on the ROV potentially caused by the movement of the surface vessel over waves, resulting in much smoother video imagery.

2.2 Survey vessels

The survey vessel MV Warrego was supplied and operated by Gun Marine Services in Exmouth.

The vessel largely drifted along the transect lines to avoid pulling the ROV and clump weight too fast (i.e. >1.5 knots). The vessel master was able to estimate drift direction and speed and run the drift transects across the nominated survey sites.

Benthic infauna sampling was conducted from a separate vessel, the Jetwave Maddison.

2.3 Timing

Benthic video surveys were undertaken from 18 to 22 December 2019. Infauna sampling was undertaken at night, from 16 to 19 December 2019.

2.4 Quality control

All field surveys were conducted in accordance with the agreed Sampling Analysis and Quality Plan (SAQP) for the survey (RPS 2019). The SAQP was approved by Santos prior to mobilisation and covered the planned survey methods, sites schedule, data handling. The key elements for survey quality control relate to sample and data integrity.

2.4.1 Time synchronisation

Given the multiple data streams were recorded concurrently, it was important that the clocks associated with the various components of the video receiving, overlay, recording and analytical systems were synchronised during or after the survey.

Equipment connected to a GPS was synchronised to the GPS satellite time code; other devices without GPS were synchronised to the satellite time.

2.4.2 Data stream management

The ROV technicians recorded the video and positional data streams from the vessel bridge and navigation systems and saved them directly to a hard drive. The data were displayed as a live stream on a monitor during transects to show they were being received, and for quantitative analysis (using Tappity).

2.4.3 Data transport

All data were backed up to a hard drive and back-up drives daily to prevent data loss while at sea and during transport to the office.

2.4.4 Habitat and biota classification

To ensure consistency between RPS' classifications of seabed types and communities during the survey with CSIRO's broader survey database, RPS' personnel reviewed and conducted the survey in accordance with the CSIRO field guide - "CSIRO tow video real-time ("Tappity") data recording guide to substrate and biohabitat categories". This provided lists of habitat and biota categories and example photographs of each category.

2.4.5 Post-survey data checks

On return to the office and prior to analysis, the data were checked by CSIRO and any necessary time code adjustments were made. Random checks of biota identifications were run by CSIRO and the dataset declared suitable for analysis.

All transect start, middle and end points were transcribed from the videos and QA/QC checked against the Survey Area plot to confirm the tabulated coordinates were correct.

2.5 Sample collection

2.5.1 Benthic video transects

2.5.1.1 Transect locations

CSIRO developed a list of sampling sites based on their preliminary habitat model, drawing on extensive regional datasets on a range of bio-physico-chemical parameters. The CSIRO approach to ecotype characterisation is described in its separate report (Keesing et al. 2020). Importantly, the ecotype characterisation presented in the CSIRO report will differ to some degree from that presented in Figure 2-1 because their report will use the findings of this study to further refine the characteristics and spatial distribution of their ecotypes (Keesing et al. 2020).

The nominal survey sites were selected to represent the range of benthic habitats, including the Ancient coastline KEF, likely to occur in the Survey Area and was based around the ecotypes developed by CSIRO for this area (Figure 2-1; see Keesing et al. 2020). At least five transects were completed within each of the five main ecotypes that were well represented in the Survey Area (ecotypes 1 to 5); ecotype six was excluded because there is minimal overlap with the Survey Area. The water depths of the sites at which benthic habitats were surveyed ranged from 75 m to 138 m. Thirty-nine sites were surveyed within the Survey Area boundary (Figure 2-2).

CSIRO’s pre-defined target site coordinates were entered into the navigation software on the vessel with a 250 m radius circle drawn around each site. The vessel was allowed to drift across the survey circle and the ROV followed adjacent the drifting vessel. The ROV transects were approximately 500 m long with the centre point of the transect close to the nominal site location. The actual survey transect sites surveyed are shown in Figure 2-2; the three points at each site represent the start, middle and end points of each 500 m transect. These coordinates are listed in Appendix A.

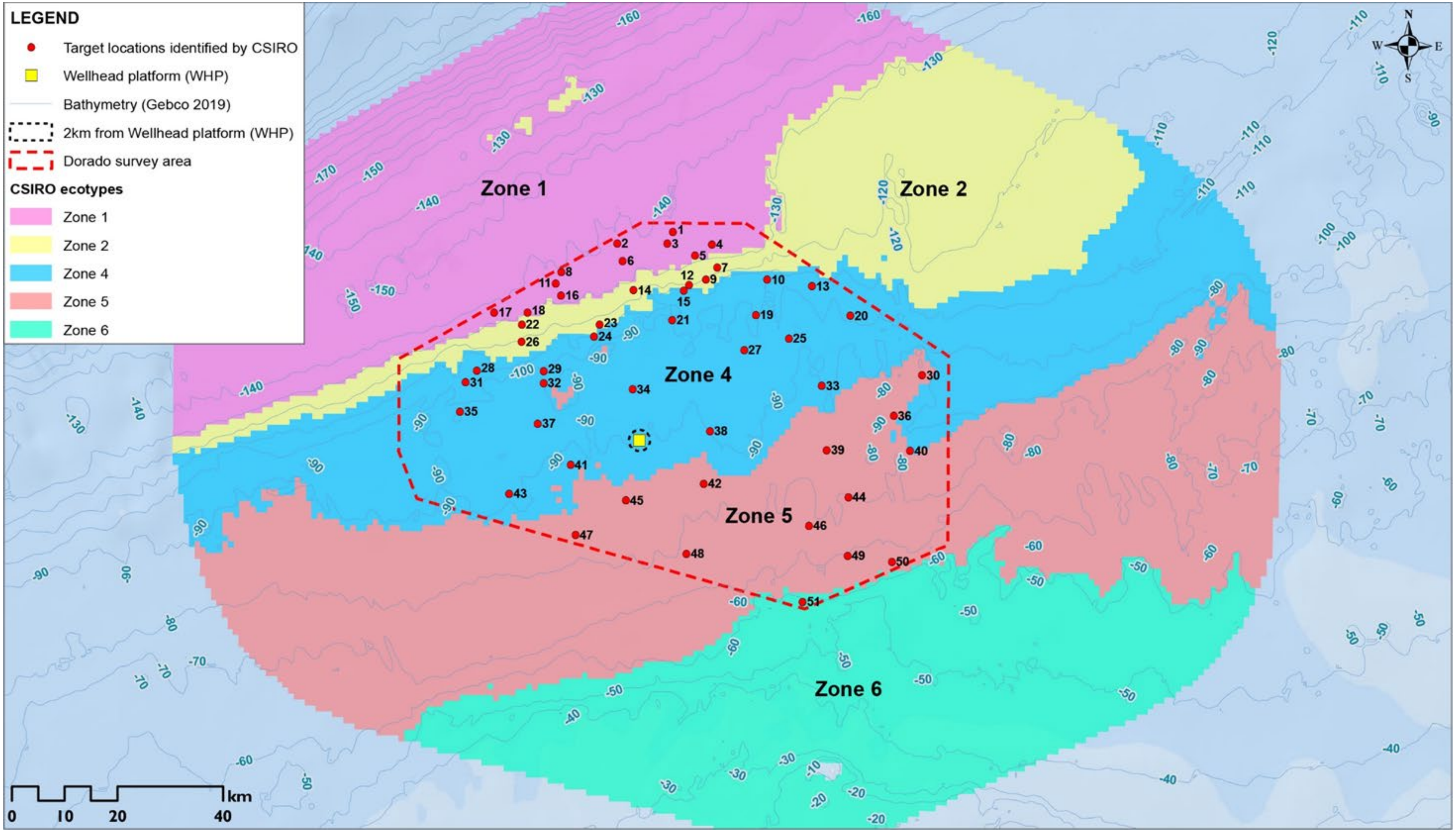


Figure 2-1: Nominal ecotype zones and sampling sites from CSIRO

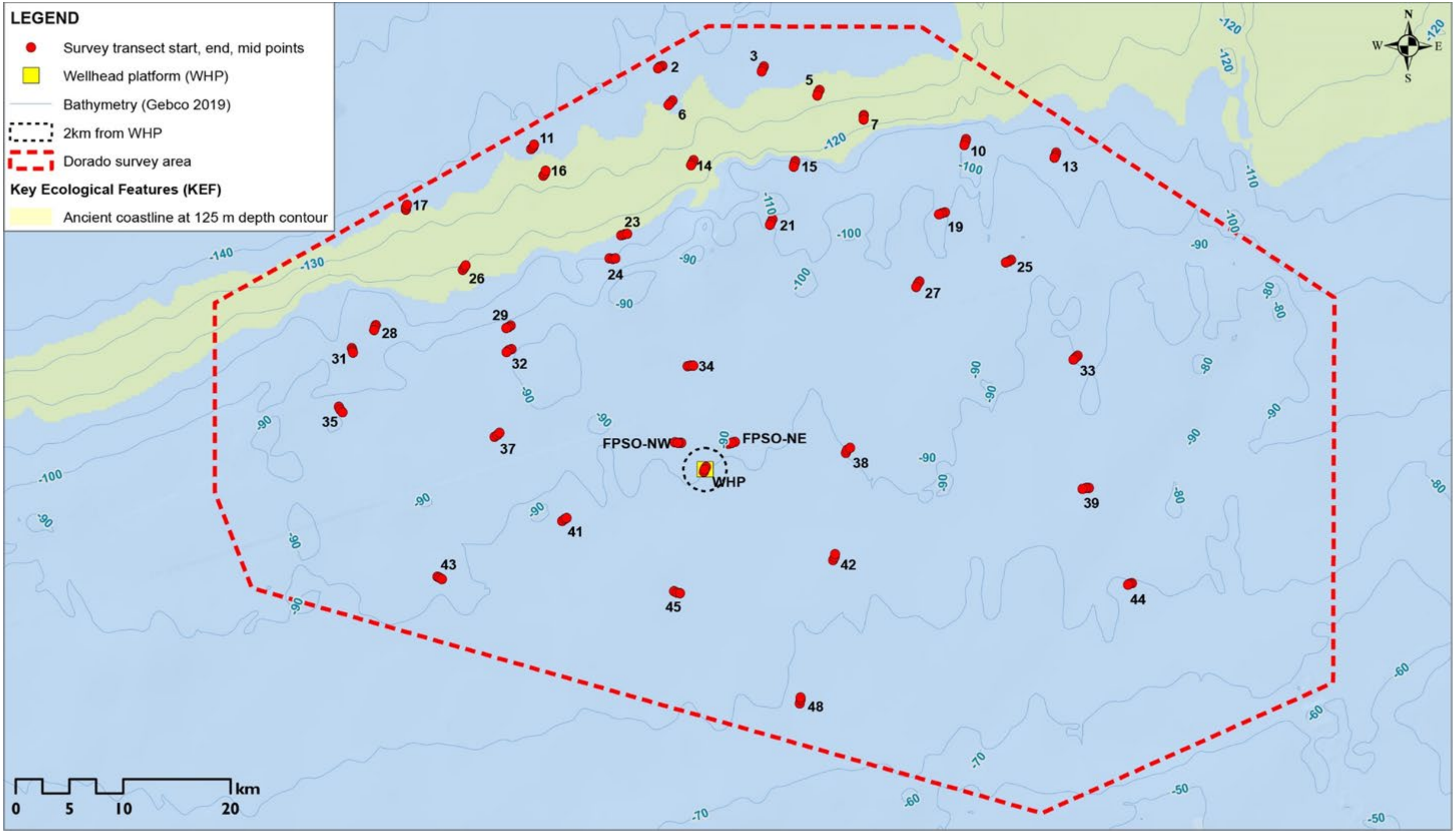


Figure 2-2: ROV benthic habitat and community transect locations

2.5.1.2 ROV survey

The ROV had on-board standard definition and a high definition, colour, zoom-capable video camera, lights, and paired, parallel lasers set 5 cm apart. A clump weight was lowered from the vessel to provide additional stability to the ROV during surveys by buffering vessel and sea surface movements. This allowed the ROV to fly at a constant height above the seabed of approximately 0.5 - 1 m and the cameras were set to face forward, to capture oblique imagery of the seabed suitable for qualitative habitat descriptions.

The vessel position was taken from the vessel GPS (using the geographic coordinate system WGS 1984) and the vessel's progress along the transect was monitored and recorded using a second GPS with external aerial on the bridge roof.

An USBL system was used to calculate the positional offset between the ROV and the vessel. This positional offset was then used to correct the positional overlays on the video image and in the survey software.

Seabed imagery was recorded to hard drive with overlays of USBL-corrected position, depth of vehicle, ROV heading along transect, time and date and site number. Positional data were also backed up to the hard drives at the end of every working day. Other data were collected to facilitate further analyses by CSIRO if required (e.g. ROV pitch and roll). The green laser points on the imagery are 5cm apart and provide scale for estimating the size of features and biota.

2.5.1.3 CSIRO Tappity software

During every ROV deployment, CSIRO's proprietary "Tappity" habitat characterisation software and hardware were used to record data on benthic substrates, habitats and biota. The data included a time code and positional code to allow its use in CSIRO's ecotype modelling. This analysis is not included in the current report but is reported separately by Keesing et al. (2020).

2.5.2 Infauna sampling

Infauna sampling was required to support characterisation of benthic habitats.

2.5.2.1 Infauna sampling sites

Infauna sampling was conducted on a separate vessel to the ROV survey (the Jetwave Maddison). Infauna sampling was undertaken as part of the sediment sampling scope as both aspects required the same sampling equipment (section 3.5.2.2). The results of infauna sampling are presented in this report and the results from the sediment sampling program are presented in Dorado Sediment Quality Survey Report (RPS, 2020).

Infaunal samples were successfully retrieved from five sites across the Survey Area (Figure 2-3). Insufficient sediment for infaunal analysis was collected from the other ten sediment sampling sites after five attempts; these are marked as "none" in Figure 2-3. Review of unsuccessful samples and the vessel sounder indicated that the substrates were likely hard within thin veneers of sediment, or highly compact sediments. Only scrapings were collected, which indicated that the grab had closed at the seabed, but did not collect sufficient sediment to meet the minimum quality control criteria for an infauna sample.

The Dorado Sediment Quality Survey Report (RPS 2020) provides further detail on the characteristics of sediments in the Survey Area.

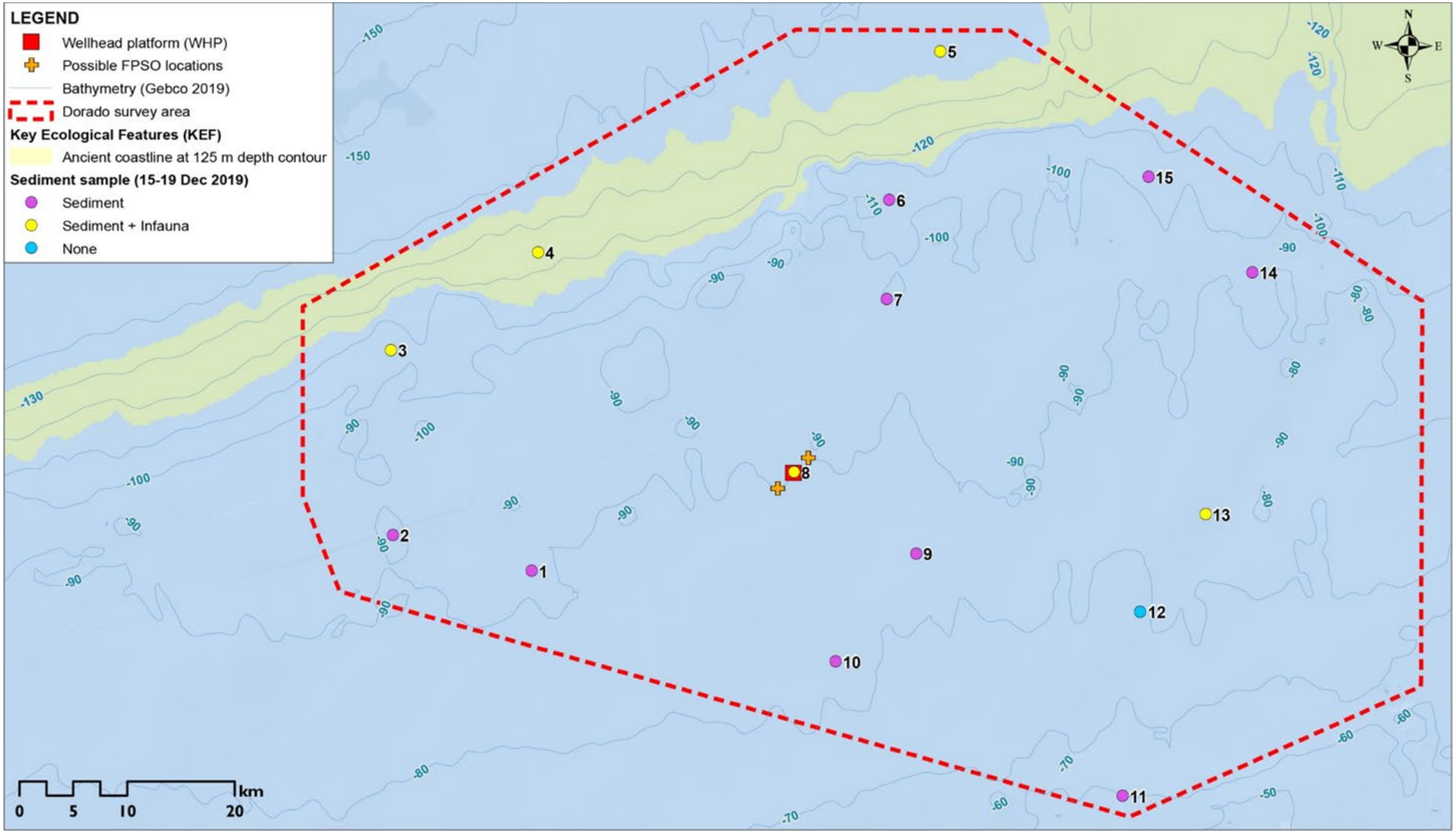


Figure 2-3: Sediment and infauna sampling sites

2.5.2.2 Infauna sampling

A 0.25 m^2 van Veen grab sampler was deployed from the stern of the survey vessel (Jetwave Maddison) using an A-frame (Plate 2-1), and lowered to the seabed at a rate of approximately 30 m per minute. A GPS position, time and water depth were recorded every time the grab hit the seabed. The grab was then recovered to the deck and lowered onto a pre-washed rubber mat.

The whole sample was removed from the grab onto the rubber mat and then sieved using a 1 mm mesh box sieve. Observations of the sample, including description of the sediment type and any conspicuous biota, were documented (see RPS 2020). The sediment and biota retained on the sieve were concentrated into one corner of the sieve and washed into a labelled sample bag with minimal sea water. To preserve the sample, 100% ethanol was added to the sample: diluting to a total concentration of approximately 80% ethanol in the seawater retained in the sample. The labelled sample bag was sealed, double-bagged, and transferred to a secure container for storage and transport.

The samples were transported to the Benthic Australia laboratory for sorting and taxonomic identification.

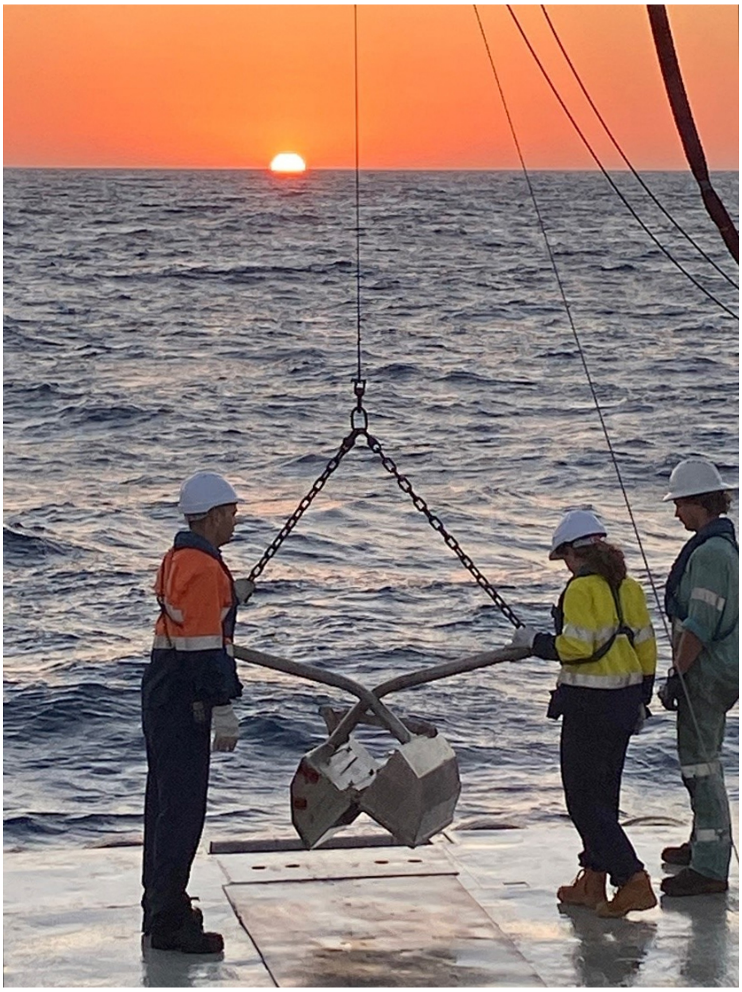


Plate 2-1: Deployment of van Veen grab sampler

2.6 Data analysis

2.6.1 Benthic habitats and macrofaunal communities

Benthic habitats were described by an experienced marine biologist during each transect, as described below. The high-level description of benthic habitats included water depth (ROV depth), seabed relief, substrate type and biotic habitats and epibiota (Appendix B).

Still images were extracted from the high resolution video imagery and used in descriptions of the main benthic habitats of the Survey Area.

2.6.2 Infauna identification

Infauna were picked from the sediment retained on the sieves by Benthic Australia. They were then analysed to the lowest practicable taxonomic level, with the abundance of each taxa recorded from each sample. A reference collection was prepared and provided to the Western Australian museum for curation.

2.7 Tappity habitat and biota classifications

The recording of bio-physical characteristics and densities of the benthic habitats and communities was largely based on the categorisation of Tappity because this was the primary data recording process during the survey. Other notes were also taken to provide more general habitat and biotic descriptions.

CSIRO's habitat classification scheme was followed when entering data on seabed habitat and biota types into the Tappity software. The Tappity classification scheme comprised pre-defined substrate and biohabitat descriptors, as listed below.

2.7.1 Substrate descriptors

- Soft mud
- Silt (sandy mud)
- Sand
- Coarse sand
- Sand waves/dunes
- Rubble (0.5 – 5 cm)
- Stones (5 – 25 cm)
- Rocks (>25 cm)
- Low relief reef
- High relief reef.

2.7.2 Biohabitat descriptors

- No biohabitat (no visible biological presence)
- Bioturbated sediment
- Tube polychaete beds (used by RPS in this case to capture the "biogenic turf"[1] commonly occurring in the Survey Area)
- Alcyonarians - dense
- Alcyonarians - medium
- Alcyonarians - sparse
- Bryozoans - dense
- Bryozoans - medium
- Bryozoans - sparse
- Seawhip garden - dense

[1] The specific composition of the biogenic turf could not be determined from the ROV imagery but is likely to comprise hydroids and other cnidarians, polychaete tubes and potentially bryozoans.

- Seawhip garden - medium
- Seawhip garden - sparse
- Gorgonian garden - dense
- Gorgonian garden - medium
- Gorgonian garden - sparse
- Sponge garden - dense
- Sponge garden - medium
- Sponge garden - sparse
- Hard coral garden - dense
- Hard coral garden - medium
- Hard coral garden - sparse
- Macroalgae - dense
- Macroalgae - sparse
- Rhodoliths
- Halimeda
- Caulerpa
- Sargassum.

2.7.3 Biota

- Solitary coral
- Mollusc
- Hydroid
- Crinoid
- Urchin
- Starfish
- Crab
- Holothurian
- Gastropod
- Ascidian
- Anemone
- Sea pen
- Commercial fish.

2.8 Additional descriptors

Hand-written field notes were also collected during the survey as a back-up for the digital dataset and to provide benthic habitat and community descriptions prior to CSIRO’s analyses. This allowed capture of biota and habitats not integrated into the automated Tappity system. These are listed below and used in the benthic habitat and community descriptions in Appendix B.

2.8.1 Seabed relief

- Flat
- Low relief reef
- Medium relief reef
- High relief reef
- Drop-off
- Sand ripples
- Dunes, sand ridges, sand waves.

2.8.2 Substrate type

- Silt
- Silty sand
- Sandy silt
- Sand
- Muddy sediment
- Sediment veneer (thin layer)
- Hard substrate (pavement reef)
- Rubble (<5 cm)
- Boulders (<25 cm).

2.8.3 Biotic habitats and epibiota

- Bare
- Biogenic turf
- Bioturbation
- Alcyonarians (soft corals)
- Sea pens
- Sponges (laminar, cup, branched)
- Sea whips
- Gorgonians (fans, branched)
- Hydroids
- Crinoids
- Others as described e.g. specific fish taxa.

3 RESULTS

3.1 Field observations

Field observations for each survey site are included in Appendix B. Appendix B also includes representative photographs from each site, and where more than one habitat type was observed on a transect, a photograph of each habitat type is included for that site.

The ROV followed the drift of the vessel and submerged clump which means the transect bearing tends to reflect the direction of seabed current in the area. The current directions were noted to change during the day probably due to tidal movements across the shelf.

3.2 Habitats

3.2.1 Soft sediment habitats

There were two main soft sediment habitat types, both of which were extensively represented across the Survey Area. These were:

- Flat, silty sand and silty mud with sparse epibiota dominated by biogenic turf and scattered sea pens, crinoids and anemones, bioturbated by small fish and invertebrates
- Low, probably mobile, sand waves supporting very little epibiota other than occasional sea pens and low density biogenic turf.

Sediments in the deeper offshore areas tended to comprise silty fine sand sediments (Plate 3-1). Over most of the Survey Area, however, the seabed sediments ranged from coarse to silty sand (Plate 3-2, Plate 3-3). A common feature observed across the Survey Area was biogenic turf (likely to comprise small hydroids, bryozoa and potentially worm tubes). In some areas, small sand waves (generally <0.2 m high but up to 0.5 m high) were scattered across the Survey Area (Plate 3-4). At several sites, coarse-sand waves were interspersed with patches of fine silty sediments in a semi-regular pattern of linear sand waves. Sand waves were generally composed of coarser sands, often with small-scale surface ripples (Plate 3-4).

Plate 3-1: Flat silty mud sediment with signs of bioturbation (e.g. fish burrows) and low density of biogenic turf

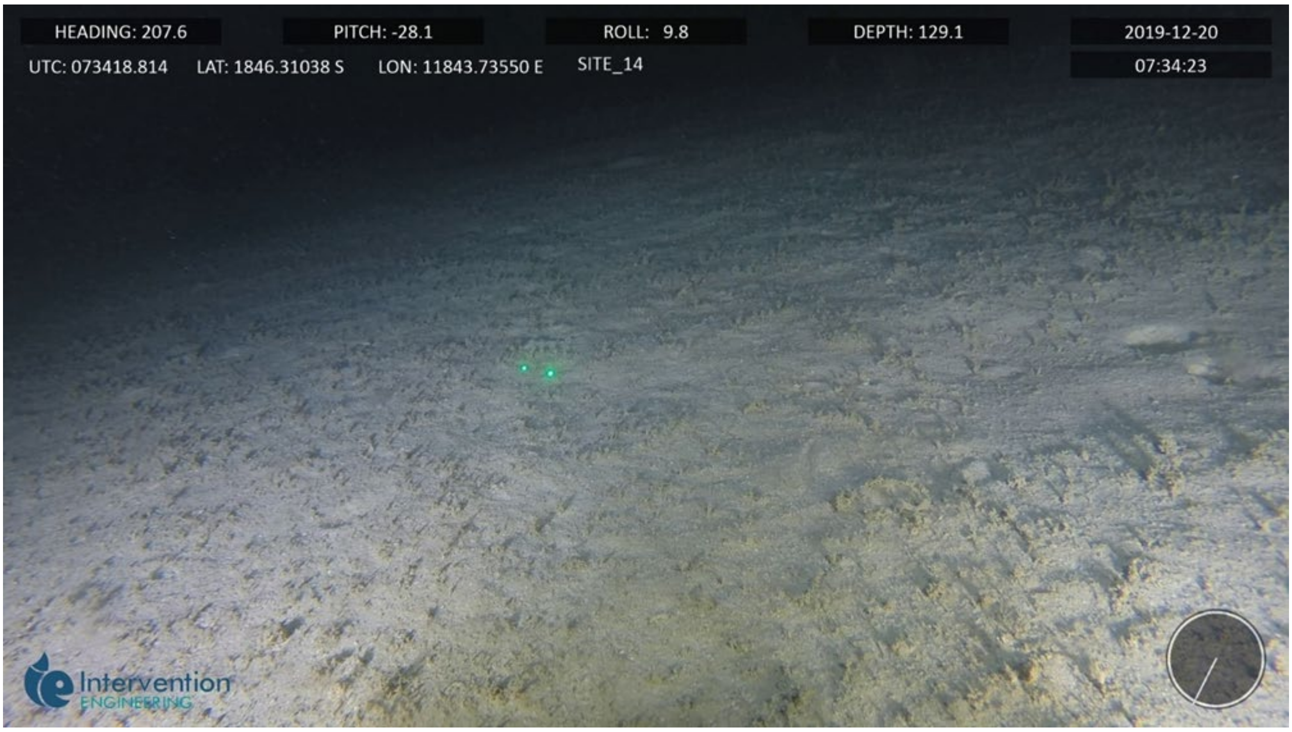


Plate 3-2: Flat, silty sediment with medium density of biogenic turf

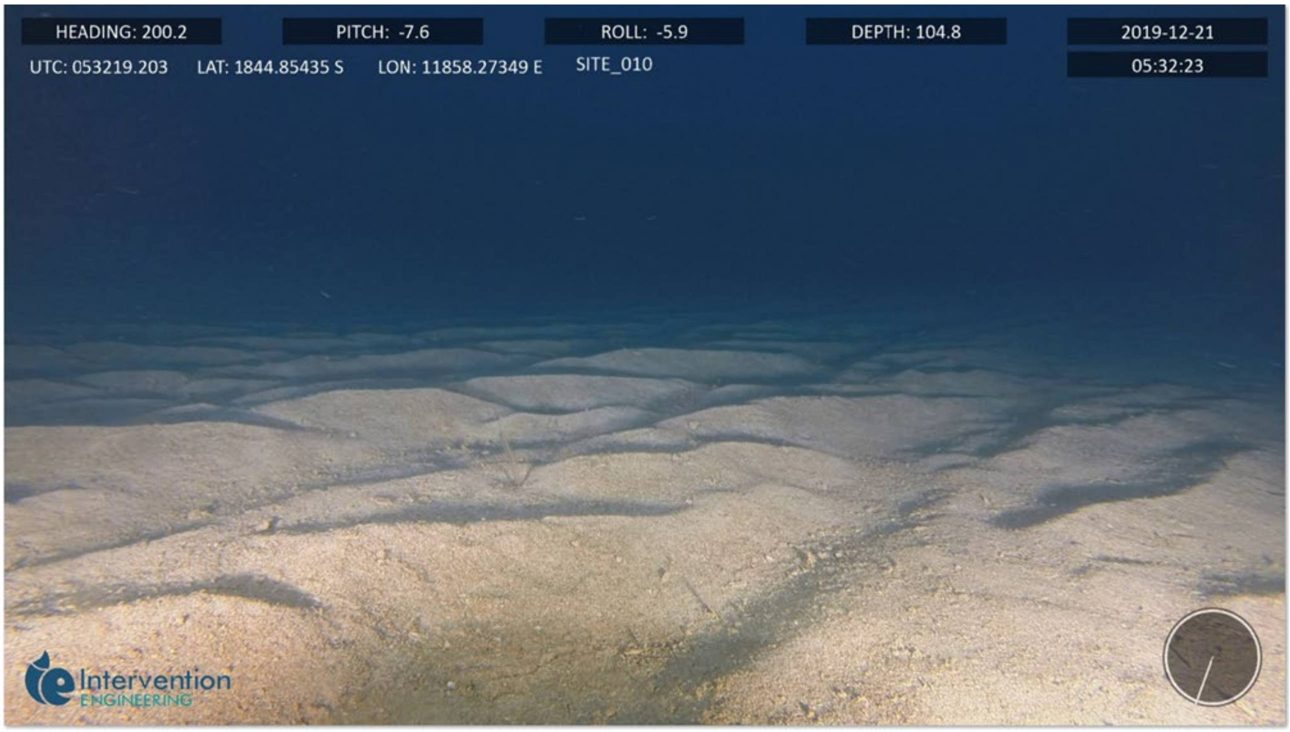


Plate 3-3: Coarse, rippled, flat, sandy sediment with very low density of biogenic turf and epibiota

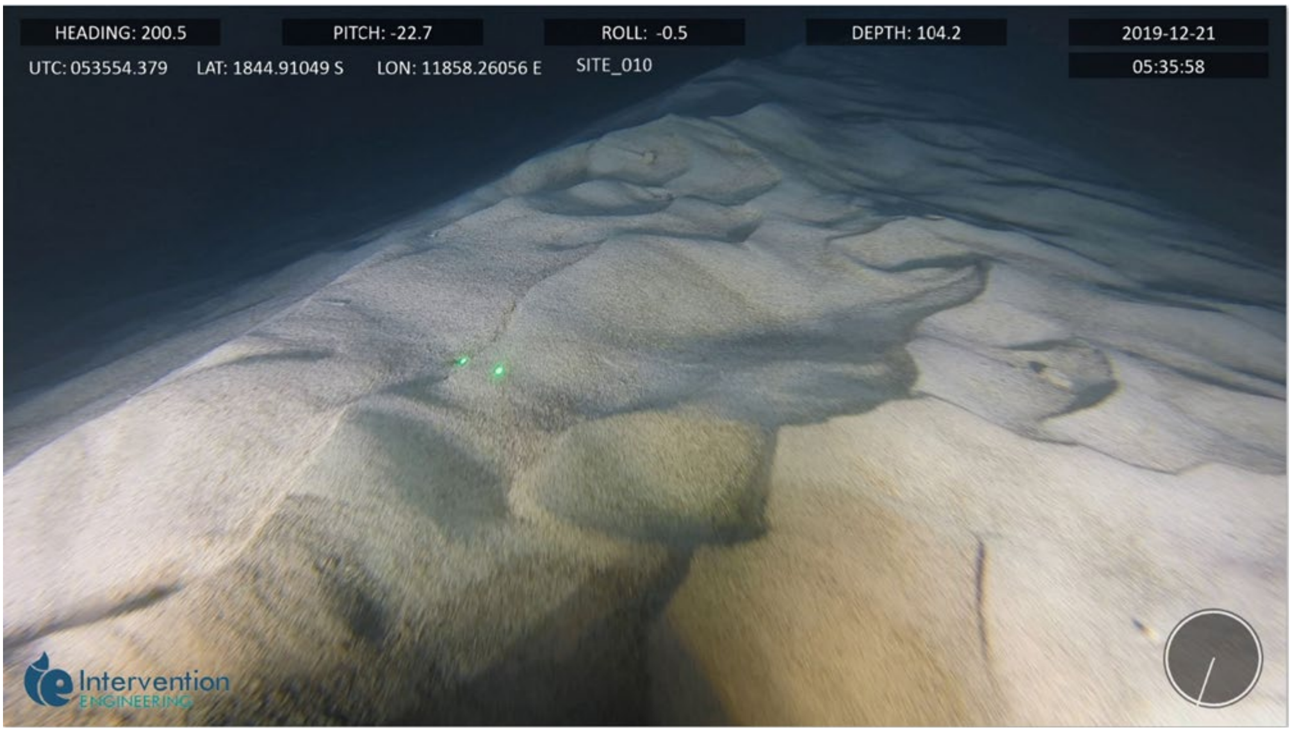


Plate 3-4: Coarse sand wave with surface ripples and very low density of biogenic turf and epibiota

3.2.2 Hard substrates

There were two main hard substrate habitat types, which were patchily distributed across the Survey Area. These were:

- Pavement reef with a veneer of sediment and scattered rubble and small boulders, which support filter-feeding assemblages including gorgonians, alcyonarians, sea whips, hydroids and sponges
- Low rocky ledges and reef substrates supporting abundant fish and generally supporting distinct communities of epibiota; however one of the sites surveyed had low densities of epibiota.

Large areas of seabed appeared to have an underlying pavement (low profile) reef, broken pavement or consolidated hard substrate with a variable thickness veneer of soft sediment on the surface. The presence of organisms which typically attach to hard substrates, for example gorgonians, protruding from the sediment veneer confirmed the presence of the underlying hard material for colonisation (e.g. Plate 3-5).

Another indicator of underlying hard substrate was the presence of scattered and partially buried boulders which were widespread across the Survey Area.

Low to medium relief reef was only observed at Site 25. The low rocky ledges at this site supported an abundant assemblage of mobile fish (*Lutjanus* spp.) and were covered with encrusting biota (e.g. bryozoans) but very sparse larger epibiota on the exposed rock (Plate 3-6, Plate 3-7). This reef was approached from the north-east and as the transect ran across the reef it changed from exposed rocky ledges to buried reef. The low densities of large epibiota suggests the reef is likely to have been recently exposed and is regularly buried and uncovered. The reef to the south-west comprised pavement reef with a thin veneer of sediment and sparse filter-feeding assemblage (Plate 3-8). While this assemblage was sparse it was more developed than the exposed low-medium profile reef to the north-east.

Plate 3-5: Pavement reef with thin veneer of sediment and emergent filter-feeding organisms attached to the rock

Plate 3-6: Low to medium relief reef with low rocky ledges and abundant Lutjanid fish

Plate 3-7: Low to medium relief reef with thin sediment veneer and very sparse epibiota

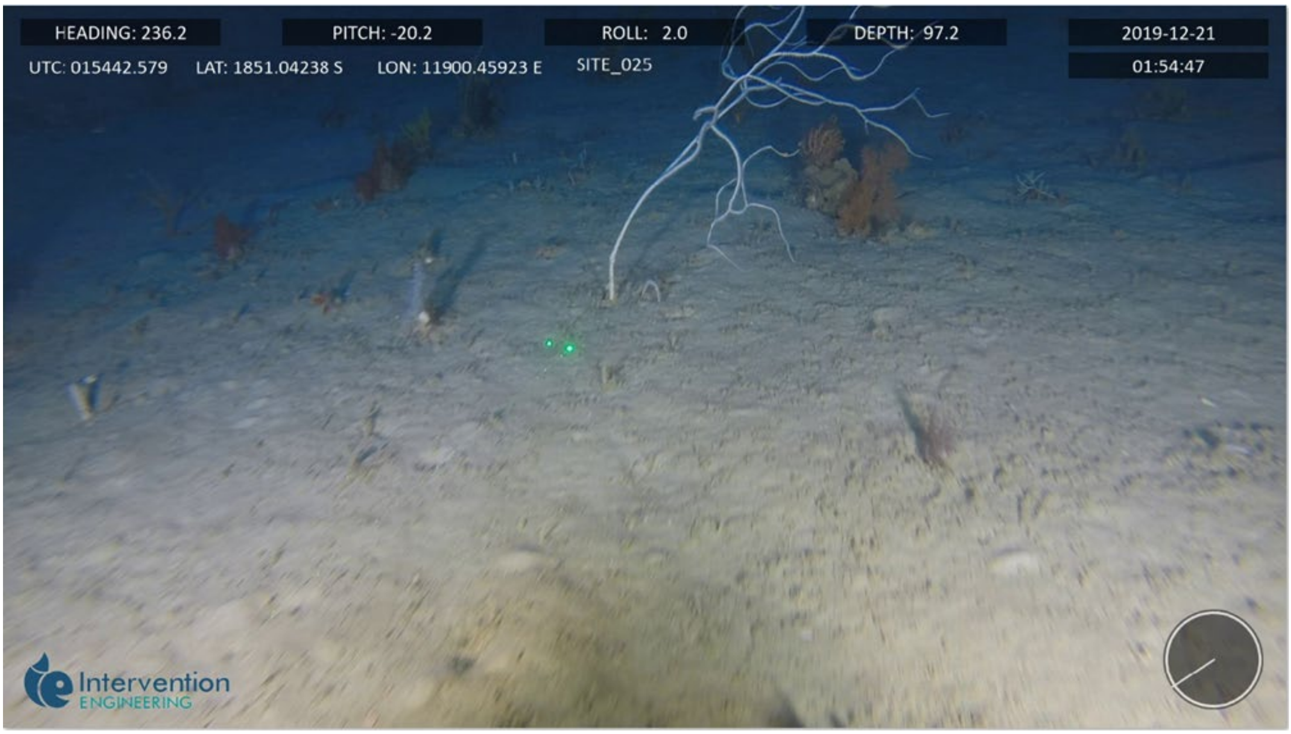


Plate 3-8: Low relief reef with thin sediment veneer and sparse epibiota

3.2.3 CSIRO ecotype model

CSIRO used the ROV survey data collected in this study to update their regional dataset and re-modelled the ecotypes in the area. The boundaries and definitions of the ecotypes varied slightly following this re-assessment, as described by Keesing et al. (2020).

3.3 Infauna

A total of 94 individuals, representing 49 taxa from 4 phyla, were recorded from the five samples collected. The full dataset can be found in Appendix C. Taxonomic nomenclature was checked using the World Register of Marine Species match taxa tool (WoRMS editorial board 2020). This tool provided the current accepted scientific name, the scientific authority, and taxonomic hierarchy for each taxa.

Descriptive statistics of infaunal community data describing the number of species (S), abundance (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Weiner diversity (H') and Simpson's alpha diversity index (1-λ) are presented in Table 3-1. Species richness and abundance were lowest at site 5 (8 individuals from 5 taxa) and greatest at site 8 (39 individuals from 26 taxa). All other metrics were also lowest at site 5 and greatest at site 8, with the exception of Pielou's evenness, where the highest evenness score was recorded at site 4 (J' = 0.983).

Table 3-1: Infaunal community descriptive statistics

Site	S	N	d	J'	H' (log^e)	1-λ
Site 3	18	23	5.422	0.965	2.789	0.972
Site 4	8	9	3.186	0.983	2.043	0.972
Site 5	5	8	1.924	0.861	1.386	0.786
Site 8	26	39	6.824	0.959	3.126	0.974
Site 13	12	15	4.062	0.978	2.431	0.971

Key: S = species richness, N = abundance, d = Margalef's species richness, J' = Pielou's evenness, H' = Shannon-Weiner diversity, 1-λ = Simpson's alpha diversity index.

The infaunal composition analysed at the phylum level is presented in Table 3-2. Annelid worms were the most abundant phylum at sites 3 and 5, whereas arthropods (mainly crustaceans) were most abundant at sites 8 and 13. Both phyla were dominant at site 4. The greatest abundance of echinoderms and molluscs were recorded at site 8. Taxa recorded were representative of a range of trophic levels, from filter feeders, predators/scavengers and omnivores, deposit feeders, and taxa that are able to utilise a number of different feeding strategies to respond to living in harsh environments.

Table 3-2: Infaunal community composition (to phylum level) and abundance at each site

Phylum	Site 3	Site 4	Site 5	Site 8	Site 13
Annelida	11	4	5	9	2
Arthropoda	9	4	3	21	12
Echinodermata	1	0	0	5	0
Mollusca	2	1	0	4	1

The cumulative occurrence of taxa at the five sites provided an indication of the variability between sample sites across the Survey Area. Only one taxon (a representative of the amphipod crustacean family Phoxocephalidae) was recorded from all five sites. This family of amphipods comprises permanent burrowers, predators of a range of vertebrate and invertebrate larvae and juveniles, and inhabits a range of muddy and sandy sediments (Oliver et al. 1982).

A species accumulation curve was generated to estimate whether the five samples collected adequately represented the biodiversity in the Survey Area. The species accumulation curve was generated by recording the total number of taxa for each increasing level of sampling effort (i.e. 1, 2, 3, 4 or 5 grabs), with the order of sites randomised. This process repeated five times to prevent bias. The results were plotted and a trendline fitted to the data (Figure 3-1). The R^2 value indicated that a linear trendline was the best fit with the data, which indicated that:

- Approximately ten new taxa were recorded for each additional grab.
- Five samples were insufficient to identify a reduction in the slope of the accumulation curve.
- The asymptote had not been reached.

This is important information that can be used to inform the planning of any potential future monitoring studies in the Dorado area.

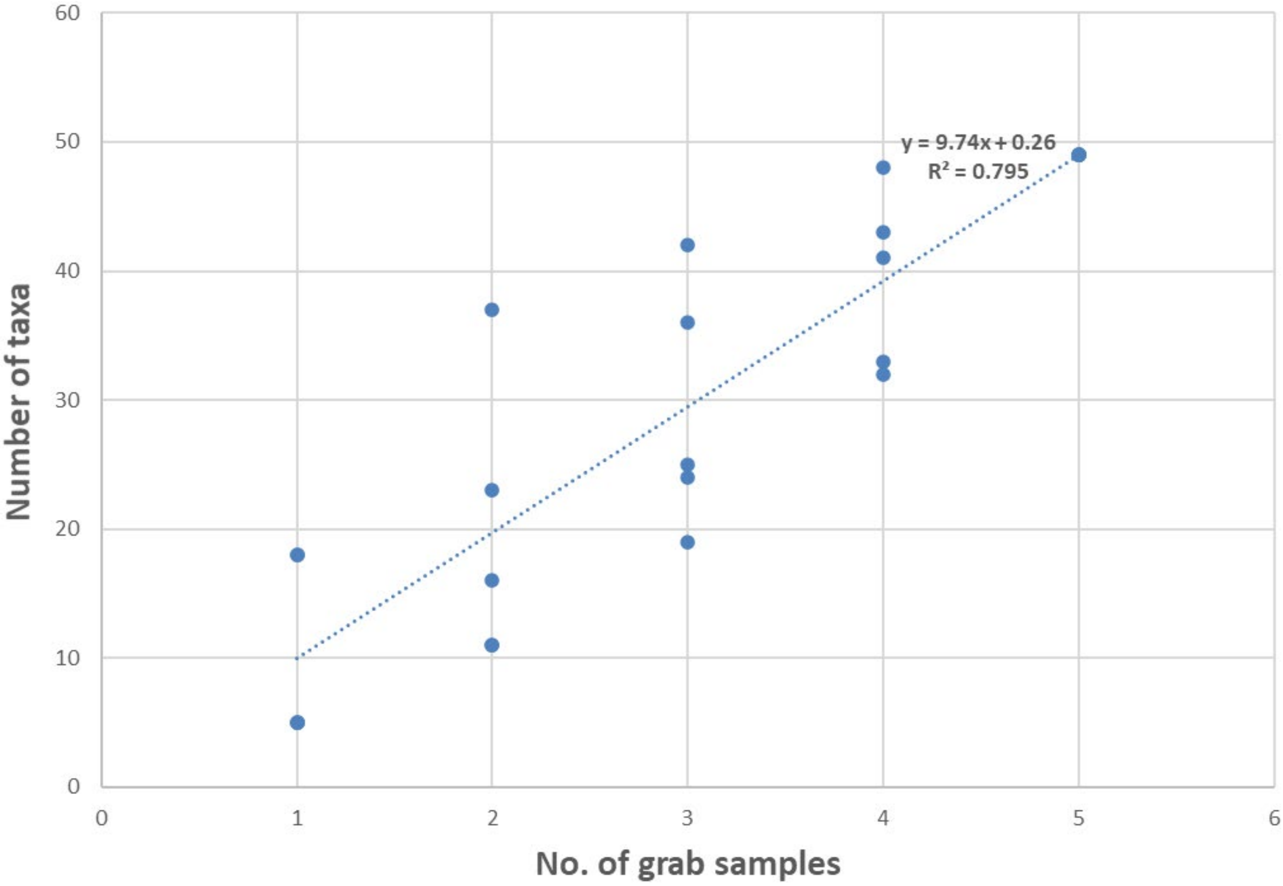


Figure 3-1: Best-fit species accumulation curve, showing R2 value and slope equation

The infaunal communities at each site can be summarised as follows:

- Site 3 (in water depth 98 m BSL; nearest to ROV site 31) was dominated by annelid worms, comprising around half of the total individuals recorded at this site (11 individuals from seven taxa). The arthropods comprised amphipods (Melitidae, *Ampelisca* spp. and Phoxocephalidae), an isopod (Anthuroidea), a mantis shrimp (Squillidae), a tanaid and a cumacean. Molluscs were represented by infaunal bivalves (*Tellina* spp.) and an aplacophoran. A single sea cucumber (Dendrochirotida) represented the echinoderms. Many of these taxa were tube-dwelling or burrowing biota, with most commonly found associated with finer muds and sands. This aligned with the sediment type found at this site, which was very poorly sorted gravelly muddy sand.
- Site 4 (water depth 118 m, nearest ROV site = site 17) was equally represented by arthropods (caprellids, a phoxocephalid amphipod and a goneplacid decapod) and annelids (*Magelona* sp., a sabellid fan worm, a syllid polychaete and *Echiura* sp. (spoon worms)). The molluscs were represented by a single aplacophoran. These taxa are generally characteristic of sands and muds. The sediment type at this site was characterised as poorly sorted, slightly gravelly, muddy sand. The caprellid amphipods also indicate the likely presence of hydroids or bryozoans. Caprellids have adapted to inhabit these epibiota, and their physiology is designed to cling on to and blend in with thin, branching structures. This camouflage is both for protection from predators (such as demersal fish), but also to ambush prey such as smaller crustaceans, small worms and protozoans. Although mainly predatory, caprellids are omnivorous, they also feed on detritus and are capable of filter feeding. Biogenic turf was observed at a range of densities across the Survey Area (e.g. see Section 4.6), and may provide habitat for these cryptic ambush predators.

- Site 5 (water depth 135 m; nearest ROV site = site 3) was found to have the lowest number of species and abundance, and was characterised by two annelid taxa (the spionid polychaete *Prionospio* spp. And catworm *Aglaophalamus* sp.) and three arthropod taxa (Caprellidae, the gammarid amphipod Phoxocephalidae, and the lyssianassid amphipod *Platyschinopus* sp.). These taxa are indicative of sandy habitats, with epibiota such as hydroids or bryozoa present. Particle size analysis identified that the sediment could be characterised as very poorly sorted gravelly muddy sand.
- Site 8 (water depth 85 m; nearest ROV site = wellhead platform site) was the most diverse site sampled, and dominated by arthropods (the amphipods *Ampelisca* sp., Aoridae, Melitidae, Corophiidae and Phoxocephalidae; the isopods Anthuroidea, Sphaeromatidae and Valvifera; Gonodactyloid mantis shrimps; decapod crustaceans represented by brachyurans and Rananidae (frog crabs); and copepods and Leptostracans). The annelid worms comprised *Lumbrineris* spp, spionids such as Prionospio spp., *Glycera* spp., the nephtyd polychaete *Aglaophalamus* spp., the eunicid *Rhamphobrachium* spp., and *Orbinia* spp Echinoid taxa present included infaunal urchins Echinoidea and *Echinocyamus* spp., and the brittlestar *Ophioplax* spp. The molluscs were represented by *Tellina* spp. and *Paphia* spp. (both infaunal bivalves), Mytilidae (mussels) and Skeneidae (small to very small gastropods). As would be expected in poorly sorted gravely sand (see sediment report), the infaunal assemblages were characterised by higher abundances of crustaceans, with several larger and more robust taxa capable of digging into coarser sediments (e.g. frog crabs), infaunal urchins that feed on organic material that accumulates in the pore spaces between the larger grains, and taxa that hunt for prey at and near the sediment surface (e.g. *Aglaophalamus* spp.).
- The infaunal assemblage at Site 13 (water depth 84 m; nearest ROV site = site 39) was dominated by arthropods (the amphipods Phoxocephalidae, Corophiidae, Oedicerotidae and Zobrachoidae; the isopods *Gnathiidae* spp. and Sphaeromatidae, and tanaids), with relatively low representation by annelids (*Glycera* spp. and *Syllidae* spp.) and molluscs (*Barbatia* sp., the bearded ark clam). Although the sediment in the grab samples was characterised as moderately sorted slightly gravelly sand, the taxa indicated that some consolidated or hard substrate is likely to occur in area. For example, Gnathiid isopods are often associated with sponges. Syllid polychaetes are active predators on rock and sandy substrate, hunting in crevices and on epibiota. The bearded ark clam is found at the sediment-water interface, securing itself to consolidated/hard substrate and other epibiota with byssus threads.

3.4 Epifauna

3.4.1 Soft sediment biota

Large expanses of the seabed were characterised by soft sediment habitats supporting low density epibiotic assemblages. In addition to the bioturbation by a range of biota from infaunal tube worms, crustaceans, bivalves and echinoderms, most sedimentary habitats were bioturbated by fish such as gurnards and gobies, to larger fauna, probably fish, which had left large feeding scars on the seabed. Some burrow-dwelling species of fish also adapt their burrow entrances to provide cover from predation. They achieve this by excavating a series of shallow trenches around their burrow in which they can prevent their body being silhouetted above the seabed, whilst being able to observe the sediment surface in the vicinity of their burrows as their eyes are high on their head (e.g. Plate 3-1).

The (visibly) dominant epibiota of the soft sediment habitats included attached or sessile organisms including anemones, sea pens, hydroids, crinoids and sponges, and mobile organisms including sea stars, sea urchins and small fish. Buried or partially-buried fauna including crinoids, sea urchins and molluscs were not reliably detected on the ROV transects. Biogenic turf was present in most areas of soft sediments, with turf densities very low in the more mobile coarse sandy sediments and higher in finer sediments (Plate 3-1, Plate 3-2).

Sand waves tended to support very sparse epibiotic assemblages. Sandy sediments with ripples had fewer signs of bioturbation by infauna, such as holes, burrows, scrapes and tracks.

3.4.2 Hard substrate biota

Exposed hard substrates supported low- to medium-density, filter-feeding assemblages which were generally dominated by small gorgonians, sea whips, soft corals and sponges (Plate 3-9, Plate 3-10). The focus of the survey was on habitat characterisation and areal coverage, so the transects were flown continuously and the ROV did not stop to identify organisms along the way. The identifications were therefore high-level but provide a good indication of the generic types of assemblages that occurred on the hard substrates.

The taxa which could be tentatively identified from the ROV footage included:

- Gorgonian fans (including Acanthogorgiidae, Plexauridaer)
- Soft corals (including Alcyoniidae, Nephtheidae)
- Sea whips (including Ellisellidae)
- Hydroids (including Plumulariidae, Aglaopheniidae)
- Sponges (including Raspailiidae).

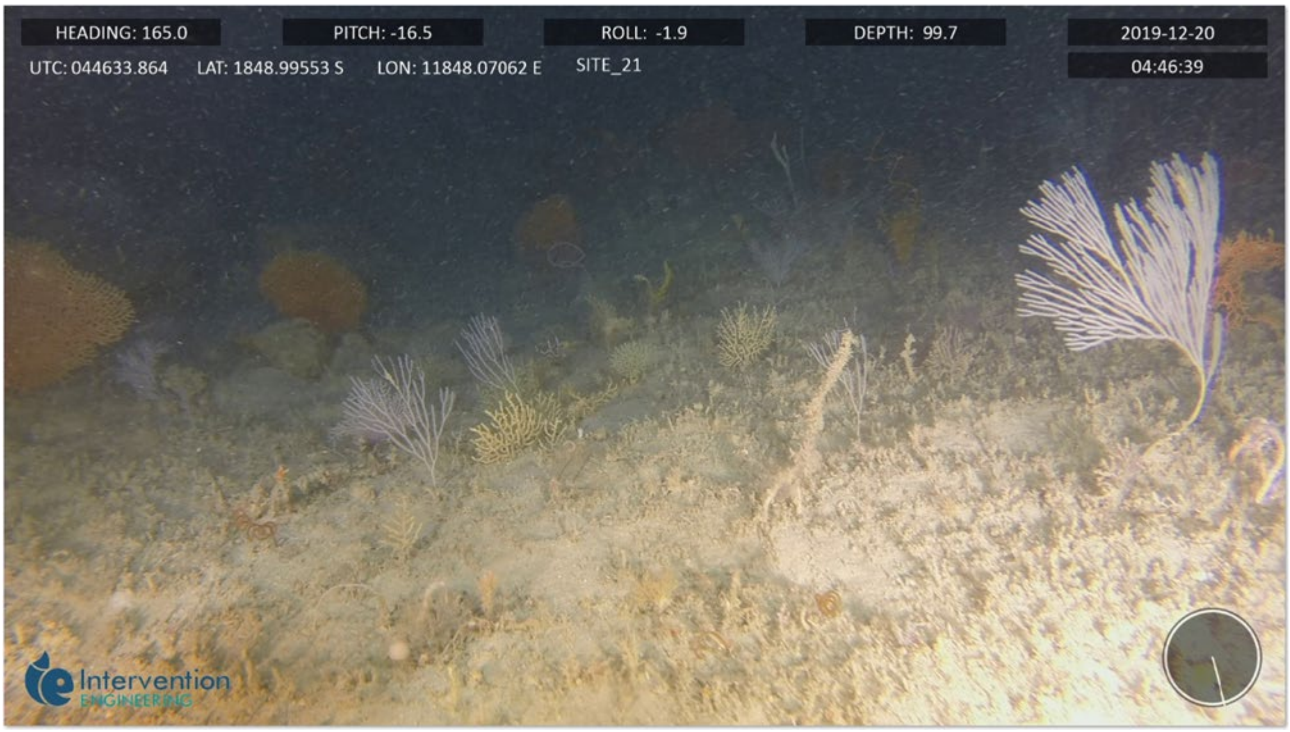


Plate 3-9: Medium-density, gorgonian-dominated, filter-feeding assemblage on pavement reef

Plate 3-10: Medium-density, filter-feeding assemblage of sponges, soft corals, sea whips and gorgonians on pavement reef

3.5 Demersal vertebrate fauna

Large, predatory mobile fish such as trevally were observed occasionally on or near the seabed (Plate 3-11).The ROV sampling technique is not suited to representative sampling of fish assemblages in open water and while some observations were recorded, these data are considered opportunistic sightings rather than community descriptors. The large trevally in Plate 3-11 are regular visitors to the demersal zone in the Survey Area. A recent baited remote underwater video systems survey in the Ancient coastline KEF adjacent to the Dorado Survey Area recorded two different species of trevally (the longnose trevally, *Carangoides chrysophrys*, and the giant trevally, *Caranx ignobilis*) in around half of the 45 deployments, which were commonly among the most abundant species recorded (RPS/UWA 2019).

The lutjanid snappers at Site 25 were aggregated around the reefal structure and tended to remain near the reef when the ROV approached. The shoal of snapper was dominated by brownstripe red snapper, *Lutjanus vitta* (Plate 3-12), but there was a mix of species in the shoal including other lutjanids (Plate 3-13).

Small fish were commonly associated with sediment habitats, where they were typically living on the seabed (e.g. flatfish), burrowing into the sediment (e.g. gurnards - Plate 3-13), or part of the mobile demersal ichthyofauna (e.g. trevally).

Elegant sea snakes (*Hydrophis elegans*) were observed on the seabed during the survey and appeared to be foraging undisturbed (Plate 3-14). They were observed in deep water (with one recorded at 134 m) and may occur across the area as they were commonly observed at the surface by survey personnel. However, they are typically found in shallower water (DAWE 2020).

Plate 3-11: Large trevally in demersal, soft sediment habitat

Plate 3-12: *Lutjanus vitta* school over medium relief reef and sediment habitat at Site 25

Plate 3-13: Demersal finfish from reef - *Lutjanus* sp. (left), *L. vitta* (centre) and sediment – *Dactyloptena* sp. (right)

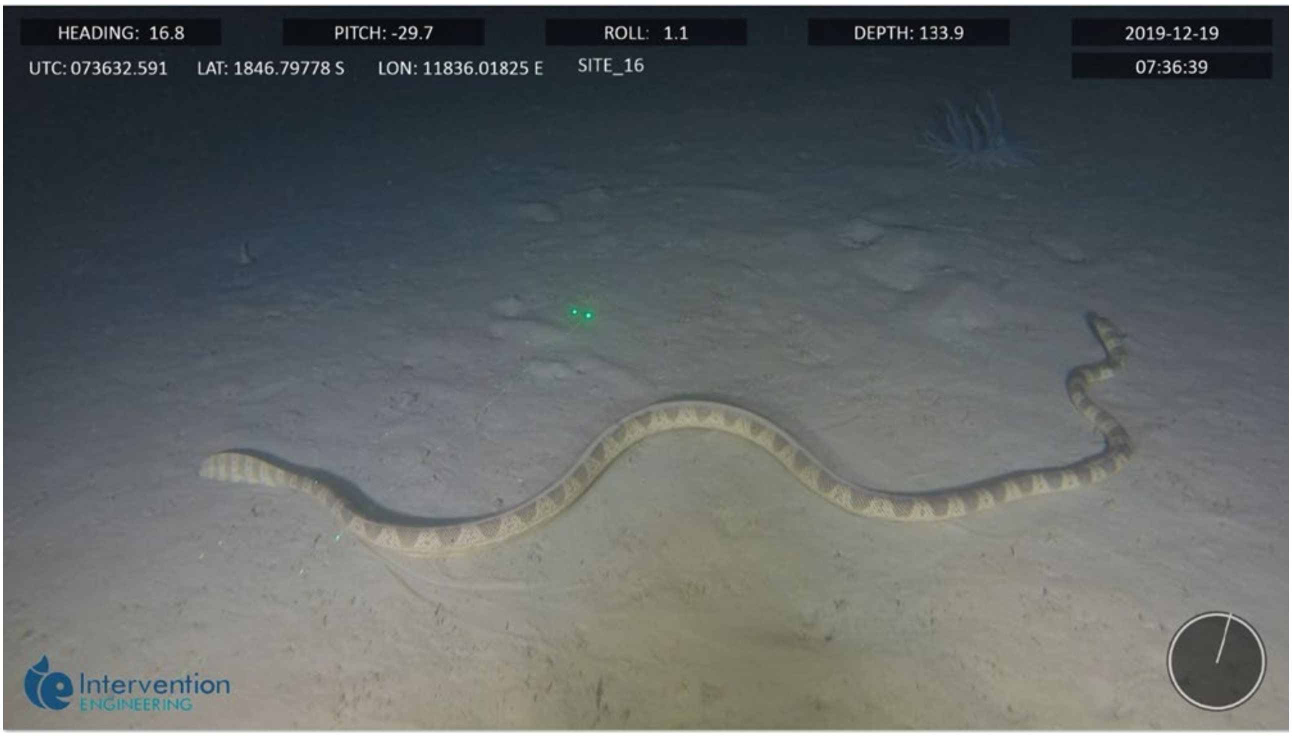


Plate 3-14: Elegant sea snake (*Hydrophis elegans*) in demersal, soft sediment habitat, with a burrowing anemone in the background

3.6 Wellhead platform site

The WHP was surveyed with one 500 m transect running from 250 m south-west of the WHP site, through the site and 250 m to the north-east of the site. The seabed was very flat with a depth difference of less than 0.5 m across the transect (~88.5 m to 89 m). It was characterised by silty sand, with scattered pebbles (<5 cm rocks), very few larger cobbles or boulders and no exposed hard substrate. The silty seabed supported extensive mats of biogenic turf and a very sparse epibiota assemblage, including urchins, larger hydroids, and sea pens. No hard substrate filter-feeder assemblages were observed.

Representative photographs are provided below (Plate 3-15, Plate 3-16, Plate 3-17, Plate 3-18, Plate 3-19).

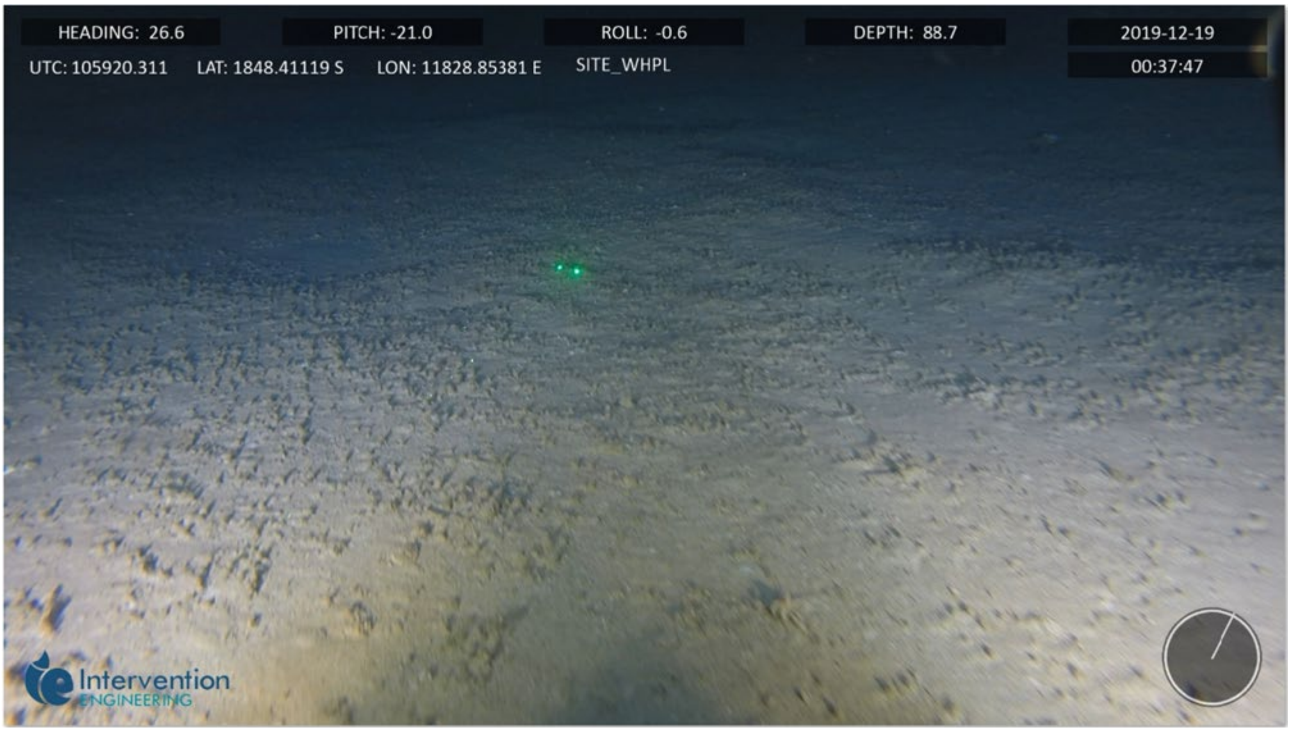


Plate 3-15: Start of transect to south-west of WHP site showing medium density biogenic turf on silty sand sediment habitat

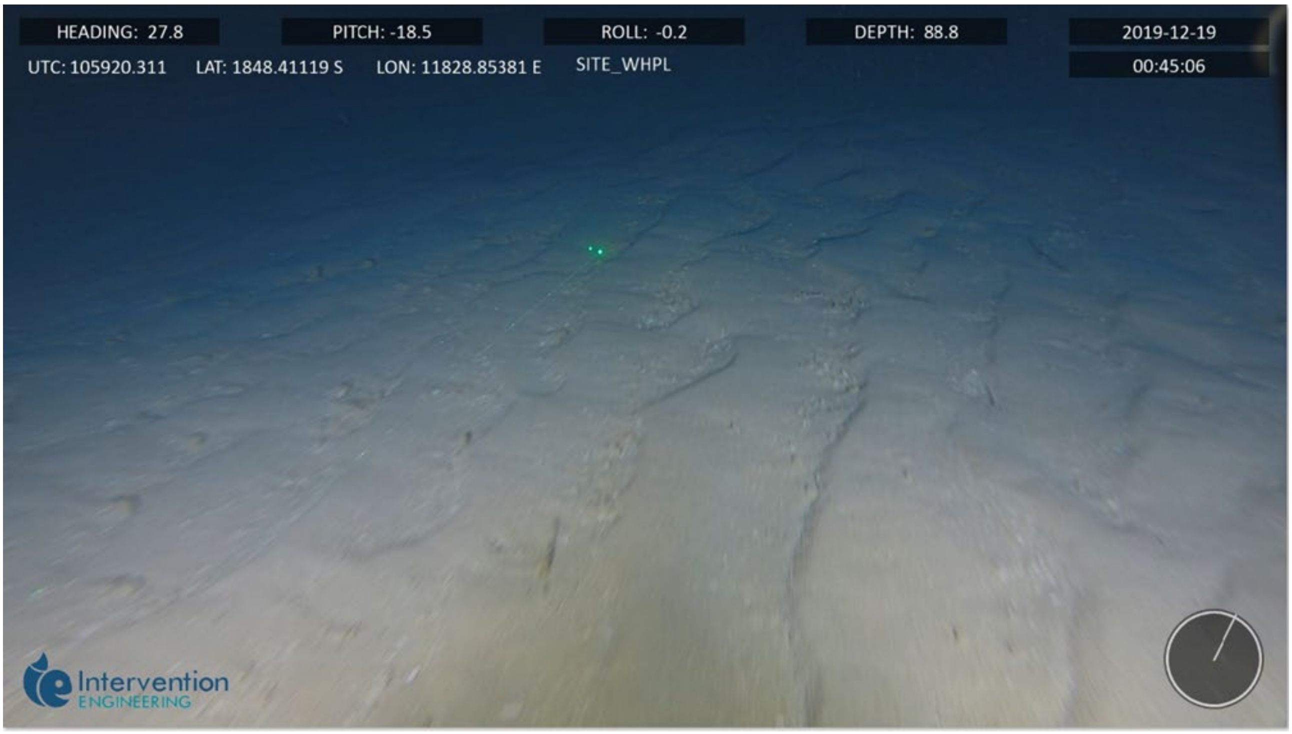


Plate 3-16: Small patch of bare rippled sand and rubble to south-west of WHP site with very low density biogenic turf

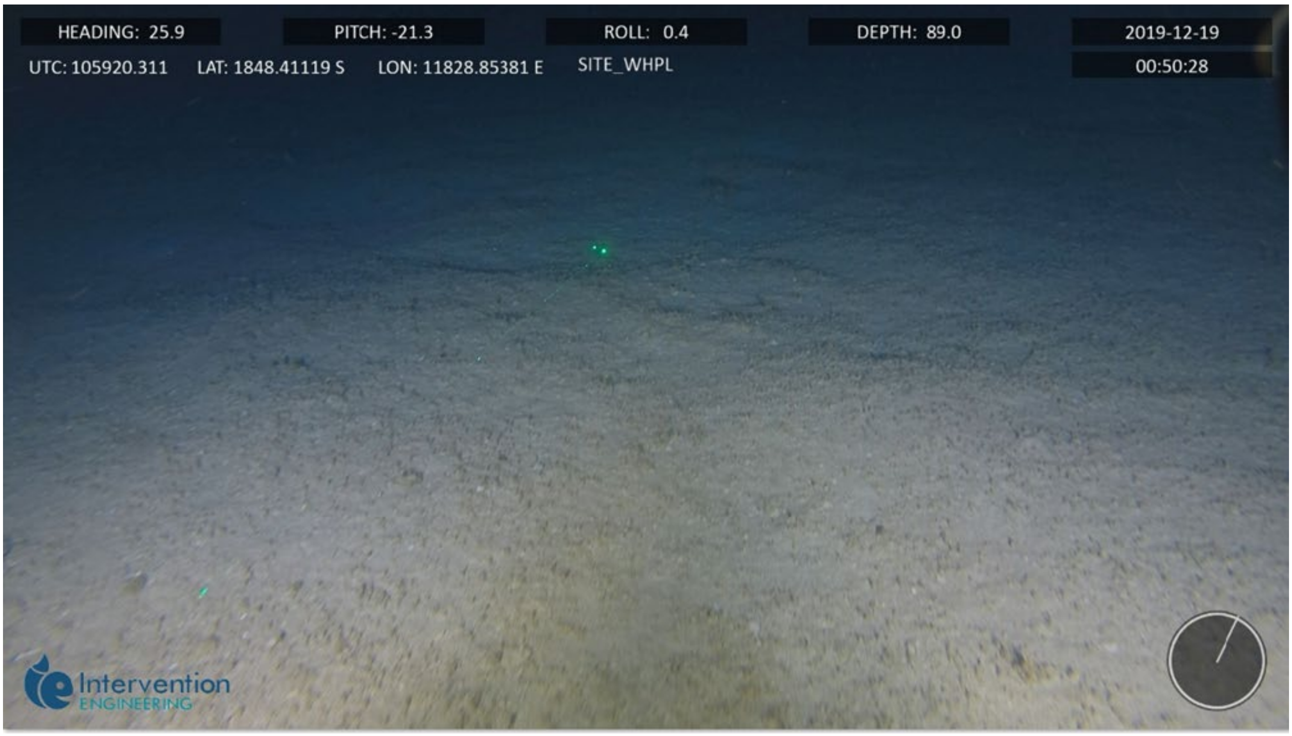


Plate 3-17: WHP site (mid-transect) with medium density biogenic turf on silty sand sediment habitat

Plate 3-18: Very sparse epibiota near WHP site (mid-transect) with sea urchin and sea star

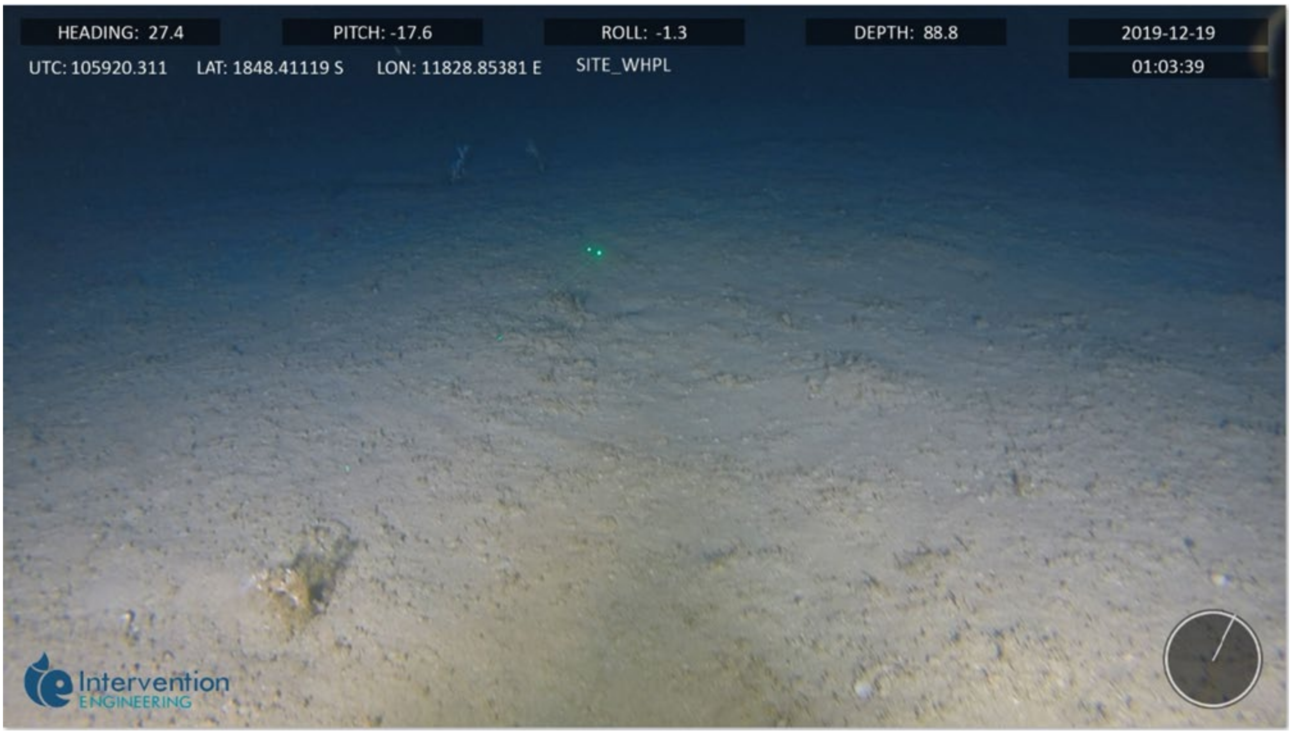


Plate 3-19: End of transect to north-east of WHP site with medium density biogenic turf on silty sand sediment habitat

3.7 Ancient coastline KEF

Five survey sites were inside the Ancient coastline KEF (Figure 3-2). These sites (5, 7, 14, 16, 26) are described in Appendix B. They were all soft sediment habitats with sparse epibiotic communities similar to many other parts of the Dorado Survey Area. There were no records of any significant benthic features; for example, no high profile reef with abundant fish, or any feature of particular conservation significance or importance to the ecology of the region were observed.

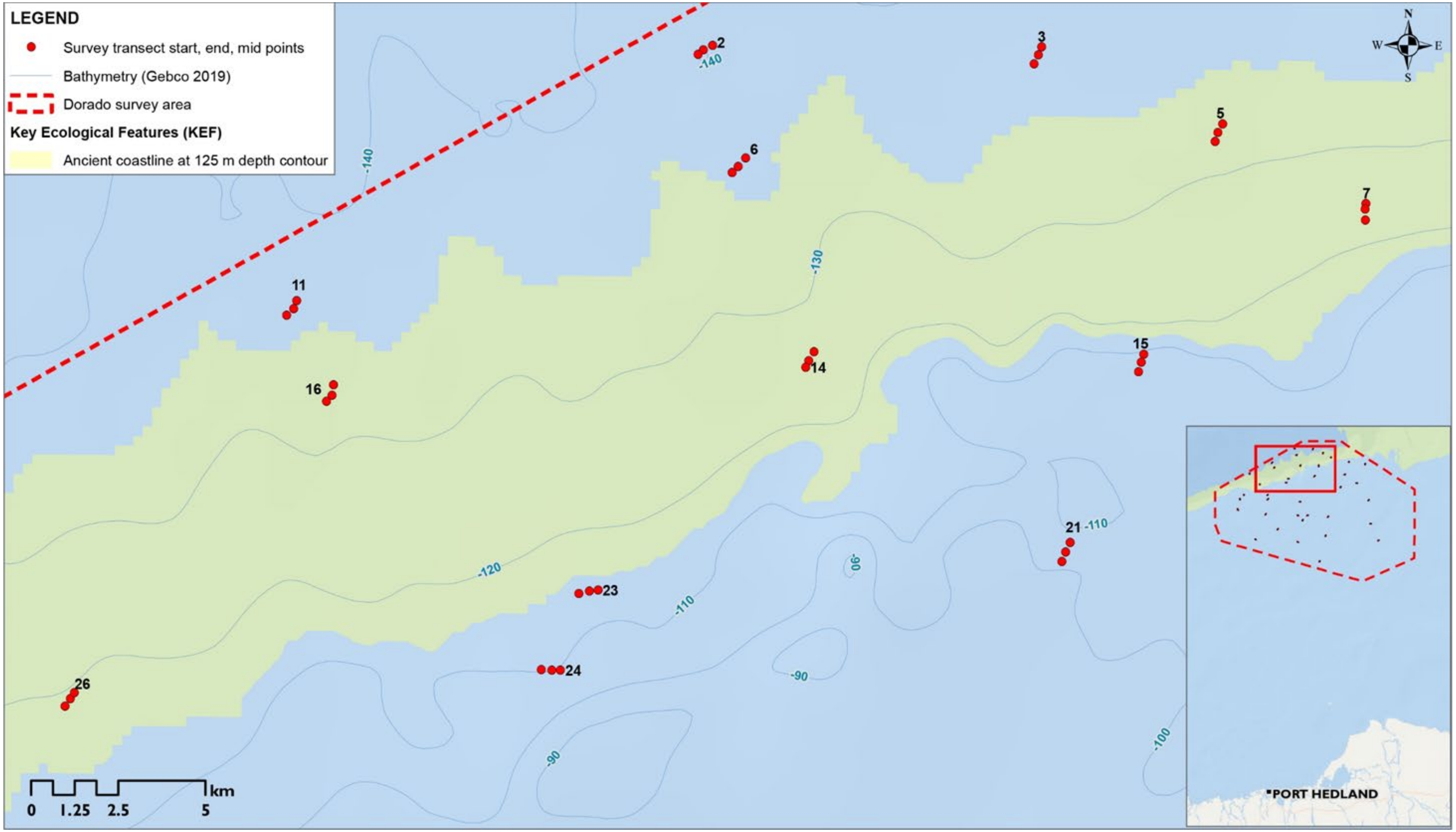


Figure 3-2: ROV transect sites over the ancient coastline KEF (green)

4 DISCUSSION

4.1 Benthic habitats and communities in the Survey Area

The benthic habitats of the Survey Area comprised two overarching sediment types – silty sand and coarser mobile sands. Low relief hard substrate habitats were also recorded across the Survey Area. These findings align with those found in recent geophysical surveys (e.g. Fugro 2015, Neptune 2019a), where two main seabed types were identified from side-scan sonar data. Particulate sediment habitats were more widespread and often supported sparse to medium density biogenic turf communities in areas where the sediments were finer and appeared more stable (i.e. not rippled by seabed currents, and/or with higher density biogenic turf). Areas of coarser bare sand were generally rippled, indicating they are being moved by seabed currents. These more mobile sediments tend to support less well-developed epibiotic assemblages, and may cause episodic inundation of finer sediments and hard substrate habitats.

It appears most of the area of soft sediment is underlain by a hard pavement reef, broken pavement or consolidated hard substrate. Where the reef was exposed, it had been colonised by epibiota. The epibiotic assemblages were dominated by filter-feeding organisms, which is typical of the North West Shelf.

It was apparent from the video transects that soft sediments throughout to area are bioturbated to varying extents. Infaunal communities were generally characteristic of sediment types, which were mainly found to be either muddy sand or sand (with shell/gravel) and indicated the presence of nearby epibiota (e.g. hydroids, bryozoans and sponges). A number of taxa recorded are capable of adopting several feeding strategies from different trophic levels (e.g. carnivores, scavengers able to filter feed), which is indicative of the harsh and changing environment often found in mobile sand wave habitats.

The distribution of the regional ecotypes across the Survey Area is described in the CSIRO report (Keesing et al. 2020) and the data from the current survey have been used to update the ecotype model with the main habitat types in the area. Refer to Keesing et al. (2020) for a map of ecotypes of the area and broader region.

4.1.1 Habitats in the Dorado Survey Area

The benthic habitats and communities were all well represented across the Survey Area. The habitats included areas of flat, silty sand sediments, with low to medium density biogenic turf, and areas of hard substrate with a veneer of sediment, supporting sparse to medium density filter-feeding assemblages.

The WHP site was flat and featureless and comprised soft sediment habitats and biota which were very well represented in the area. No features of high conservation significance or commercial fish habitat value were observed. The homogeneity of the transect indicates this seabed type is likely to continue well beyond the surveyed transect. This interpretation is supported by recent geophysical and geotechnical surveys (e.g. Fugro 2015, NGI 2017, Neptune 2019a, Neptune 2019b, Neptune 2019c).

The proposed FPSO sites had a combination of soft sediment and hard substrate habitats and communities. Both of these habitat types and the associated assemblages are well represented in the Survey Area. While the hard substrate assemblages have higher local environmental value, they are not significant in the broader area and there are equivalent or better examples at other sites, for example at Site 21, which had extensive low to medium density filter-feeder communities.

The biogenic turf recorded during the present study is worthy of note. It is likely to occur widely, but is often simply overlooked. This habitat component appears to stabilise sediments to some degree (especially at high densities), and is likely to be habitat for small epibiota, e.g. caprellid amphipods, annelid worms and molluscs, and it may provide a food source for demersal fish.

4.1.2 Vertebrates

Mobile demersal fish, including commercially important species, were uncommon. This may partly reflect their under-representation in the video transect data due to their active avoidance of the ROV and the absence of habitats that they may aggregate around, such as high profile reef. The one area of higher profile reef at Site 25 supported a high abundance of lutjanid snappers (cf. *Lutjanus vitta, Lutjanus* spp.) which were not observed in surrounding sediment habitats or on pavement reef habitats. This indicates they tend to aggregate in areas of higher habitat complexity and will be largely absent from, or transient visitors in, the greater proportion of the Survey Area which are characterised by flat seabed morphologies.

No aggregations of commercially-important fish species were observed on any transect other than Site 25 (~100 m water depth). The sites in the remodelled ecotype zone 2, which broadly represents the Ancient coastline KEF (Keesing et al. 2020), did not appear to have any habitat of any greater value to fish than any other site in the broader Survey Area. This probably reflects the absence of emergent or high relief reef habitat in the KEF area.

Small benthic fish associated with seabed habitats such as burrows and boulders, and small fish living on the sediment surface such as gurnards and flatfish, were observed at very low to low densities on most transects. Estimates of fish density should be considered as underestimates though, as the presence of the ROV (including lights) are known to disturb of startle fish, which may have either found refugia or left the area covered by the lights before they could be recorded or identified.

Large pelagic fish including marlin and several species of shark were observed at the sea surface (upper 40 m of water column) but not at the seabed. Previous studies have identified that the following sharks occur in the Survey Area:

- Greater hammerhead shark *Sphyrna mokarran*
- Scalloped hammerhead shark *S. lewini*
- Silvertip shark, *Carcharinus albimarginatus*
- Whitecheck shark, *C. coatesi*
- Sandbar shark, *C. plumbeus*
- School shark, *C. sorrah*
- Tiger shark, *Galeocerdo cuvier*
- Sliteye shark, *Loxodon macrorhinus* (RPS and UWA 2019).

Elegant sea snakes seemed unperturbed by the presence of the ROV and were probably represented at reliable densities in the footage. Only two sea snakes were observed on the seabed in approximately 20 km of transect survey, indicating a very low density on the seabed in the area. They are listed as a Marine species under the Environment Protection and Biodiversity Conservation Act 1999 and are broadly distributed from the Shark Bay to approximately Newcastle on the mid NSW coast and do not have a recovery plan in place (DAWE 2020). The Survey Area is unlikely to represent critical foraging habitat for the species but is part of their very broad range.

4.2 Habitat and community stability

The current study has shown that there are low sand waves throughout the area and the coarse, rippled nature of the sand waves suggests that they are being moved by seabed currents. Recent near seabed current measurements showed that internal tides are the dominant current driver (with a distinct spring-neap cycle). Tidal currents ebb to the north-west and flood to the south-east. Seabed drift currents are driven by the interactions of the ebb and flow tidal currents, and vary slightly between locations and seasons. Near seabed drift currents vary with location and season, but generally range from between west-north-west and north-east (RPS 2019). In summarising the available literature on the dynamics of soft sediments of the North West Shelf, Wilson (2013) describes dynamic benthic sediment movements associated with cyclonic activity, internal waves and tidal currents.

The north-west to south-east orientation of seabed features (e.g. sand ripples, sand waves, sand ribbons, ridges and mounds) identified in previous geophysical and geotechnical surveys of the area commissioned by Santos (e.g. Fugro 2015, Neptune 2019c) are likely to be primarily due to near seabed currents (RPS 2019), but are also likely to be influenced by underlying geology (NGI 2017). Several sea floor and subsea floor palaeochannels occur in the Survey Area, which run from south to north (e.g. the Roc channel), or south-south-east to north-north-west (e.g. the Dorado channel and the West Roc channel). These channels have been infilled by sandy material, acting as a pathway for modern sediment transport (NGI 2017).

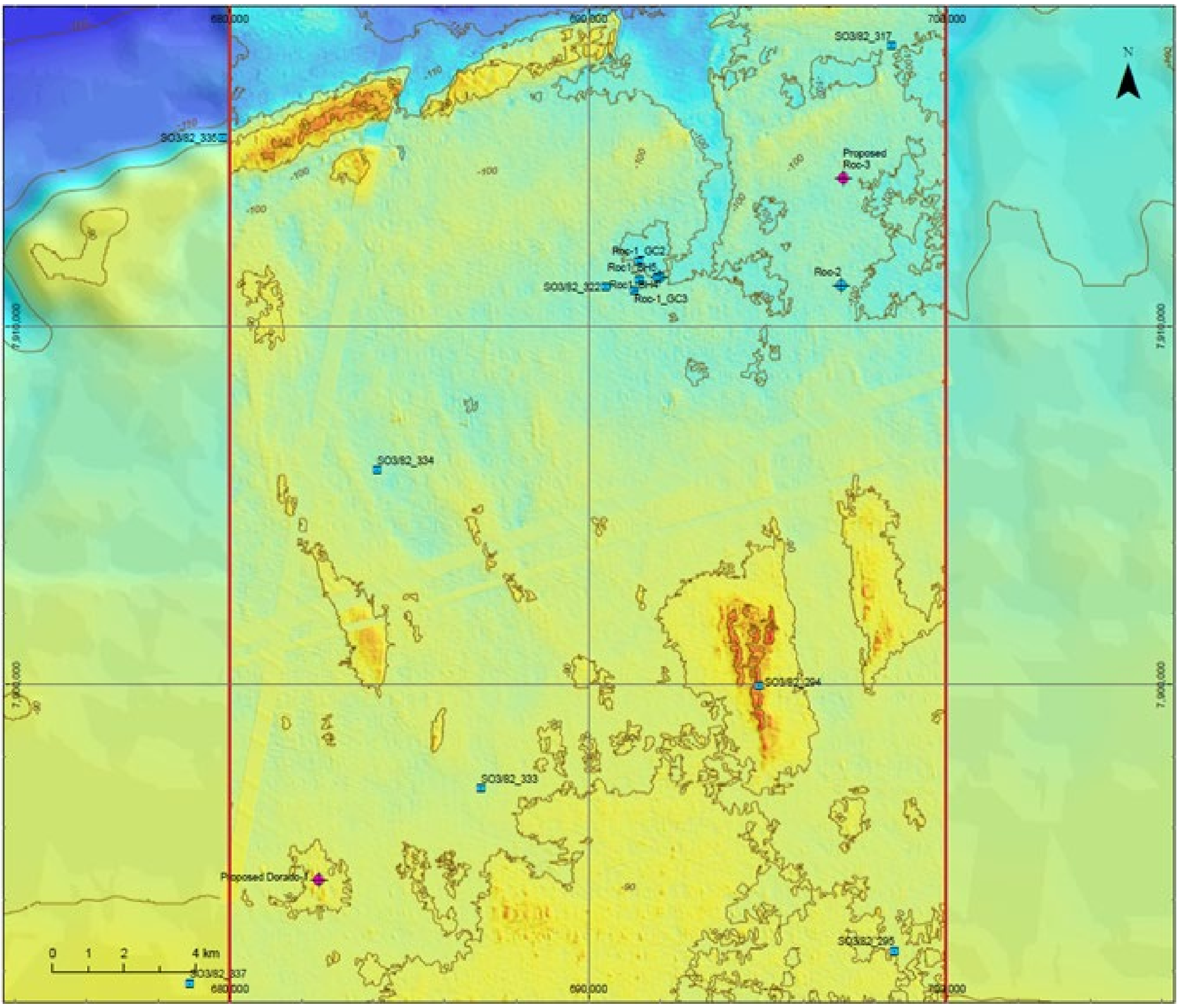
This indicates that benthic features observed in the Survey Area are dynamic in space and time, and are likely to periodically bury benthic communities or uncover new habitat as they migrate. The scales of the changes in the habitat and the associated communities are unknown. While the temporal stability of the sand waves is not known, the sparsity of epibiota on these features indicates that they are likely to be highly mobile

Few of the filter-feeder communities appeared to be well established because most individual organisms were relatively small. Sites such as Site 21 where the filter-feeder community was better developed and populated by large individuals, appear to be in areas of less frequent sediment movement. In other areas, the benthic communities may be stunted by periods of burial (and no growth) and erosion, or they may reflect more recent settlement and recruitment events.

This supports the hypotheses that the benthic communities are adapted to intermediate levels of perturbation due to sediment movement and this is reflected in the abundance/density and diversity of filter-feeding organisms on exposed hard substrates. It also indicates that the persistence of these communities in the region is dependent on their ability to recolonise exposed hard substrates as they become available.

4.3 Local and regional significance

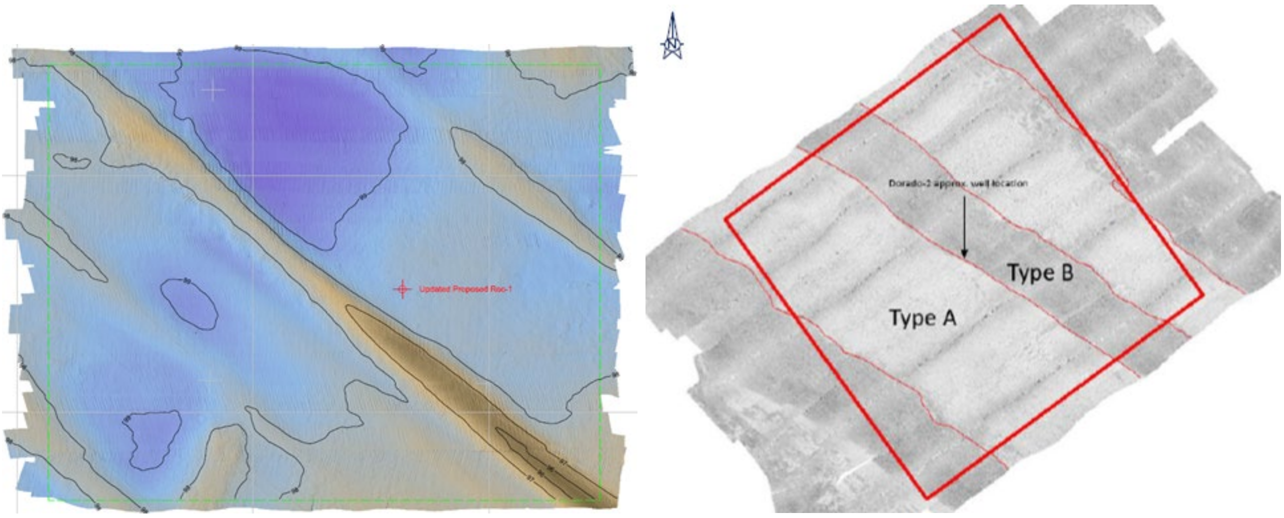
Santos geophysical reports from well site geophysical, debris clearance and bathymetric surveys within the Survey Area (Fugro 2015, Neptune 2018, Neptune 2019a, b, c, and NGI 2017) included collecting seabed imagery and mapping seabed features. These reports reveal broad patterns in surficial sediments, sediment features and geology that characterise the habitat types in the Survey Area. The findings of the present study are consistent with these reports, providing additional context on the biological assemblages that are associated with each type of habitat. The geophysical and geotechnical surveys encompasses most of the Survey Area and therefore provide valuable context for interpretation of the distribution of sediments and seabed types (Figure 4-1).This context indicates that the habitats and communities recorded in the ROV survey are likely to be representative of the broader Survey Area.



Source: NGI 2017

Figure 4-1: Extent of seabed surveys and reviews in geophysical reports (red polygon)

The geophysical reports have confirmed the seabed in the area broadly comprises very fine to coarse sandy sediment with shell fragments, with features such as sand ripples and ribbons occurring across the Survey Area. The sand ripples and ribbons show a predominant north-west to south-east orientation. Examples include linear sand ripple features at the Roc area (north-east of Dorado) and the similarly aligned seabed types at Dorado are shown in Figure 4-2.



Source: Neptune 2018; 2019

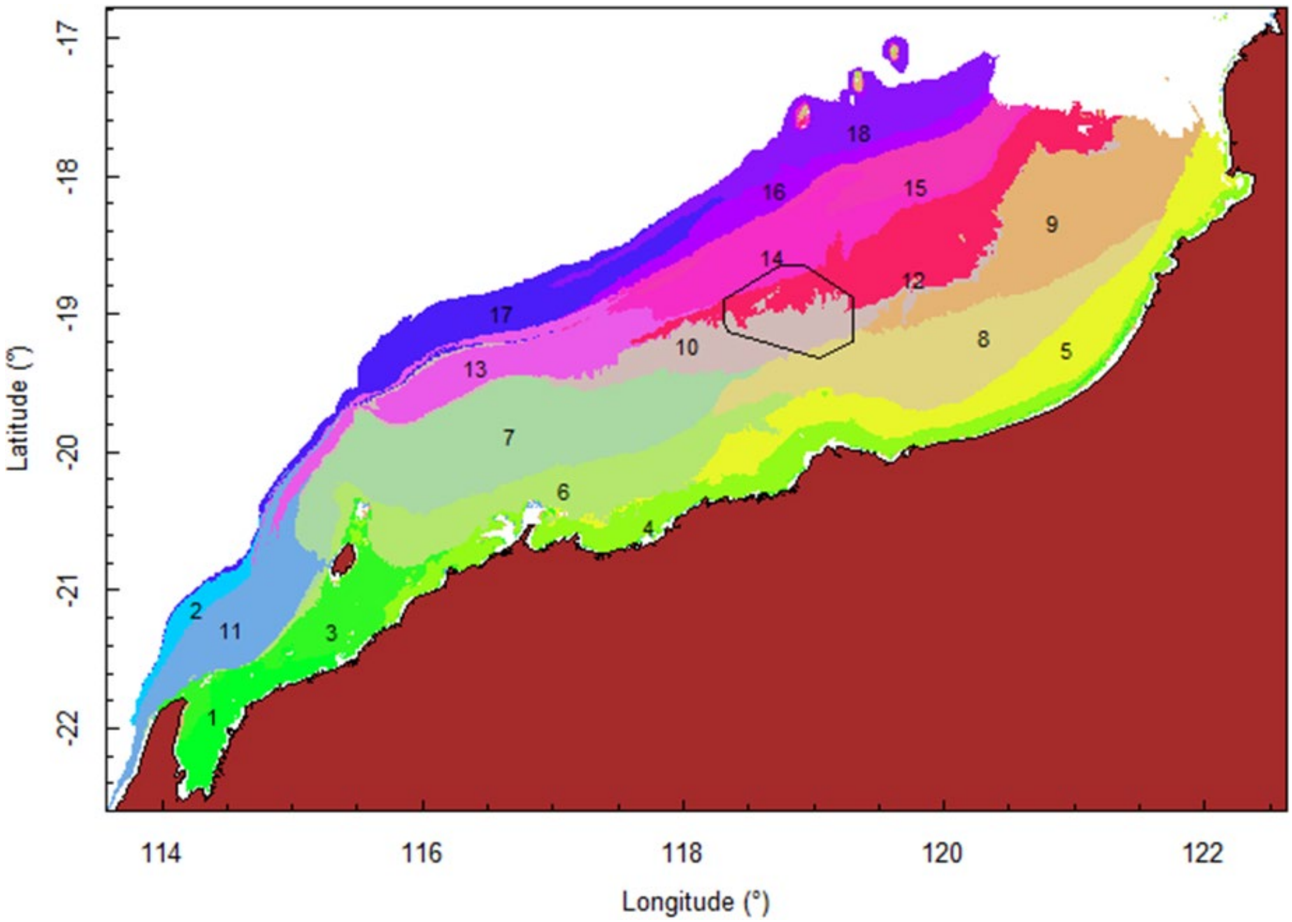
Figure 4-2: Patterns of sand waves in Roc area (left) and Dorado area (right)

The dynamic nature of the sandy seabed habitats was described by the NGI (2019) expert interpretation of the combined datasets from the Roc area. Neptune (2019) surveyed the seabed in the Dorado-1 area and confirmed that the seabed is generally flat across the area, and is likely sandy with low amplitude sand waves across most of the site. The sand waves have wavelengths between 5 and 8 m with amplitudes of mostly 15 – 20 cm up to 30 cm. No rocky outcrops were detected in the Dorado-1 site surveys.

The Geoscience Australia bathymetry and sub bottom profiling data confirm the regional nature of the seabed sand ripple features (NGI 2019).

The CSIRO ecotypes have been re-modelled for the region and are shown to extend well beyond the immediate area of interest (Figure 4-3). These ecotypes are described in more detail in the Keesing et al. (2020) report.

There are no known geographical barriers to larval dispersion between the Survey Area and adjacent areas, and no rare or restricted habitat values were recorded in the Survey Area. This indicates that there are no high conservation value areas or communities in the Survey Area.



Source: Keesing et al. 2020

Figure 4-3: Regional distribution of biological assemblages on the North West Shelf

5 CONCLUSIONS

The benthic habitat and communities survey revealed that the Dorado Survey Area is relatively flat, homogeneous soft sediment, with low sand waves (ripples) and scattered rocky reef. The sediment habitats support very sparse to sparse infauna and epifauna and the rocky substrates support low to medium density filter-feeder communities and other fauna including fish at low densities. Infaunal taxa were characteristic of the sediments recorded at the sample sites (RPS 2020), and indicated where epibiota (e.g. hydroids, bryozoans and sponges) and consolidated/hard substrate may also be present.

No high conservation significant ecological values, habitats, communities of species were identified and the habitats and communities within the Dorado Survey Area are very well represented in the region.

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Appendix A
Transect coordinates

APPENDIX A: TRANSECT COORDINATES

Site	Transect position	Date	ROV heading (deg)	ROV depth (m)	Latitude (DDM)	Longitude (DDM)
Site_2	start	2019-12-20	224.4	140.5	-18 41.328'	118 42.159'
Site_2	mid	2019-12-20	240.4	140.5	-18 41.394'	118 42.007'
Site_2	end	2019-12-20	166.1	140.4	-18 41.466'	118 41.924'
Site_3	start	2019-12-21	218.7	138.6	-18 41.295'	118 47.523'
Site_3	mid	2019-12-21	207.6	138.1	-18 41.426'	118 47.474'
Site_3	end	2019-12-21	209.9	138.3	-18 41.565'	118 47.406'
Site_5	start	2019-12-21	102.2	134	-18 42.469'	118 50.492'
Site_5	mid	2019-12-21	202.4	134.2	-18 42.603'	118 50.410'
Site_5	end	2019-12-21	201.3	133.6	-18 42.741'	118 50.368'
Site_6	start	2019-12-20	235	138.5	-18 43.075'	118 42.715'
Site_6	mid	2019-12-20	221.6	138	-18 43.203'	118 42.599'
Site_6	end	2019-12-20	219.9	137.3	-18 43.301'	118 42.497'
Site_7	start	2019-12-21	184.1	125.7	-18 43.686'	118 52.836'
Site_7	mid	2019-12-21	179.3	125.7	-18 43.768'	118 52.824'
Site_7	end	2019-12-21	179.5	124.4	-18 43.938'	118 52.832'
Site_10	start	2019-12-21	205.8	104.8	-18 44.857'	118 58.270'
Site_10	mid	2019-12-21	203.7	104.4	-18 44.997'	118 58.230'
Site_10	end	2019-12-21	204.9	105.6	-18 45.151'	118 58.165'
Site_11	start	2019-12-19	83.7	137.7	-18 45.578'	118 35.257'
Site_11	mid	2019-12-19	51.6	137.2	-18 45.479'	118 35.372'
Site_11	end	2019-12-19	61.5	138.1	-18 45.350'	118 35.419'
Site_13	start	2019-12-21	204.2	112.7	-18 45.486'	119 3.046'
Site_13	mid	2019-12-21	202.6	112.5	-18 45.620'	119 2.992'
Site_13	end	2019-12-21	203	112	-18 45.736'	119 2.950'
Site_14	start	2019-12-20	210.1	129.3	-18 46.072'	118 43.862'
Site_14	mid	2019-12-20	207.3	129	-18 46.217'	118 43.779'
Site_14	end	2019-12-20	207.1	129	-18 46.317'	118 43.729'
Site_15	start	2019-12-20	190.5	106.3	-18 46.060'	118 49.241'
Site_15	mid	2019-12-20	206.6	107	-18 46.182'	118 49.199'
Site_15	end	2019-12-20	188.9	107.7	-18 46.335'	118 49.159'
Site_16	start	2019-12-19	38.1	133.9	-18 46.919'	118 35.919'
Site_16	mid	2019-12-19	44.4	133.9	-18 46.822'	118 36.008'
Site_16	end	2019-12-19	1.4	133.8	-18 46.658'	118 36.031'
Site_17	start	2019-12-18	49.9	135.3	-18 48.683'	118 28.657'
Site_17	mid	2019-12-18	100.7	136	-18 48.565'	118 28.666'
Site_17	end	2019-12-18	47.8	136.2	-18 48.441'	118 28.726'
Site_19	start	2019-12-21	271.1	100.2	-18 48.553'	118 57.188'
Site_19	mid	2019-12-21	260.1	98.3	-18 48.611'	118 57.011'
Site_19	end	2019-12-21	260.2	99.1	-18 48.662'	118 56.869'
Site_21	start	2019-12-20	162	99.4	-18 48.996'	118 48.071'
Site_21	mid	2019-12-20	198.4	97.9	-18 49.146'	118 48.002'
Site_21	end	2019-12-20	235.6	98.9	-18 49.294'	118 47.942'
Site_23	start	2019-12-19	77	114.2	-18 49.864'	118 40.064'

Site	Transect position	Date	ROV heading (deg)	ROV depth (m)	Latitude (DDM)	Longitude (DDM)
Site_23	mid	2019-12-19	70.9	114.4	-18 49.826'	118 40.238'
Site_23	end	2019-12-19	78.8	114.6	-18 49.808'	118 40.376'
Site_24	start	2019-12-19	72.2	110.3	-18 51.052'	118 39.464'
Site_24	mid	2019-12-19	93.3	111.1	-18 51.059'	118 39.633'
Site_24	end	2019-12-19	65.8	111.6	-18 51.054'	118 39.777'
Site_25	start	2019-12-21	207.8	99.6	-18 50.924'	119 0.720'
Site_25	mid	2019-12-21	235.2	99.5	-18 50.990'	119 0.574'
Site_25	end	2019-12-21	236.2	96.2	-18 51.045'	119 0.451'
Site_26	start	2019-12-18	53.9	119.1	-18 51.683'	118 31.694'
Site_26	mid	2019-12-18	47	119.3	-18 51.574'	118 31.779'
Site_26	end	2019-12-18	52.9	119.6	-18 51.480'	118 31.851'
Site_27	start	2019-12-20	206.2	99.2	-18 52.051'	118 55.876'
Site_27	mid	2019-12-20	202	99.5	-18 52.189'	118 55.775'
Site_27	end	2019-12-20	202.9	98.7	-18 52.342'	118 55.710'
Site_28	start	2019-12-22	227.2	103.9	-18 54.500'	118 27.127'
Site_28	mid	2019-12-22	199	103.4	-18 54.624'	118 27.068'
Site_28	end	2019-12-22	197.5	102.9	-18 54.748'	118 27.026'
Site_29	start	2019-12-22	234.5	99	-18 54.469'	118 34.269'
Site_29	mid	2019-12-22	235.4	96.9	-18 54.535'	118 34.146'
Site_29	end	2019-12-22	231.5	96.9	-18 54.610'	118 34.028'
Site_31	start	2019-12-22	174.5	105.2	-18 55.667'	118 25.863'
Site_31	mid	2019-12-22	172.3	106.3	-18 55.812'	118 25.892'
Site_31	end	2019-12-22	178	107.2	-18 55.923'	118 25.924'
Site_32	start	2019-12-22	228	92.2	-18 55.654'	118 34.308'
Site_32	mid	2019-12-22	232	92.4	-18 55.723'	118 34.177'
Site_32	end	2019-12-22	225.1	91.8	-18 55.813'	118 34.052'
Site_33	start	2019-12-20	222.4	91.7	-18 55.687'	119 4.306'
Site_33	mid	2019-12-20	217.4	91.7	-18 55.794'	119 4.184'
Site_33	end	2019-12-20	215.8	92.4	-18 55.894'	119 4.073'
Site_34	start	2019-12-19	86.4	92.9	-18 56.427'	118 43.652'
Site_34	mid	2019-12-19	28.9	95.1	-18 56.403'	118 43.801'
Site_34	end	2019-12-19	61	95.1	-18 56.407'	118 43.947'
Site_35	start	2019-12-22	143.1	100.5	-18 58.638'	118 25.186'
Site_35	mid	2019-12-22	143.2	98.2	-18 58.779'	118 25.264'
Site_35	end	2019-12-22	141.9	98.3	-18 58.918'	118 25.385'
Site_37	start	2019-12-18	63.6	95.3	-19 0.091'	118 33.458'
Site_37	mid	2019-12-18	54.1	96	-18 59.976'	118 33.614'
Site_37	end	2019-12-18	52.2	95.3	-18 59.890'	118 33.707'
Site_38	start	2019-12-21	43.5	93	-19 0.720'	118 52.077'
Site_38	mid	2019-12-21	40.7	93.1	-19 0.572'	118 52.133'
Site_38	end	2019-12-21	32.5	93.4	-19 0.473'	118 52.286'
Site_39	start	2019-12-20	261.5	87.5	-19 2.366'	119 4.967'
Site_39	mid	2019-12-20	261.4	87.5	-19 2.368'	119 4.816'
Site_39	end	2019-12-20	260.2	86.7	-19 2.408'	119 4.646'
Site_41	start	2019-12-18	38.6	91.1	-19 4.303'	118 37.077'

Site	Transect position	Date	ROV heading (deg)	ROV depth (m)	Latitude (DDM)	Longitude (DDM)
Site_41	mid	2019-12-18	39.1	90.3	-19 4.196'	118 37.217'
Site_41	end	2019-12-18	44.1	90.3	-19 4.147'	118 37.321'
Site_42	start	2019-12-18	40	85.6	-19 6.119'	118 51.462'
Site_42	mid	2019-12-18	40.3	85.7	-19 5.966'	118 51.534'
Site_42	end	2019-12-18	44.8	85.8	-19 5.838'	118 51.564'
Site_43	start	2019-12-22	122.3	92.3	-19 7.138'	118 30.500'
Site_43	mid	2019-12-22	116.5	92.4	-19 7.196'	118 30.599'
Site_43	end	2019-12-22	109.6	91.9	-19 7.278'	118 30.738'
Site_44	start	2019-12-19	253.6	83.5	-19 7.115'	119 7.333'
Site_44	mid	2019-12-19	249.6	83.5	-19 7.153'	119 7.206'
Site_44	end	2019-12-19	250.4	83.2	-19 7.203'	119 7.109'
Site_45	start	2019-12-18	97	85.3	-19 7.777'	118 43.055'
Site_45	mid	2019-12-18	99.3	85.1	-19 7.842'	118 43.214'
Site_45	end	2019-12-18	96.2	85.4	-19 7.880'	118 43.371'
Site_48	start	2019-12-18	349.1	77.7	-19 13.373'	118 49.774'
Site_48	mid	2019-12-18	0.6	78.1	-19 13.200'	118 49.807'
Site_48	end	2019-12-18	357.2	78.4	-19 13.064'	118 49.805'
FPSP (61)	start	2019-12-19	66.9	90.5	-19 0.324'	118 45.865'
FPSP (61)	mid	2019-12-19	50.8	89.5	-19 0.270'	118 46.049'
FPSP (61)	end	2019-12-19	66	90.5	-19 0.237'	118 46.197'
FPSPNW (62)	start	2019-12-22	264.9	92.4	-19 0.297'	118 43.344'
FPSPNW (62)	mid	2019-12-22	272.4	92.5	-19 0.291'	118 43.185'
FPSPNW (62)	end	2019-12-22	258	92.4	-19 0.274'	118 43.025'
WHPL (60)	start	2019-12-19	27.5	88.9	-19 1.759'	118 44.555'
WHPL (60)	mid	2019-12-19	25.8	89	-19 1.633'	118 44.613'
WHPL (60)	end	2019-12-19	27.4	88.8	-19 1.515'	118 44.675'

Appendix B
Transect descriptions

APPENDIX B: TRANSECT DESCRIPTIONS

Table B-1: Transect description – Site 002

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	9:24:34	224.4	140.5	-18.688798	118.702649
Midpoint		9:33:47	240.4	140.5	-18.689896	118.700121
End		9:43:01	166.1	140.4	-18.691107	118.698736

Benthic habitat and biota description

Flat, silty, bioturbated sediment with medium density tube worms and very sparse epifaunal assemblage. Epibiota include crinoids, sea stars, small fish (e.g. gurnards), alcyonarians, hydroids, anemones.

Representative photographs

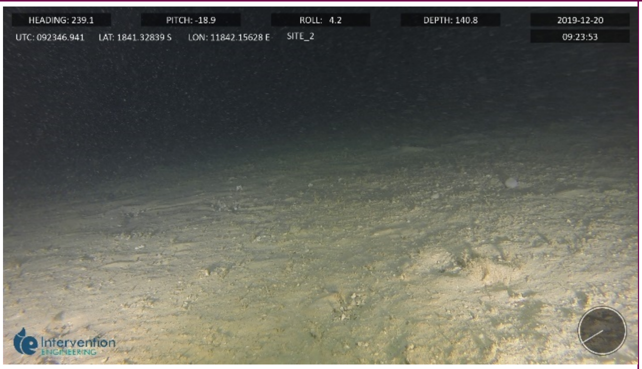

Plate B.1: Silty sediment with medium density of biogenic turf

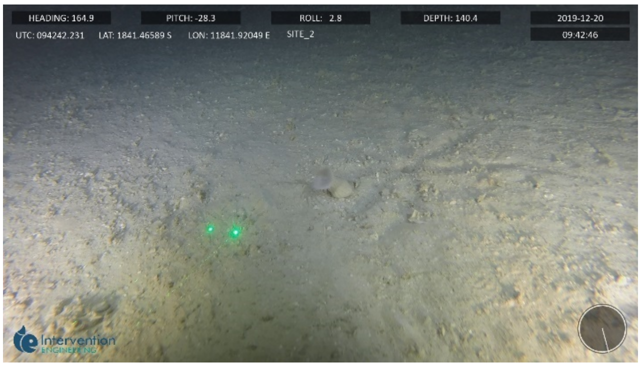

Plate B.2: Anemone on silty sediment and fish burrow

Plate B.3: Bioturbation by small fish

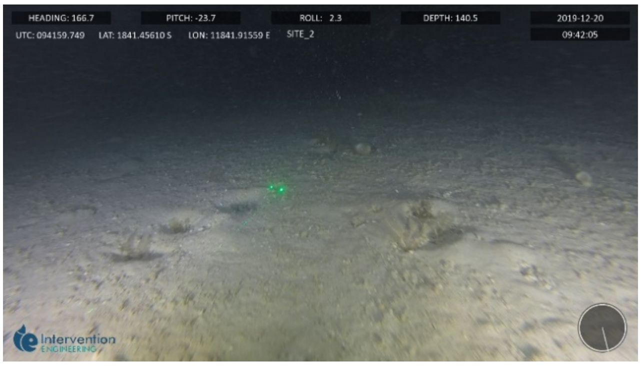

Plate B.4: Hydroids and anemones

Table B-2: Transect description – Site 003

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	9:07:07	218.7	138.6	-18.688246	118.792055
Midpoint		9:15:38	207.6	138.1	-18.690439	118.791232
End		9:24:09	209.9	138.3	-18.692757	118.790105

Benthic habitat and biota description

Mainly flat homogeneous silty to sandy sediment, with very sparse epibiota. Biogenic turf at up to medium density and moderate bioturbation in silty sediments. Occasional alcyonaceans, sponges, small fish.

Representative photographs

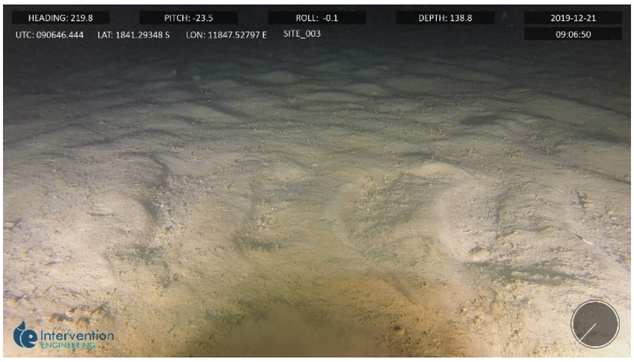

Plate B.5: Silty sand sediments with low density of biogenic turf and small ripples

Plate B.6: Alcyonacean on silty sand with small ripples

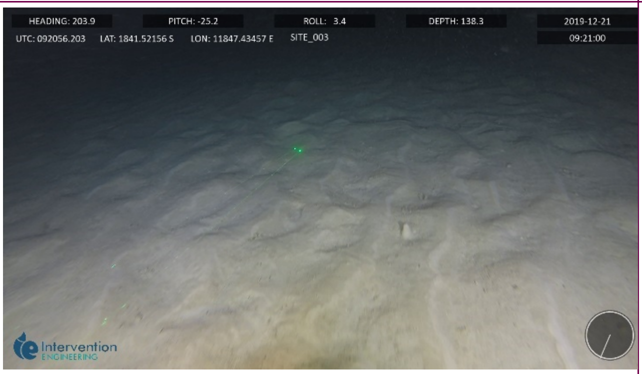

Plate B.7: Small sponge

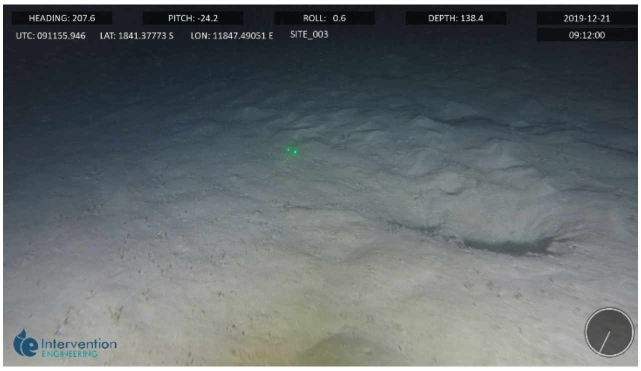

Plate B.8: Bioturbated silty sediment

Table B-3: Transect description – Site 005

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	8:01:46	102.2	134	-18.707814	118.84153
Midpoint		8:11:10	202.4	134.2	-18.710053	118.840167
End		8:20:34	201.3	133.6	-18.712349	118.839475

Benthic habitat and biota description

Mainly flat homogeneous with very sparse epibiota, biogenic turf in silty sediment up to medium density, occasional predatory fish (e.g. trevally), sea stars, small fish, anemones. Moderate bioturbation in silty areas. Low sand waves (< 0.5 m high).

Representative photographs

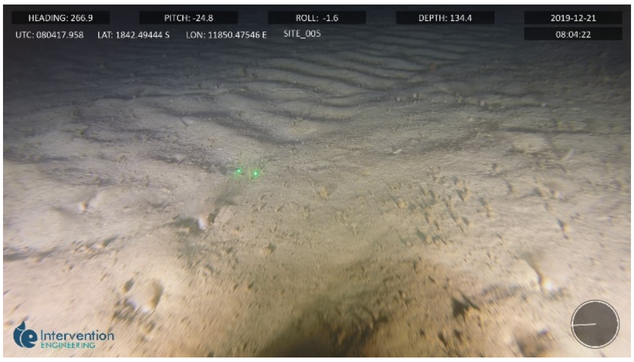

Plate B.9: Anemones on transition from silty sand to sand with ripples

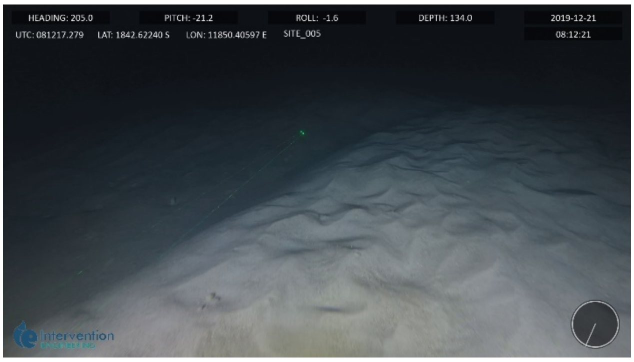

Plate B.10: Low sand wave with very sparse epibiota

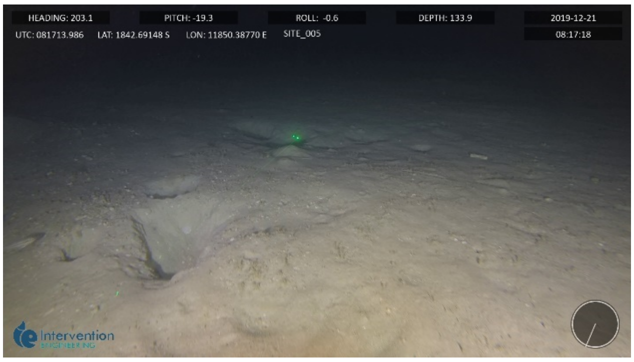

Plate B.11: Silty sediment with bioturbation by small fish

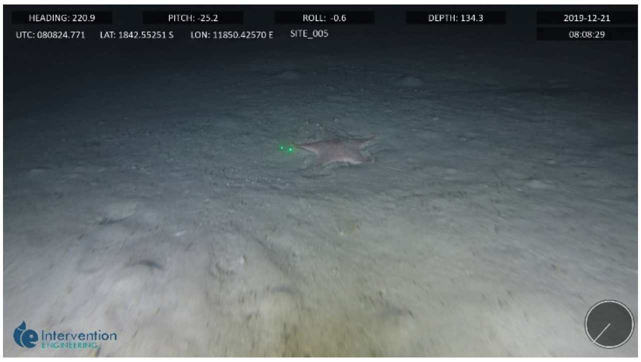

Plate B.12: Sea star and bioturbation

Table B-4: Transect description – Site 006

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	8:22:58	235	138.5	-18.717915	118.711915
Midpoint		8:33:08	221.6	138	-18.720055	118.709978
End		8:43:17	219.9	137.3	-18.721681	118.708281

Benthic habitat and biota description

Flat homogeneous silty to sandy sediment, with very sparse epibiota. Biogenic turf at low to medium density and moderate bioturbation in silty sediments. Very sparse epibiota including heart urchins, hydroids, sea pens, small sponges, anemones, small fish in burrows, crinoids, sea whips, occasional predatory fish (e.g. trevally).

Representative photographs

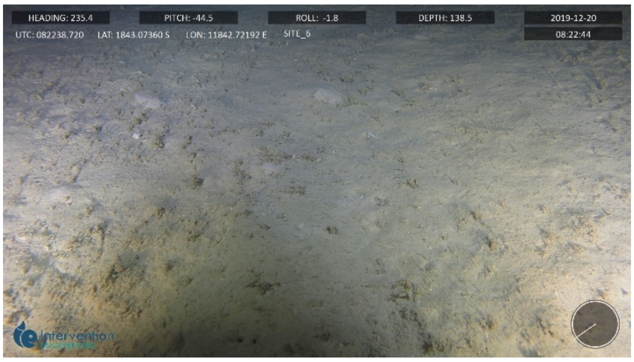

Plate B.13: Flat silty sediment with medium density of biogenic turf

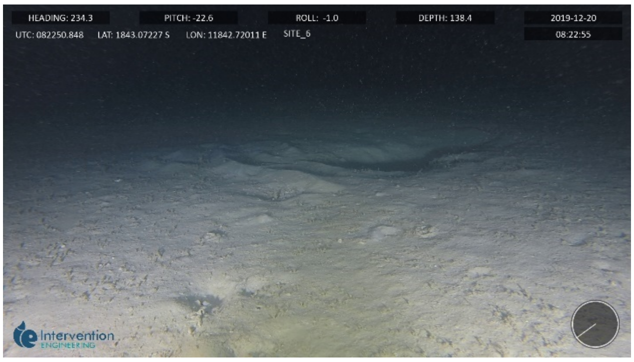

Plate B.14: Flat silty sediment with medium density of biogenic turf and large feeding scars

Table B-5: Transect description – Site 007

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	6:57:06	184.1	125.7	-18.7281	118.880594
Midpoint		7:06:49	179.3	125.7	-18.729459	118.880393
End		7:16:32	179.5	124.4	-18.732296	118.880532

Benthic habitat and biota description

Flat silty bottom with small boulders indicating sediment veneer over rock. Supporting low and open filter-feeding assemblage of gorgonians, alcyonarians, sea whips, small sponges, dead sponges (unburied in recent years?), zoanthids, hydroids. Moderate bioturbation, often with small fish in holes.

Representative photographs

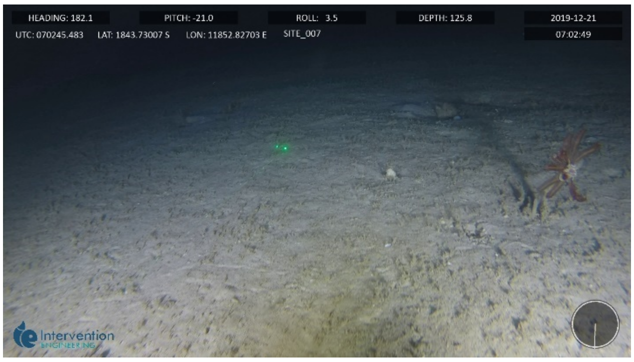

Plate B.15: Medium density biogenic turf on silty sediment with anemone and crinoid.

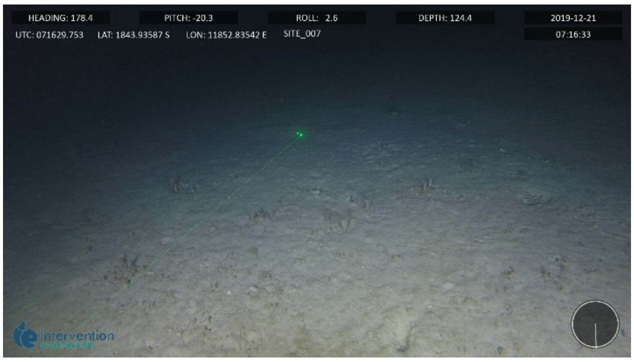

Plate B.16: Silty sediment over pavement with sparse epibiota including small sponges

Plate B.17: Alcyonacean on silty sediment

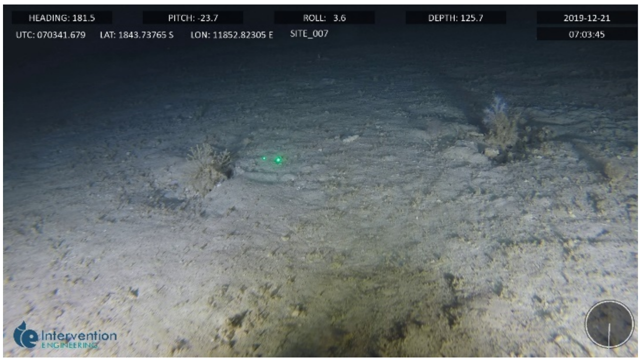

Plate B.18: Small boulders in silty sediment with small gorgonian and soft coral

Table B-6: Transect description – Site 010

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	5:32:37	205.8	104.8	-18.74762	118.971167
Midpoint		5:44:25	203.7	104.4	-18.749946	118.970508
End		5:56:13	204.9	105.6	-18.752515	118.969411

Benthic habitat and biota description

Sediments appear mobile and very little epibiota visible, occasional sea pens and biogenic turf present but at low densities throughout transect. Low sand waves with rippled sand on top, interspersed with silty sediments.

Representative photographs

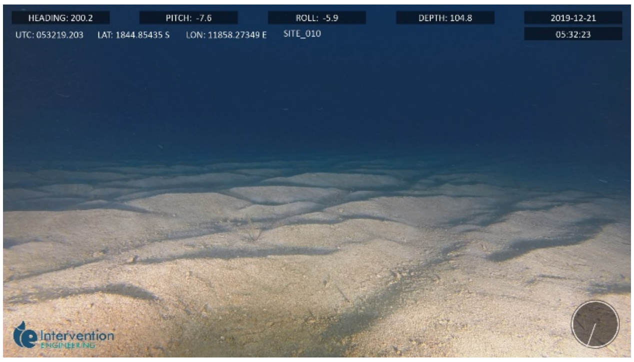

Plate B.19: Coarse sandy sediments

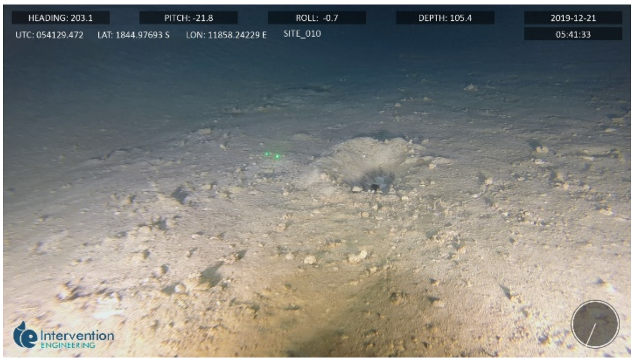

Plate B.20: Silty sediments

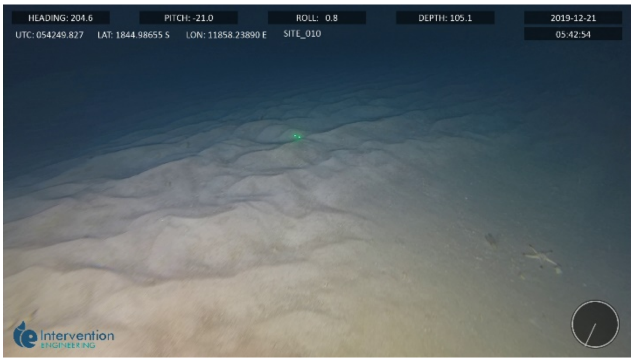

Plate B.21: Low sand wave with adjacent fine sediment and sea star

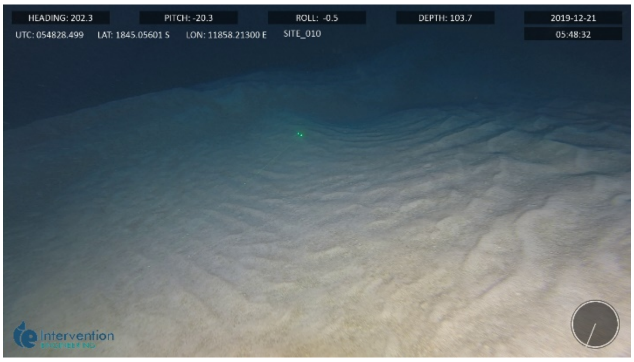

Plate B.22: Low sand waves with ripples

Table B-7: Transect description – Site 011

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	8:37:07	83.7	137.7	-18.759627	118.587622
Midpoint		8:48:51	51.6	137.2	-18.757978	118.589532
End		9:00:35	61.5	138.1	-18.755835	118.590309

Benthic habitat and biota description

Flat, silty mud sediments with abundant bioturbation (and associated small fish and crustaceans) and biogenic turf in soft sediments, very sparse epibiota including anemones, crinoids.

Representative photographs

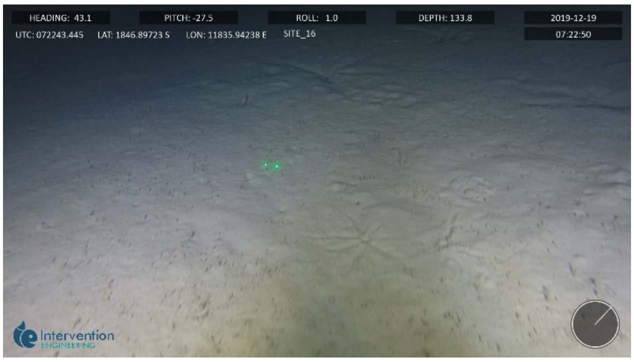

Plate B.23: Silty mud with biogenic turf and bioturbation

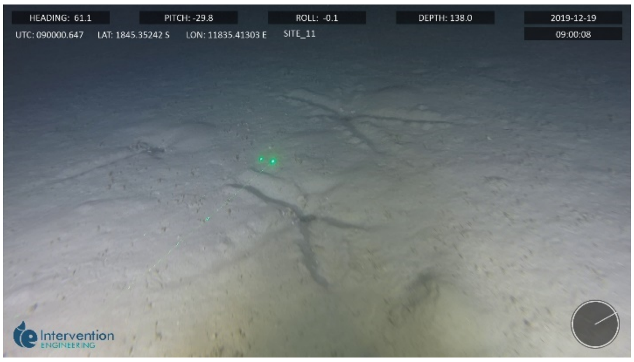

Plate B.24: Bioturbated silty mud with fish burrows

Plate B.25: Burrowing anemone on sediment

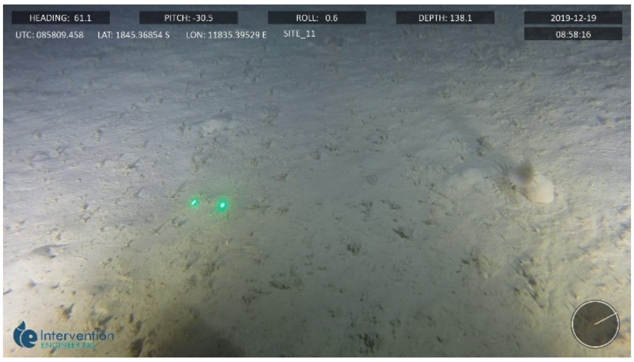

Plate B.26: Anemone on sediment

Table B-8: Transect description – Site 013

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	4:12:12	204.2	112.7	-18.758096	119.050764
Midpoint		4:19:51	202.6	112.5	-18.760328	119.049868
End		4:27:30	203	112	-18.762266	119.049168

Benthic habitat and biota description

Flat, sandy sediment supporting very sparse epibiota, occasional sea pens, anemones, small sponges.

Representative photographs

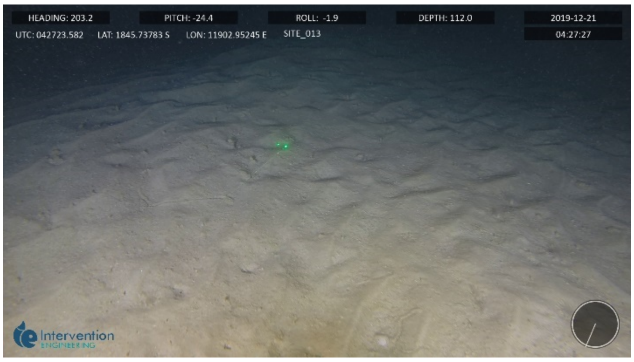

Plate B.27: Rippled sandy sediment with bioturbation

Plate B.28: Sandy silt with sponge and biogenic turf

Table B-9: Transect description – Site 014

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	7:13:49	210.1	129.3	-18.767865	118.731026
Midpoint		7:24:14	207.3	129	-18.770289	118.729643
End		7:34:39	207.1	129	-18.771953	118.728818

Benthic habitat and biota description

Flat, sandy silt sediment with occasional low sand waves. Silty sediments with medium to high density of tube worms, sandy sediments with very low worm tube densities. Very sparse epibiota including anemones, sea pens, bioturbation with small fish in the holes.

Representative photographs

Plate B.29: Silty sand sediment with bioturbation

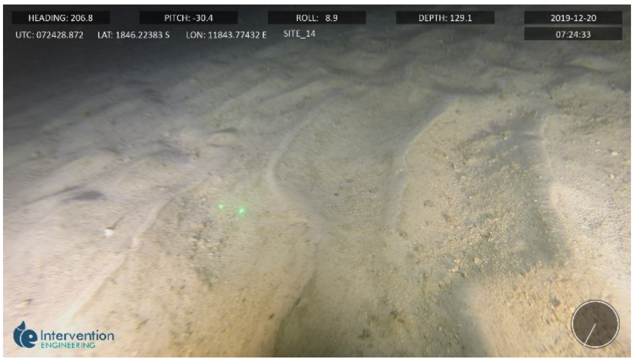

Plate B.30: Rippled sandy sediment in low wave

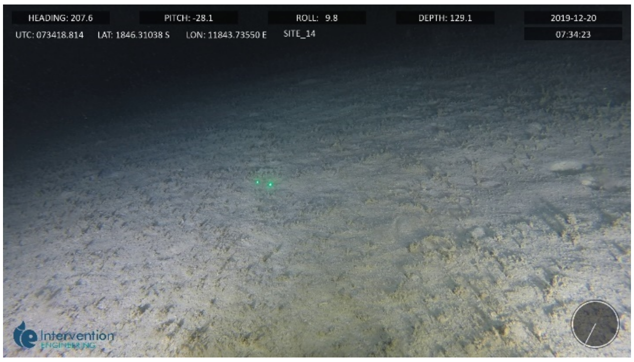

Plate B.31: Medium density biogenic turf in silty sediment

Plate B.32: Sea pen on silt with medium density biogenic turf

Table B-10: Transect description – Site 015

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	6:00:09	190.5	106.3	-18.767662	118.820681
Midpoint		6:08:30	206.6	107	-18.7697	118.819975
End		6:16:50	188.9	107.7	-18.772251	118.819314

Benthic habitat and biota description

Flat, silty sand sediments support low- medium density of biogenic turf and sparse epibiota including sea pens, small sponges, hydroids, crinoids and small fish in holes. Areas of hard substrate underlying thin veneer of sediment and scattered boulders supporting sparse epibiota including sea whips, hydroids, crinoids, gorgonians, sponges, few fish.

Representative photographs

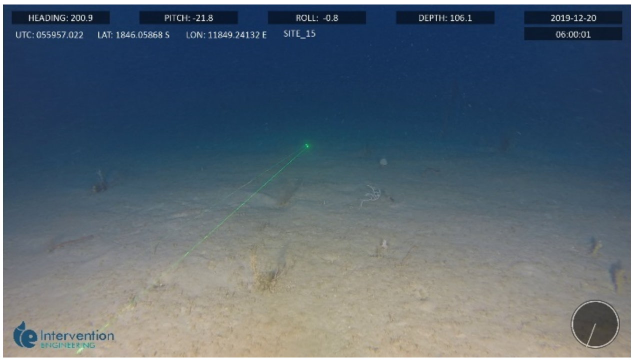

Plate B.33: Sparse epibiota over buried hard substrate

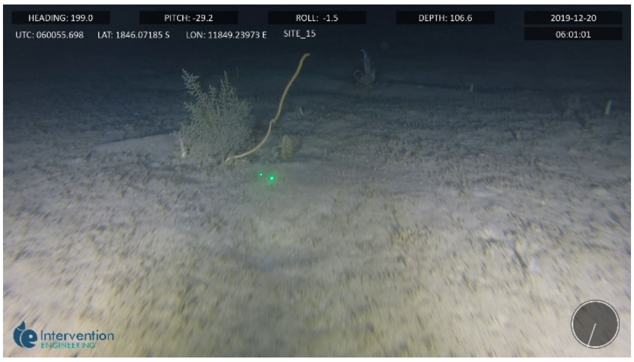

Plate B.34: Sea whip and gorgonian on buried rock

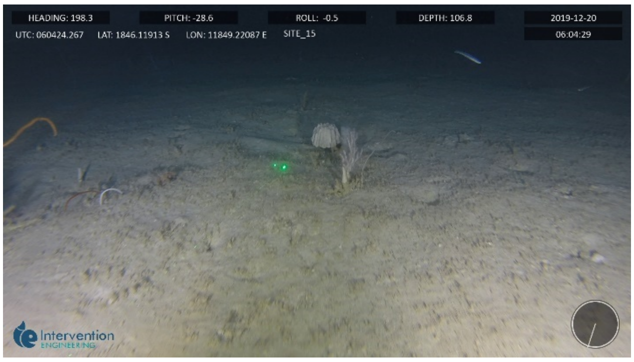

Plate B.35: Sea whips, sponges and gorgonians on buried rock

Plate B.36: Boulders with sponges and small epibiota

Table B-11: Transect description – Site 016

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	7:20:23	38.1	133.9	-18.78198	118.598657
Midpoint		7:34:23	44.4	133.9	-18.780361	118.600132
End		7:48:24	1.4	133.8	-18.777636	118.600525

Benthic habitat and biota description

Flat, sandy silt to mud sediments with abundant bioturbation (and associated small fish and crustaceans) and biogenic turf in soft sediments, very sparse epibiota including anemones. Areas of rippled coarse sand in low waves with very sparse epibiota.

One trevally.

Representative photographs

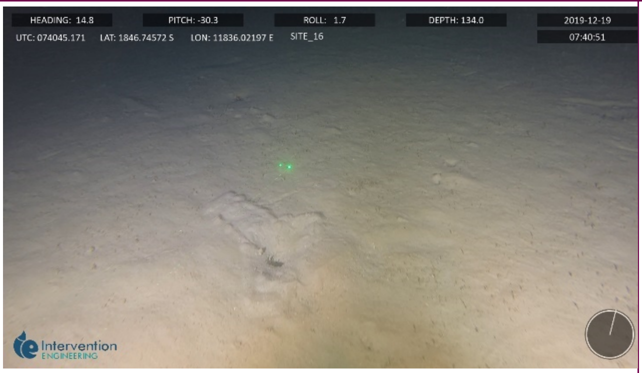

Plate B.37: Bioturbated muddy sediment with fish burrows

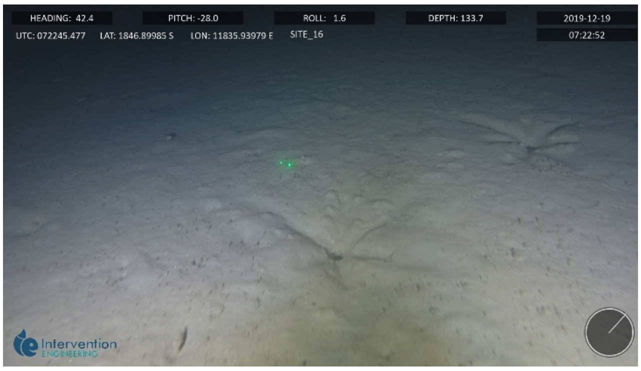

Plate B.38: Bioturbated muddy sediment with fish burrows

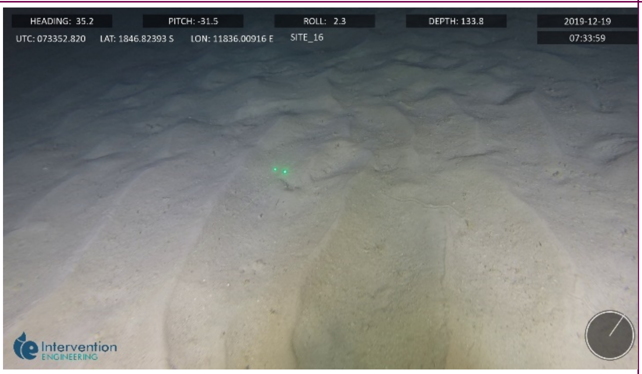

Plate B.39: Rippled sandy sediment

Plate B.40: Large trevally attracted to laser points from ROV

Table B-12: Transect description – Site 017

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	10:12:31	49.9	135.3	-18.81138	118.477624
Midpoint		10:29:49	100.7	136	-18.809422	118.477768
End		10:47:07	47.8	136.2	-18.807349	118.47877

Benthic habitat and biota description

Transect was aborted due to inability to stay on transect line under strong currents. Sufficient coverage for benthic description.

Flat, silty sand with sparse epifauna, little bioturbation, few fish, patches of tube worms in troughs with rubble, occasional urchins and anemones. Areas of rippled bare sand with very sparse epibiota.

Representative photographs

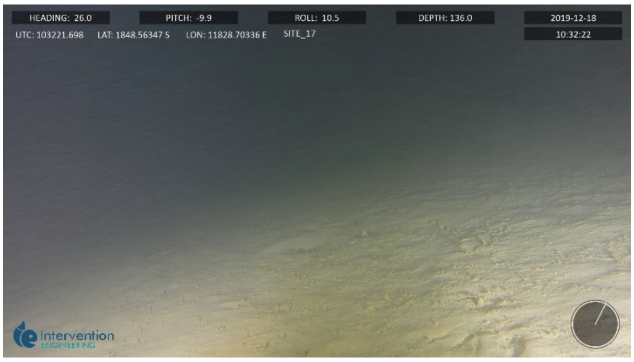

Plate B.41: Silty sand with low density biogenic turf

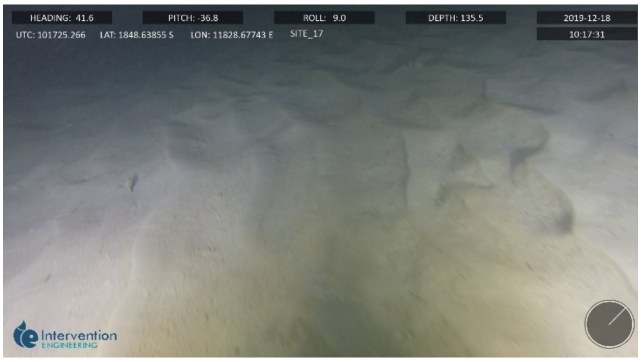

Plate B.42: Rippled bare sand

Table B-13: Transect description – Site 019

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	2:43:51	271.1	100.2	-18.809218	118.953131
Midpoint		2:57:11	260.1	98.3	-18.810187	118.950187
End		3:10:32	260.2	99.1	-18.811038	118.947813

Benthic habitat and biota description

Flat sandy silt with low sand waves and flat rippled sand interspersed, biogenic turf in silt and sand to a lesser degree, not in waves. Soft sediment and sand wave epibiota very sparse and limited to occasional anemones, sea pens, hydroids. More hydroids towards end in silty area.

Representative photographs

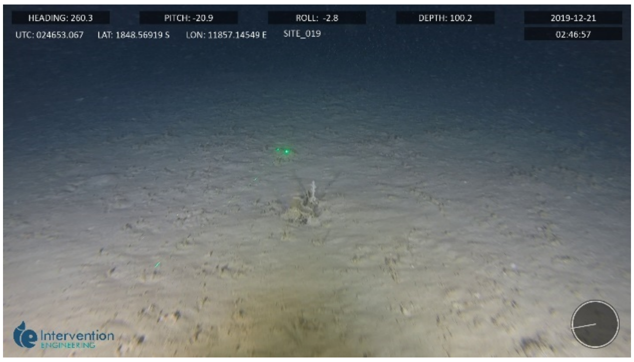

Plate B.43: Flat silty sediment with low density biogenic turf and very sparse epibiota

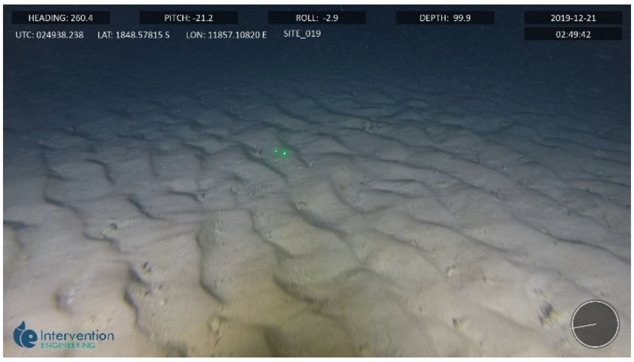

Plate B.44: Rippled sand with very sparse epibiota

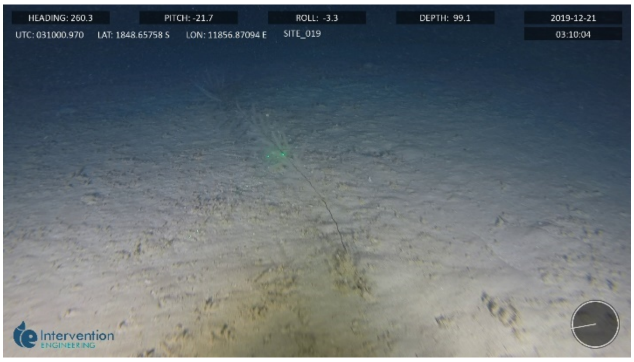

Plate B.45: Hydroid on silty sediment

Table B-14: Transect description – Site 021

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	4:47:01	162	99.4	-18.816605	118.801186
Midpoint		4:56:18	198.4	97.9	-18.819096	118.800025
End		5:05:34	235.6	98.9	-18.82157	118.799032

Benthic habitat and biota description

Flat pavement reef and few low rocky ridges (up to ~ 1m high), with variable sediment veneer supporting low to medium, occasionally dense, density filter-feeding assemblage. Hard substrate supports filter-feeder assemblage including gorgonians, alcyonarians, sponges, sea whips.

Soft sediments towards south-west end of transect supported low- medium biogenic turf and sea pens.

Representative photographs

Plate B.46: Sea whips and gorgonians on rocky ridge

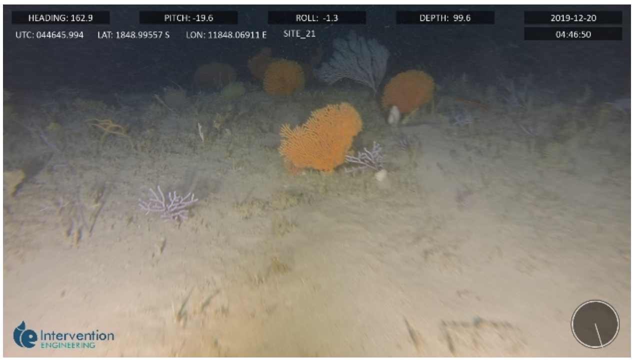

Plate B.47: Sea whips and gorgonians on rocky ridge

Plate B.48: Laminar sponge, alcyonarian, sea whips and gorgonians on rocky ridge

Plate B.49: Cup sponge and sea whips on flat pavement reef

Table B-15: Transect description – Site 023

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	5:58:33	77	114.2	-18.831068	118.667727
Midpoint		6:06:58	70.9	114.4	-18.830438	118.670629
End		6:15:22	78.8	114.6	-18.83013	118.672928

Benthic habitat and biota description

Flat, silty sediments with biogenic turf at low-medium density. Sparse epibiota including occasional sea pens, anemones. Very few fish.

Representative photographs

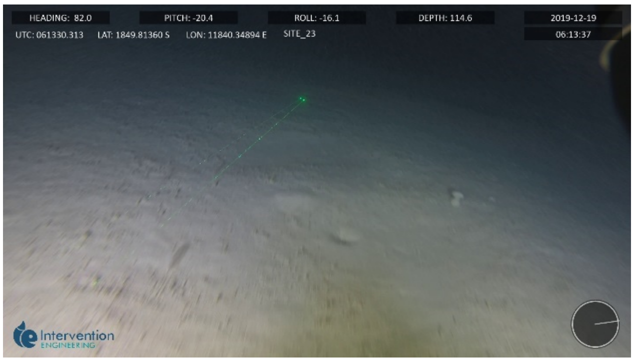

Plate B.50: Anemone on silty sediment with low density biogenic turf

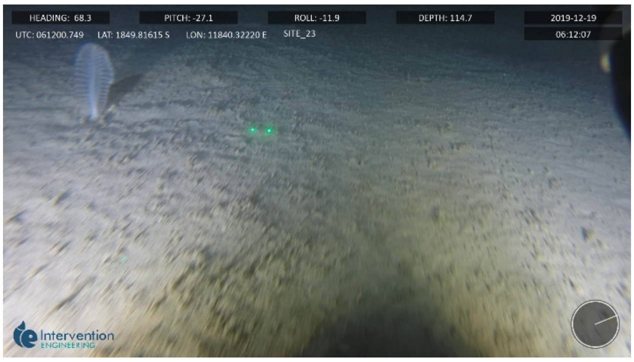

Plate B.51: Sea pen on silty sediment with medium density biogenic turf

Table B-16: Transect description – Site 024

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	4:55:37	72.2	110.3	-18.85087	118.657734
Midpoint		5:03:07	93.3	111.1	-18.850987	118.660551
End		5:10:36	65.8	111.6	-18.850903	118.662946

Benthic habitat and biota description

Flat, silty sediment with low to medium density biogenic turf and sparse epibiota including sea pens, anemones, crinoids, hydroids. Isolated boulders with small gorgonians, sponges, crinoids, very few fish visible, no indication of ancient coastline feature (upstanding reef and fish).

Representative photographs

Plate B.52: Silty sand sediment with medium density biogenic turf

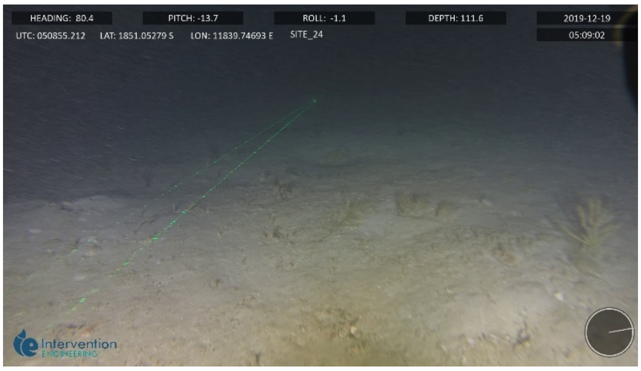

Plate B.53: Hydroids on silty sediment with low density biogenic turf

Plate B.54: Crinoid on silty sediment and rubble with medium density biogenic turf

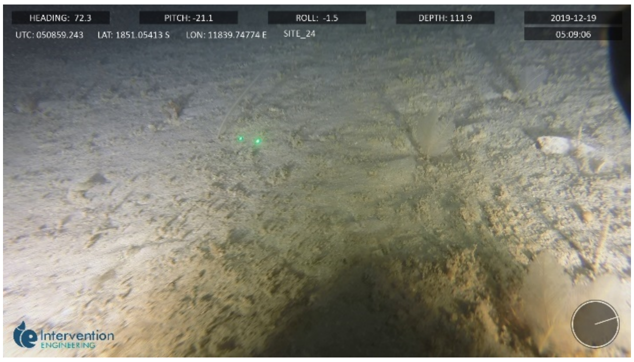

Plate B.55: Hydroids on silty sediment with medium density biogenic turf

Table B-17: Transect description – Site 025

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	1:37:58	207.8	99.6	-18.84874	119.012006
Midpoint		1:46:39	235.2	99.5	-18.84983	119.009563
End		1:55:21	236.2	96.2	-18.850746	119.007509

Benthic habitat and biota description

First half off transect in flat sandy silt with low sand waves to 0.5 m high, with low density biogenic turf and very sparse epibiota including sea pens. Some areas of sand have underlying pavement and ridges of rock as evident form emergent epibiota and small partially buried boulders.

Reef and rocky bottom supported low density gorgonian, sponge and sea whip assemblage, scattered alcyonarians and crinoids. Low to medium profile reef with abundant fish (*Lutjanus* spp, including *L. vitta*) on rocky ledges.

Representative photographs

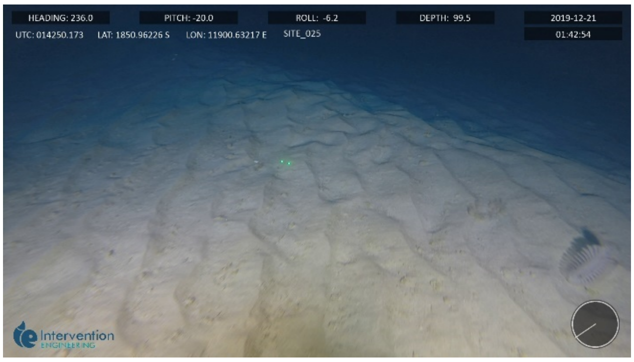

Plate B.56: Sea pen on low sand wave with ripples

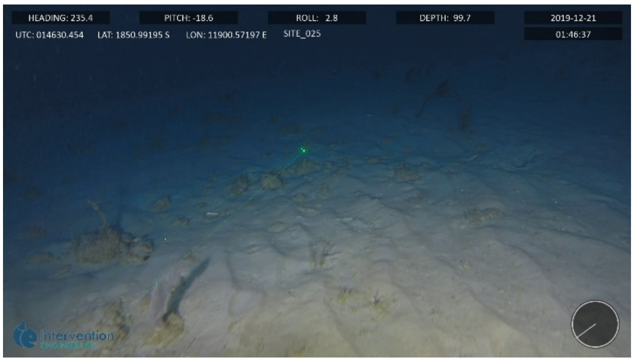

Plate B.57: Sparse epibiota on cobbles and boulders

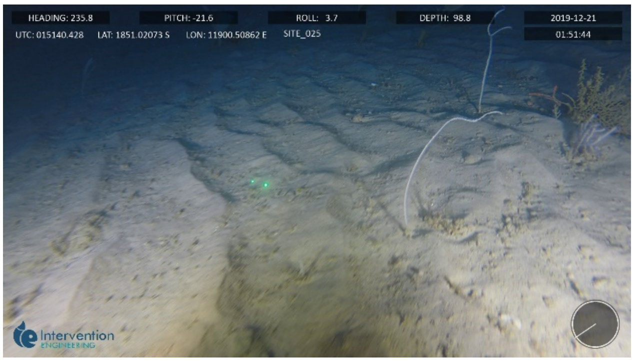

Plate B.58: Pavement reef with sediment veneer, sea whips and gorgonians

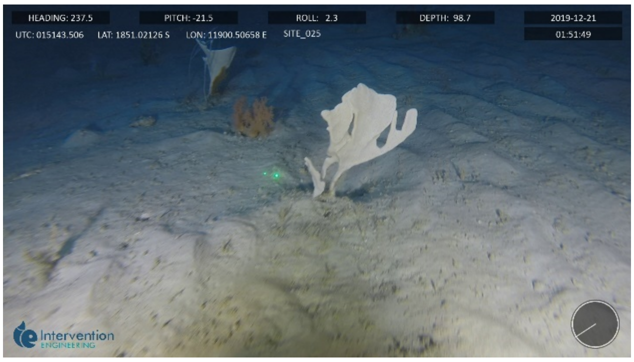

Plate B.59: Sponges, sea whips soft coral on buried reef

Plate B.60: Low-medium profile reef with *Lutjanus* spp.

Plate B.61: Rocky ridge with sediment veneer and sparse epibiota

Table B-18: Transect description – Site 026

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	8:47:19	53.9	119.1	-18.861387	118.52823
Midpoint		9:00:09	47	119.3	-18.859565	118.529648
End		9:12:59	52.9	119.6	-18.858	118.530844

Benthic habitat and biota description

Flat silty sediment with bioturbation and biogenic turf over entire transect, very sparse epibiota, few small fish (e.g. gurnards). No hard substrates. Patch es of rippled coarser sand with very sparse epibiota.

Representative photographs

Plate B.62: Bioturbated silty sediment and medium density biogenic turf

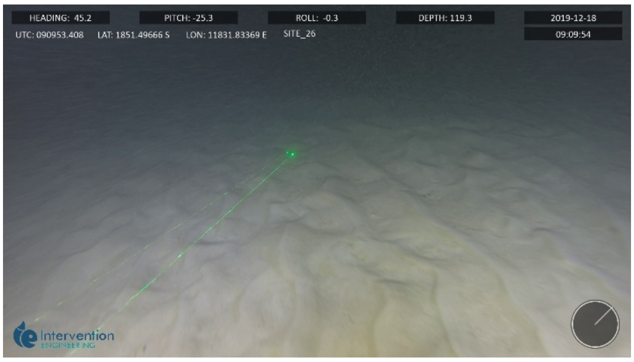

Plate B.63: Rippled sand with very sparse epibiota

Plate B.64: Gurnard on silty sediment

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Table B-19: Transect description – Site 027

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	2:50:45	206.2	99.2	-18.867521	118.93126
Midpoint		3:01:48	202	99.5	-18.869812	118.92958
End		3:12:50	202.9	98.7	-18.872368	118.928497

Benthic habitat and biota description

Flat, silty seabed with biogenic turf, hydroids, sea whips, small digitate sponges. Low, rippled coarse sand dunes to < 0.5 m high and patches of coarse sand running across silty seabed. Area with underlying pavement reef or boulders evident from hard substrate biota including very occasional alcyonarians, sea whips and small gorgonians.

Representative photographs

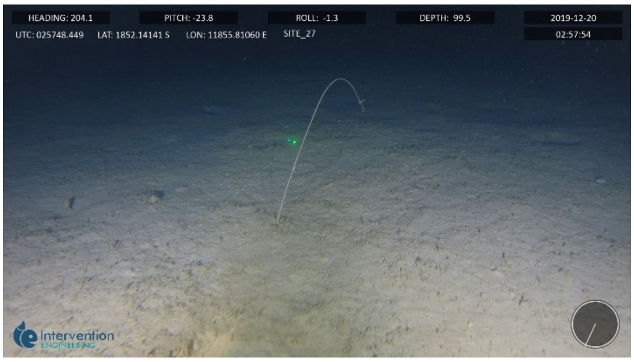

Plate B.65: Sea whip on silty sediment over rock

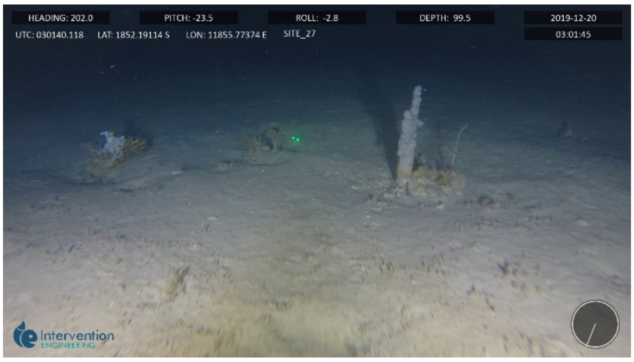

Plate B.66: Small soft coral and sparse epibiota on buried boulders or reef

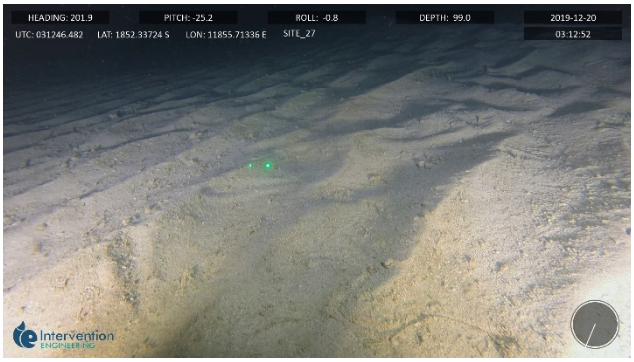

Plate B.67: Rippled coarse sand with low density biogenic turf and bioturbation

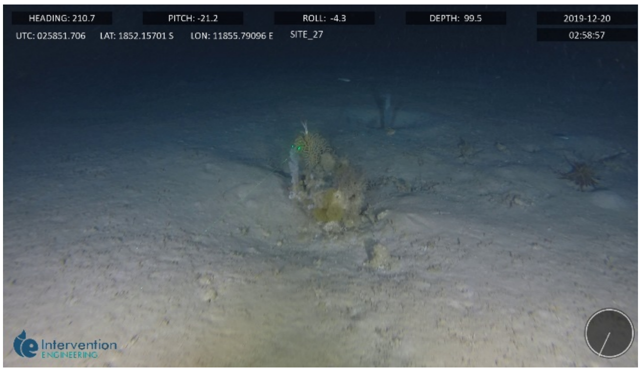

Plate B.68: Small gorgonians on buried boulder

Table B-20: Transect description – Site 028

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	5:49:49	227.2	103.9	-18.90834	118.45212
Midpoint		5:59:03	199	103.4	-18.910393	118.451132
End		6:08:17	197.5	102.9	-18.912461	118.450433

Benthic habitat and biota description

Flat, sandy silt to mud with biogenic turf and very sparse epibiota including sea pens and anemones. Low to moderate levels of bioturbation including by small fish in holes. Areas of coarser, rippled sand with very sparse epibiota.

Representative photographs

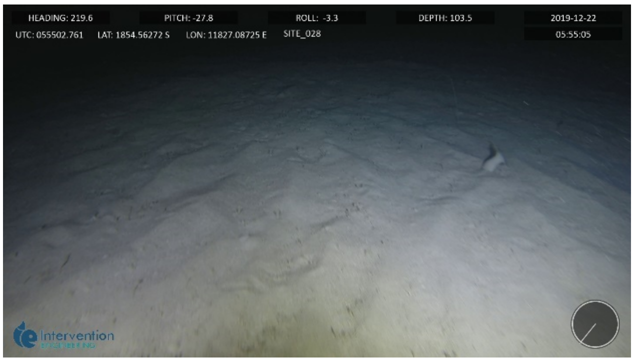

Plate B.69: Anemone on rippled sandy sediment

Plate B.70: Sea pen on silty sediment with medium density biogenic turf

Table B-21: Transect description – Site 029

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	3:53:54	234.5	99	-18.907812	118.571158
Midpoint		4:01:37	235.4	96.9	-18.908921	118.569101
End		4:09:20	231.5	96.9	-18.910167	118.567127

Benthic habitat and biota description

Flat, sandy sediment with low sand waves to 10 -20 cm high, some to 0.5 m high. Very sparse epibiota including sea pens, soft corals, hydroids, sea stars, anemones. Siltier sediment in the lee of sand waves bioturbated and support tube worms, small fish and anemones.

Representative photographs

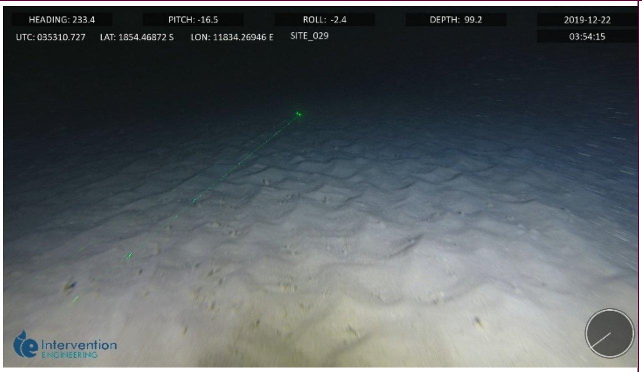

Plate B.71: Flat sandy sediment with low density biogenic turf

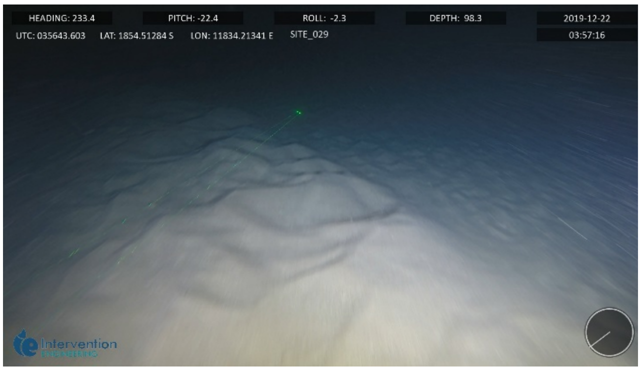

Plate B.72: Low sand wave with rippled sand

Plate B.73: Larger sand wave

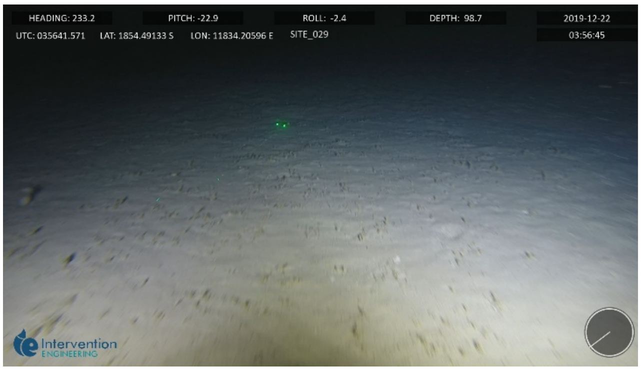

Plate B.74: Silty sediment with medium density biogenic turf

Table B-22: Transect description – Site 031

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	6:43:47	174.5	105.2	-18.927786	118.431051
Midpoint		6:53:25	172.3	106.3	-18.930194	118.431533
End		7:03:04	178	107.2	-18.932055	118.432069

Benthic habitat and biota description

Flat, sandy silt, bioturbated sediment with very sparse epibiota including sea pens, sea stars, anemones, small fish, and biogenic turf at medium density throughout transect. 1 flute mouth fish.

Representative photographs

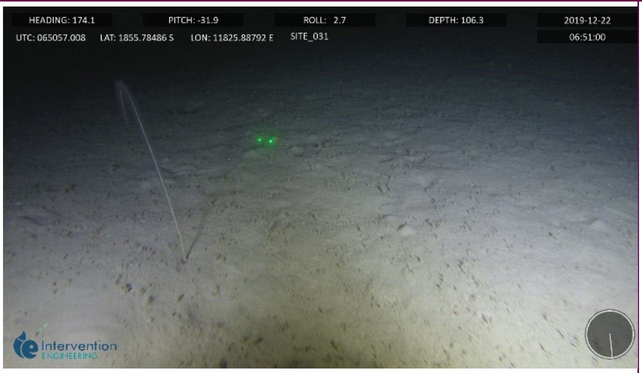

Plate B.75: Sea pen on sandy silt sediment with medium density biogenic turf

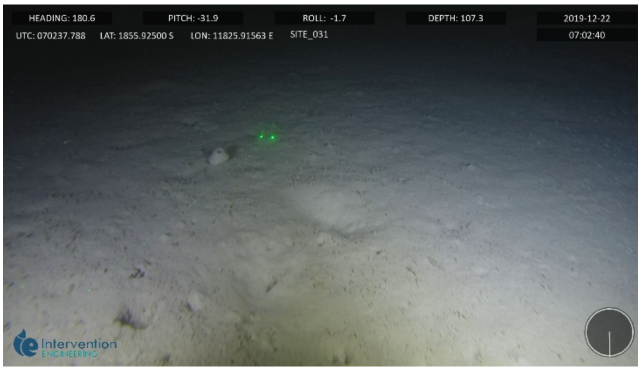

Plate B.76: Anemone on sandy silt sediment

Plate B.77: Bioturbation in sandy silt sediment

Plate B.78: Sea star on sandy silt sediment

Table B-23: Transect description – Site 032

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	2:58:57	228	92.2	-18.927563	118.571793
Midpoint		3:06:58	232	92.4	-18.928712	118.56962
End		3:15:00	225.1	91.8	-18.930218	118.567532

Benthic habitat and biota description

Flat pavement reef, rubble and boulders with sediment veneer supporting low to medium density filter-feeding assemblage including sea whips, gorgonians, alcyonarians, sponges, crinoids, basket star, hydroids possibly black coral. Some larger fish in adjacent patches of epibiota e.g. Serranidae, Ballistidae. Flat, sandy silt sediment with low sand waves (~ 10 cm high) and patches of rippled sand. Epibiota very sparse, including sea urchins, sea stars, sponges in patches of softer sediments with biogenic turf.

Representative photographs

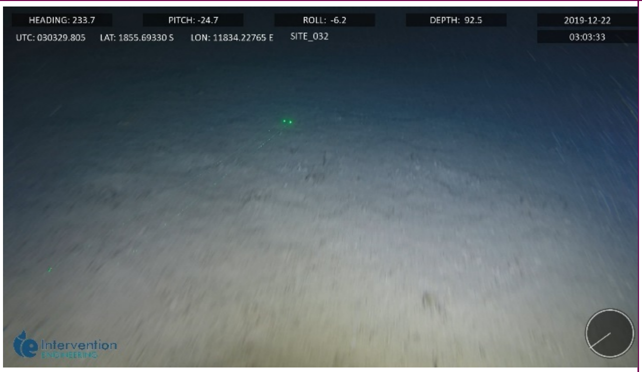

Plate B.79: Silty sediment over pavement reef

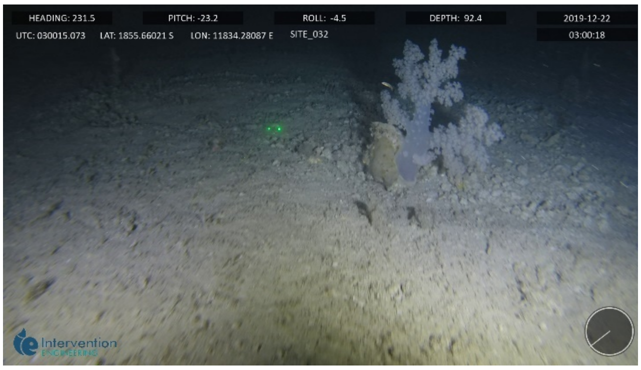

Plate B.80: Soft coral in silt and rubble

Plate B.81: Serranid and epibiota on boulders

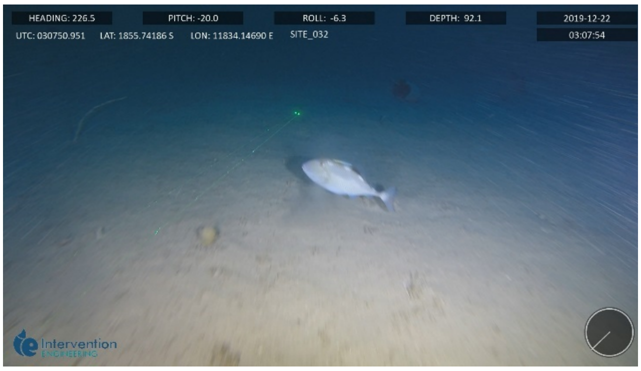

Plate B.82: Ballistid over sediment covered reef

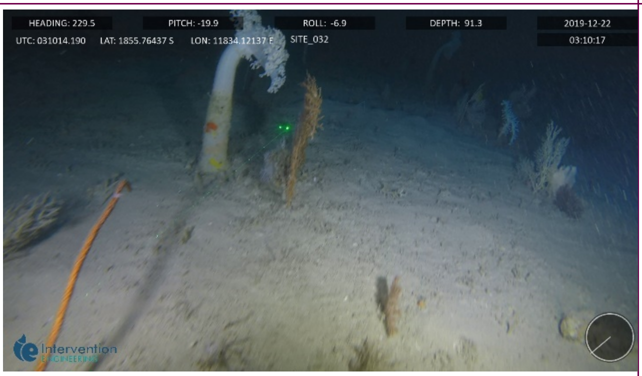

Plate B.83: Soft coral, gorgonians, sea whips

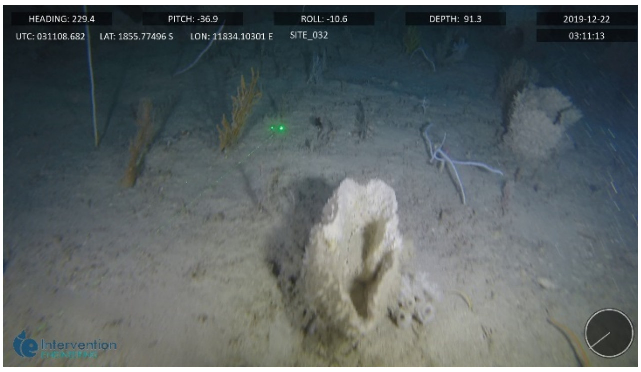

Plate B.84: Sponges, sea whips, gorgonians

Table B-24: Transect description – Site 033

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	1:21:01	222.4	91.7	-18.928109	119.071764
Midpoint		1:28:33	217.4	91.7	-18.9299	119.069741
End		1:36:04	215.8	92.4	-18.931573	119.067882

Benthic habitat and biota description

Flat, fine to coarse sand and rubble, with patches of rippled sand and occasional sand waves (< 0.5 m high).

Very sparse assemblage with sand crinoids, biogenic turf at low densities, small alcyonarians, occasional hydroids and sea whips.

Representative photographs

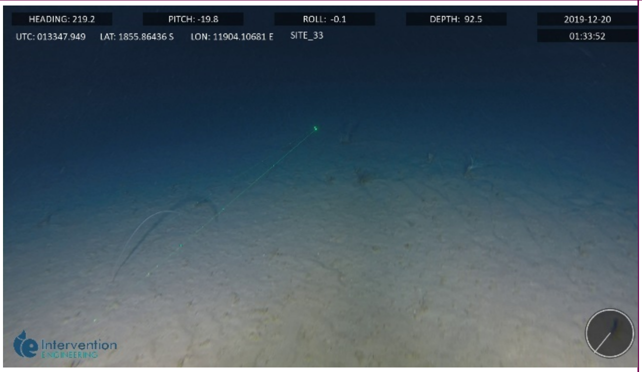

Plate B.85: Flat sandy sediment with sea pen

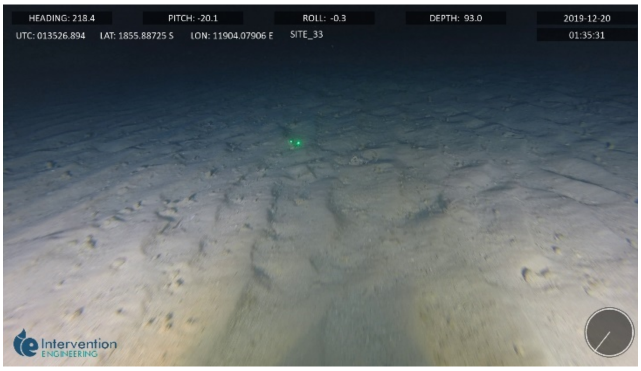

Plate B.86: Rippled coarse sand and low density biogenic turf

Plate B.87: Crinoid on sand and rubble

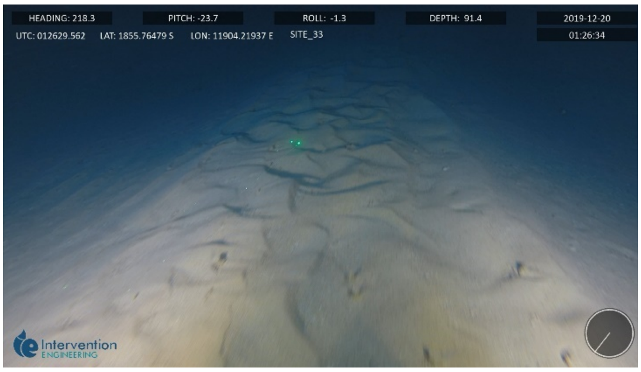

Plate B.88: Low sand wave

Table B-25: Transect description – Site 034

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	3:12:07	86.4	92.9	-18.940446	118.727525
Midpoint		3:20:44	28.9	95.1	-18.940058	118.730016
End		3:29:22	61	95.1	-18.940122	118.732452

Benthic habitat and biota description

Flat silt sediment with low to high density biogenic turf, patches of rippled sand. Sparse epibiota including sea pens, hydroids, anemones, digitate sponges and urchins. Buried hard substrates and partially exposed boulders supported low density assemblage of sponges, gorgonians, sea whips and some alcyonarians.

Representative photographs

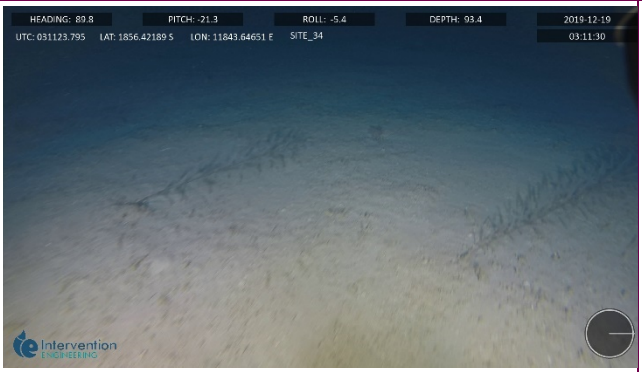

Plate B.89: Sandy silt sediment with hydroids

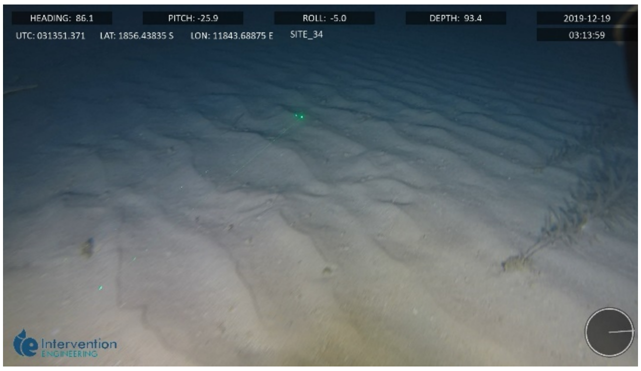

Plate B.90: Rippled sand with hydroids

Plate B.91: Buried pavement with sea whip, sponge, crinoids

Plate B.92: Buried pavement with soft coral, gorgonians

Table B-26: Transect description – Site 035

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	7:52:09	143.1	100.5	-18.977299	118.419762
Midpoint		8:05:45	143.2	98.2	-18.979646	118.421059
End		8:19:21	141.9	98.3	-18.981959	118.423084

Benthic habitat and biota description

Flat, sandy silt sediment over pavement and partly exposed boulders. Patches of mixed filter-feeding assemblages on harder substrates with silt veneer. Dominated by small gorgonians to 10 – 15 cm high (new assemblage?), sea whips, sponges, hydroids, alcyonarians, crinoids.

Soft sediments with abundant sea pens, occasional anemones, small finger sponges (5 – 10 cm high) and low-density biogenic turf.

Representative photographs

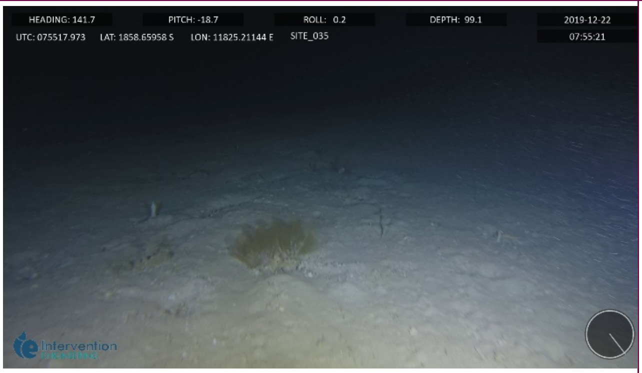

Plate B.93: Hydroid on buried rubble

Plate B.94: Sea pen in bioturbated sandy silt

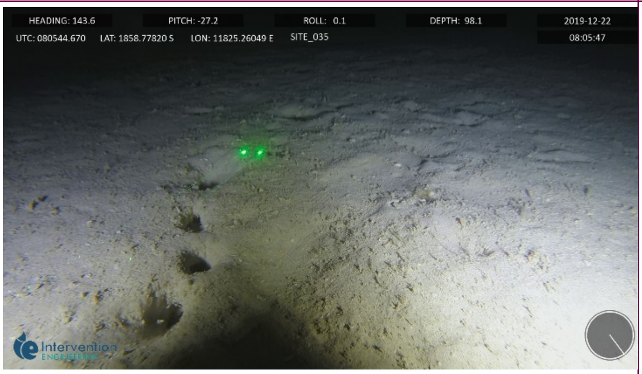

Plate B.95: Bioturbated sandy silt with low density biogenic turf

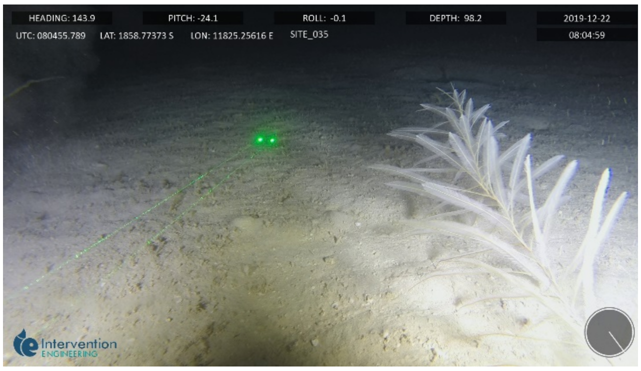

Plate B.96: Stalked hydroid on sandy silt

Plate B.97: Gorgonians on buried pavement

Plate B.98: Gorgonians, sea whip, soft coral

Table B-27: Transect description – Site 037

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	7:01:15	63.6	95.3	-19.001521	118.557633
Midpoint		7:13:25	54.1	96	-18.999604	118.560235
End		7:25:35	52.2	95.3	-18.998161	118.561791

Benthic habitat and biota description

Flat sandy silt with scattered patches of rippled sand and partially buried boulders. Sediments with sparse assemblage of sea pens, sea urchins, biogenic turf along most of transect, occasional small fish. Boulders and buried pavement substrate with low to medium density patches of gorgonians, hydroids, sponges, sea whips, soft corals.

Representative photographs

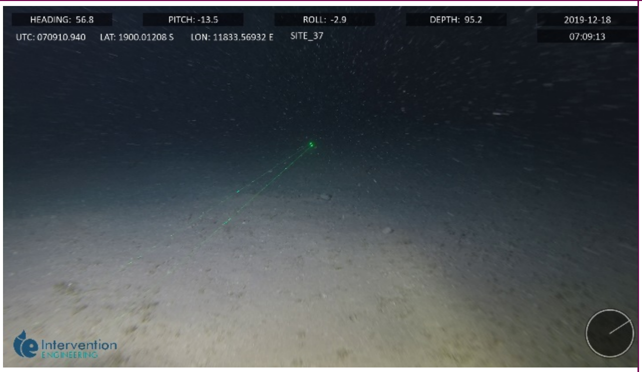

Plate B.99: Sandy silt, rubble and urchin

Plate B.100: Boulder with sea whips, sponges, soft corals

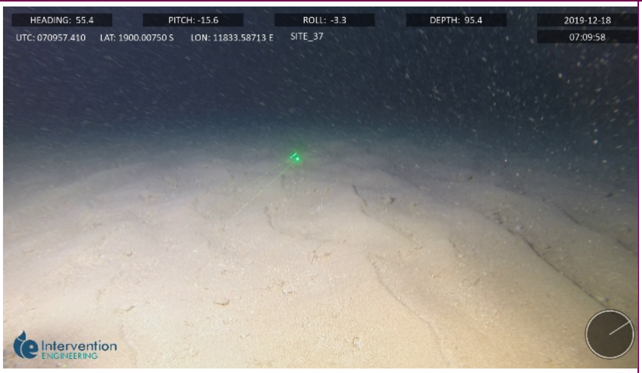

Plate B.101: Rippled coarse sand

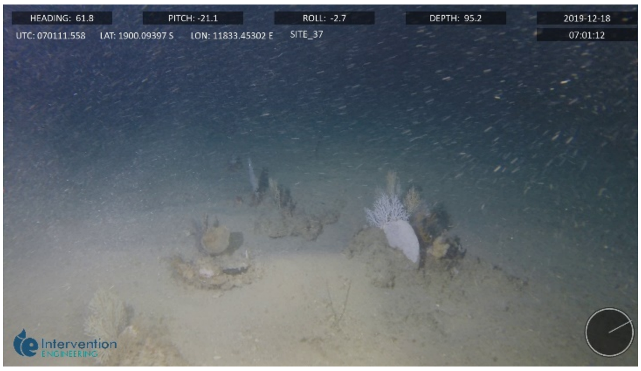

Plate B.102: Partly buried boulders with epibiota

Table B-28: Transect description – Site 038

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-21	23:31:16	43.5	93	-19.011994	118.867953
Midpoint		23:46:38	40.7	93.1	-19.009528	118.868881
End		0:02:00	32.5	93.4	-19.007882	118.871438

Benthic habitat and biota description

Flat sandy sediment with ripples and rubble, with sparse epibiota including sand crinoids, free-living basket stars, sea stars, sea urchins, anemones, one octopus, small fish, sea pens.

Representative photographs

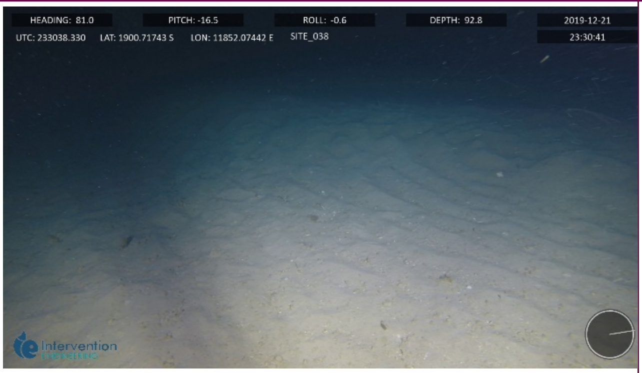

Plate B.103: Rippled, silty sand and rubble

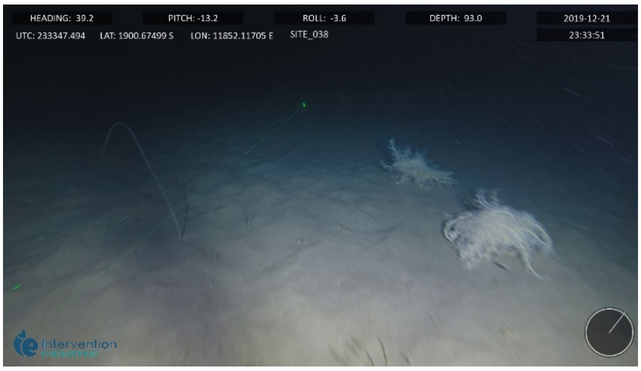

Plate B.104: Basket stars and sea pen

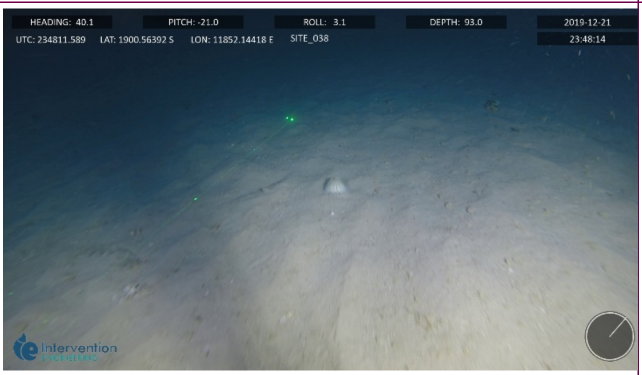

Plate B.105: Sea urchin (*Echinocardium* sp.) on sand

Plate B.106: Sea star on silty sand

Table B-29: Transect description – Site 039

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-20	23:57:57	261.5	87.5	-19.03944	119.082776
Midpoint		0:05:38	261.4	87.5	-19.039466	119.080272
End		0:13:19	260.2	86.7	-19.040131	119.077432

Benthic habitat and biota description

Flat silty sand sediments with biogenic turf and sparse epibiota including hydroids, small sponges, sea pens. Patches of boulders and buried hard substrate supporting low to medium density epibiota assemblage, including sponges (digitate and laminar), gorgonians, sea whips.

Representative photographs

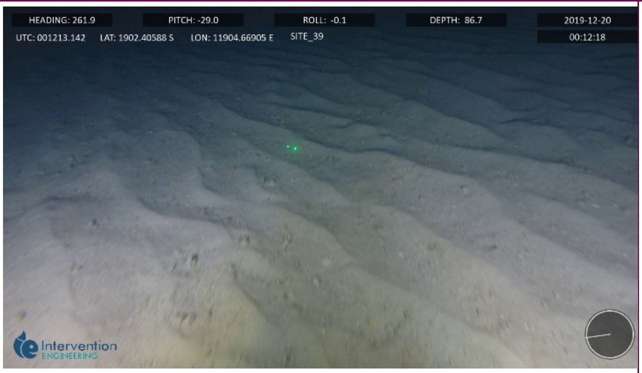

Plate B.107: Rippled silty sand and rubble

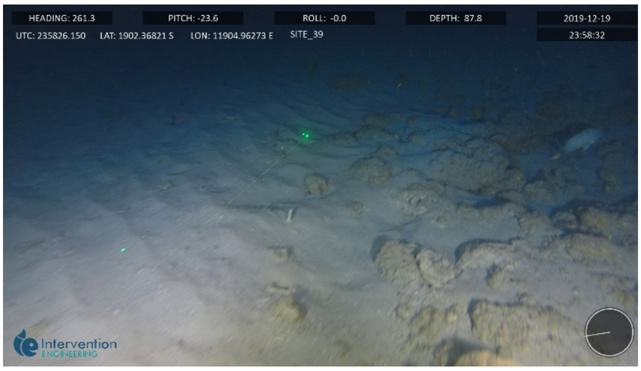

Plate B.108: Partially buried boulders and cobbles

Plate B.109: Sponges, sea whips on boulders

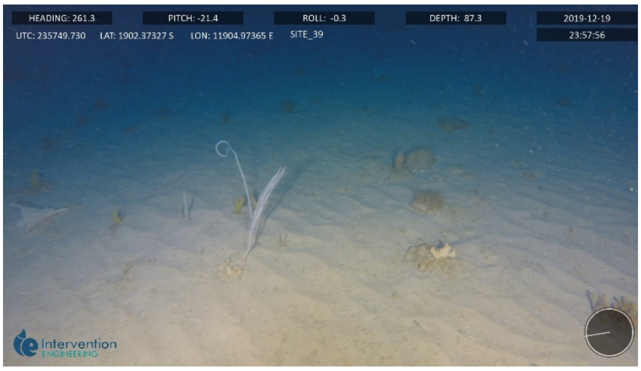

Plate B.110: Epibiota on boulders and buried reef

Table B-30: Transect description – Site 041

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	5:37:45	38.6	91.1	-19.071709	118.617942
Midpoint		5:46:53	39.1	90.3	-19.069933	118.620286
End		5:56:01	44.1	90.3	-19.069123	118.622014

Benthic habitat and biota description

Flat, silty sand with high density of biogenic turf and occasional sea pens. Rocky lumps and surrounding sediments with sponges, gorgonians, alcyonarians, hydroids, scattered sea pens, low-medium density of small gorgonians (30 – 40 cm high) in first half of transect, occasional sponges, small fish in associations with epifaunal habitats, occasional sea pens in sandy sections.

Representative photographs

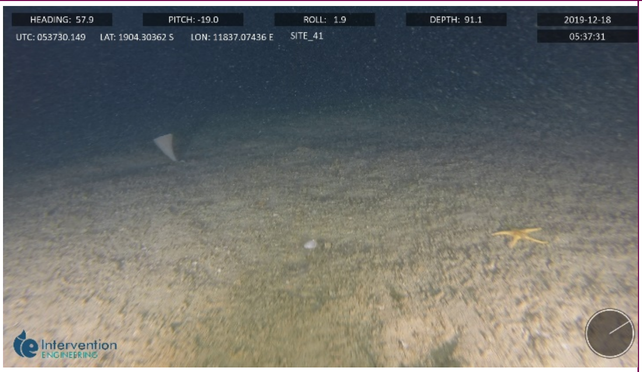

Plate B.111: Silty sand with high density biogenic turf, sponge, sea star

Plate B.112: Buried reef with sea whips, gorgonians

Plate B.113: Rippled sand with crinoids

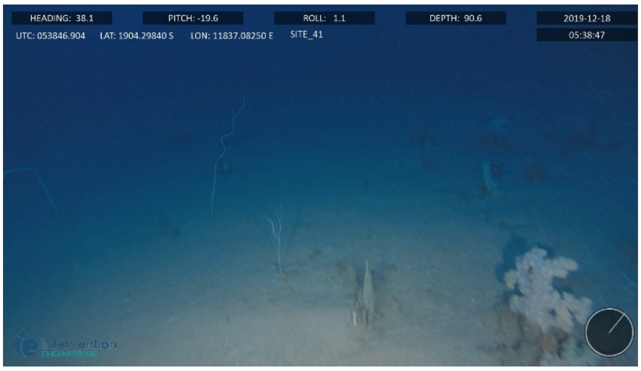

Plate B.114: Boulders and buried reef with epibiota

Table B-31: Transect description – Site 042

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	22:43:40	40	85.6	-19.10198	118.857693
Midpoint		22:54:59	40.3	85.7	-19.099433	118.858895
End		23:06:18	44.8	85.8	-19.097302	118.859407

Benthic habitat and biota description

Flat, silty sand to coarse rippled sand with low densities of biogenic turf. Buried rock or boulders support very sparse assemblages of gorgonians, sponges, soft corals, crinoids. Large area of biogenic turf (medium density) towards mid third of transect, start of transect with scattered medium to low density assemblage of sponges (cup and digitate), gorgonians and sea whips. Scattered hydroids in sandy areas, low abundance of fish (e.g. leatherjacket). Little bioturbation in sandy area at end of transect.

Representative photographs

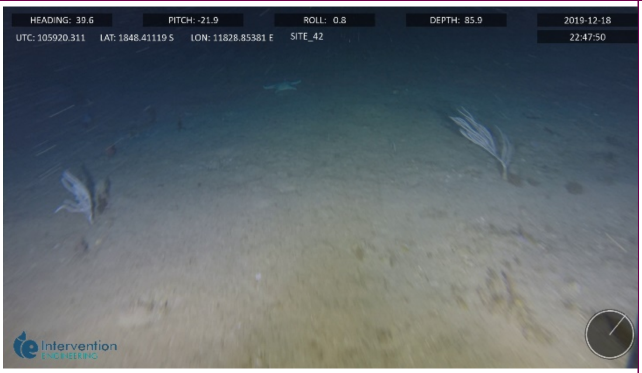

Plate B.115: Branching sea whips and sea star on sandy silt and rubble

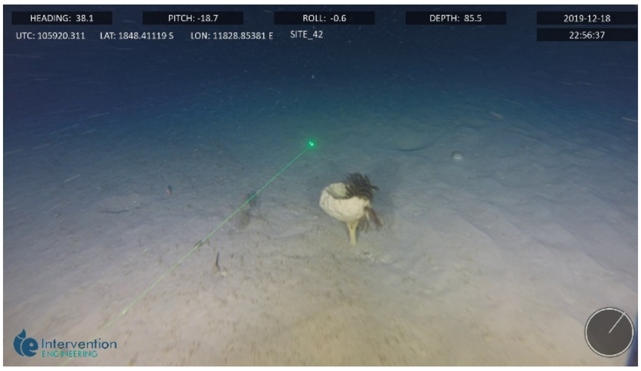

Plate B.116: Cup sponge, crinoid, sea urchin on sandy silt

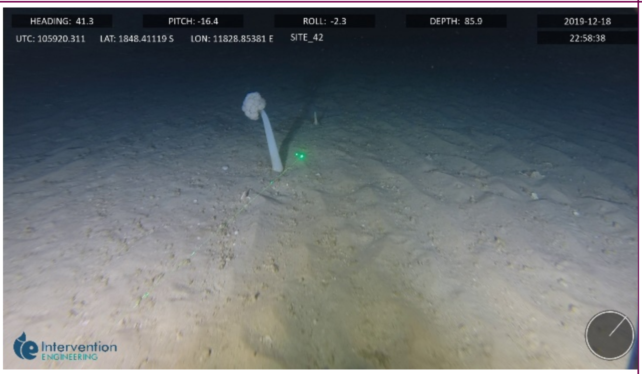

Plate B.117: Rippled sand, rubble and soft coral

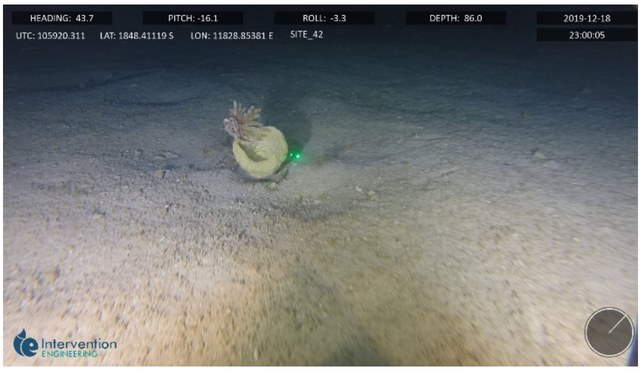

Plate B.118: Sponge, crinoid on sandy silt with medium density biogenic turf

Table B-32: Transect description – Site 043

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	9:31:12	122.3	92.3	-19.118959	118.508331
Midpoint		9:37:54	116.5	92.4	-19.119927	118.509979
End		9:44:35	109.6	91.9	-19.121296	118.512298

Benthic habitat and biota description

Flat sandy sediment and buried pavement reef. Hard substrate supports low density filter-feeding assemblage, including gorgonians, sponges, alcyonarians and sea whips. One red emperor and assorted other reef fish associated with filter feeder assemblage. Sand waves bare, sediments between with sparse sea pens, biogenic turf.

Representative photographs

Plate B.119: Sparse epibiota on buried pavement reef

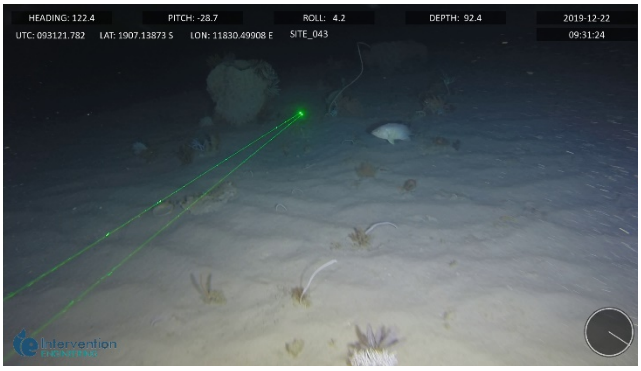

Plate B.120: Sparse epibiota on rock covered with rippled sand

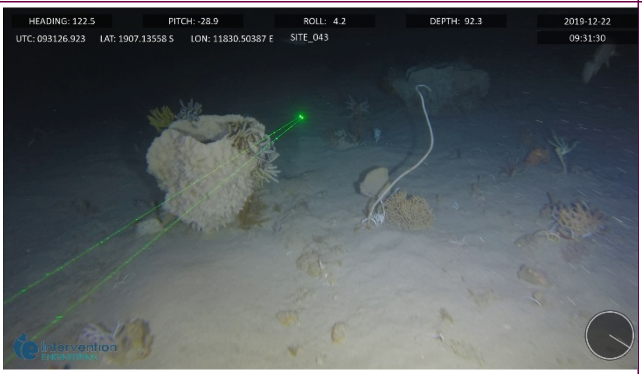

Plate B.121: Medium density filter-feeder assemblage of sponges, sea whips, crinoids, gorgonians and mobile fish

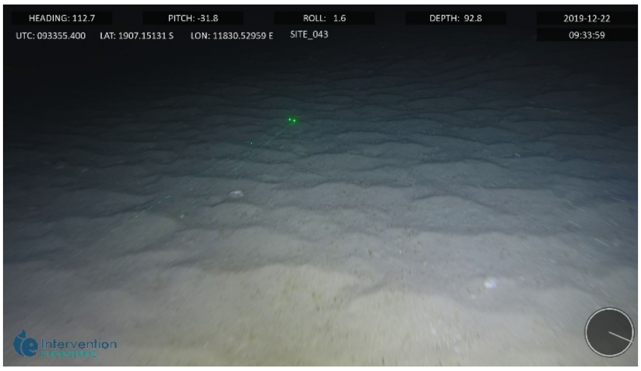

Plate B.122: Rippled sand with very sparse epibiota

Table B-33: Transect description – Site 044

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	22:38:35	253.6	83.5	-19.11859	119.122214
Midpoint		22:46:28	249.6	83.5	-19.119217	119.120099
End		22:54:22	250.4	83.2	-19.120055	119.118491

Benthic habitat and biota description

Flat, rippled sand and rubble in troughs and occasional low sand waves. Sparse to medium densities of epibiota including abundant crinoids buried in sediments (up to ~5/m^2); sea pens, hydroids, anemones, alcyonarians and biogenic turf at low density across transect.

Representative photographs

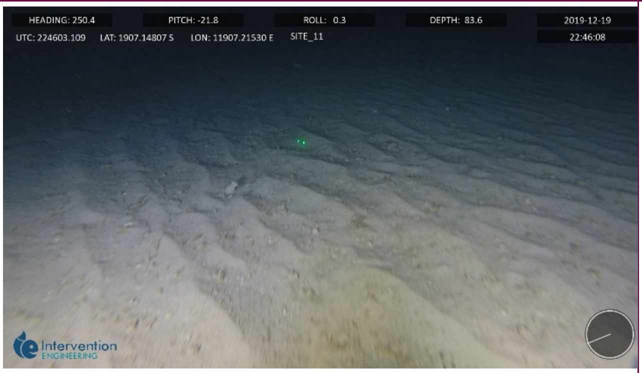

Plate B.123: Rippled sand with anemone

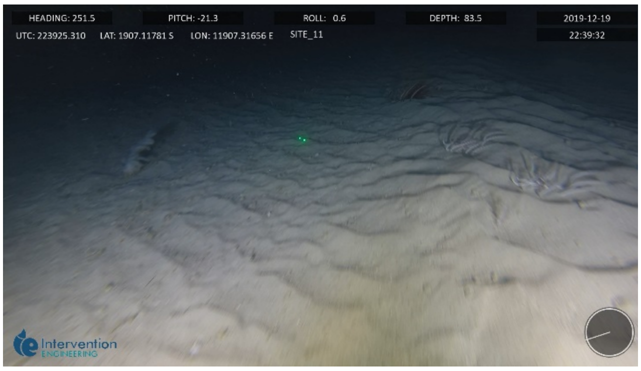

Plate B.124: Low rippled sand wave with crinoids

Plate B.125: Rippled sand with crinoids

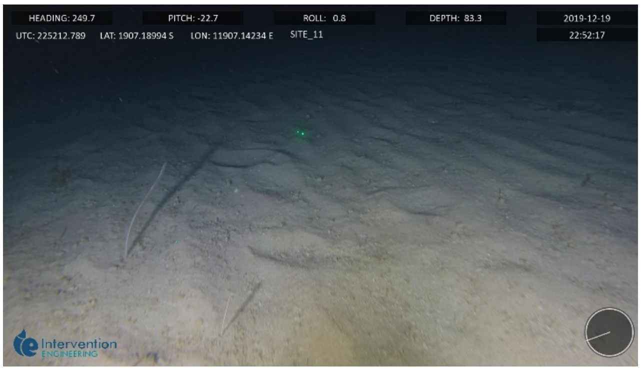

Plate B.126: Sea pens on sandy silt

[Note site number on video overlay incorrectly shows site 11]

Table B-34: Transect description – Site 045

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	3:55:55	97	85.3	-19.129622	118.717588
Midpoint		4:03:15	99.3	85.1	-19.130695	118.72023
End		4:10:35	96.2	85.4	-19.131337	118.722846

Benthic habitat and biota description

Flat, bioturbated, rippled, fine to coarse sand with rubble and occasional sand waves to ~0.5 m high. Biogenic turf over second half of transect, and very sparse epifaunal assemblage including starfish, hydroids, small fish (not abundant) and sea pens.

Representative photographs

Plate B.127: Soft coral on rippled sand and rubble

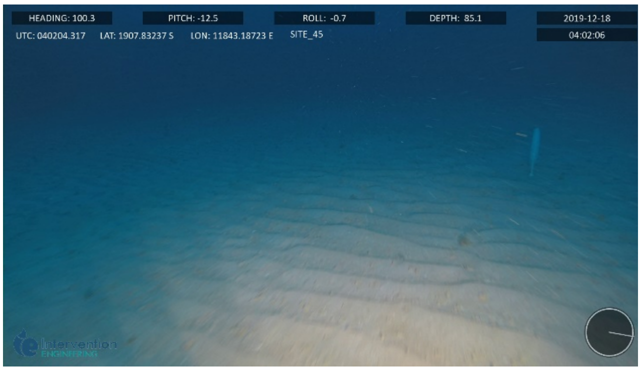

Plate B.128: Sea pen on rippled sand

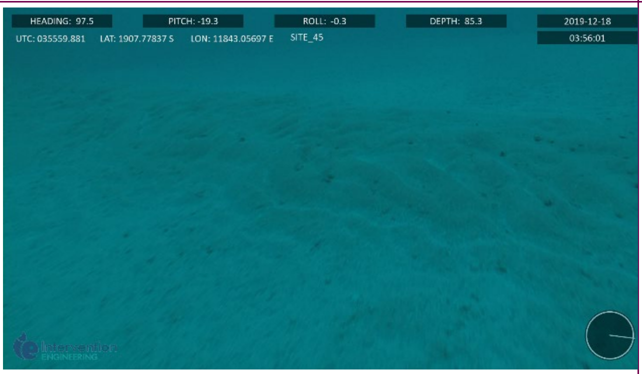

Plate B.129: Low sand wave with sparse epibiota

Plate B.130: Rippled coarse sand and rubble with crinoid

Table B-35: Transect description – Site 048

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-18	1:08:40	349.1	77.7	-19.222876	118.829561
Midpoint		1:25:19	0.6	78.1	-19.22	118.830115
End		1:41:58	357.2	78.4	-19.217732	118.830077

Benthic habitat and biota description

Flat sandy silt to rippled sand and rubble with low sand waves. Silty sediment with low to medium density biogenic turf and sparse epibiota. Epifauna very sparse on sandy sediments. Epifaunal assemblage included alcyonarians (soft corals), sea pens, occasional sponges, small fish, cuttlefish, anemones. To the NW of the transect end are small patches of boulders with sponges and hydroids.

Representative photographs

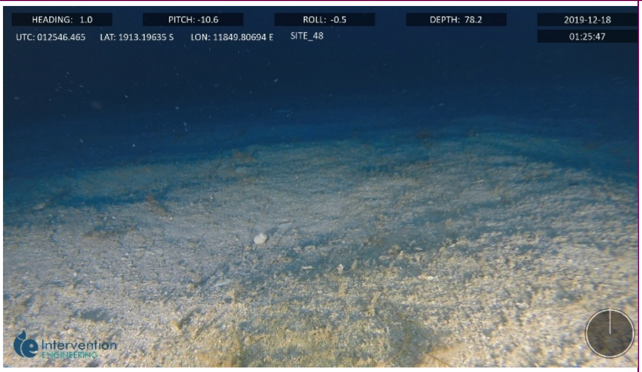

Plate B.131: Anemone on sandy silt and medium density biogenic turf

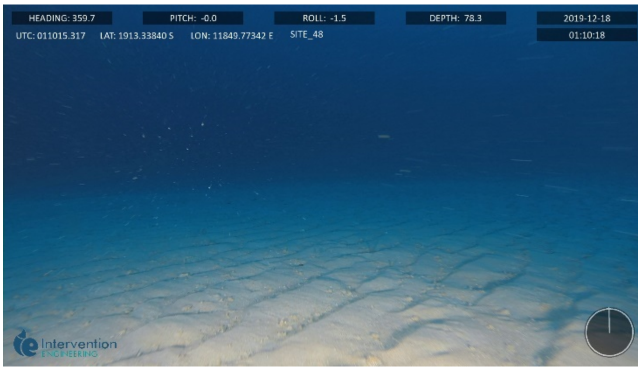

Plate B.132: Rippled sand with rubble in troughs very sparse epibiota

Plate B.133: Sandy silt with low density biogenic turf, starfish, crinoid, sea pen

Plate B.134: Soft coral, crinoid on rippled sand

Table B-36: Transect description –Site WHPL (060)

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	0:37:41	27.5	88.9	-19.029317	118.742583
Midpoint		0:50:40	25.8	89	-19.027215	118.743558
End		1:03:39	27.4	88.8	-19.025245	118.74459

Benthic habitat and biota description

Flat, silty sand, rubble with low to medium density tube worms and very sparse epibiota including urchins, hydroids, sea pens, crinoids, sea whips. Very few larger rocks or boulders.

Representative photographs

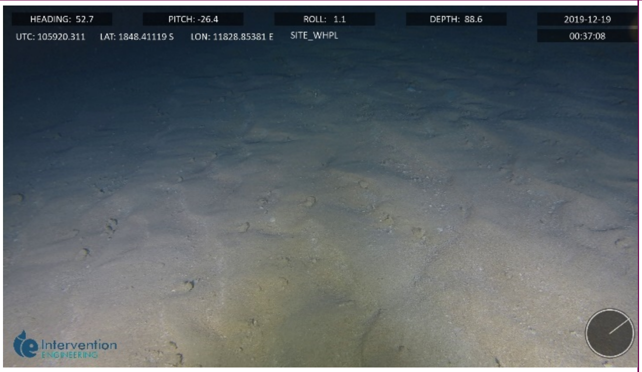

Plate B.135: Rippled sand, low density biogenic turf, very sparse epibiota

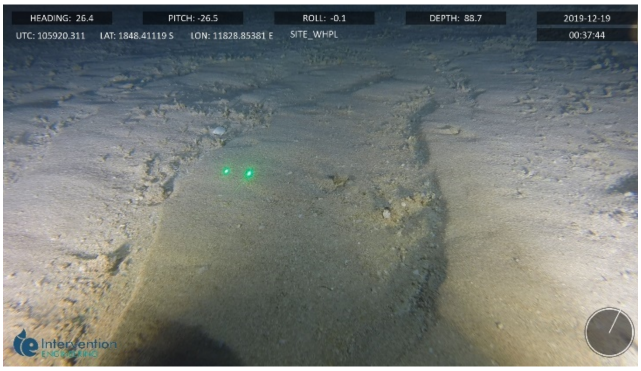

Plate B.136: Rippled sand, rubble and biogenic turf

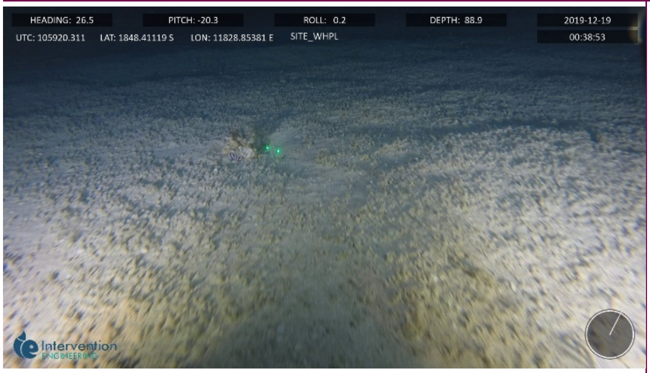

Plate B.137: Medium density biogenic turf, silty sand

Plate B.138: Sparse epibiota on scattered boulders and rocks

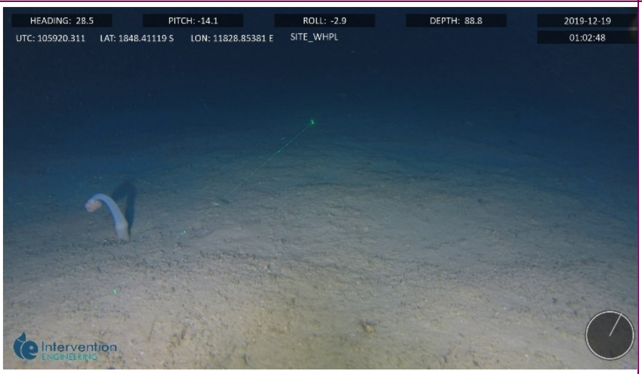

Plate B.139: Soft coral on silty sand

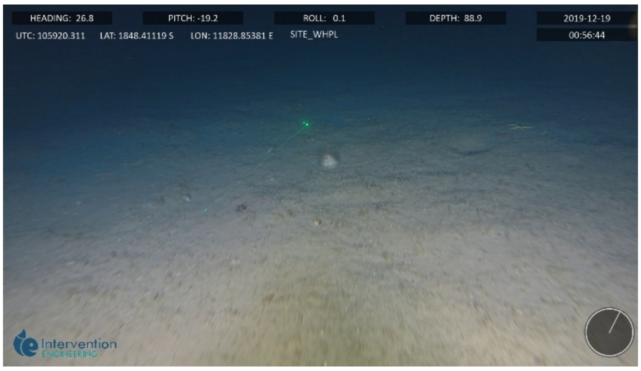

Plate B.140: Sea urchin and sea star on silty sand

Table B-37: Transect description –Site FPSP (061)

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-19	1:46:27	66.9	90.5	-19.005395	118.764418
Midpoint		2:03:39	50.8	89.5	-19.004508	118.767487
End		2:20:52	66	90.5	-19.003958	118.769955

Benthic habitat and biota description

Flat silty sand with patches of boulders. Denser epibiota towards start of transect and end of transect; large stretch of tube worms in silty sediment in the middle. Boulders and smaller rocks supported low density assemblage of sponges (digitate, cup, branched), sea whips, gorgonians (fans and branched), hydroids on sand, alcyonarians. Few fish visible.

Representative photographs

Plate B.141: Gorgonians and soft coral. Sponge, crinoid of silty sand

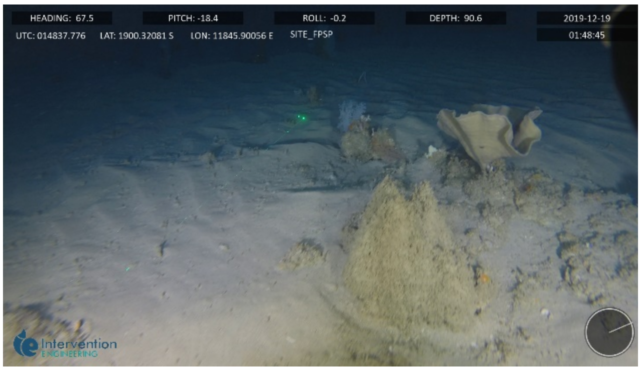

Plate B.142: Live and dead sponges on partly buried boulders

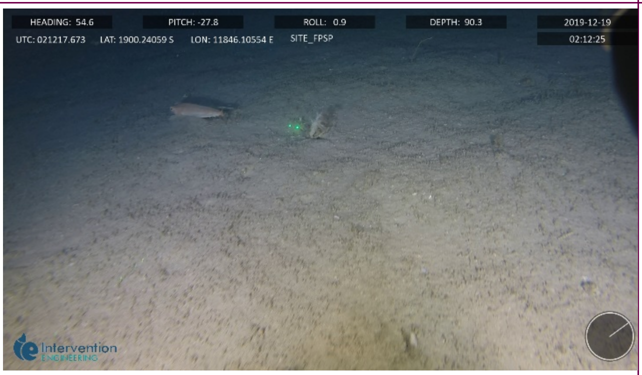

Plate B.143: Gurnard, small invertebrates, biogenic turf

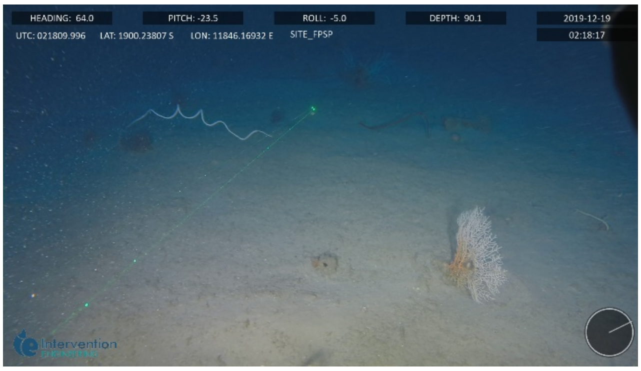

Plate B.144: Gorgonians, sea whips on partly buried boulders

Table B-38: Transect description –Site FPSPNW (062)

Position	Date	Time stamp	Heading (°)	Depth (m)	Coordinates in WGS84	
					Latitude	Longitude
Start	2019-12-22	1:18:16	264.9	92.4	-19.004958	118.722408
Midpoint		1:28:45	272.4	92.5	-19.004849	118.719756
End		1:39:14	258	92.4	-19.004564	118.71708

Benthic habitat and biota description

Flat, silty sediments with buried reef and boulders (5 – 25 cm), with low to medium density filter-feeding assemblage. Filter-feeding assemblage dominated by fan and branching gorgonians and sea whips and alcyonarians, sponges (laminar, cup, branched), occasional hydroids, sea stars and anemones with low densities of biogenic turf on soft sediments.

Representative photographs

Plate B.145: Gorgonians, sponges on buried hard substrate

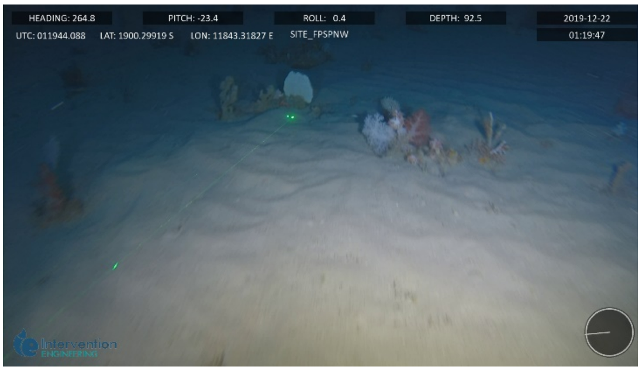

Plate B.146: Soft corals, sponges on exposed parts of boulders

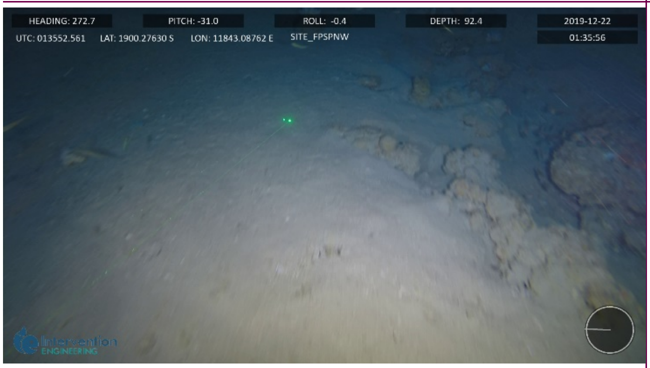

Plate B.147: Partly uncovered, low relief reef and boulders

Plate B.148: Low sand wave over hard substrate with filter-feeders

Plate B.149: Fish around gorgonian on buried rock

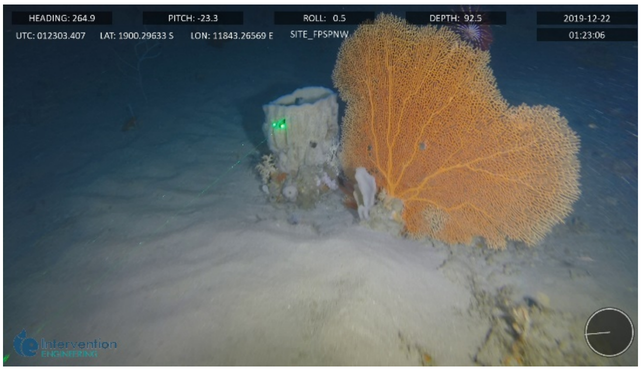

Plate B.150: Gorgonian, sponge on buried rock

Appendix C
Infaunal data

APPENDIX C: INFAUNAL DATA

Table C-1: Taxonomic analysis of infauna data

#Codes[1]	Phylum	Class/ order	Family	Taxonomic unit	S3	S4	S5	S8	S13
17	Annelida	Polychaeta	Capitellidae	*Notomastus spp.1*	1	0	0	0	0
41	Annelida	Polychaeta	Glyceridae	*Glycera spp.1*	0	0	0	1	1
40	Annelida	Polychaeta	Lumbrineridae	*Lumbrineris spp.1*	0	0	0	3	0
19	Annelida	Polychaeta	Magelonidae	*Magelona spp.1*	1	1	0	0	0
5	Annelida	Polychaeta	Nephtyidae	*Aglaophamus spp.1*	1	0	1	1	0
16	Annelida	Polychaeta	Onuphidae	*Rhamphobrachium spp.1*	3	0	0	1	0
39	Annelida	Polychaeta	Orbiniidae	*Orbinia spp.1*	0	0	0	1	0
18	Annelida	Polychaeta	Paralacydoniidae	*Paralacydonia spp.1*	1	0	0	0	0
20	Annelida	Polychaeta	Polynoidae	*Lepidonotus spp.1*	1	0	0	0	0
21	Annelida	Polychaeta	Sabellidae	*Sabellidae spp.1*	0	1	0	0	0
4	Annelida	Polychaeta	Spionidae	*Prionospio spp.1*	3	0	4	2	0
22	Annelida	Polychaeta	Syllidae	*Syllidae spp.1*	0	1	0	0	1
8	Crustacea	Amphipoda	Ampeliscidae	*Ampelisca spp.1*	1	0	0	4	0
42	Crustacea	Amphipoda	Aoridae	*Aoridae spp.1*	0	0	0	2	0
3	Crustacea	Amphipoda	Caprellidae	*Caprellidae spp.1*	0	2	1	0	0
43	Crustacea	Amphipoda	Corophiidae	*Corophiidae spp.1*	0	0	0	1	1
10	Crustacea	Amphipoda	Melitidae	*Melitidae spp.1*	2	0	0	2	0
11	Crustacea	Amphipoda	Melitidae	*Melitidae spp.2*	1	0	0	0	0
45	Crustacea	Amphipoda	Oedicerotidae	*Oedicerotidae spp.1*	0	0	0	0	1
2	Crustacea	Amphipoda	Phoxocephalidae	*Phoxocephalidae spp.1*	1	1	1	1	2
1	Crustacea	Amphipoda	Platyischnopidae	*Platyischnopus spp.1*	0	0	1	0	0
48	Crustacea	Amphipoda	Zobrachoidae	*Zobrachoidae spp.1*	0	0	0	0	1
33	Crustacea	Brachyura	Brachyura	*Brachyura spp.1 (juv.)*	0	0	0	1	0
24	Crustacea	Brachyura	Goneplacidae	*Goneplacidae spp.1*	0	1	0	0	0
34	Crustacea	Brachyura	Raninidae	*Raninidae spp.1*	0	0	0	1	0
30	Crustacea	Copepoda	Copepoda	*Copepoda spp.1*	0	0	0	1	0
7	Crustacea	Cumacea	Cumacea	*Cumacea spp.1*	1	0	0	0	0
6	Crustacea	Isopoda	Anthuridea	*Anthuridea spp.1*	1	0	0	3	0
46	Crustacea	Isopoda	Gnathiidae	*Gnathiidae spp.1*	0	0	0	0	2
47	Crustacea	Isopoda	Gnathiidae	*Gnathiidae spp.2*	0	0	0	0	1
32	Crustacea	Isopoda	Sphaeromatidae	*Sphaeromatidae spp.1*	0	0	0	1	1
31	Crustacea	Isopoda	Valvifera	*Valvifera spp.1*	0	0	0	1	0
29	Crustacea	Leptostraca	Leptostraca	*Leptostraca spp.1*	0	0	0	1	0
9	Crustacea	Stomatopoda	Squillidae	*Squillidae spp.2*	1	0	0	0	0
25	Crustacea	Stomatopoda	Stomatopoda	*Gonodactyloidea spp.1*	0	0	0	2	0
14	Crustacea	Tanaidacea	Tanaidae	*Tanaidae spp.1*	1	0	0	0	2
44	Crustacea	Tanaidacea	Tanaidae	*Tanaidae spp.2*	0	0	0	0	1
27	Echinodermata	Echinoidea	Echinocyamidae	*Echinocyamus spp.1*	0	0	0	1	0
28	Echinodermata	Echinoidea	Echinoidea	*Echinoidea spp.2 (juv.)*	0	0	0	1	0
13	Echinodermata	Holothuroidea	Dendrochirotida	*Dendrochirotida spp.1*	1	0	0	0	0
26	Echinodermata	Ophiuroidea	Ophionereididae	*Ophioplax spp.1*	0	0	0	3	0
23	Echiura	Echiura	Echiura	*Echiura spp.1*	0	1	0	0	0
15	Mollusca	Aplacophora	Aplacophora	*Aplacophora spp.1*	1	1	0	0	0
49	Mollusca	Bivalvia	Arcidae	*Barbatia spp.1*	0	0	0	0	1
36	Mollusca	Bivalvia	Mytilidae	*Mytilidae spp.1 (juv.)*	0	0	0	1	0
12	Mollusca	Bivalvia	Tellinidae	*Tellina spp.1*	1	0	0	0	0
35	Mollusca	Bivalvia	Tellinidae	*Tellina spp.2*	0	0	0	1	0
37	Mollusca	Bivalvia	Veneridae	*Paphia spp.1*	0	0	0	1	0
38	Mollusca	Gastropoda	Skeneidae	*Skeneidae spp.2 (juv.)*	0	0	0	1	0

1 #codes refer to the codes used for the reference collection sent to the Western Australia museum

Table C-2: Results of the taxon-matching search tool via the World Register of Marine Species (WoRMS Editorial Board 2020)

Taxa	Scientific name (accepted)	Authority	Phylum	Class	Order	Family	Genus	Citation
Notomastus spp.	Notomastus	M. Sars, 1851	Annelida	Polychaeta		Capitellidae	*Notomastus*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Capitellidae Grube, 1862. Accessed through: World Register of Marine Species
Glycera spp.	Glyceridae	Lamarck, 1818	Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Glyceridae Grube, 1850. Accessed through: World Register of Marine Species
Lumbrineris spp.	Lumbrineridae	Blainville, 1828	Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Lumbrineridae Schmarda, 1861. Accessed through: World Register of Marine Species
Magelona spp.	Magelona	F. Müller, 1858	Annelida	Polychaeta		Magelonidae	*Magelona*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Magelona F. Müller, 1858. Accessed through: World Register of Marine Species
Aglaophamus spp.	Aglaophamus	Kinberg, 1866	Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Aglaophamus Kinberg, 1866. Accessed through: World Register of Marine Species
Rhamphobrachium spp.	Onuphidae	Ehlers, 1887	Annelida	Polychaeta	Eunicida	Onuphidae	*Rhamphobrachium*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Onuphidae Kinberg, 1865. Accessed through: World Register of Marine Species
Orbinia spp.	Orbiniidae	Quatrefages, 1866	Annelida	Polychaeta		Orbiniidae	*Orbinia*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Orbiniidae Hartman, 1942. Accessed through: World Register of Marine Species
Paralacydonia spp.	Paralacydonia	Fauvel, 1913	Annelida	Polychaeta	Phyllodocida	Paralacydoniidae	*Paralacydonia*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Paralacydonia Fauvel, 1913. Accessed through: World Register of Marine Species
Lepidonotus spp.	Polynoidae	Leach, 1816	Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Polynoidae Kinberg, 1856. Accessed through: World Register of Marine Species
Sabellidae	Sabellidae	Latreille, 1825	Annelida	Polychaeta	Sabellida	Sabellidae		Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Sabellidae Latreille, 1825. Accessed through: World Register of Marine Species
Prionospio spp.	Spionidae	Malmgren, 1867	Annelida	Polychaeta	Spionida	Spionidae	*Prionospio*	Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Spionidae Grube, 1850. Accessed through: World Register of Marine Species
Syllidae	Syllidae	Grube, 1850	Annelida	Polychaeta	Phyllodocida	Syllidae		Read, G.; Fauchald, K. (Ed.) (2020). World Polychaeta database. Syllidae Grube, 1850. Accessed through: World Register of Marine Species
Ampelisca spp.	Ampeliscidae	Krøyer, 1842	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Ampelisca*	Horton, T. et al. (2020). World Amphipoda Database. Ampeliscidae Krøyer, 1842. Accessed through: World Register of Marine Species
Aoridae	Aoridae	Stebbing, 1899	Arthropoda	Malacostraca	Amphipoda	Aoridae		Horton, T. et al. (2020). World Amphipoda Database. Aoridae Stebbing, 1899. Accessed through: World Register of Marine Species
Caprellidae	Caprellidae	Leach, 1814	Arthropoda	Malacostraca	Amphipoda	Caprellidae		Horton, T. et al. (2020). World Amphipoda Database. Caprellidae Leach, 1814. Accessed through: World Register of Marine Species
Corophiidae	Corophiidae	Leach, 1814	Arthropoda	Malacostraca	Amphipoda	Corophiidae		Horton, T. et al. (2020). World Amphipoda Database. Corophiidae. Leach, 1814. Accessed through: World Register of Marine Species
Melitidae	Melitidae	Bousfield, 1973	Arthropoda	Malacostraca	Amphipoda	Melitidae		Horton, T. et al. (2020). World Amphipoda Database. Melitidae Bousfield, 1973.. Accessed through: World Register of Marine Species
Oedicerotidae	Oedicerotidae	Lilljeborg, 1865	Arthropoda	Malacostraca	Amphipoda	Oedicerotidae		Horton, T. et al. (2020). World Amphipoda Database. Oedicerotidae Lilljeborg, 1865. Accessed through: World Register of Marine Species
Phoxocephalidae	Phoxocephalidae	G.O. Sars, 1891	Arthropoda	Malacostraca	Amphipoda	Phoxocephalidae		Horton, T. et al. (2020). World Amphipoda Database. Phoxocephalidae G.O. Sars, 1891. Accessed through: World Register of Marine Species
Platyischnopus spp.	Platyischnopidae	Barnard & Drummond, 1979	Arthropoda	Malacostraca	Amphipoda	Platyischnopidae	*Platyischnopus*	Horton, T. et al. (2020). World Amphipoda Database. Platyischnopidae Barnard & Drummond, 1979. Accessed through: World Register of Marine Species
Zobrachoidae	Zobrachoidae	Barnard & Drummond, 1982	Arthropoda	Malacostraca	Amphipoda	Zobrachoidae		Horton, T. et al. (2020). World Amphipoda Database. Zobrachoidae Barnard & Drummond, 1982. Accessed through: World Register of Marine Species
Brachyura	Brachyura	Latreille, 1802	Arthropoda	Malacostraca	Decapoda			WoRMS (2020). Brachyura.
Goneplacidae	Goneplacidae	MacLeay, 1838	Arthropoda	Malacostraca	Decapoda	Goneplacidae		WoRMS (2020). Goneplacidae MacLeay, 1838.
Raninidae	Raninidae	De Haan, 1839 [in De Haan, 1833-1850]	Arthropoda	Malacostraca	Decapoda	Raninidae		WoRMS (2020). Raninidae De Haan, 1839 [in De Haan, 1833-1850].
Copepoda	Copepoda	Milne Edwards, 1840	Arthropoda	Hexanauplia				WoRMS (2020). Copepoda.
Cumacea	Cumacea	Krøyer, 1846	Arthropoda	Malacostraca	Cumacea			Watling, L.; Gerken, S. (2020). World Cumacea Database. Cumacea. Accessed through: World Register of Marine Species
Anthuridea	Anthuroidea	Leach, 1914	Arthropoda	Malacostraca	Isopoda			Boyko, C.B. et al. (Eds) (2008 onwards). World Marine, Freshwater and Terrestrial Isopod Crustaceans database. Anthuridea. Accessed through: World Register of Marine Species

Taxa	Scientific name (accepted)	Authority	Phylum	Class	Order	Family	Genus	Citation
Gnathiidae	Gnathiidae	Leach, 1814	Arthropoda	Malacostraca	Isopoda	Gnathiidae		Boyko, C.B. et al. (Eds) (2008 onwards). World Marine, Freshwater and Terrestrial Isopod Crustaceans database. Gnathiidae Leach, 1814. Accessed through: World Register of Marine Species
Sphaeromatidae	Sphaeromatidae	Latreille, 1825	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae		Boyko, C.B. et al. (Eds) (2008 onwards). World Marine, Freshwater and Terrestrial Isopod Crustaceans database. Sphaeromatidae Latreille, 1825. Accessed through: World Register of Marine Species
Valvifera	Valvifera	G. O. Sars, 1883	Arthropoda	Malacostraca	Isopoda			Boyko, C.B. et al. (Eds) (2008 onwards). World Marine, Freshwater and Terrestrial Isopod Crustaceans database. Valvifera. Accessed through: World Register of Marine Species
Leptostraca	Leptostraca	Claus, 1880	Arthropoda	Malacostraca	Leptostraca			Mees, J.; Meland, K. (Eds) (2012 onwards). World List of Lophogastrida, Stygiomysida and Mysida. Leptostraca. Accessed through: World Register of Marine Species
Squillidae	Squillidae	Latreille, 1802	Arthropoda	Malacostraca	Stomatopoda	Squillidae		WoRMS (2020). Squillidae Latreille, 1802.
Stomatopoda	Stomatopoda	Latreille, 1817	Arthropoda	Malacostraca	Stomatopoda			WoRMS (2020). Stomatopoda.
Tanaidae	Tanaididae	Nobili, 1906	Arthropoda	Malacostraca	Tanaidacea	Tanaidæ		WoRMS (2020). Tanaidæ Dana, 1849.
Echinocyamus spp.	Echinoidea	Van Phelsum, 1774	Echinodermata	Echinoidea	Clypeasteroida	Fibulariidae	*Echinocyamus*	WoRMS (2020). Echinoidea.
Dendrochirotida	Holothuroidea	Grube, 1840	Echinodermata	Holothuroidea	Dendrochirotida			WoRMS (2020). Holothuroidea.
Ophioplax spp.	Ophiuroidea	Layman, 1875	Echinodermata	Ophiuroidea	Amphilepidida	Ophionereididae	*Ophioplax*	Stöhr, S.; O'Hara, T.; Thuy, B. (Eds) (2020). World Ophiuroidea Database. Ophiuroidea. Accessed through: World Register of Marine Species
Echiura	Echiura	Sedgwick, 1898	Annelida	Polychaeta				WoRMS (2020). Echiura.
Aplacophora	Aplacophora		Mollusca	Aplacophora				MolluscaBase eds. (2020). MolluscaBase. Aplacophora. Accessed through: World Register of Marine Species
Barbatia spp.	Barbatia	Gray, 1842	Mollusca	Bivalvia	Arcida	Arcidae	*Barbatia*	MolluscaBase eds. (2020). MolluscaBase. Barbatia Gray, 1842. Accessed through: World Register of Marine Species
Mytilidae	Mytilidae	Rafinesque, 1815	Mollusca	Bivalvia	Mytilida	Mytilidae		MolluscaBase eds. (2020). MolluscaBase. Mytilidae Rafinesque, 1815. Accessed through: World Register of Marine Species
Tellina spp.	Tellina	Linnaeus, 1758	Mollusca	Bivalvia	Cardiida	Tellinidae	*Tellina*	MolluscaBase eds. (2020). MolluscaBase. Tellina Linnaeus, 1758. Accessed through: World Register of Marine Species
Paphia spp.	Paphia	Röding, 1798	Mollusca	Bivalvia	Venerida	Veneridae	*Paphia*	MolluscaBase eds. (2020). MolluscaBase. Paphia Röding, 1798. Accessed through: World Register of Marine Species
Skeneidae	Skeneidae	W. Clark, 1851	Mollusca	Gastropoda	Trochida	Skeneidae		MolluscaBase eds. (2020). MolluscaBase. Skeneidae W. Clark, 1851. Accessed through: World Register of Marine Species

Attachment 3 Benthic Habitat Modelling

Santos Dorado Seabed Characterisation and Habitat Mapping

Final Report

John Keesing, Roland Pitcher, Wayne Rochester, John Pogonoski, Margaret Miller, Emma Westlake, Alan Williams, Franzis Althaus, Chris Berry, Karl Forcey, Nick Mortimer and Dirk Slawinski

CSIRO Oceans and Atmosphere Research

6 March 2020

Purpose of this report

This report has been prepared by CSIRO for Santos Limited for use in planning for its Dorado Development.

CSIRO contact

Dr John Keesing
Senior Principal Research Scientist
CSIRO Oceans & Atmosphere Research
Indian Ocean Marine Research Centre
M097, 35 Stirling Highway, Crawley 6009 AUSTRALIA
t: +61 8 93336500
john.keesing@csiro.au

Santos contact

Sonja Mavrick
HSE Team Lead Dorado Development
Santos Limited, Level 7 100 St Georges Terrace, 6000
t: +61 8 6218 7154
sonja.mavrik@santos.com

Important disclaimer

Contents

Figures

Tables

List of acronyms and definitions

AFD – Australian Faunal Directory

ALA – Atlas of Living Australia

ANFC – CSIRO Australian National Fish Collection database

BRUV – Baited Remote Underwater Video

CAAB – Codes for Aquatic Australian Biota database

CARS – CSIRO Atlas of Regional Seas

CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora – international agreement between governments aiming to ensure that international trade in specimens of wild animals and plans does not threaten their survival

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DEM – Digital Elevation Model – An array of regularly spaced elevation values that produce a 3D representation of a terrain's surface

DLI – Dufrene-Legendre Indicator – calculates the indicator value (fidelity and relative abundance) of species in clusters of types

Ecotype – Areas with characteristic biological assemblages and environmental properties

EPBC Act – Environment Protection and Biodiversity Conservation Act 1999 – Australian Government's key piece of environmental legislation providing a national scheme of environment and heritage protection and biodiversity conservation

FB – Frank and Bryce – type of trawl net design

FnB – Frank and Bryce – type of trawl net design

IMCRA – Integrated Marine and Coastal Regionalisation of Australia – Spatial framework for classifying Australia's marine environment into bioregions that make sense ecologically and are at a scale useful for regional planning

IUCN – International Union for Conservation of Nature

KEF – Key Ecological Feature – Geomorphic features or regionally important species or habitats. They are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity.

MARS – Geosciences Australia Marine Sediments database

MRT – Multivariate regression tree – Statistical technique used to explore, describe and predict relationships between multispecies data and environmental characteristics

NASA – National Aeronautics and Space Administration

NO_3 – Nitrate

NOPSEMA – National Offshore Petroleum Safety and Environmental Management Authority – Australia's independent expert regulator for health and safety, environmental management, structural and well integrity for offshore petroleum facilities and activities in Commonwealth waters

NWS – North West Shelf – Region off the north-west Australian coast in the Pilbara region

OPP – Offshore Petroleum Proposal – A requirement of all offshore petroleum projects to prepare and submit a proposal for NOPSEMA assessment. This includes, but is not limited to, a description of the project and the environment including impacts and risks, environmental performance outcomes, feasible project alternatives, legislation pertaining to the project, and reflects a level of transparency and an opportunity for public comment

PAR – Photosynthetically Active Radiation – Light of wavelengths 400–700 nm and the portion of the light spectrum utilised by plants for photosynthesis.

PO_4 – Phosphate

ROV – Remotely Operated Vehicle

RPS – RPS Group – A global professional services firm working across property, energy, transport, water, resources, defence and government sectors

SBRUV – Stereo Baited Remote Underwater Video

TEPS – Threatened, Endangered or Protected Species

WHPL – Well Head/Platform Location

Executive summary

Background

Santos is planning to develop the Dorado field on the North West Shelf (NWS) and is developing an Offshore Petroleum Proposal (OPP) as required under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. Santos is required to assess all environmental impacts and risks from the Dorado Project and, as such, requires information about the benthic habitats and assemblages to inform this assessment. In particular, those assemblages associated with the ancient coastline key ecological feature (KEF) are of importance in determining the extent of biologically rich marine habitats in the area.

This report provides an analysis of ecotypes, or areas with characteristic biological assemblages and environmental properties, spatial patterns and composition of these biological assemblages in and around the area of the proposed Dorado development. It gives detailed descriptions of the substratum, topography and benthic biohabitats, especially the composition of habitat forming filter feeder assemblages, and provides a description of the fish and invertebrate biodiversity of the Dorado Survey Area (herein referred as the survey area) placing this in the broader context of the NWS region as a whole.

Study description

The analysis draws on five historical datasets. These include primarily fish trawl catch and benthic imagery held by CSIRO (up to 1997) that extend through, or partly through the survey area, and more recent data including remote fish videos, ROV seabed imagery, and a high-resolution model of the bathymetry. Forty-one environmental variables, including bathymetry-derived, sedimentary, ocean colour and bottom water attributes (gridded at 0.01°) were also used to spatially stratify seabed habitats and assemblages. Additionally, detailed descriptions of the substrate and biota from seabed imagery from 67 historical and recently surveyed sites were undertaken and public databases of fish and marine invertebrate biodiversity were used to determine the level of representativeness and uniqueness of the recently surveyed sites within the Dorado Survey Area relative to the broader NWS region.

Summary of findings – spatial distribution of habitat and biotic assemblages

The mapping of ecotypes (areas with characteristic biological assemblages and environmental properties) in and around the area of the Dorado development identified seven ecotypes (Table 1) of which four comprise the majority of the survey area (Figure 1). The most important environmental influences on ecotypes include the seasonal range and annual average of bottom-water attributes such as oxygen, salinity, nutrients and temperature. Some of the ecotype boundaries align with depth because several of these important variables vary with depth, although in non-linear ways. So, although the distribution of the ecotypes is not explained by depth *per se*, it is convenient to classify the most offshore and inshore ecotypes (three in total) according to depth:

- Ecotype 1 – largely associated with waters 130 m and deeper, overlaps the survey area only at the northern margin;
- Ecotype 6 – associated with waters between approximately 40 and 60 m and intersects the survey area to very minor extent in the south;
- Ecotype 7 – located further inshore (< 40 m) and does not intersect the survey area at all.

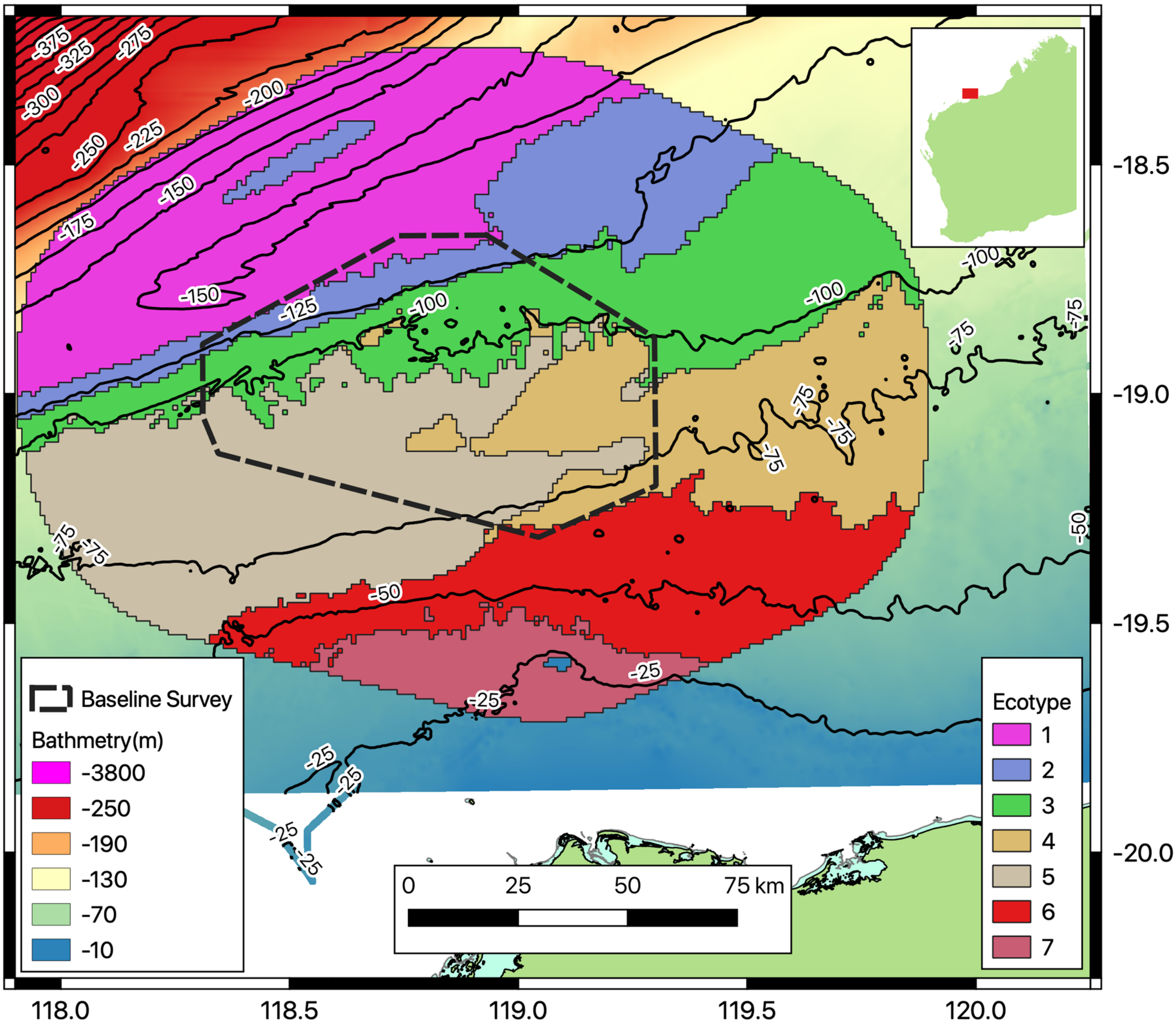

Figure 1. Map showing the spatial distribution of the seven ecotypes, identified by colour and number, within the survey area. The black polygon shows the survey area boundary. White area = area of < 10 m depth.

The area of interest for the proposed Dorado development focuses mainly around four ecotypes. The deepest, ecotype 2, forms a mostly narrow depth-parallel area at about 120–130 m and is characterised by sandy silt and soft mud habitats with usually < 5% cover of habitat-forming filter-feeder species. The transition between ecotype 2 and 3 overlays the area of the ancient coastline KEF, defined by depth (115–135 m water depth). This area has the most notably steep depth gradients and distribution of topographically complex terrain features within the study area. Ecotypes 3, 4 and 5 comprise the majority of the survey area and fall mainly in 60–100 m depths. While the majority of all sites surveyed both historically and recently comprise habitats composed largely by fine sediments (typically > 90% cover), each of these three ecotypes exhibit notable areas of habitat forming filter feeder communities, especially whip corals, gorgonians and sponges. These vary greatly from 10%–70% cover from site to site and typically 30%–40% cover. While biohabitat cover and composition varies to much the same degree among ecotypes 3, 4 and 5, the influence of environmental variables varies between each and the dominance of different fish species in terms of their distribution, abundance and biomass contributed to the delineation of ecotypes 3, 4 and 5. The analysis in the report documents these differences and provides examples of indicator species in each ecotype.

Table 1. Summary of the seven ecotypes in and around the area of the proposed Dorado development.

Ecotype 1	Silty-sand substrate Largely associated with waters 130 m and deeper, very low cover of benthic filter-feeder habitats. Much of the substrate is bioturbated sediment. Filter-feeders tend to be non-habitat forming types typical of soft sediments like anemones, sea pens and free-living crinoids.
Ecotype 2	Silty-sand and soft mud substrates Forms a mostly narrow depth-parallel band at about 120–130 m characterised by silty-sand and soft mud (silt) habitats. Usually < 5% habitat-forming filter-feeder species.
Ecotype 3	Variable substrates from silty-sand to hard reef with steep depth gradients and topographically complex terrain features Majority of ecotype 3 characterised by silty-sand substrates with notable areas of hard, topographically complex reef substrate, particularly in the area of the ancient coastline feature. Sea-whip habitat was a feature of hard substrate areas and filter-feeder habitat made up 10–65% of cover. Large seasonal range in water column properties such as oxygen and nutrients indicating a dynamic water column environment.
Ecotype 4	Variable substrate, predominantly silty-sand or coarse sand but with significant proportions of rubble. Ecotype 4 sites had between 20% and 45% of diverse filter-feeder biohabitat with sponges, soft corals, gorgonians, sea pens and whips. Some areas of soft bottom substrate with very abundant non-habitat forming filter-feeders, anemones and free-living crinoids.
Ecotype 5	Variable substrate ranging from silty-sand to rubble and stones Generally flat topography with an absence of terrain features and lacking in notable depth gradients. However, had the highest species richness for several datasets examined and the highest proportion of filter-feeder biohabitat cover (30%–65%) with sponges, gorgonians, hydroids, whips and sea pens most important. Ecotype 5 was the only ecotype exhibiting a notable number of ascidians.
Ecotype 6	Variable sandy and hard reef substrate Mostly less than 60 m depth. Majority excluded from study area thus substrate distribution not examined extensively. Some areas marked change in depth

	gradients and terrain features indicated hard substrate in some areas consistent with the presence of habitat-forming filter-feeders such as sponges. High biomass of soft bottom fish species such as goatfish also indicative of presence of extensive areas of largely featureless soft bottom habitats. Large seasonal range in temperature and bottom stress indicating important tidal influence.
Ecotype 7	Variable sandy and hard reef substrate Mostly inshore, less than 40 m depth and falling completely outside study area. Few data on proportion of substrate distribution but can be inferred from notable variations in depth gradient and terrain features, large proportion of area with sponge and sea-whip filter-feeder habitat and very high diversity and biomass of fish. Like ecotype 6, ecotype 7 also has large seasonal range in temperature and bottom stress indicating importance of large tidal range.

Summary of findings – fish and invertebrate biodiversity

Analysis of Atlas of Living Australia (ALA) records for seven phyla of marine invertebrates revealed a total of 722 species recorded from the survey area representing 18% of species recorded from the NWS Province as a whole. Overall, 15% of species of marine invertebrates recorded from the NWS Province were recorded only from the survey area. No firm conclusion can be made regarding differences in biodiversity between the survey and surrounding areas due to a sparsity of biodiversity data from this area, poor taxonomic knowledge of some animal groups, and incomplete ALA records. However, data for fishes, a group that has been relatively much better sampled and for which the taxonomy is very mature, showed no differentiation between the survey area and surrounding areas. Three hundred and seventy species were recorded from the survey area, with only two species not recorded elsewhere in the NWS Province. It is possible, however, that these 2 species represent errors in identification.

A number of species of particular conservation interest, including threatened, endangered or protected species (TEPS), have been recorded from the survey area but all have also been recorded elsewhere to the north and south on the NWS. These include four elasmobranch species: the Scalloped Hammerhead, *Sphyrna lewini*, currently listed as Conservation Dependent by the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and critically endangered by the International Union for Conservation of Nature Red List of Threatened Species (herein IUCN Redlist), Oceanic Whitetip Shark, *Carcharhinus longimanus,* and Whitespotted Guitarfish, *Rhynchobatus australiae,* both listed as critically endangered by the IUCN Redlist, and the Silky Shark, *Carcharhinus falciformis,* (IUCN Redlist vulnerable) and listed in the EPBC Act as migratory and subject to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals). In addition, three syngnathid species known from the survey area are listed as marine species under the EPBC Act. These are Western Spiny Seahorse, *Hippocampus angustus,* Gunther's Pipehorse, *Solegnathus lettiensis*, and the Pallid Pipehorse, *Solegnathus* sp., all of which have a maximum depth range of between 63m and 190 m.

Concluding summary

The vast majority of the survey area consists of soft bottom habitats with little macro-benthic biota, however patches of diverse habitat-forming filter-feeder biota, typical of the NWS region occur throughout the area, mainly as sparse or medium density habitats. These habitats account for the diverse array of fish and invertebrate species recorded for the area including some species characterised as TEPS. These are however, in the most part, either highly mobile elasmobranchs or syngnathid species which occur elsewhere on the NWS. The study confirmed that the ancient coastline key ecological feature (KEF), which has notable changes in depth gradient and complex seabed terrain features associated with biological features, was an important influence on the characterisation and spatial stratification of habitats and species assemblages in the area. Furthermore, the information provided in this report provides a baseline for future monitoring of habitats and species assemblages in the area.

1 Introduction

1.1 Background and purpose

Santos is planning to develop the Dorado field on the North West Shelf (NWS) and is developing an Offshore Petroleum Proposal (OPP) as required under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. Santos is required to assess all environmental impacts and risks from the Dorado Project and, as such, requires information about the benthic habitats and assemblages to inform this assessment. In particular, the assemblages associated with the ancient coastline key ecological feature (KEF) are of importance in determining the extent of biologically rich marine habitats in the area.

The first (Phase 1) report (CSIRO 2019) provided an interim prediction of spatial patterns and composition of ecotypes (areas with characteristic biological assemblages and environmental properties) in the general area of the proposed Dorado development, based on existing datasets held by CSIRO, mostly from the 1980s and 1990s.

Building on Phase 1, Phase 2 (CSIRO 2020) provided an updated habitat stratification by incorporating three more recent datasets: (1) fish data in the region of the ancient coastline KEF from stereo baited remote underwater video (SBRUV) deployments made in about 100m depths in October 2018 (RPS 2019); (2) towed video data of benthic habitat types in the area south of the Dorado field in about 50 m depths (RPS 2019); and (3) an improved digital elevation model (DEM) of the bathymetry produced by CSIRO (Berry 2019) based on data provided by Santos. Phase 2 (CSIRO 2020) also made recommendations for the site locations and sampling strategy for the benthic habitat video data acquisition voyage conducted in December 2019 by RPS (RPS 2020) within the survey area (Figure 2).

Phase 3 and Final Report includes Phase 1 and 2 results and provides a further update of the spatial patterns and composition of ecotypes in and around the area of the proposed Dorado development by incorporating the results of the December 2019 survey (RPS 2020). In addition, this report provides a more detailed description of the substrate, topography and benthic biohabitats from both the historical and most recent survey and an analysis of the fish and invertebrate biodiversity of the survey area placing this in the broader context of the NWS region as a whole.

1.2 Study area

The study area is defined as the Dorado Survey Area (Figure 2), herein referred to as the survey area. The survey area was proposed within the initial stages of the Dorado development engineering and was designed to capture all potential engineering options and future tiebacks at the time, as well as providing sufficient area to characterise the spatial distribution of habitat and biotic assemblages.

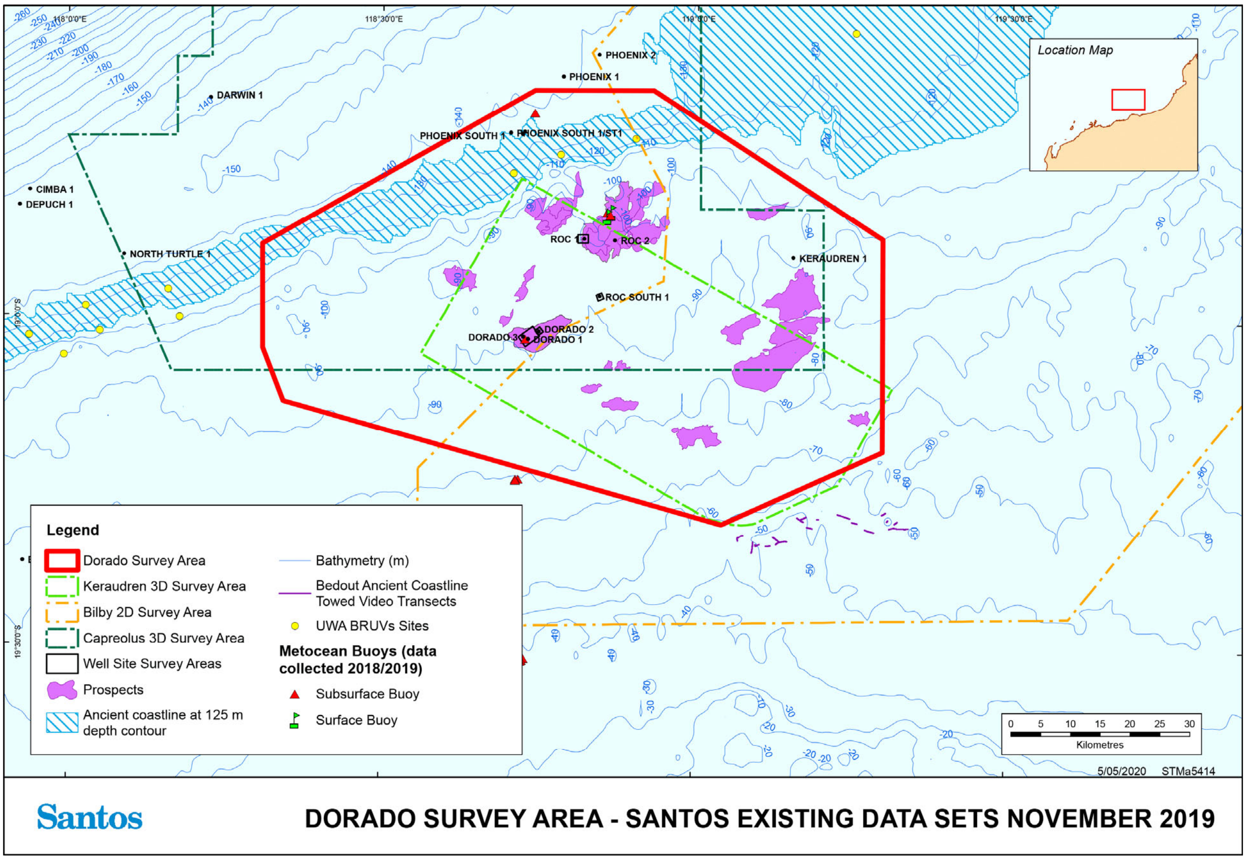

Figure 2. Map of the survey area showing bathymetry, extent of oil prospects and a range of locations for previous data acquisition events.

2 Seabed Characterisation and Habitat Mapping

2.1 Study domain

The initial survey area (Figure 3, grey line) was buffered by ~45 km (red dashed polygon) to provide a local study area for predictions of benthic biological assemblages in the vicinity. Figure 3 shows the depth range within the study prediction area from ~10 m (red) to ~210 m (dark blue). The black polygon is the final survey area boundary. The prediction area is about four-times larger than the survey area. The grey dotted polygon is the area from which data were selected for analyses (an additional 45 km buffer, ~8 x the survey area).

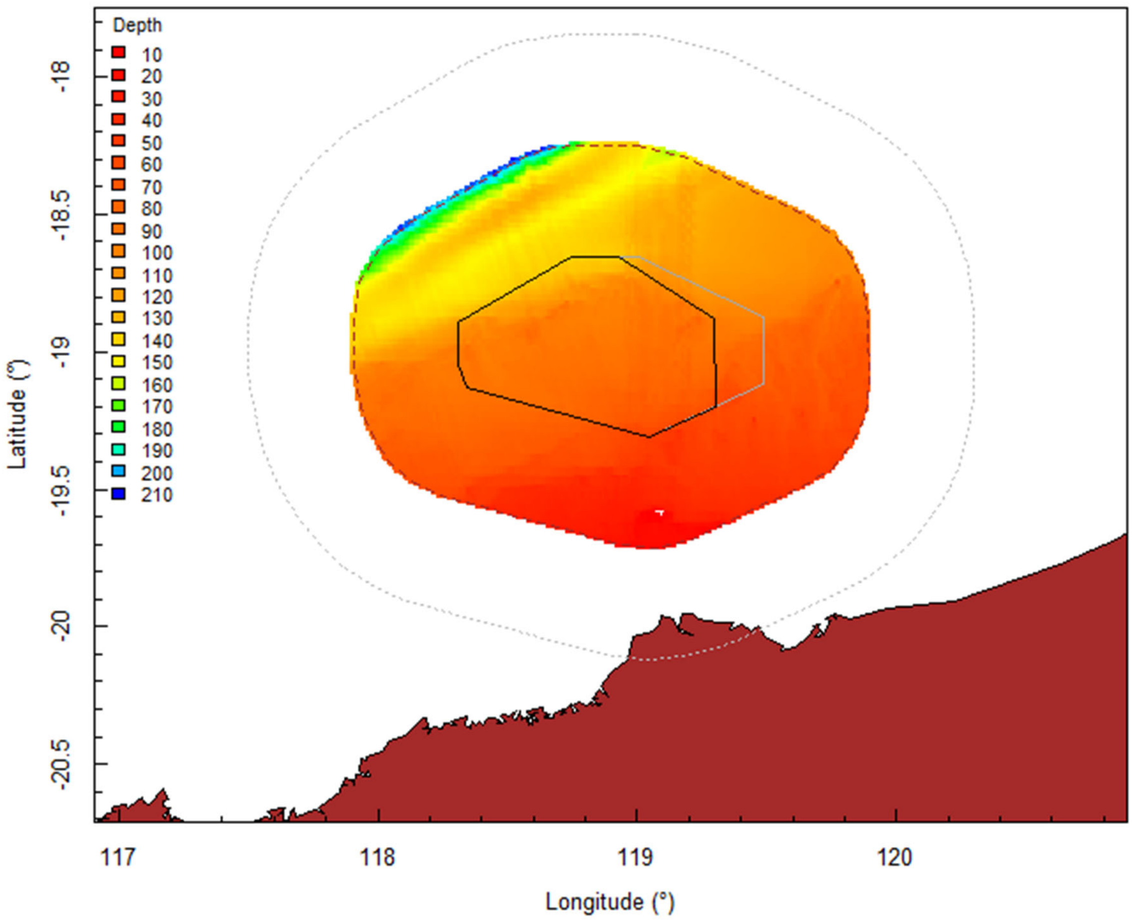

Figure 3. The survey area off the NWS showing continuous bathymetry overlain on the areal extent of habitat prediction grid (red dashed line). Very outer dotted line = extent from which data were selected to make predictions, based on buffering the initial survey area (grey line). Black polygon = final survey area boundary.

2.2 Data sets used in the analyses

2.2.1 Biological data sets

CSIRO (2019; 2020) provided interim habitat maps for the area based on five historical datasets held by CSIRO (up to 1997) which extended through or partly through the survey area, two datasets held by Santos (2018 surveys by RPS [RPS 2019]), and a detailed 2018 bathymetric survey transformed into a new digital elevation model [DEM] for the area by (Berry 2019). More recently, a Remotely Operated Vehicle (ROV) survey by RPS (RPS 2020) within the survey area acquired further data on seabed habitats at observed sites. For the final stratification of seabed habitats and assemblages, we have used all these available datasets to provide a final seabed habitat and benthic invertebrate/demersal fish assemblage characterisation. This was facilitated using analyses of seabed compositional change along environmental gradients for 41 variables mapped on a 0.01° grid for Australia's shelf and slope. The sites of the survey datasets are mapped (Figure 4) onto bathymetry (range 10–210 m).

The figures and tables below use the following abbreviations to refer to these datasets:

> NWS FnB Trawl – refers to fish trawl surveys made by CSIRO on the NWS between 1982 and 1991 using a Frank and Bryce design commercial scale trawl net. These trawls were made on voyages to determine the effects of trawling as part of the Sainsbury (1987; 1991; 1993; 1997) studies.
>
> NWS McKenna Trawl – refers to fish trawl surveys made by CSIRO on the NWS in 1995 and 1997 using a McKenna design commercial scale trawl net. It differs in minor ways to the Frank and Bryce net. The McKenna net is that used in current fishing operations on the NWS. Its use on the NWS is described in Wassenberg et al. (2002). This net was also used in the latter stages of the Sainsbury (1987; 1991; 1993; 1997) studies.
>
> NWS Photo-benthos – refers to a subset of the above two datasets that used a trawl headline camera to capture images of the seabed, which were then scored to count the abundance and size of different benthic habitat forming biota.
>
> Data Trawler FB trawl – refers to older fish trawl surveys conducted prior to the Sainsbury (1987; 1991; 1993; 1997) studies, but which also used the Frank and Bryce trawl net.
>
> Soviet Trawl – refers to fish trawl surveys conducted by the Russian fleet between 1966 and 1972.

The majority of these available data fall within the western part of the survey area and extend farther to the south west. Less data was available for the eastern part of the survey area and to the north east (Figure 4).

Four more recent datasets have been incorporated into the final analyses:

New high-resolution DEM – this was produced by Berry (2019) based on Santos seismic data and provided improved resolution of bathymetry and slope, from which new improved estimates of terrain shape variables: ridge, channel, peak, passage, pit and plane, were calculated.

Santos BRUVS – new demersal fish data collected in October 2018 (RPS 2019) in the area of the ancient coastline key ecological feature (about 100 m depth). Data used from this study was BRUVS maxN data for 56 species at 12 sites with 5 BRUVs each, but only 14 species occurred at > 5 sites and could be used in the analysis.

Santos Vid – tow-video derived habitat data from October 2018 (RPS 2019) for 59 benthos morpho-types at 144 transect-segments from 17 transects of 3–19 segments each. Data were of presence/absence type with 41 morpho-types having > 3 presences.

Santos.VidSvy2 – ROV survey seabed habitat data from 2019 conducted by RPS (RPS 2020) along 500 m transects at 38 sites scoring seabed substrate and filter feeder biohabitat cover in real time.

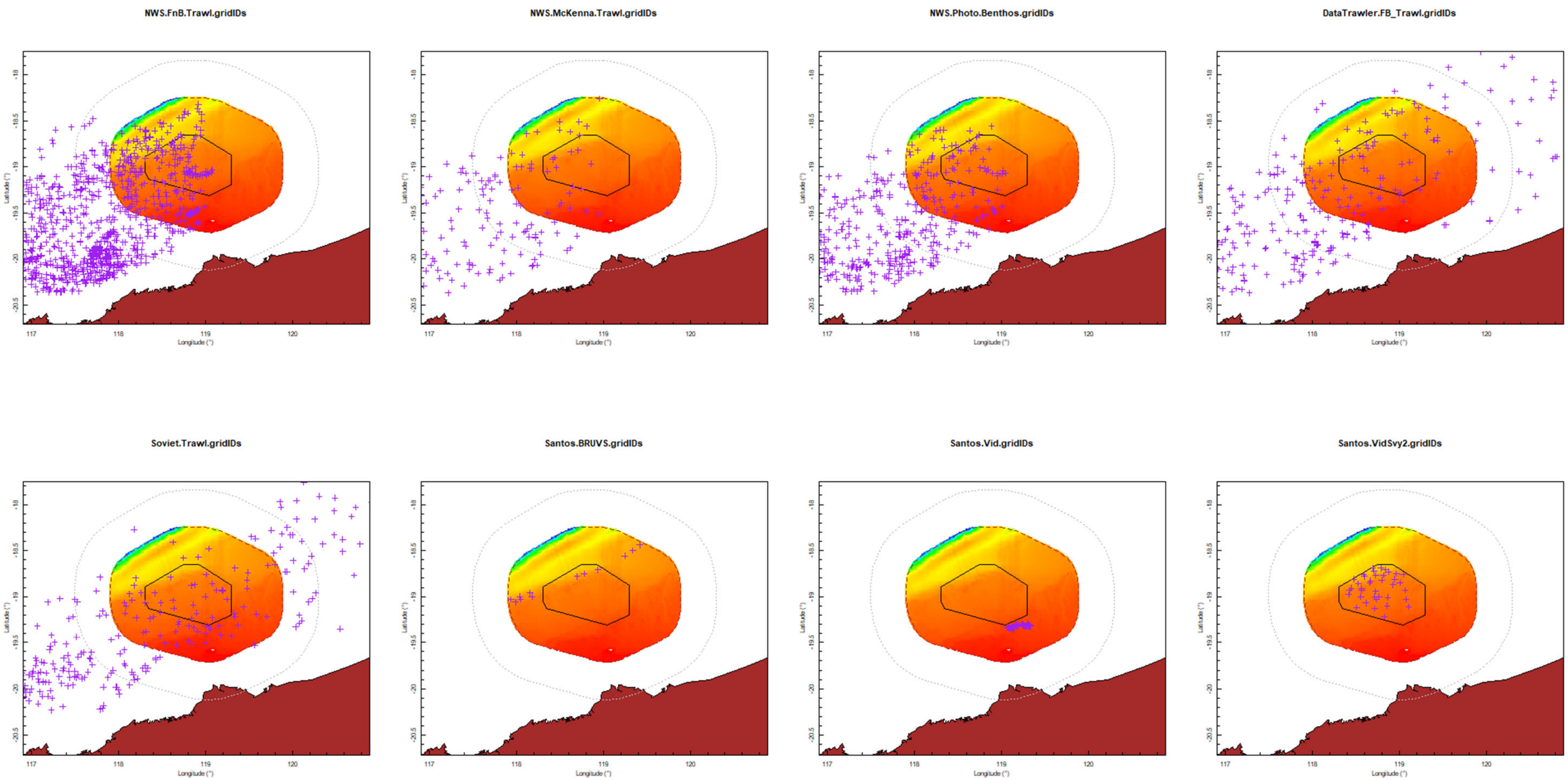

Figure 4. Distribution of sample sites overlain on bathymetry for each dataset in the vicinity of the survey area boundaries. Very outer dotted line = extent from which data were selected to make predictions, based on buffering the initial survey area (grey line). Black polygon = final survey area boundary.

2.3 Environmental datasets

A total of 41 geophysical and biochemical environmental variables were used as potential predictors of patterns in biological assemblages. These were drawn from a range of datasets, including the new bathymetric DEM product (Berry 2019) (3 variables) and from which 6 terrain variables were derived, the Geosciences Australia Marine Sediments (MARS) database (4 variables), the CSIRO Atlas of Regional Seas (CARS) (12 variables), NASA Oceancolour satellite derived variables (14 variables), and the CSIRO Ribbon Model (2 variables) which is a shelf scale hydrodynamic model covering the Australian region.

To derive the 6 terrain variables, the bathymetry map was classified into terrain features using the method of Wood (1996). With this method, each cell in the raster bathymetry map is assigned to a feature class (peak, ridge, pass, channel, pit or plane) based on morphometric parameters (e.g. slope and curvature), which are calculated on the cells within a window centred on the cell. To provide a more robust terrain characterisation, the classification is repeated at multiple scales (window sizes), and the resulting classifications are summarised as the percentage of times each cell is assigned to each feature class (Wood 1996). The classification was performed using the GRASS GIS command r.param.scale (GRASS Development Team 2019) at seven scales from 1.5 km to 7.5 km. The summary percentages for the six terrain features were used as the terrain predictor variables in the gradientForest analysis.

Table 2 provides the detail of each variable and the acronyms used in the analyses and figures which follow later in the report.

Table 2. Environmental variables used as potential predictors of habitat type and biological assemblages within the survey area.

Variable	Description	Aggregation	Units	Source
GA_BATHY	Bathymetry		m	Berry 2019
GA_SLOPE	Slope		degrees	Berry 2019
GA_ASPECT	Aspect		degrees	Berry 2019
GA_SAND	Sediment percent sand		%	MARS
GA_MUD	Sediment percent mud		%	MARS
GA_GRAVEL	Sediment percent gravel		%	MARS
GA_CRBNT	Sediment percent carbonate		%	MARS
RBN_BSTRESS	Tidal current stress (annual average)	RMS	N/m^2	ribbon model
RBN_BSTRESS_SR	Tidal current stress (seasonal range)			
CRS_T_AV	Bottom temperature (annual average)	average	deg. C	CARS
CRS_T_SR	Bottom temperature (seasonal range)			
CRS_S_AV	Bottom salinity (annual average)	average	PPT	CARS
CRS_S_SR	Bottom salinity (seasonal range)			
CRS_O2_AV	Bottom oxygen (annual average)	average	mL/L	CARS
CRS_O2_SR	Bottom oxygen (seasonal range)			
CRS_SI_AV	Bottom silicate (annual average)	average	uM	CARS
CRS_SI_SR	Bottom silicate (seasonal range)			
CRS_NO3_AV	Bottom nitrate (annual average)	average	uM	CARS
CRS_NO3_SR	Bottom nitrate (seasonal range)			
CRS_PO4_AV	Bottom phosphate (annual average)	average	uM	CARS
CRS_PO4_SR	Bottom phosphate (seasonal range)			
SST_AV	Sea surface temperature (annual average)	average	deg. C	MODIS
SST_SR	Sea surface temperature (seasonal range)			
PAR_AV	Photosynthetically active radiation (annual average)	average	Einsteins/m^2/day	MODIS
PAR_SR	Photosynthetically active radiation (seasonal range)			
BIR_AV	Benthic irradiance (annual average) PAR * exp(-K490 * depth)	average	Einsteins/m^2/day	MODIS

BIR_SR	Benthic irradiance (seasonal range) PAR * exp(-K490 * depth)			
CHLA_AV	Chlorophyll (annual average)	average	mg/m^3	MODIS
CHLA_SR	Chlorophyll (seasonal range)			
K490_AV	Attenuation coefficient at wavelength 490 nm (annual average)	average	/m	MODIS
K490_SR	Attenuation coefficient at wavelength 490 nm (seasonal range)			
NPP_AV	Net primary production (annual average)	average	mg C/m^2/day	MODIS
NPP_SR	Net primary production (seasonal range)			
EPOC_AV	Export particulate organic carbon flux (annual average)	average	mg C/m^2/day	MODIS
EPOC_SR	Export particulate organic carbon flux (seasonal range)			
TERAN_PLAN	Terrain plane topography calculated from the detailed bathymetry			
TERAN_PIT	Terrain Pit topography calculated from the detailed bathymetry			CSIRO (2020)
TERAN_CHAN	Terrain Channel topography calculated from the detailed bathy.			CSIRO (2020)
TERAN_PASS	Terrain Pass topography calculated from the detailed bathy.			CSIRO (2020)
TERAN_RIDG	Terrain Ridge topography calculated from the detailed bathymetry			CSIRO (2020)
TERAN_PEAK	Terrain Peak topography calculated from the detailed bathymetry			CSIRO (2020)

2.4 Statistical analysis of data and spatial ecotype distribution prediction

Methods for predictively modelling the spatial distribution of ecotypes (or biological assemblages) closely follows those used in Pitcher et al. (2016) to provide a regional habitat and species assemblage characterisation of the Pilbara region. The spatial characterisation was achieved by analysing the biological datasets summarised above in an integrative analysis method, R package 'gradientForest' (http://r-forge.r-project.org/projects/gradientforest/; Ellis et al. 2012; Pitcher et al. 2012). GradientForest was used to obtain evidence-based relationships between species compositional change (turnover) and multiple environmental gradients, which were then used to transform all environmental data layers to the same 'biological' scale (for details, see http://gradientforest.r-forge.r-project.org/biodiversity-survey.pdf). The transformed layers provide a multi-dimensional biological space that represents biotic composition as associated with the environmental variables. The biological space was mapped in geographic space to provide a continuous characterisation, and an appropriate number of ecotypes defined by an evidence-based clustering procedure to provide a classified assemblage map for the region. These steps are explained further in the report.

Initially, multivariate regression tree (MRT) analysis of each dataset was used to provide a cross-validated estimate of the number of justifiable partitions of the species composition for each dataset, based on predictions on the environmental variables (Figure 5,Figure 6). These results are later used as one of the guides to the total number of assemblages or ecotypes in the survey area.

The NWS FnB trawl, NWS McKenna trawl (Figure 5) and NWS photo-benthos (Figure 6) datasets appear to discriminate some sites around the location of the ancient coastline as different from nearby sites, whereas the Data Trawler FB trawl and Santos.VidSvy2 datasets split clearly along the ancient coastline (Figure 6). The Soviet Trawl dataset appears to have little structure associated with the environmental gradients (Figure 5).

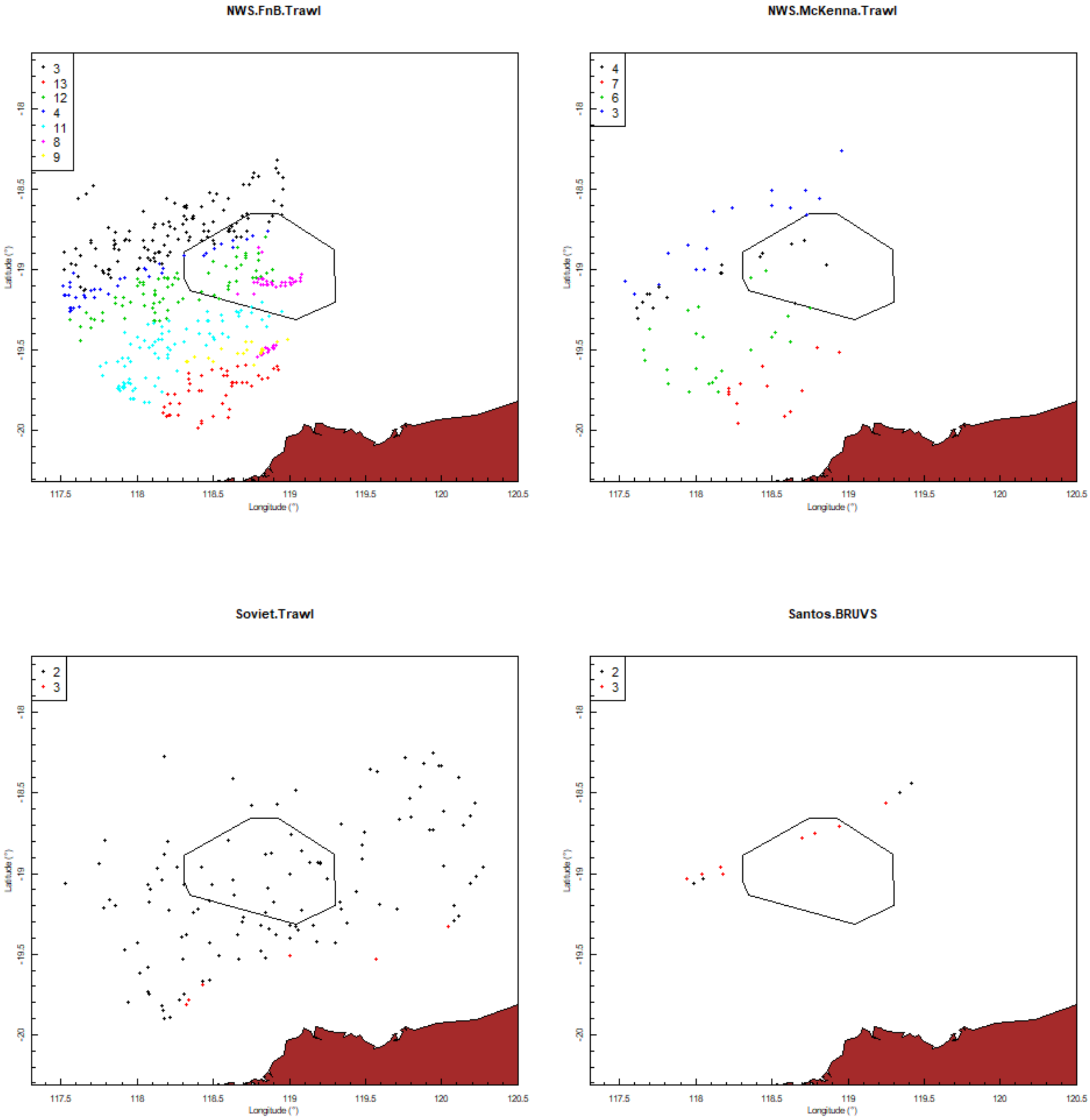

Figure 5. Distribution of sites sorted using MRT analysis of each dataset to provide a cross-validated estimate of the number of justifiable partitions of the species composition for each dataset, given predictions on the environmental variables. Black polygon = survey area boundary.

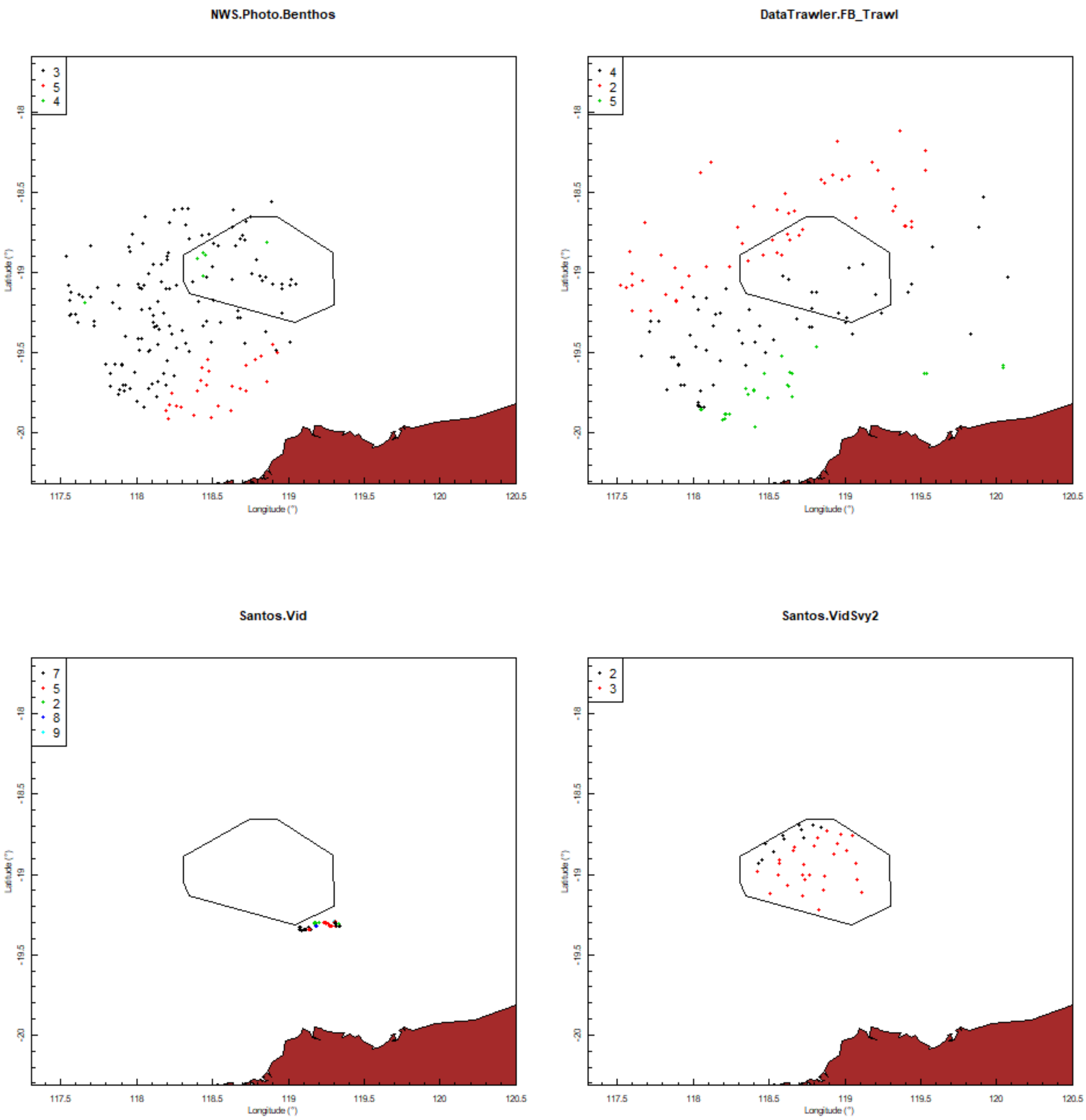

Figure 6. Distribution of sites sorted using MRT analysis of each dataset to provide a cross-validated estimate of the number of justifiable partitions of the species composition for each dataset, given predictions on the environmental variables. Black polygon = survey area boundary.

2.5 Regional Context

Ecoregions (ecotypes mapped at larger spatial scales) provide regional context for the survey area. Thus, the greater NWS has 18 of the 217 ecoregions mapped nationally (Pitcher et al. 2018). The survey area primarily overlaps two ecoregions (10 and 12) and has minor overlap with a shallower shelf ecoregion (8) and an upper-slope/shelf-break ecoregion (14) (Figure 7).

Ecoregions provide a broader regionalisation but are based on similar analyses used to define ecotypes but using 13 datasets with broad coverage of the NWS region. The outer-shelf ecotypes 10 and 12, which overlap the survey area, extend substantially along the shelf to the southwest and northeast. The ancient coastline occurs approximately at the boundary of ecotypes 12 and 14 (and also 10 & 7 with 13). The survey area overlaps slightly with the upper slope ecotype 14 and the shallower shelf ecotype 8.

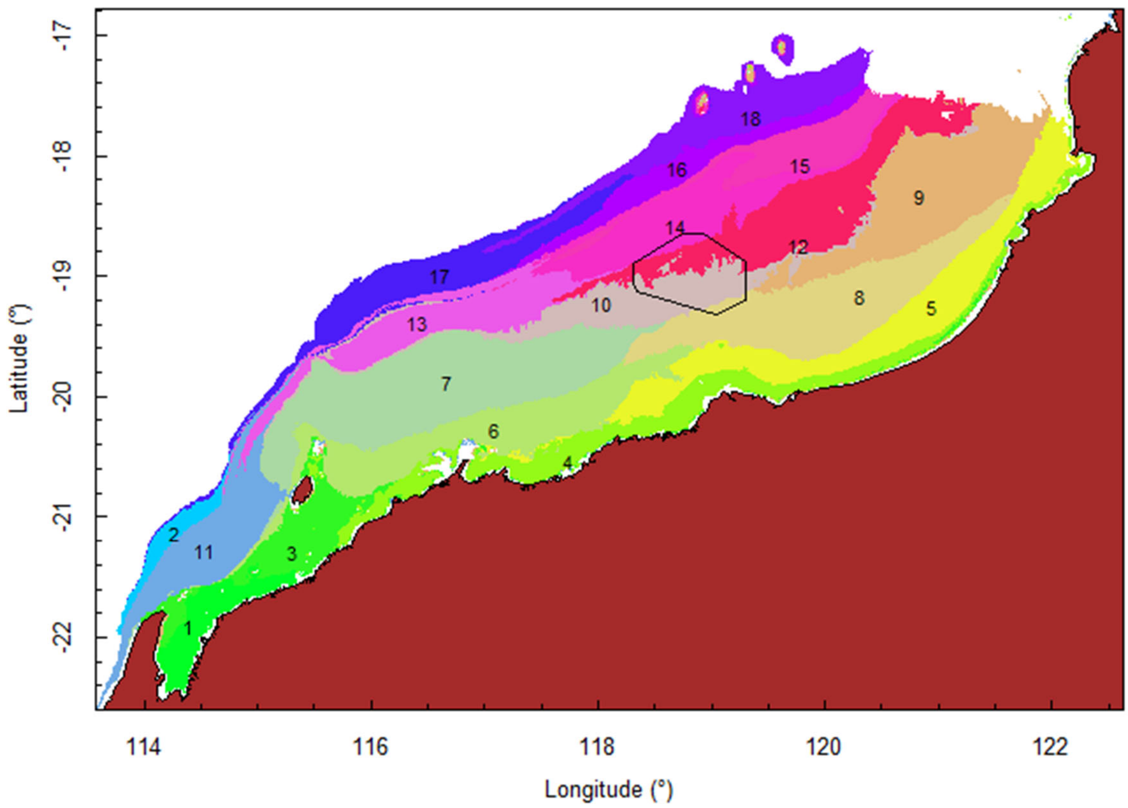

Figure 7. Regional distribution of biological assemblages on the NWS (from Pitcher et al. 2018). Colours and numbers 1–18 correspond to assemblages mapped by Pritcher et al. (2018). Maroon = Australian landmass. Black polygon = survey area boundary.

2.6 Spatial patterns in the Dorado Survey Area

2.6.1 North West Shelf Photo-benthos dataset

As an initial assessment of the historical sites was made with benthic photographic data (Figure 8, Figure 9), to plot maps of the observed abundance distributions of each type of sessile benthic morphotype were together with their MRT groupings (Figure 5, Figure 6). This shows that some of the previous observations of the distribution of branching sponges, gorgonians and whip corals (hereafter whips) is coincident with the ancient coastline and provides a good indication that the MRT clustering of habitats based on these data is revealing spatial patterns that are consistent with expected biota distributions.

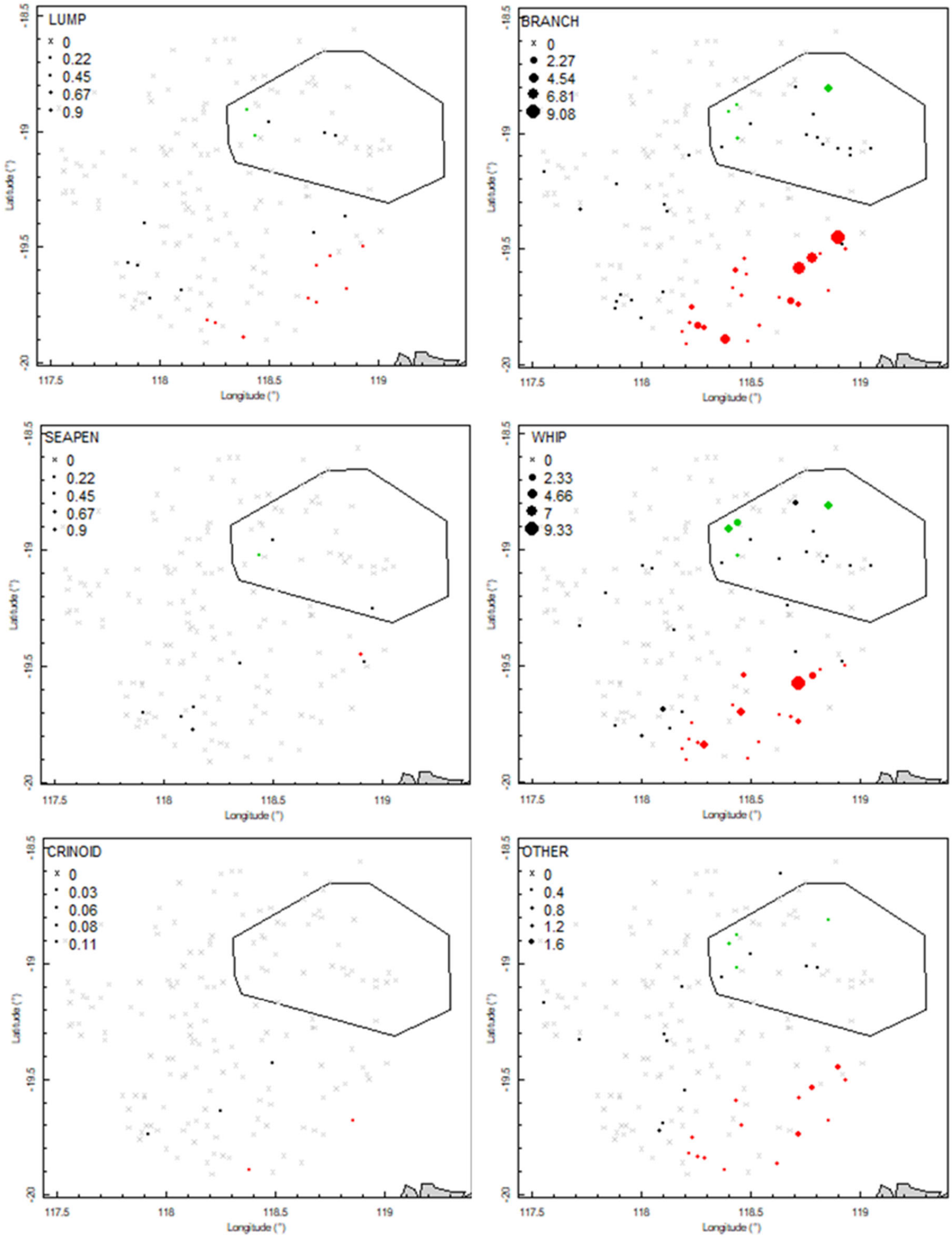

Figure 8. Distribution and relative abundance of habitat forming benthic filter feeder morphotypes from historical surveys within the survey area. Symbol colours (green, black, red) indicate the MRT nodes (or clusters) for the NWS Photo-benthos dataset shown in Figure 6. Morphotypes referred to are: lump-shaped sponges (lump), branched sponges (branch), seapens (seapen), sea whips (whip), crinoids (crinoid), and other difficult to distinguish types (other). Black polygon = survey area boundary.

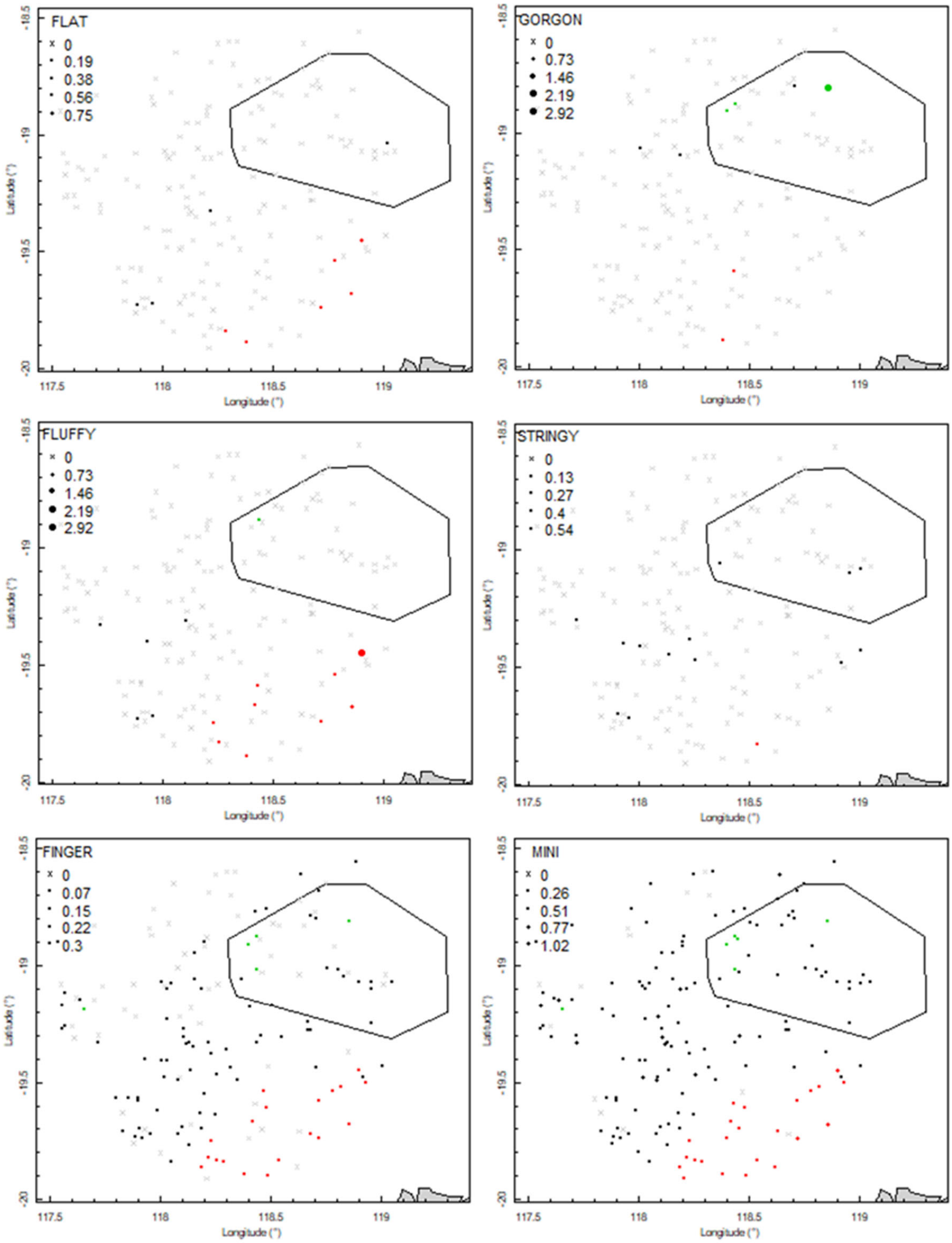

Figure 9. Distribution and relative abundance of habitat forming benthic filter feeder morphotypes for from historical surveys within the survey area. Symbol colours (green, black, red) indicate the MRT nodes (or clusters) for the NWS Photo-benthos dataset shown in Figure 6. Morphotypes referred to are: flat growth-form sponges (flat), gorgonians sea fans (gorgon), fluffy appearance biota mostly hydroids (fluffy), stringy appearance biota mostly hydroids (stringy), finger-shaped sponges (finger), and small filter feeders < 5 cm (mini). Black polygon = survey area polygon.

2.6.2 Influence of environmental gradients

Following bio-physical analysis of each dataset, using ‘gradientForest’ (Ellis et al. 2012; Pitcher et al. 2012), which quantifies the magnitude of compositional change along each environmental gradient for each dataset and for the combined response (Figure 10), the gridded environmental variables are transformed to a multidimensional ‘biological space’, using the combined response, which provides a prediction of the continuous compositional patterns that are associated with the environment (biplot, first 2 of 40 dimensions only) and to geographic space (Figure 11).

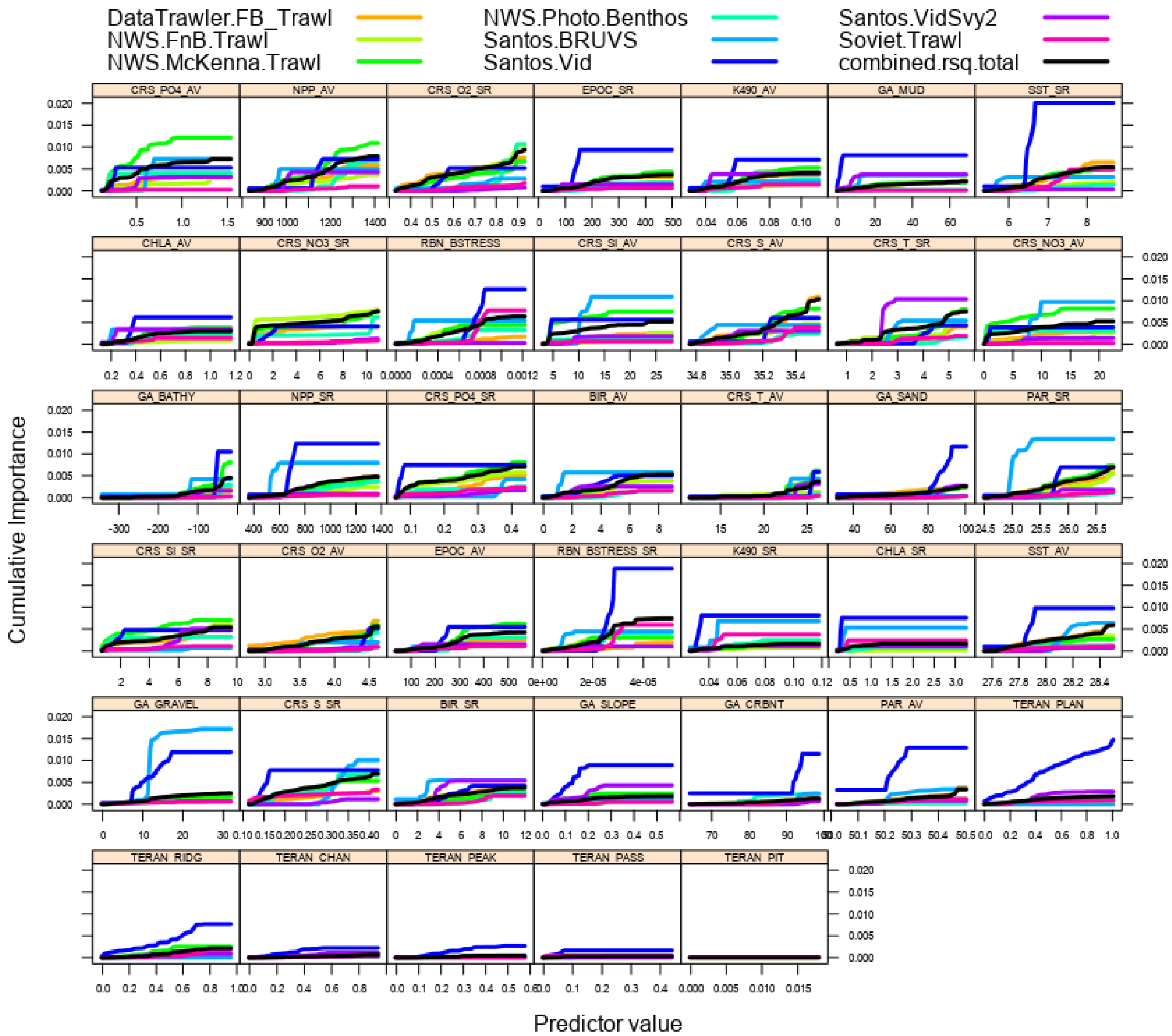

Figure 10. Magnitude of compositional change along each environmental gradient for each of the eight biological datasets and the combined response.

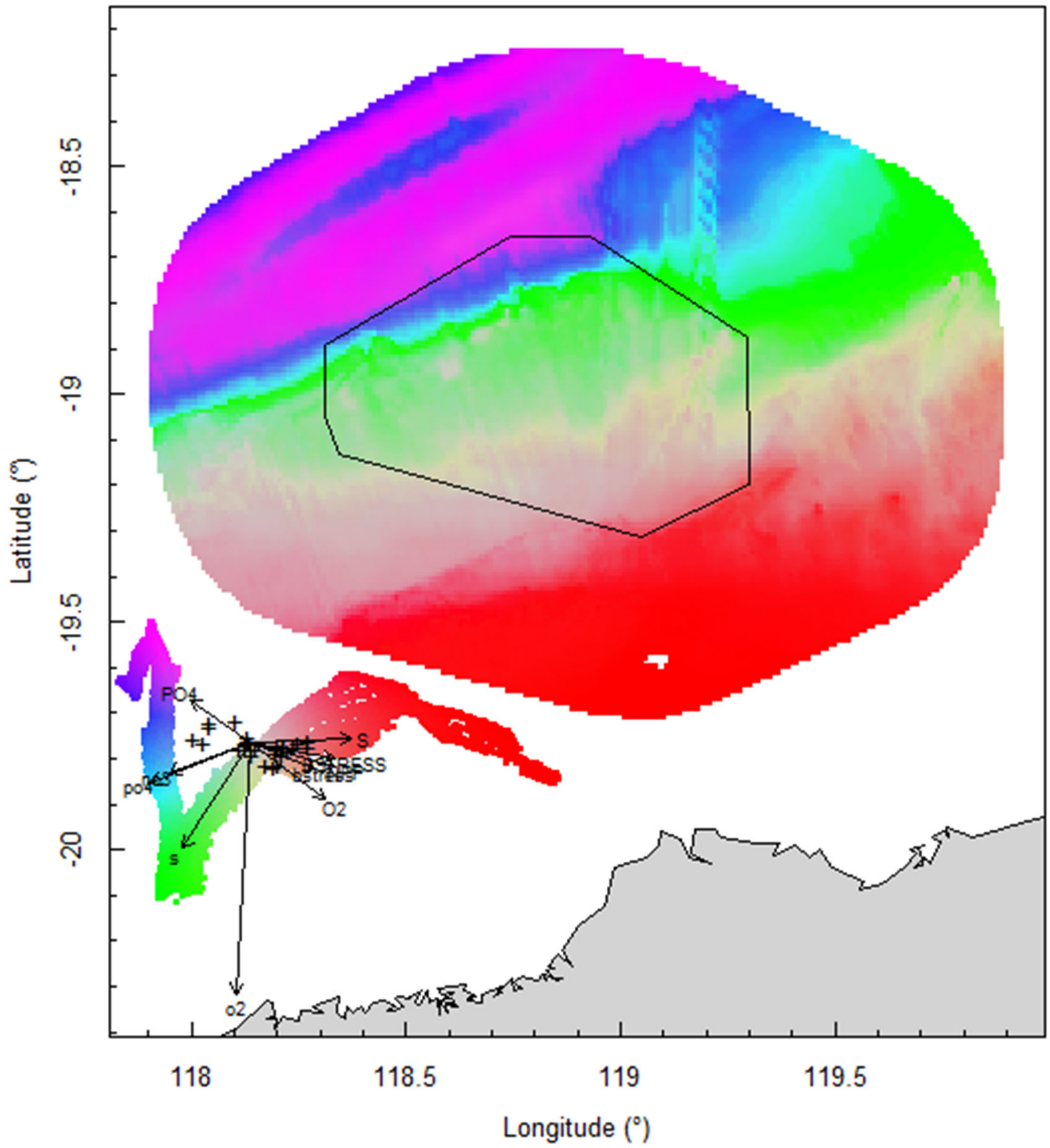

Figure 11. Prediction of the continuous change in compositional patterns of biological assemblages in relation to the environment (biplot) and to geographic space within the survey area. The biplot legend at lower left shows the continuous environmental variables in the first 2 dimension of multidimensional space; vectors indicate the direction of the key environmental variables (see Table 2 for list of environmental variables). Black polygon = survey area boundary.

2.6.3 Clustering of discrete habitats or ecotypes

While real compositional changes of species assemblages are continuous, many applications require a classified version where classes represent predicted assemblages or eco-types – these are the 'habitats' in terms of the environmental combinations where each mix of species compositions is distributed. Classification is achieved by cluster analysis, however some evidence supported objective basis is required for the appropriate number of clusters. The earlier MRT analysis results, and a multi-variate F-ratio statistic are used to help guide the selection of an appropriate number of clusters.

The MRT criterion (Figure 12) indicates the minimum number of regional clusters that is required to split each dataset according to the MRT analysis. The multi-variate F-ratio indicates how well each regional clustering, as a factor, explains the variation due to structure in each dataset. The smallest number of clusters that satisfies the MRT criterion for all datasets is seven (excluding the initial Santos video survey, which is an unreliable outlier in terms of MRT results – see Figure 5, Figure 6), because the sampling was focused within a very small geographic area and was not designed to determine the distribution of habitats in that area, rather it was targeted around trying to locate pearl oyster habitat. Moreover, seven clusters had a higher F ratio than any other number of clusters that satisfies the MRT criterion (Figure 13). Thus, a 7-cluster solution provided a reasonable balance between representing the most informative datasets, partitioning the environmental/biological patterns in sufficient detail but not too many to over-complicate, or over-interpret, the patterns.

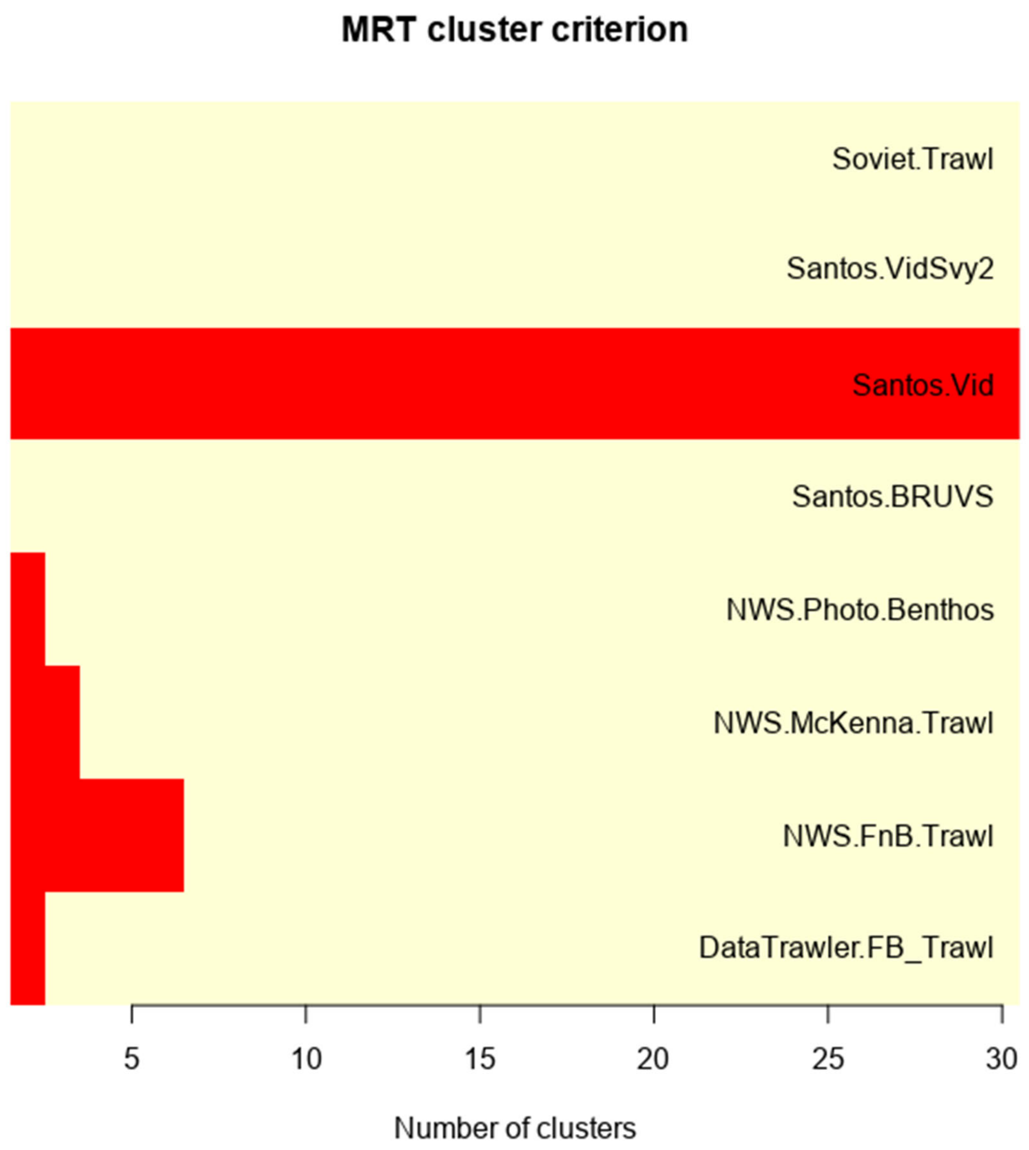

Figure 12. Multivariate regression tree results for each of the eight biological datasets.

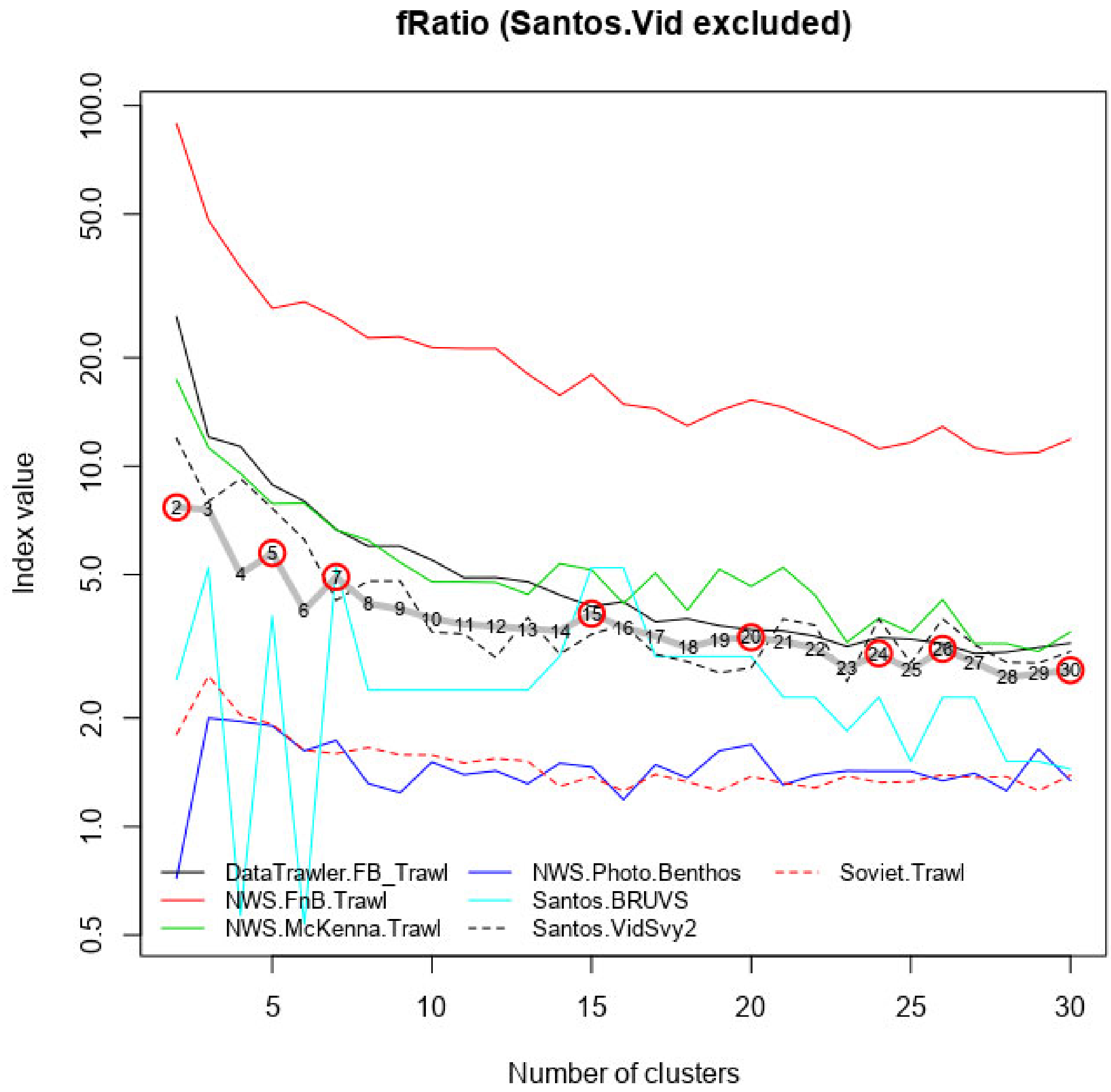

Figure 13. Multivariate F-ratio for each of the biological datasets. This statistic indicates the variation (or structure) in each dataset explained by each clustering in a range of numbers of clusters of the entire environment space of the study area in each dataset and assists with a more objective selection of the optimal number of ecotypes. The thick grey line indicates the weighted average F-ratio of across datasets for each cluster. Red circled numbers = local peaks in F-ratio for the cluster number.

2.6.4 Ecotypes present in the Dorado Survey Area

Figure 14 shows the map of the 7-cluster characterisation and prediction of seabed assemblages or ecotypes, along with a biplot showing associated distributions in the first 2 dimensions of ‘biological space’ and directions and magnitudes of the major environmental influences.

The most important environmental influences include the seasonal range and annual average of bottom water attributes such as oxygen, salinity, nutrients and temperature (Figure 15). The cluster boundaries align with depth even though depth *per se* is relatively unimportant – this is because several of the important variables vary with depth though in non-linear ways. The ancient coastline is located primarily near the outer boundary of ecotype 3 (see Figure 16 and Figure 17).

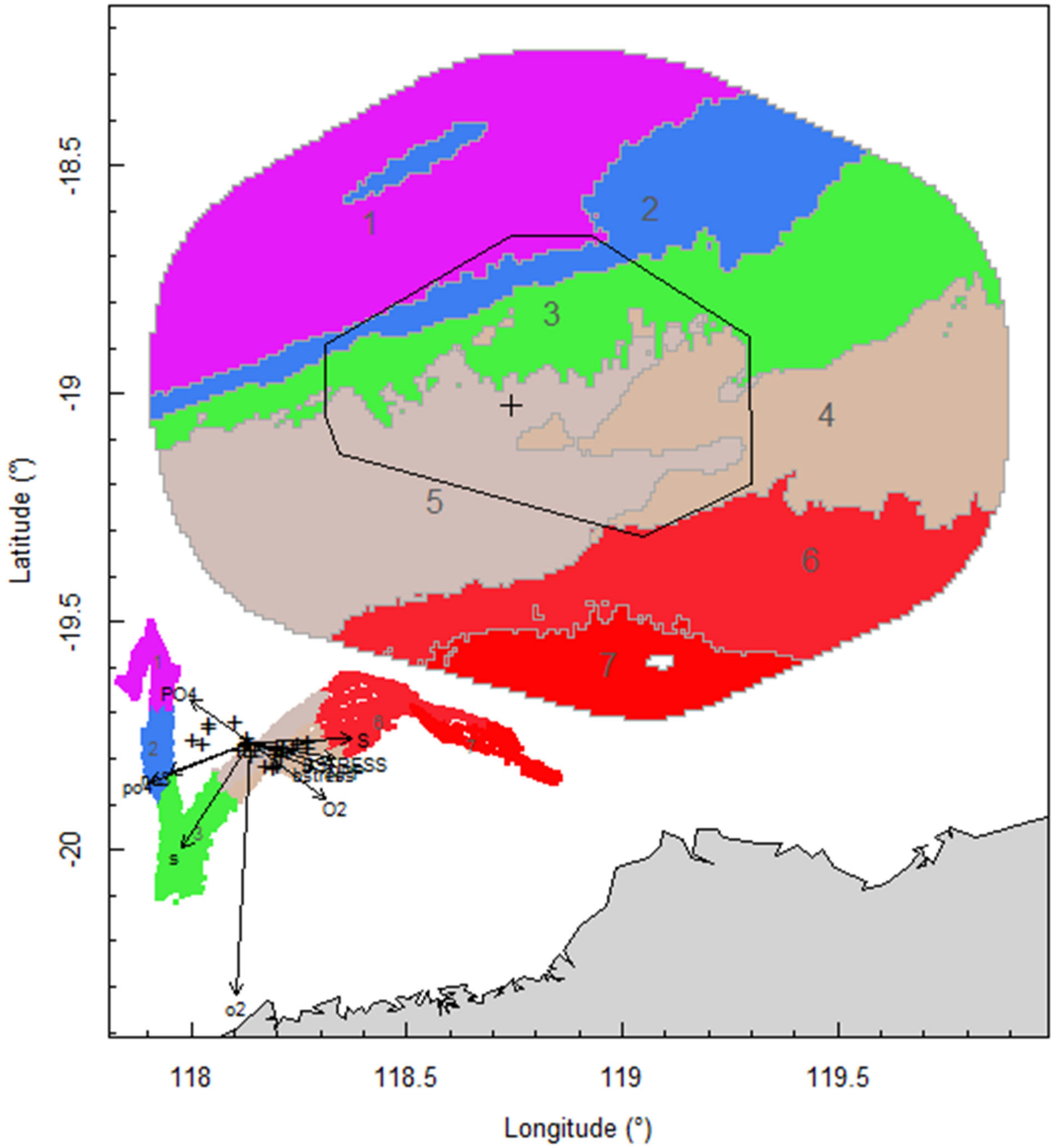

Figure 14. Map showing the spatial distribution of the seven ecotypes, identified by colour and number, within the survey area. The biplot legend at lower left shows the corresponding clustered environmental variables in the first 2 dimensions of multidimensional space; vectors indicate the direction of the key environmental variables (see Table 1 for list of environmental variables). "+" = WHPL. Outer grey line = initial survey area. Black polygon = survey area boundary. White area = area of < 10 m depth.

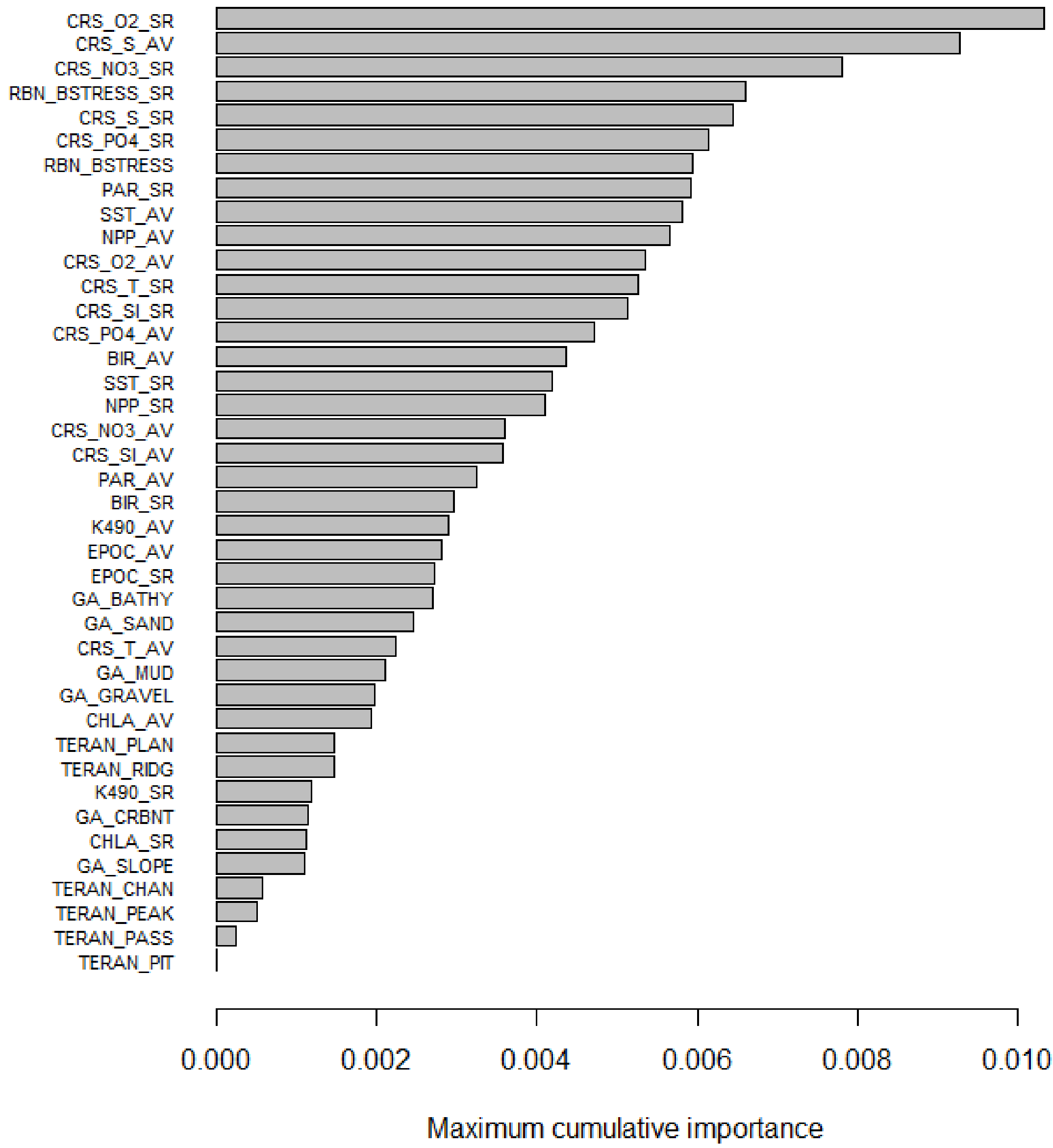

Figure 15. Relative importance of each of the environmental variables in predicting spatial patterns in biological attributes within the survey area. The maximum cumulative importance is the maximum of the combined cumulative importance in Figure 10.

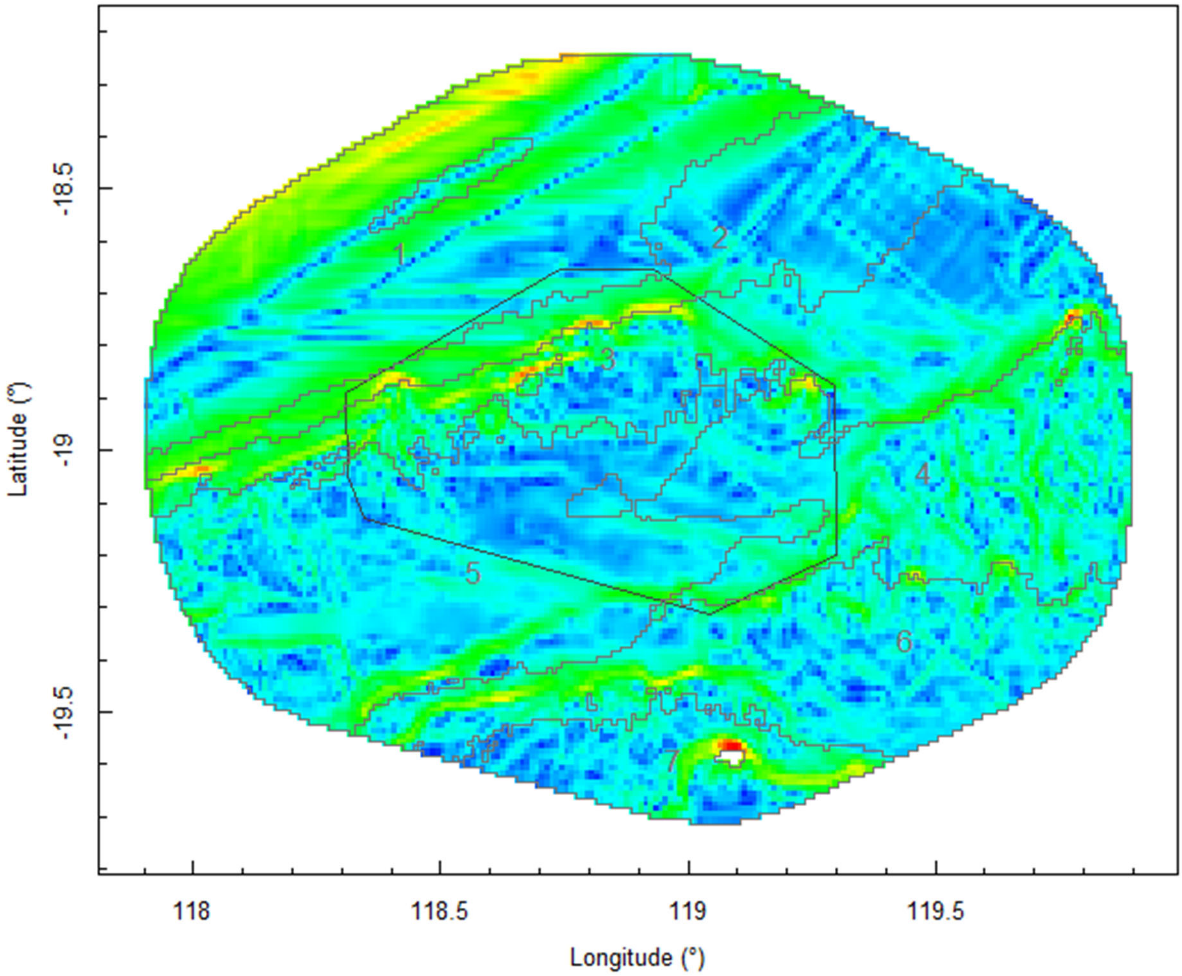

Figure 16. Map showing the seven ecotypes superimposed on the slope gradient derived from the bathymetry. Blue is the shallowest or flattest slope and red is the steepest slope. Numbers and lines correspond to ecotypes. Outer grey line = initial survey area. Black polygon = survey area boundary.

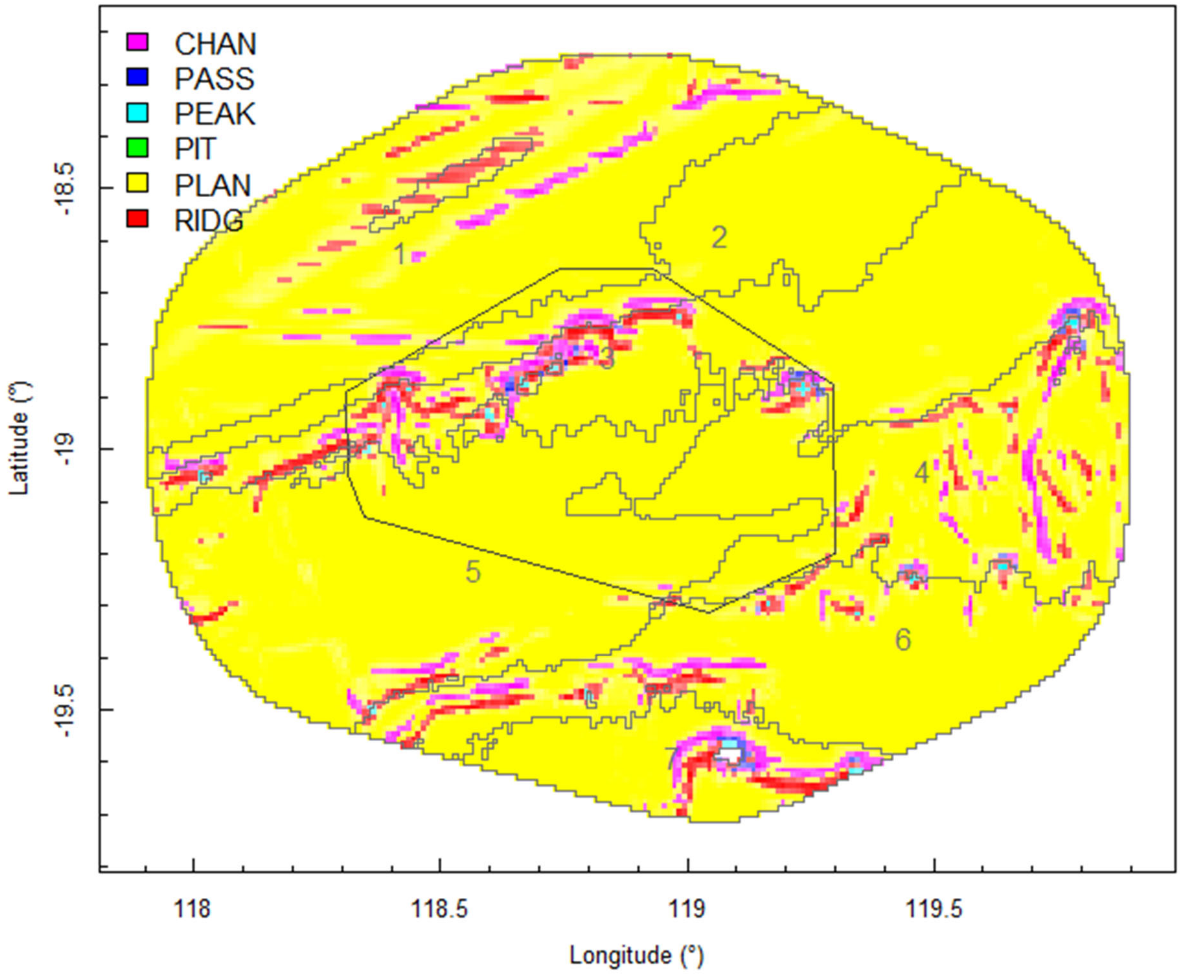

Figure 17. Map showing the seven ecotypes superimposed on the terrain features derived from the bathymetry. The terrain features are: channel, pass, peak, pit, plane and ridge (see Section 2.3 for explanation of terrain types). Each cell is coloured by its maximum terrain class probability and the probability value by respective colour intensity. Numbers and lines correspond to ecotypes. Outer grey line = initial survey area. Black polygon = study area boundary.

2.6.5 Environmental attributes of each ecotype

Box plots summarising the characteristic environmental attributes of each eco-type are shown in Figure 21 – Figure 21. Ecotype 3 – associated with the ancient coastline – stands out in having the highest seasonal range in oxygen, as well as high seasonal range for salinity and nutrients (NO_3 and PO_4). Most ecotypes are sand-dominated although silt/mud content (GA_MUD) increases with depth (Figure 20Figure 21) and is greatest for ecotype 1; note when the percentage of mud reaches 20%, it can substantially alter the characteristics of the sediment and the associated biota composition. Coarser substrates are more frequent in shallower ecotypes within the survey area (Figure 22, Figure 23).

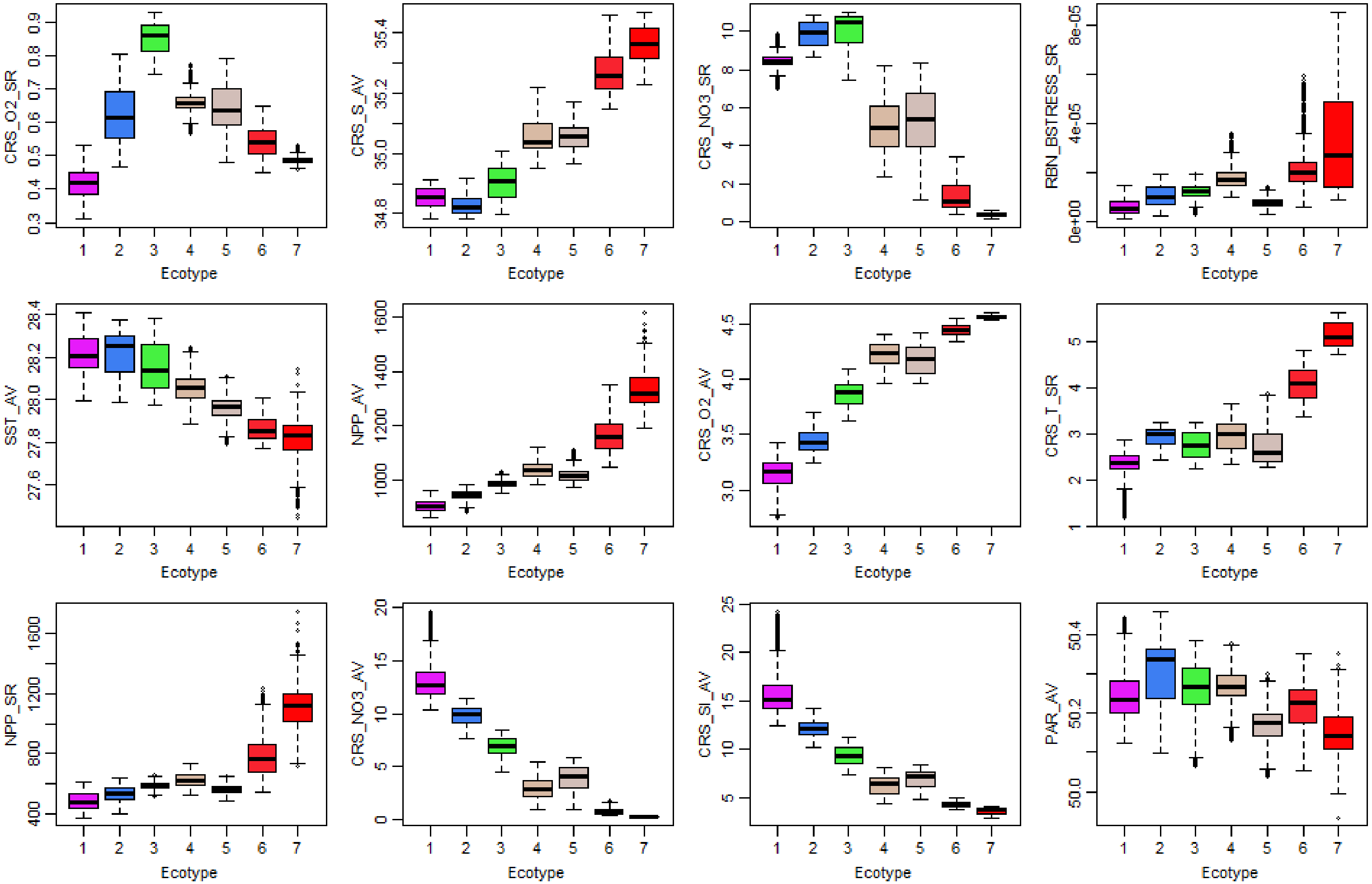

Figure 18. Predictor variables for each of the seven ecotypes within the survey area. Boxplots comprise median, first and third quartile, and 'whiskers' extending to the minimum of (a) the most extreme data point that is no more than 1.5x the interquartile range from the box, or (b) 1.5x the interquartile range from the box. Dots = outliers, values of any data points that are beyond the whiskers.

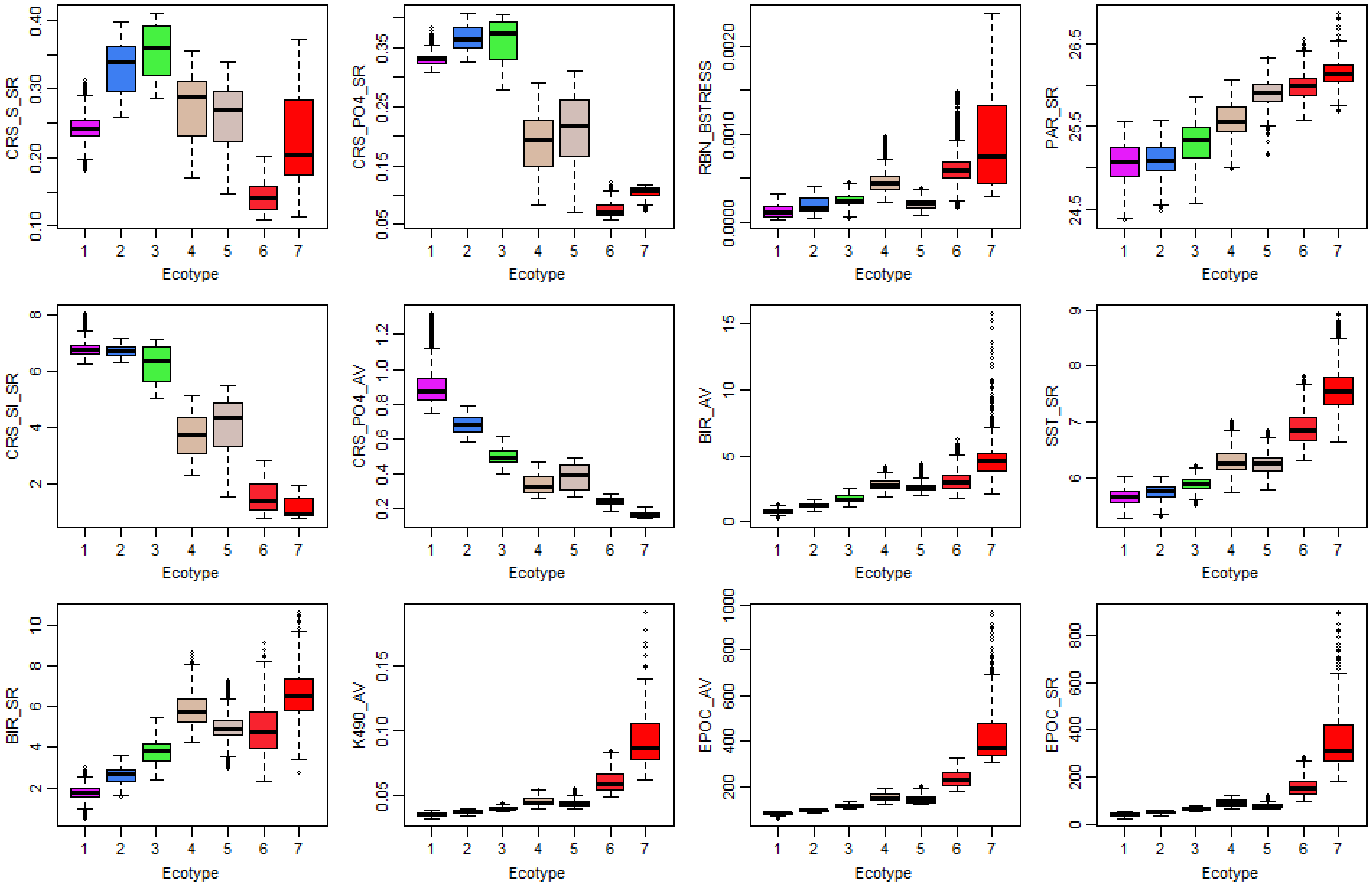

Figure 19. Predictor variables for each of the seven ecotypes within the survey area. Dots = outliers, values of any data points that are beyond boxplot whiskers.

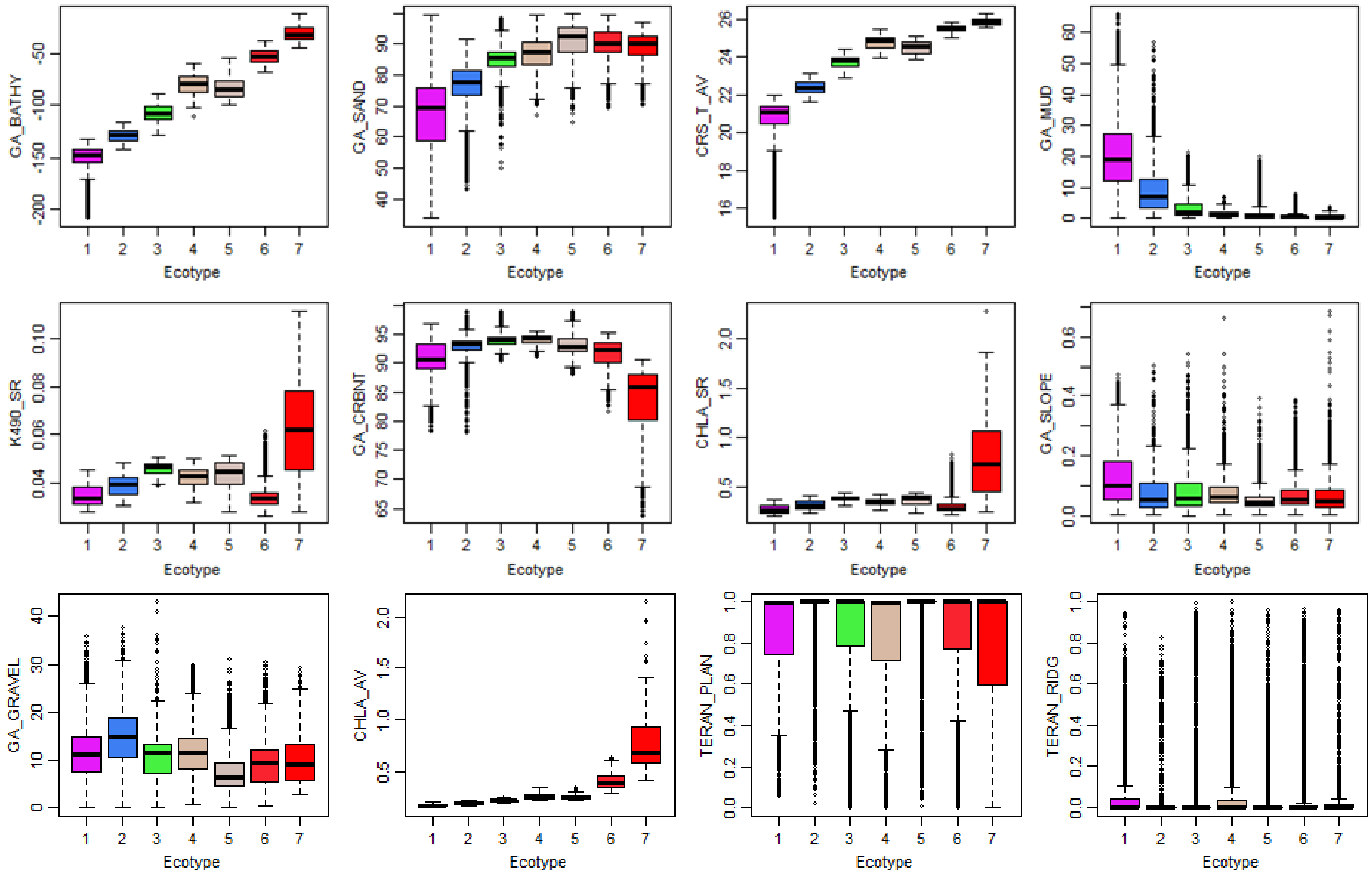

Figure 20. Predictor variables for each of the seven ecotypes within the survey area. Dots = outliers, values of any data points that are beyond boxplot whiskers.

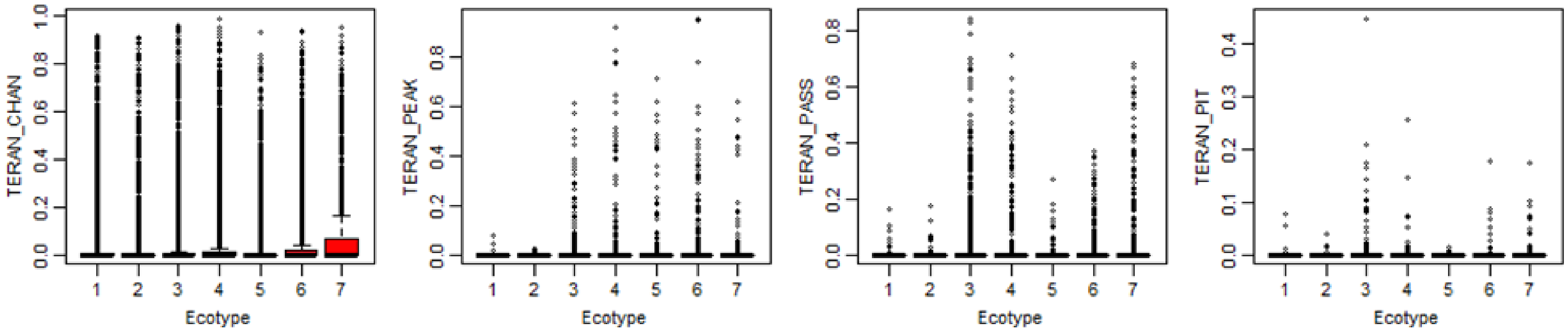

Figure 21. Predictor variables for each of the seven ecotypes within the survey area. Dots = outliers, values of any data points that are beyond boxplot whiskers.

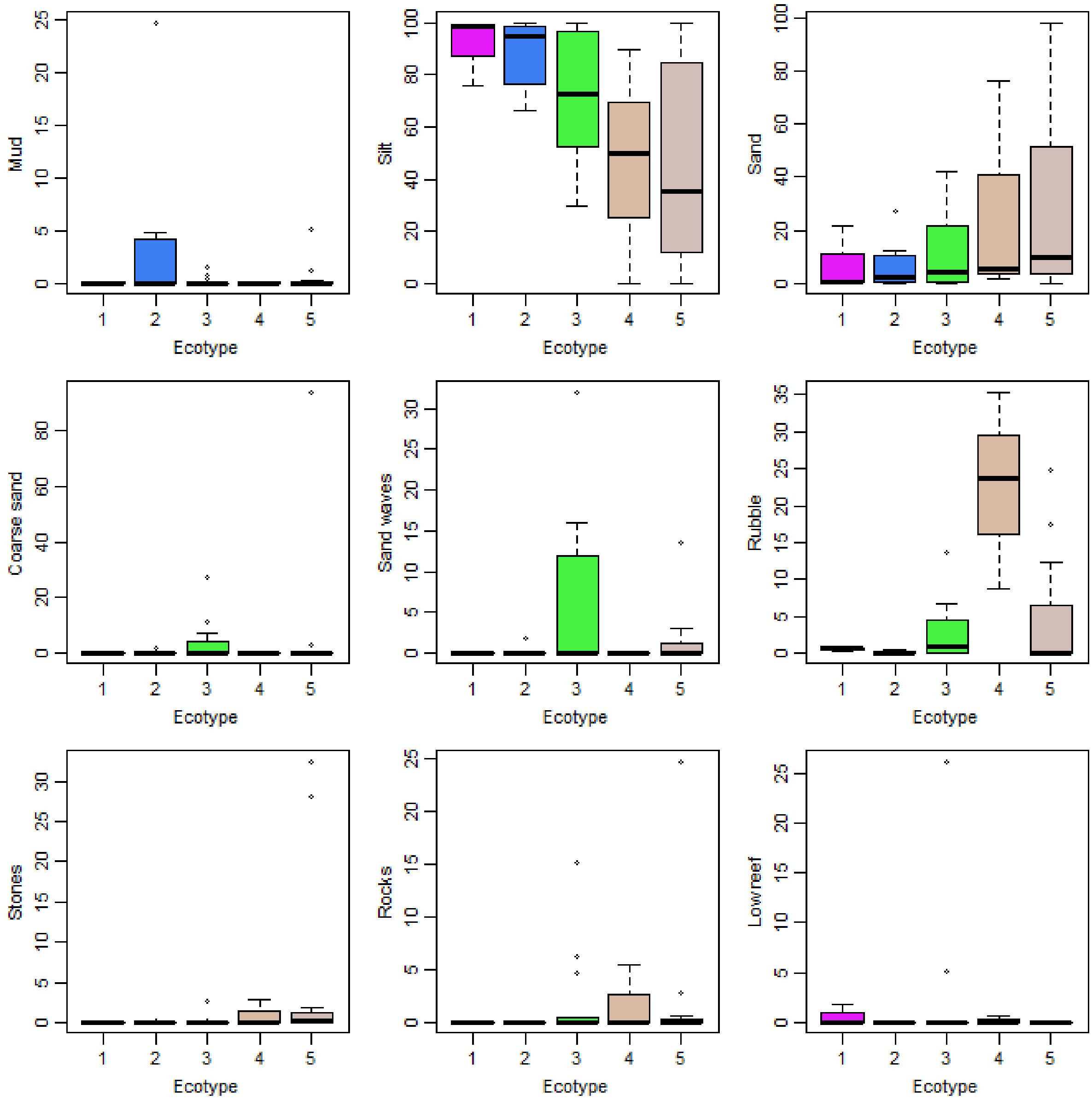

Figure 22. Box plots of substrate cover scores for sites within five ecotypes (out of a total of seven) that were represented within the survey area. Data are from the December 2019 RPS survey. Dots = outliers, values of any data points that are beyond the whiskers.

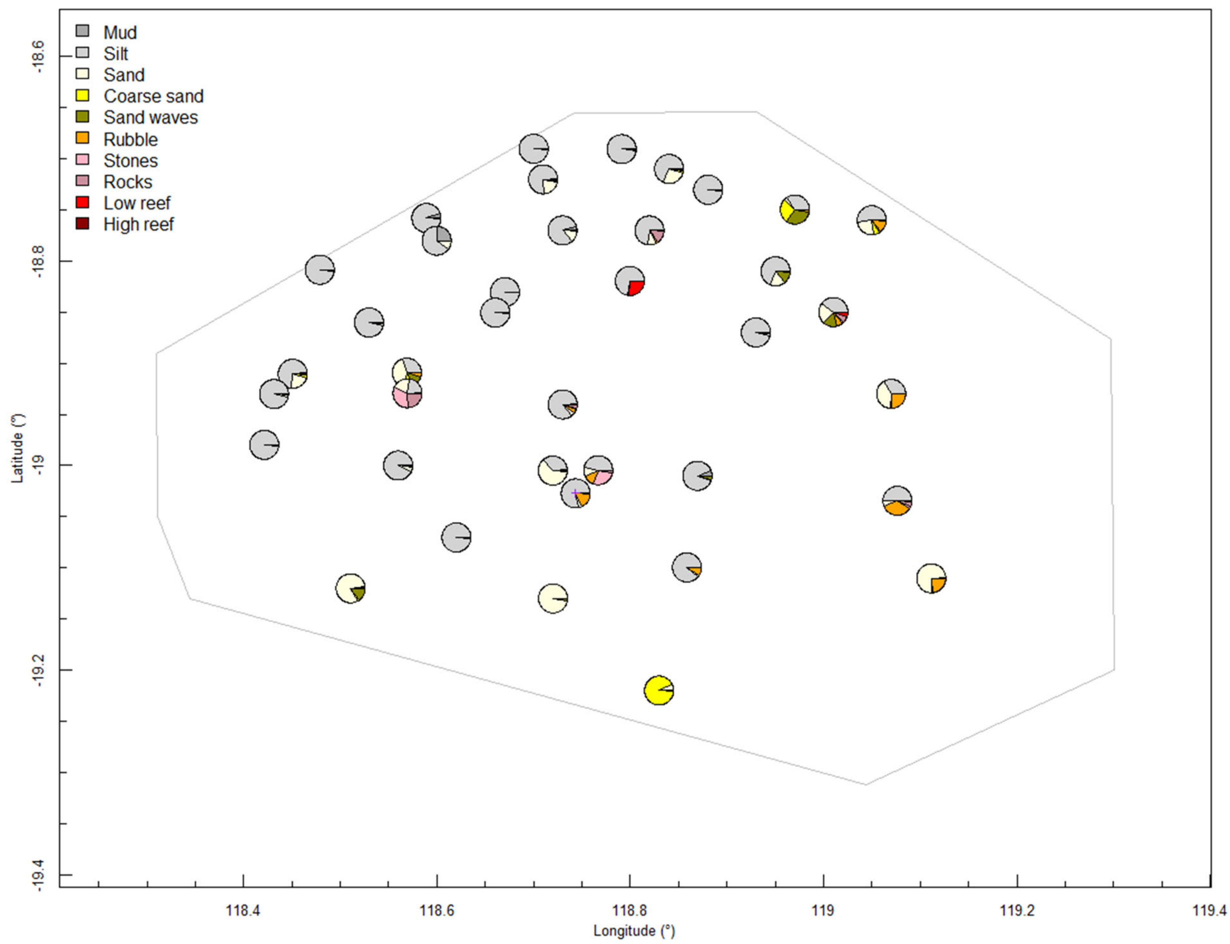

Figure 23. Site by site data for the proportion of substrate scores from ROV video data summarised by ecotype in Figure 22. Data are from the December 2019 RPS survey. See also Chapter 3 for detailed graphs plotted for each site. Grey line = survey area boundary.

2.6.6 Taxonomic richness and biomass of trawl samples of each ecotype

Box plots summarizing the taxonomic richness and biomass of trawl samples for sites that overlap each ecotype are shown in Figure 24. These samples are primarily dominated by fishes. The shallower ecotype 7 tends to have higher richness and biomass in some datasets.

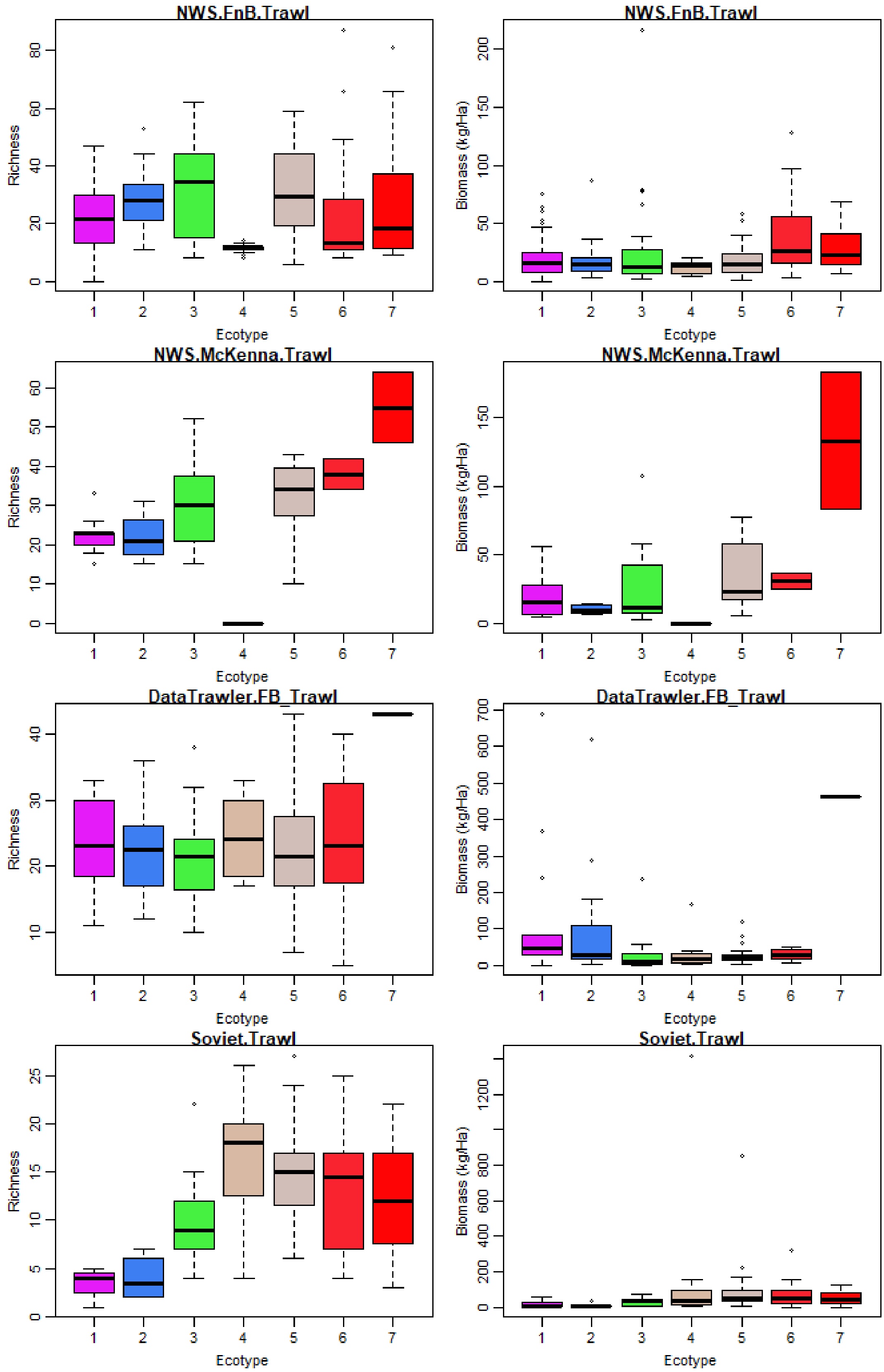

Figure 24. Taxonomic richness and biomass comparisons among the seven ecotypes within the survey area for each of the four trawl datasets analysed. Note that not all datasets include samples from within all ecotypes. Dots = outliers, values of any data points that are beyond boxplot whiskers.

2.6.7 Sessile benthic filter-feeder morphotypes characteristic of each ecotype

Box plots summarizing the observed sessile benthos morpho-types of each ecotype, for sites that overlap each ecotype are shown in Figure 25. While the shallower ecotype 7 has larger abundances of many of the benthos types, ecotype 3 – associated with the ancient coastline – also has notable abundances of several types. In the areas that have existing data, most of the other ecotypes tend to lack significant abundances of the larger benthos forms such as lump and branching sponges, gorgonians and whips. Somewhat similar patterns were observed among ecotypes 1-5 from the December 2019 RPS survey (Figure **26**, Figure 27, Figure 28 and Figure 29).

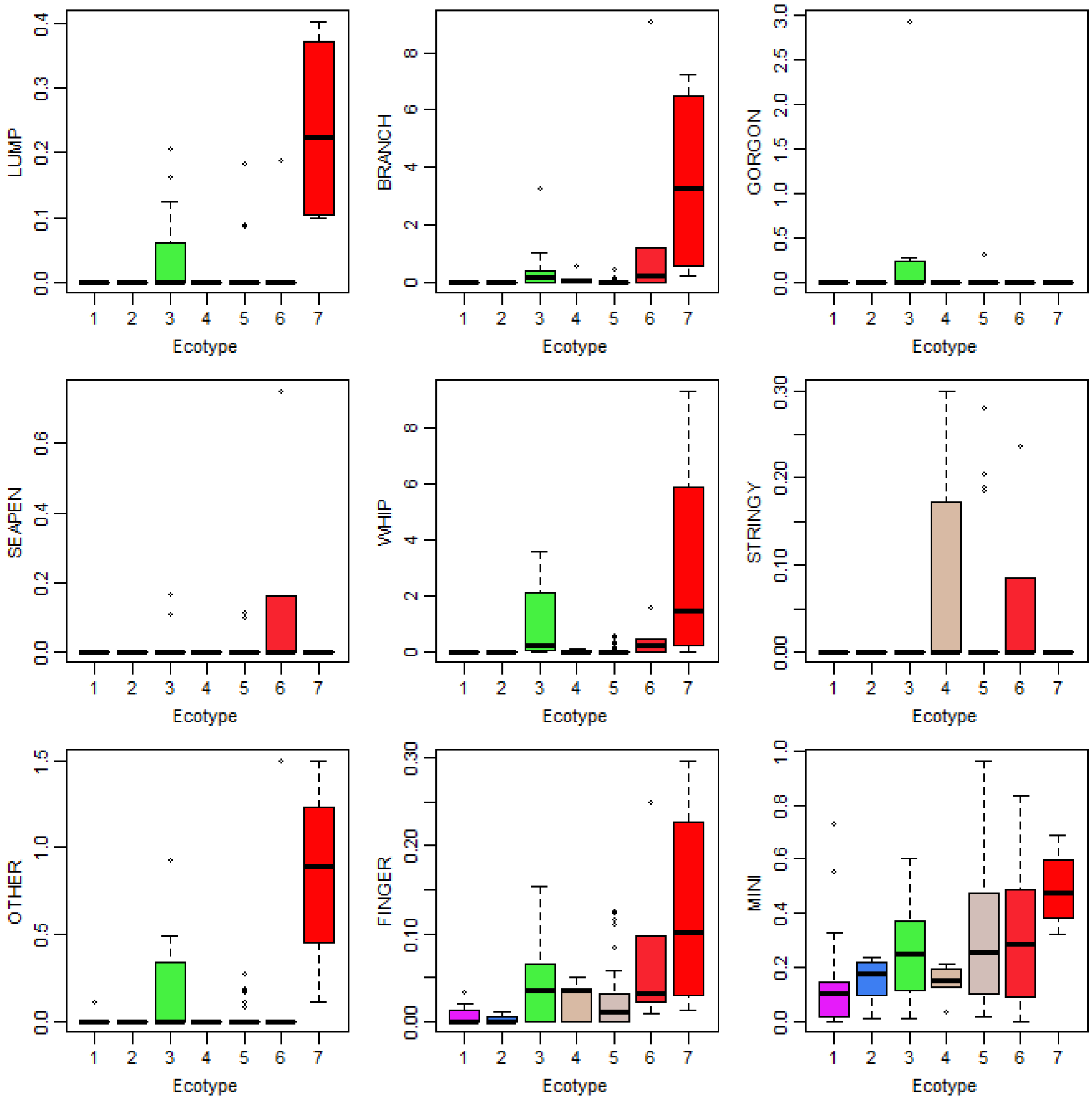

Figure 25. Distribution of habitat forming benthic filter feeder morphotypes by ecotype within the survey area. Data are from historical NWS photo-benthos dataset. Morphotypes referred to are: lump-shaped sponges (lump), branched sponges (branch), gorgonians sea fans (gorgon), seapens (seapen), sea whips (whip), stringy appearance biota mostly hydroids (stringy), other difficult to distinguish types (other), finger-shaped sponges (finger), and small filter feeders < 5 cm (mini). Dots = outliers, values of any data points that are beyond boxplot whiskers.

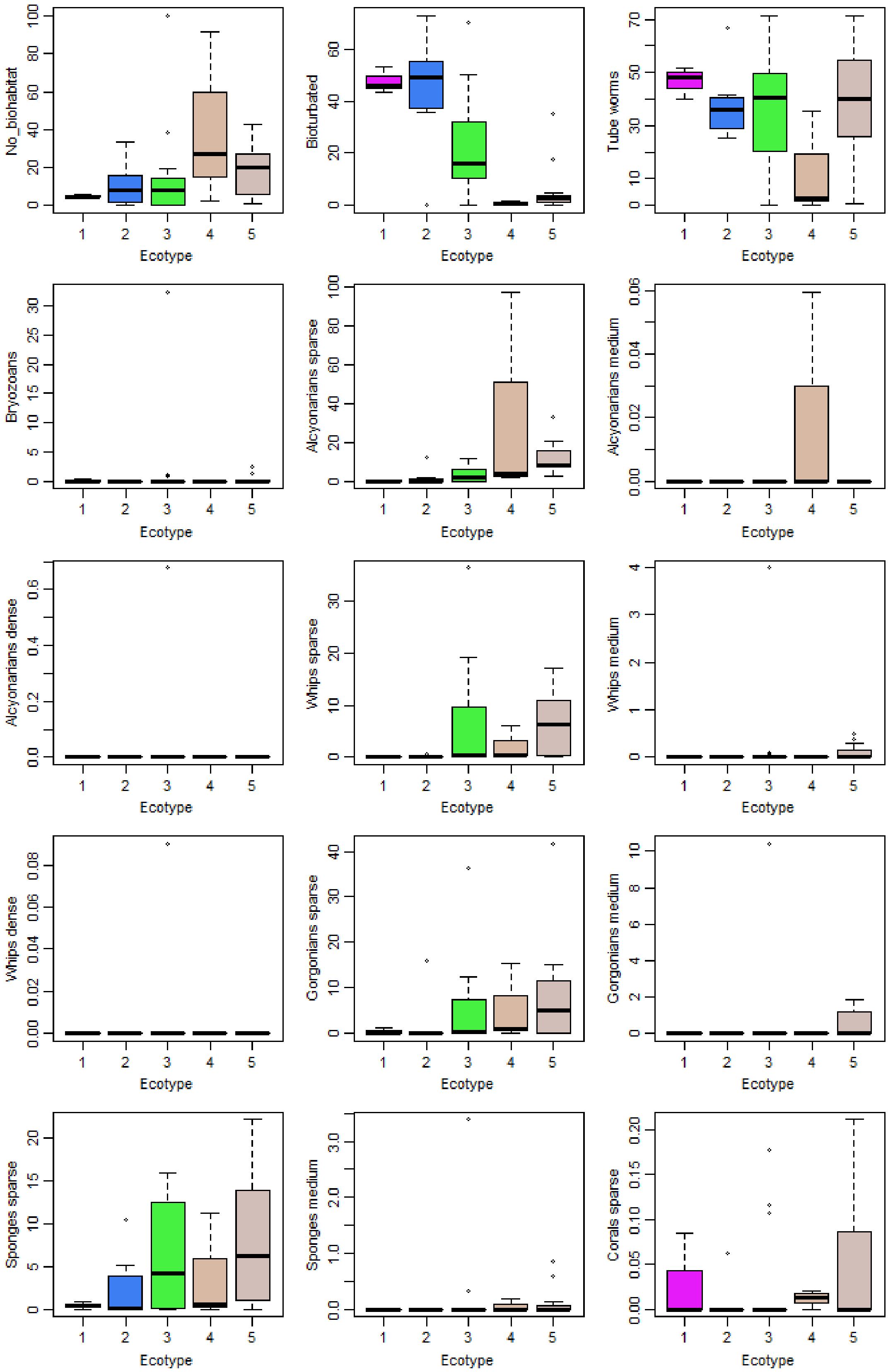

Figure 26. Box plots of biohabitat cover scores for sites within each of the five ecotypes (out of a total of seven) that were represented within the survey area. Data are from the December 2019 RPS survey. Dots = outliers, values of any data points that are beyond boxplot whiskers.

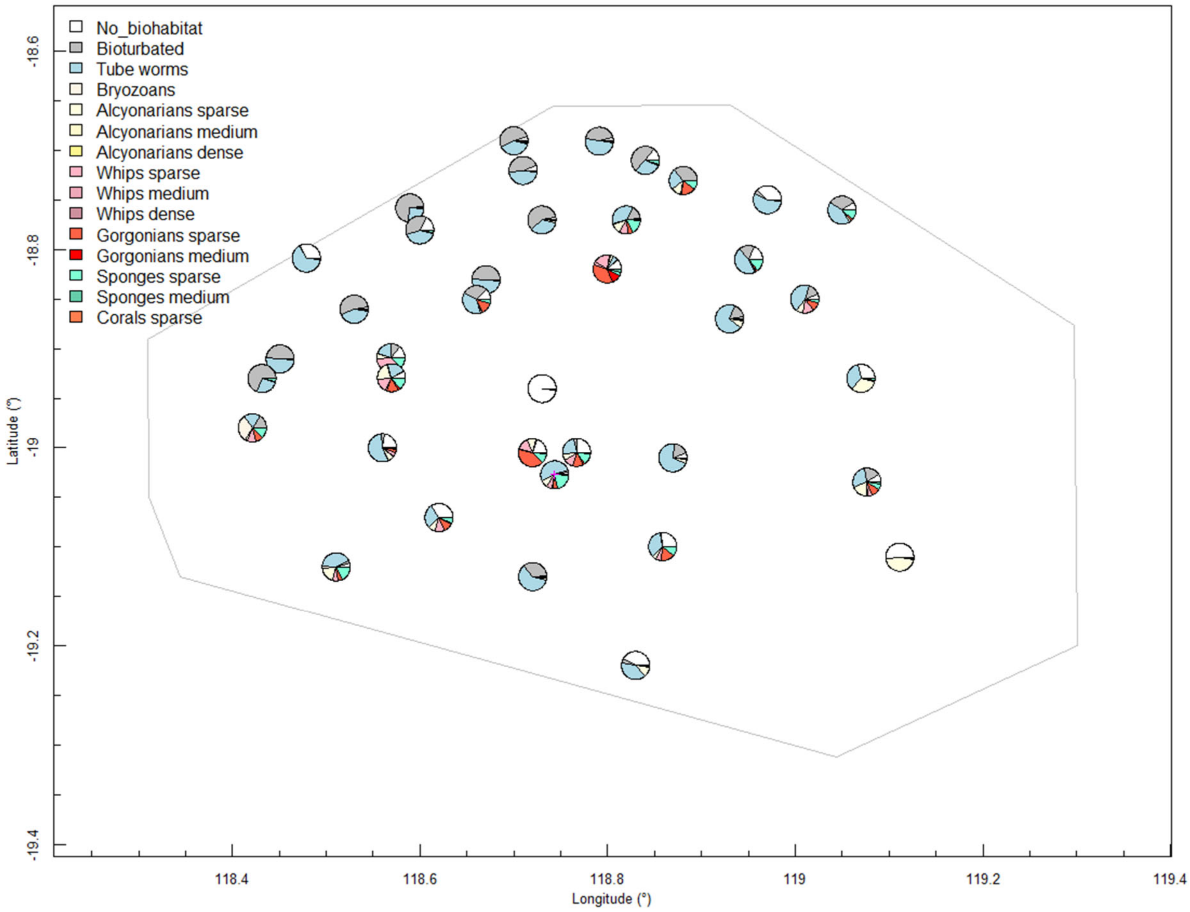

Figure 27. Site by site data for the proportion of biohabitat scores from ROV video data summarised by ecotype in Figure 26. Data are from the December 2019 RPS survey. See also Chapter 3 for detailed graphs plotted for each site. Grey line = survey area boundary.

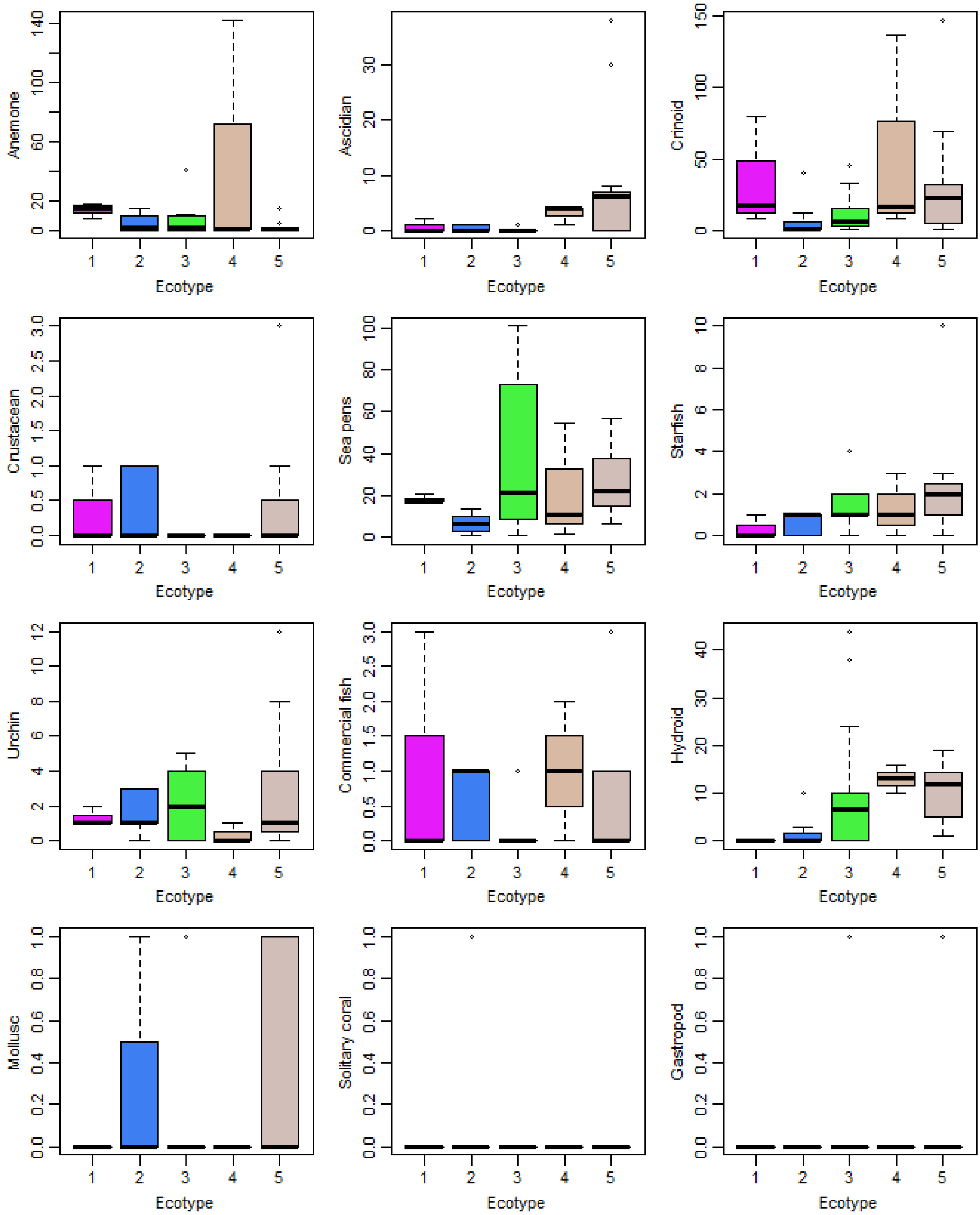

Figure 28. Box plots of animals (non-habitat forming biota) scored from videos for sites within each of the five ecotypes (out of a total of seven) that were represented within the survey area. Data are from the December 2019 RPS survey. Dots = outliers, values of any data points that are beyond boxplot whiskers.

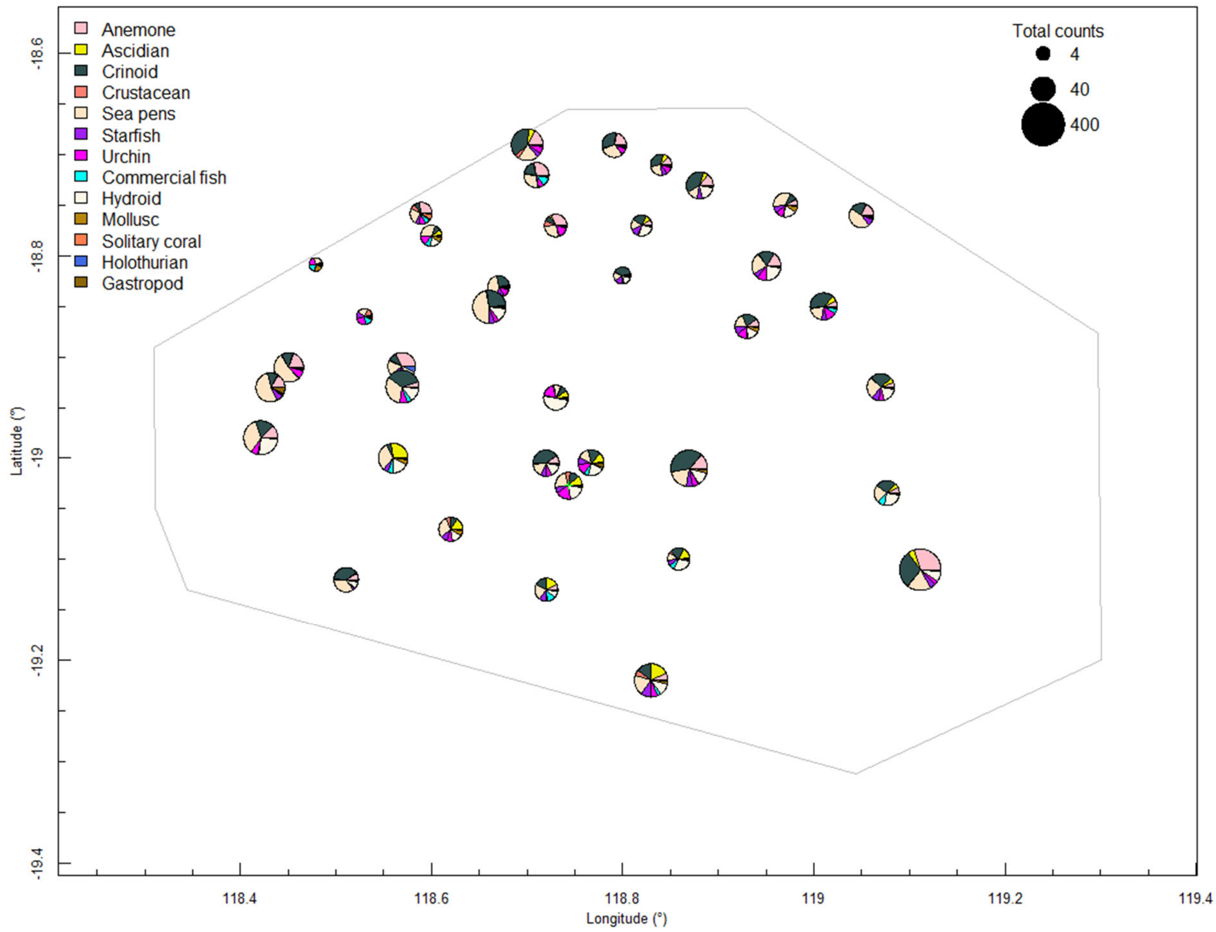

Figure 29. Site by site data for the animal event scores from ROV video data summarised by ecotype in Figure 28. Data are from the December 2019 RPS survey. See also Chapter 3 for detailed graphs plotted for each site. Grey line = survey area boundary.

2.7 Dominant taxa by ecotype

Tables 3 to 7 show the Dufrene-Legendre Indicator (DLI) for fish and some invertebrate taxa in each of the seven ecotypes in each the five biological datasets. The DLI is a measure of the extent to which a particular taxon is associated with a particular ecotype. A DLI of 1 indicates that a taxon was unique to that ecotype in the dataset examined. Only the top 20% (80^{th} percentile) of all DLI values are shown. Some clusters may not have any species in the 80^{th} percentile of DLIs. The column "MaxCl" indicates the ecotype for which the taxa had the highest DLI.

Tables 8 to 12 show the most abundant taxa (average biomass by ecotype), with only species in the top 5% (95^{th} percentile) of observed average ecotype abundances shown, and give an indication of the taxa that dominate each ecotype.

2.7.1 North West Shelf FnB Trawl dataset

There were 49 taxa spread across the seven ecotypes with DLI values in the top 20% (80^{th} percentile, Table 3). Among these, only one species, Grass Emperor, *Lethrinus laticaudis,* was indicated in more than two ecotypes, indicating each ecotype had a relatively distinct set of characteristic taxa. High DLI values (> 0.5) for each ecotype were as follows: Barred Javelin, *Pomadasys kaakan,* and Elongate Ponyfish, *Equulites elongatus* (ecotype 1), Malabar Trevally, *Carangoides malabaricus* (ecotype 2), sea lilies (crinoids) (ecotype 4) and Brownstripe Snapper, *Lutjanus vitta* (ecotype 7). The shallowest ecotype (7) had the largest number of taxa (14) in the top 20% (80^{th} percentile), suggesting a diverse set indicator fish fauna occurs in this ecotype, followed by ecotype 3 (11 taxa) associated with the ancient coastline KEF (Table 3). The top DLI scores in ecotype 4 were the invertebrates including crinoids, starfish, echinoids and bryozoa.

In terms of biomass, sponges were important in ecotype 6. Goatfishes occurred in the top taxa for biomass across all 7 ecotypes but the importance of different species varied between the deeper and shallow ecotypes. Bartail Goatfish, *Upeneus tragula,* and Luzon Goatfish, *U. luzonius,* were greatest in ecotypes 5, 6 and 7 and Opalescent Goatfish, *Paupeneus heptacanthus*, in ecotypes 1,2 and 3. Ecotype 3, associated with the ancient coastline KEF, had the largest number of taxa (18) with biomass in the top 5% (95^{th} percentile). The highest biomass for any species was Gulf Damselfish, *Pristotis obtusirostris*, in ecotypes 1 and 2 (Table 8).

2.7.2 North West Shelf McKenna Trawl dataset

The shallowest ecotype (7) had 22 of the 26 taxa with DLI scores in the top 80^{th} percentile. Fourteen of these had a DLI score of 0.98 or higher, indicating the importance of a wide range of species that characterised that ecotype (Table 4). Ecotype 1 had just Brownstripe Snapper, *Lutjanus vitta*, and Rosy Threadfin Bream, *Nemipterus furcosus*, while ecotypes 2, 3 and 4 had no species with a DLI in the top 80^{th} percentile, indicating there were no taxa in this dataset that specifically characterised these ecotypes.

For biomass, sponges were most important in ecotypes 2, 3, 5, 6 and 7. The shallowest ecotype (7) had the highest number of species (16) with biomass in the top 95th percentile. Threadfin bream and snappers had the highest biomass in the ancient coastline ecotype 3 (Table 9).

2.7.3 Datatrawler FB Trawl dataset

This dataset revealed similar patterns to the NWS McKenna Trawl dataset with 26 of 28 species with DLI scores in the top 80th percentile being in the shallowest ecotype (7). Thirteen of these species had DLI scores > 0.9 (Table 5).

In terms of biomass, the pattern was similar with 24 of 33 taxa with the highest biomasses (95th percentile) occurring in ecotype 1. There was a clear separation among species which dominated the shallowest ecotype (1) and the two deepest ecotypes (1 and 2, Table 10).

2.7.4 Soviet Trawl dataset

Most of the indicator taxa were in ecotype 4. All had moderate values between 0.22 and 0.4 with the most important being Notchedfin Threadfin Bream, *Nemipterus peroni*, and Spotted Bigeye *Priacanthus macracanthus* (Table 6). For biomass, most indicator species were in ecotypes 4 and 7. Starry Triggerfish *Abalistes stellatus* were the only indicator species for biomass in the deepest ecotype (1, Table 11).

2.7.5 North West Shelf Photo-benthos

Only the shallowest ecotype (7) had DLI indicator species in the top 20%, the highest of these were branched sponges and lump sponges. For abundance, branched sponges and whips were dominant indicators for the shallowest ecotype (7) while whips characterised the abundance in ecotype 3 associated with the ancient coastline KEF (Table 12).

Table 3. Dufrene-Legendre Indicator (DLI) by taxa by ecotype for the NWS FnB Trawl dataset. Only the top 20% (80th percentile) all DLI values are shown. Some clusters may not have any species in the 80th percentile of DLIs. The column "MaxCl" indicates the ecotype for which the taxa had highest DLI.

				Ecotype/cluster						
Lowest taxonomic classification	**Family/Class/Phyla**	**Common family name**	**MaxCl**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Ariomma indicum	Ariommatidae	Eyebrowfishes	7							0.48
Brachypleura novaezeelandiae	Citharidae	Largescale flounders	7							0.24
Carangoides fulvoguttatus	Carangidae	Jacks/trevallies	7							0.22
Choerodon vitta	Labridae	Wrasses	7							0.25
Congrogadus spinifer	Pseudochromidae	Eel blennies	7							0.38
Lethrinus genivittatus	Lethrinidae	Emperors	7							0.31
Lutjanus vitta	Lutjanidae	Snappers	7							0.68
Parapercis nebulosa	Pinguipedidae	Grubfishes	7							0.34
Parupeneus chrysopleuron	Mullidae	Goatfishes	7							0.41
Pentapodus porosus	Nemipteridae	Threadfin breams	7							0.29
Psettodes erumei	Psettodidae	Halibuts	7							0.33
Pseudorhombus jenynsii	Paralichthyidae	Sand flounders	7							0.23
Porifera	Porifera	Sponges	6						0.28	
Upeneus luzonius	Mullidae	Goatfishes	6						0.25	
Upeneus tragula	Mullidae	Goatfishes	6						0.41	0.31
Champsodon longipinnis	Champsodontidae	Gapers	5					0.32		
Gymnocranius griseus	Lethrinidae	Emperors	5					0.24		
Lagocephalus sceleratus	Tetraodontidae	Pufferfishes/toadfishes	5					0.27		
Lethrinus laticaudis	Lethrinidae	Emperors	5				0.22	0.28	0.26	
Pentaprion longimanus	Gerreidae	Silverbiddies	5					0.43		
Saurida filamentosa	Synodontidae	Lizardfishes	5				0.23	0.37		
Teuthida	Teuthoidea	Squids	5					0.26		
Torquigener pallimaculatus	Tetraodontidae	Pufferfishes/toadfishes	5					0.28		
Asteroidea	Asteroidea	Sea stars	4				0.32		0.25	
Crinoidea	Crinoidea	Feather stars	4				0.54			
Echinoidea	Echinoidea	Sea urchins	4				0.44			
Gymnolaemata	Bryozoa	Bryozoa	4				0.42			
Bathycallionymus bifilum	Callionymidae	Dragonets	3			0.30				
Chaetodontoplus personifer	Pomacanthidae	Angelfishes	3			0.29				
Erosa erosa	Synanceiidae	Stonefishes	3			0.28				
Gymnocranius elongatus	Lethrinidae	Emperors	3			0.34				0.23
Lutjanus lutjanus	Lutjanidae	Snappers	3			0.46				
Priacanthus macracanthus	Priacanthidae	Bigeyes	3			0.48				
Pseudochromis quinquedentatus	Pseudochromidae	Eel blennies	3			0.37				
Roa australis	Chaetodontidae	Butterflyfishes	3			0.36				

Scolopsis monogramma	Nemipteridae	Threadfin breams	3			0.22
Scolopsis meridiana	Nemipteridae	Threadfin breams	3			0.31
Upeneus moluccensis	Mullidae	Goatfishes	3			0.29
Carangoides malabaricus	Carangidae	Jacks/trevallies	2		0.50	
Parupeneus heptacanthus	Mullidae	Goatfishes	2		0.48	
Pristotis obtusirostris	Pomacentridae	Damselfishes	2	0.32	0.43	
Pseudorhombus argus	Paralichthyidae	Sand flounders	2	0.24	0.42	
Argyrops bleekeri	Sparidae	Breams	1	0.45	0.24	
Carangidae	Carangidae	Jacks/trevallies	1	0.32		
Equulites elongatus	Leiognathidae	Ponyfishes	1	0.58		
Netuma thalassinus	Ariidae	Forktail catfishes	1	0.44	0.27	
Onigocia macrolepis	Platycephalidae	Flatheads	1	0.22		
Pomadasys kaakan	Haemulidae	Grunts	1	0.70		
Sargocentron rubrum	Holocentridae	Squirrelfishes	1	0.29		

Table 4. Dufrene-Legendre Indicator (DLI) by taxa by ecotype for the NWS McKenna Trawl dataset. Only the top 20% (80th percentile) all DLI values are shown. Some clusters may not have any species in the 80th percentile of DLIs. The column “MaxCl” indicates the ecotype for which the taxa had highest DLI.

				Ecotype/cluster						
Lowest taxonomic classification	**Family**	**Common family name**	**MaxCl**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Ostorhinchus septemstriatus	Apogonidae	Cardinal fishes	7							0.92
Carangoides fulvoguttatus	Carangidae	Jacks/trevallies	7							1.00
Champsodon longipinnis	Champsodontidae	Gapers	7							0.94
Chelmon marginalis	Chaetodontidae	Butterflyfishes	7							1.00
Choerodon cephalotes	Labridae	Wrasses	7							0.98
Choerodon sugillatum	Labridae	Wrasses	7							1.00
Coradion altivelis	Chaetodontidae	Butterflyfishes	7							0.93
Neotrygonleylandi	Dasyatidae	Stingrays	7							0.77
Lagocephalus lunaris	Tetraodontidae	Pufferfishes/toadfishes	7							0.89
Lagocephalus sceleratus	Tetraodontidae	Pufferfishes/toadfishes	7							1.00
Equulite elongatus	Leiognathidae	Ponyfishes	7							0.82
Lethrinus	Lethrinidae	Emperors	7							1.00
Nemipterus zysron	Nemipteridae	Threadfin breams	7							1.00
Parascolopsis tanyactis	Nemipteridae	Threadfin breams	7							0.84
Parupeneus indicus	Mullidae	Goatfishes	7							0.98
Pristotis obtusirostris	Pomacentridae	Damselfishes	7							1.00
Pseudorhombus dupliciocellatus	Paralichthyidae	Sand flounders	7							0.85
Rhynchostracion nasus	Ostraciidae	Boxfishes	7							1.00
Scarus ghobban	Scaridae	Parrotfishes	7							0.99
Sufflamen fraenatum	Balistidae	Triggerfishes	7							1.00
Torquigener pallimaculatus	Tetraodontidae	Pufferfishes/toadfishes	7							1.00
Uranoscopus cognatus	Uranoscopidae	Stargazers	7							0.99
Pseudorhombus argus	Paralichthyidae	Sand flounders	6						0.74	
Chaetodontoplus duboulayi	Pomacanthidae	Angelfishes	5					0.75		
Lutjanus vitta	Lutjanidae	Snappers	1	0.76						
Nemipterus furcosus	Nemipteridae	Threadfin breams	1	0.86						

Table 5. Dufrene-Legendre Indicator (DLI) by taxa by ecotype for the Datatrawler FB Trawl dataset. Only the top 20% (80th percentile) all DLI values are shown. Some clusters may not have any species in the 80th percentile of DLIs. The column “MaxCl” indicates the ecotype for which the taxa had highest DLI.

				Ecotype/cluster						
Lowest taxonomic classification	**Family**	**Common family name**	**MaxCl**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Nemipterus virgatus	Nemipteridae	Threadfin breams	7							1.00
Gymnocranius griseus	Lethrinidae	Emperors	7							1.00
Centriscus scutatus	Centriscinae	Razorfishes	7							1.00
Decapterus macrosoma	Carangidae	Jacks/trevallies	7							0.99
Choerodon sugillatum	Labridae	Wrasses	7							0.99
Gnathanodon speciosus	Carangidae	Jacks/trevallies	7							0.99
Pentapodus porosus	Nemipteridae	Threadfin breams	7							0.98
Alepes apercna	Carangidae	Jacks/trevallies	7							0.97
Scolopsis meridiana	Nemipteridae	Threadfin breams	7							0.96
Psenopsis humerosa	Centrolophidae	Medusafishes	7							0.93
Rhynchostracion nasus	Ostraciidae	Boxfishes	7							0.92
Coradion chrysozonus	Chaetodontidae	Butterflyfishes	7							0.91
Nemipterus celebicus	Nemipteridae	Threadfin breams	7							0.90
Sphyraena obtusata	Sphyraenidae	Barracudas	7							0.89
Carangoides chrysophrys	Carangidae	Jacks/trevallies	7							0.86
Carangoides gymnostethus	Carangidae	Jacks/trevallies	7							0.85
Lutjanus sebae	Lutjanidae	Snappers	7							0.79
Synodus sageneus	Synodontidae	Lizardfishes	7							0.78
Upeneus asymmetricus	Mullidae	Goatfishes	7							0.74
Ostorhinchus fasciatus	Apogonidae	Cardinal fishes	7							0.73
Pristotis obtusirostris	Pomacentridae	Damselfishes	7							0.72
Hemigaleus australiensis	Hemigaleidae	Weasel sharks	7							0.68
Lethrinus genivittatus	Lethrinidae	Emperors	7							0.67
Chaetodontoplus personifer	Pomacanthidae	Angelfishes	7							0.67
Psettodes erumei	Psettodidae	Halibuts	7							0.66
Lutjanus lutjanus	Lutjanidae	Snappers	7							0.61
Nemipterus peronii	Nemipteridae	Threadfin breams	1	0.78						
Acropoma japonica	Acropomatidae	Temperate seabasses	1	0.76						

Table 6. Dufrene-Legendre Indicator (DLI) by taxa by ecotype for the Soviet Trawl dataset. Only the top 20% (80th percentile) all DLI values are shown. Some clusters may not have any species in the 80th percentile of DLIs. The column "MaxCl" indicates the ecotype for which the taxa had highest DLI.

				Ecotype/cluster						
Lowest taxonomic classification	**Family**	**Common family name**	**MaxCl**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dentex spariformis	Sparidae	Breams	7							0.28
Saurida undosquamis	Synodontidae	Lizardfishes	7							0.27
Acanthopagrus pacificus	Sparidae	Breams	6						0.29	
Dactyloptena orientalis	Dactylopteridae	Flying gurnards	4				0.24			
Fistularia petimba	Fistulariidae	Flutemouths	4				0.26			
Nemipterus peronii	Nemipteridae	Threadfin breams	4				0.37			
Priacanthus macracanthus	Priacanthidae	Bigeyes	4				0.40			
Priacanthus tayenus	Priacanthidae	Bigeyes	4				0.22			
Trichiurus lepturus	Trichiuridae	Cutlassfishes	4				0.22			
Upeneus tragula	Mullidae	Goatfishes	4				0.30			
Abalistes stellatus	Balistidae	Triggerfishes	1	0.25						

Table 7. Dufrene-Legendre Indicator (DLI) by taxa by ecotype for the NWS Photo-benthos dataset. Only the top 20% (80th percentile) all DLI values are shown. Some clusters may not have any biota forms in the 80th percentile of DLIs. The column "MaxCl" indicates the ecotype for which the taxa had highest DLI.

				Ecotype/cluster				
Taxa	**MaxCl**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Branched Sponges	7							0.58
Lump sponges	7							0.74
Other	7							0.64

Table 8. Biomass by taxa by ecotype for NWS FnB Trawl dataset. Data are average biomass (log kg) by ecotype. Only species in the top 5% [95th percentile] of average ecotype abundances shown.

			Ecotype/cluster						
Lowest taxonomic classification	**Family/Class/Phyla**	**Common family name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Upeneus tragula	Mullidae	Goatfishes					0.20	0.89	0.95
Lutjanus vitta	Lutjanidae	Snappers						0.35	0.69
Pentapodus porosus	Nemipteridae	Threadfin breams			0.45		0.35	0.31	0.58
Congrogadus spinifer	Pseudochromidae	Eel blennies						0.31	0.57
Parupeneus chrysopleuron	Mullidae	Goatfishes							0.48
Lethrinus laticaudis	Lethrinidae	Emperors				0.67	0.69	0.73	0.47
Lethrinus lentjan	Lethrinidae	Emperors							0.43
Saurida filamentosa	Synodontidae	Lizardfishes			0.30	0.75	0.83	0.51	0.37
Psettodes erumei	Psettodidae	Halibuts						0.22	0.36
Neotrygon leylandi	Dasyatidae	Stingrays							0.36
Sphyraena obtusata	Sphyraenidae	Barracudas			0.33		0.31	0.21	0.35
Ariomma indicum	Ariommatidae	Eyebrowfishes							0.30
Teuthida	Teuthoidea	Squids			0.28	0.19	0.36	0.19	0.22
Echinodermata	Echinodermata	Echinoderms		0.21					0.21
Porifera	Porifera	Sponges				0.80		0.99	0.21
Percoidei	Percoidei								0.20
Gymnocranius elongatus	Lethrinidae	Emperors							0.20
Chaetodontoplus personifer	Pomacanthidae	Angelfishes			0.46				0.19
Upeneus luzonius	Mullidae	Goatfishes					0.22	0.39	
Rhynchobatus australiae	Rhinidae	Guitarfishes						0.18	
Scolopsis meridiana	Nemipteridae	Threadfin breams			0.55		0.37	0.18	
Pentapodus nagasakiensis	Nemipteridae	Threadfin breams					0.25		
Priacanthus macracanthus	Priacanthidae	Bigeyes			0.48		0.23		
Gymnocranius griseus	Lethrinidae	Emperors				0.19	0.22		
Selar boops	Carangidae	Jacks/trevallies	0.23	0.30	0.37		0.20		
Crinoidea	Crinoidea	Feather stars				0.29			
Echinoidea	Echinoidea	Sea urchins				0.20			
Netuma thalassinus	Ariidae	Forktail catfishes	0.98	0.81	0.46				
Scolopsis monogramma	Nemipteridae	Threadfin breams	0.35	0.30	0.46				
Lutjanus lutjanus	Lutjanidae	Snappers			0.40				
Pristotis obtusirostris	Pomacentridae	Damselfishes	1.20	1.36	0.38				
Zabidius novemaculeatus	Ephippidae	Batfishes			0.38				
Teleostei	Teleostei	Ray-finned fishes			0.28				
Parupeneus heptacanthus	Mullidae	Goatfishes	0.20	0.75	0.23				

Hapalogenys dampieriensis	Hapalogenyidae	Velvetchins			0.21
Roa australis	Chaetodontidae	Butterflyfishes			0.19
Diagramma pictum	Haemulidae	Grunts			0.19
Carangoides malabaricus	Carangidae	Jacks/trevallies	0.21	0.41	
Pomadasys kaakan	Haemulidae	Grunts	0.73	0.30	
Caranx ignobilis	Carangidae	Jacks/trevallies	0.18	0.26	
Fistularia commersonii	Fistulariidae	Flutemouths		0.19	
Nemipterus peronii	Nemipteridae	Threadfin breams	0.45		
Equulites elongatus	Leiognathidae	Ponyfishes	0.29		
Argyrops bleekeri	Sparidae	Breams	0.27		

Table 9. Biomass by taxa by ecotype for NWS McKenna Trawl dataset. Data are average biomass (log kg) by ecotype. Only species in the top 5% [95th percentile] of average ecotype abundances shown.

			Ecotype/cluster						
Lowest taxonomic classification	**Family/Phyla**	**Common family name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Porifera	Porifera	Sponges		0.80	1.90		2.03	1.88	4.06
Carangoides fulvoguttatus	Carangidae	Jacks/trevallies							2.17
Parupeneus indicus	Mullidae	Goatfishes							2.11
Nemipterus zysron	Nemipteridae	Threadfin breams							1.76
Lethrinus spp.	Lethrinidae	Emperors							1.64
Pseudomonacanthus elongatus	Monacanthidae	Leatherjackets					1.25	1.57	1.59
Choerodon cephalotes	Labridae	Wrasses							1.53
Nemipterus virgatus	Nemipteridae	Threadfin breams					1.08		0.92
Chelmon marginalis	Chaetodontidae	Butterflyfishes							0.88
Parascolopsis tanyactis	Nemipteridae	Threadfin breams							0.83
Sepiidae	Sepiidae	Cuttlefishes							0.77
Upeneus asymmetricus	Mullidae	Goatfishes							0.74
Iniistius opalus	Labridae	Wrasses							0.73
Lethrinus lentjan	Lethrinidae	Emperors						1.60	0.73
Seriolina nigrofasciata	Carangidae	Jacks/trevallies							0.68
Trachinocephalus trachinus	Synodontidae	Lizardfishes					0.79	0.75	0.59
Gymnocranius elongatus	Lethrinidae	Emperors					0.61	1.33	
Nemipterus bathybius	Nemipteridae	Threadfin breams						0.73	
Lutjanus spp.	Lutjanidae	Snappers			0.60		0.68	0.72	
Argyrops bleekeri	Sparidae	Breams						0.57	
Lutjanus malabaricus	Lutjanidae	Snappers					0.61		
Plectropomus maculatus	Serranidae	Groupers					0.59		
Fistularia petimba	Fistulariidae	Flutemouths			0.67				
Rhynchobatus australiae	Rhinidae	Guitarfishes			0.58				
Saurida longimanus	Synodontidae	Lizardfishes	1.16	0.77					
Nemipterus furcosus	Nemipteridae	Threadfin breams	1.30						
Upeneus luzonius	Mullidae	Goatfishes	0.84						
Lutjanus vitta	Lutjanidae	Snappers	0.69						

Table 10. Biomass by taxa by ecotype for the Datatrawler FB Trawl dataset. Data are average biomass (log kg) by ecotype. Only species in the top 5% [95th percentile] of average ecotype abundances shown.

			Ecotype/cluster						
Lowest taxonomic classfiication	**Family**	**Common family name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Decapterus macrosoma	Carangidae	Jacks/trevallies							5.20
Gymnocranius griseus	Lethrinidae	Emperors							5.02
Lutjanus sebae	Lutjanidae	Snappers				0.90	0.74		3.08
Psenopsis humerosa	Centrolophidae	Medusafishes							2.50
Sphyraena obtusata	Sphyraenidae	Barracudas							2.45
Scolopsis monogramma	Nemipteridae	Threadfin breams				2.03	1.45	1.45	2.29
Scolopsis meridiana	Nemipteridae	Threadfin breams							2.26
Upeneus	Mullidae	Goatfishes							2.22
Carangoides chrysophrys	Carangidae	Jacks/trevallies							2.07
Lethrinus genivittatus	Lethrinidae	Emperors							1.92
Saurida undosquamis	Synodontidae	Lizardfishes				0.74	1.31	1.75	1.82
Pentapodus porosus	Nemipteridae	Threadfin breams							1.80
Coradion chrysozonus	Chaetodontidae	Butterflyfishes							1.74
Alepes apercna	Carangidae	Jacks/trevallies							1.67
Ostorhinchus fasciatus	Apogonidae	Cardinal fishes							1.60
Pristotis obtusirostris	Pomacentridae	Damselfishes							1.57
Nemipterus virgatus	Nemipteridae	Threadfin breams							1.55
Carangoides gymnostethus	Carangidae	Jacks/trevallies							1.54
Upeneus asymmetricus	Mullidae	Goatfishes							1.45
Priacanthus hamrur	Priacanthidae	Bigeyes		1.06					1.16
Nemipterus celebicus	Nemipteridae	Threadfin breams							1.02
Gnathanodon speciosus	Carangidae	Jacks/trevallies							0.99
Centriscus scutatus	Centriscinae	Razorfishes							0.95
Choerodon sugillatum	Labridae	Wrasses							0.94
Nemipterus furcosus	Nemipteridae	Threadfin breams						0.95	
Paramonacanthus oblongus	Monacanthidae	Leatherjackets					0.81		
Parupeneus heptacanthus	Mullidae	Goatfishes	2.05	1.87	1.07				
Hapalogenys dampieriensis	Hapalogenyidae	Velvetchins	1.13	1.21					
Leiognathus	Leiognathidae	Ponyfishes	1.49	1.04					
Nemipterus peronii	Nemipteridae	Threadfin breams	2.04	0.94					
Saurida filamentosa	Synodontidae	Lizardfishes	0.96	0.93					
Selar boops	Carangidae	Jacks/trevallies	0.71	0.76					
Acropoma japonica	Acropomatidae	Temperate seabasses	1.02						

Table 11. Biomass by taxa by ecotype for the Soviet Trawl dataset. Data are average biomass (log kg) by ecotype. Only species in the top 5% [95th percentile] of average ecotype abundances shown.

			Ecotype/cluster						
Lowest taxonomic classification	**Family**	**Common family name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Platax pinnatus	Ephippidae	Batfishes						0.63	1.31
Lutjanus fulviflamma	Lutjanidae	Snappers				0.88	0.75		1.03
Upeneus tragula	Mullidae	Goatfishes				1.85	1.18		0.94
Acanthopagrus pacificus	Sparidae	Breams						0.81	0.85
Pristipomoides typus	Lutjanidae	Snappers							0.81
Dentex spariformis	Sparidae	Breams							0.57
Selar boops	Carangidae	Jacks/trevallies							0.54
Trichiurus lepturus	Trichiuridae	Cutlassfishes				0.77	0.81		
Nemipterus peronii	Nemipteridae	Threadfin breams				0.85			
Pristipomoides filamentosus	Lutjanidae	Snappers				0.65			
Nemipterus spp.	Nemipteridae	Threadfin breams				0.58			
Priacanthus macracanthus	Priacanthidae	Bigeyes				0.55			
Fistularia petimba	Fistulariidae	Flutemouths				0.54			
Lutjanus vitta	Lutjanidae	Snappers		0.58					
Abalistes stellatus	Balistidae	Triggerfishes	1.34						

Table 12. Abundance by taxa by ecotype for the NWS photo-benthos dataset. Data are average count in photos by ecotype. Only biota forms in the top 5% (95th percentile) of average ecotype abundances shown.

	Ecotype/cluster						
Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Branched sponges						0.59	1.21
Whips			0.58				1.00
Other							0.57

3 Descriptions of benthic substrate and biota

3.1 Historical data sources

Some of the historical datasets available for the NWS were described in the previous chapter. This section also makes use of data collected on the 1982–1997 CSIRO North West Shelf (NWS) Effects of Trawling project (Sainsbury 1988; 1991). Data used to describe benthic substrates and biota are principally derived from still camera images taken from the trawl headline camera which captured images ahead of the demersal trawl net every 3 seconds or about every 4 m. This is the NWS Photo-benthos dataset described in Chapter 2. A detailed description of the methods used to collect, score and analyse the images is given in Keesing (2019). The location of the trawl samples relative to the seven ecotypes identified for the broader area is shown in Figure 30.

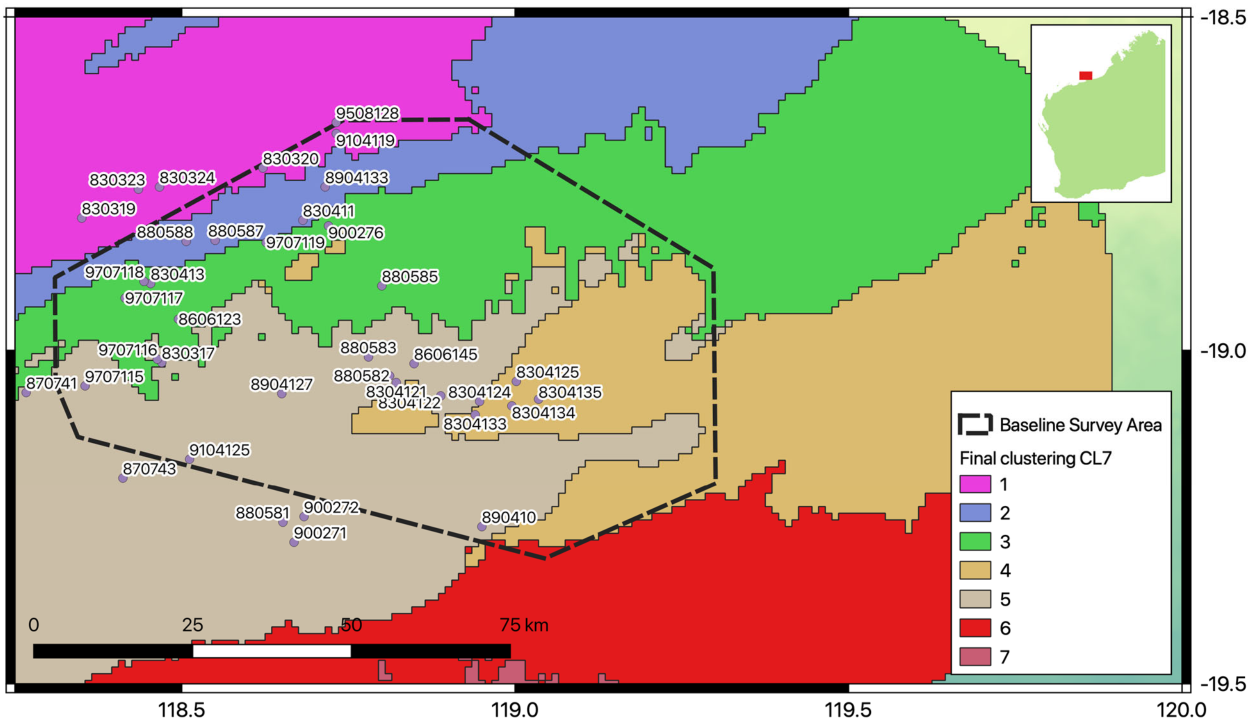

Figure 30. Location of historical trawls from 1982–1997 (blue) for which biota data were available. A table showing the start latitude and longitude for each trawl transect is given in Appendix Table A.2. Trawl number starts with the year, followed by the voyage number for that year and then the site number (e.g. 970758 was site 58 on the seventh voyage in 1997).

3.2 Recent data sources

More recent data was collected for this study in December 2019 using a Remotely Operated Vehicle (ROV). The detail of operation of the ROV are given in RPS 2020. Location of the ROV sites relative to the seven ecotypes identified for the broader area is shown in Figure 31.

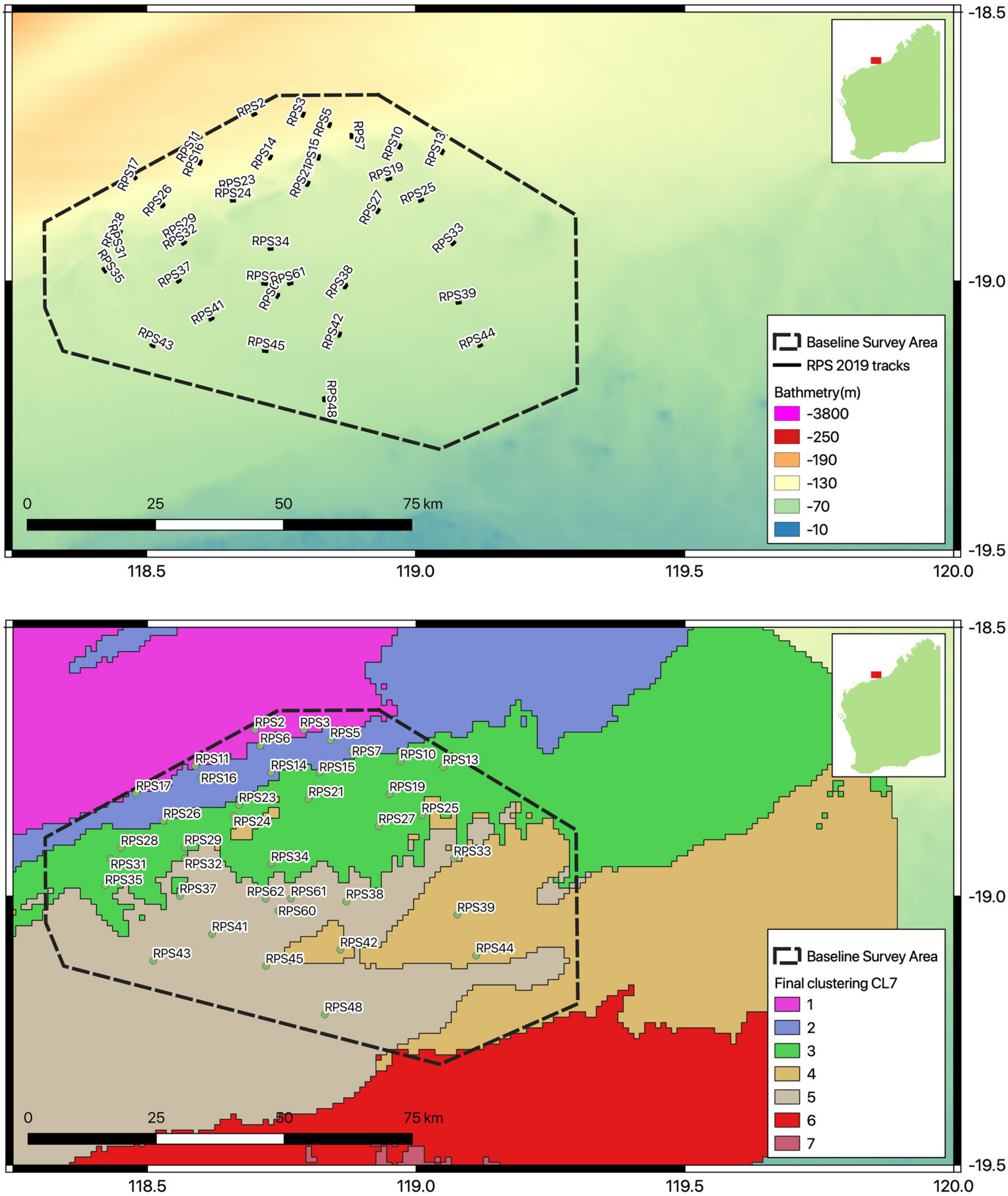

Figure 31. Location of ROV survey sites conducted in December 2019 overlain on bathymetry (top) and each of the seven ecotypes (bottom). A table showing the midpoint latitude and longitude for each transect is given in Appendix A (Table A.1).

3.3 Benthic substrate and topography

3.3.1 Classification of categories of substrate and topography

For the historical voyages (Figure 30), five substrate types were recognised from the camera images; silt, fine sand, coarse sand, rock and rubble and various combinations of these substrate types. Similarly, four types of topography were recognised from the camera images of soft bottom habitats; flat bottom, flat bottom with bioturbation, fine sand ripples and fine ripples with furrows. Examples of the substrate and topography categories from the historical voyages are illustrated in Figure 32 and Figure 33 respectively. For the December 2019 survey, substrate type was scored continuously in real time (RPS 2020) into ten categories: soft mud, silt/sandy mud, sand, coarse sand, sand waves/dunes, rubble 5–50 mm, stones 50–250 mm, rocks > 250 mm, low relief reef and high relief reef. Imagery from each site for the 2019 surveys is shown in RPS 2020.

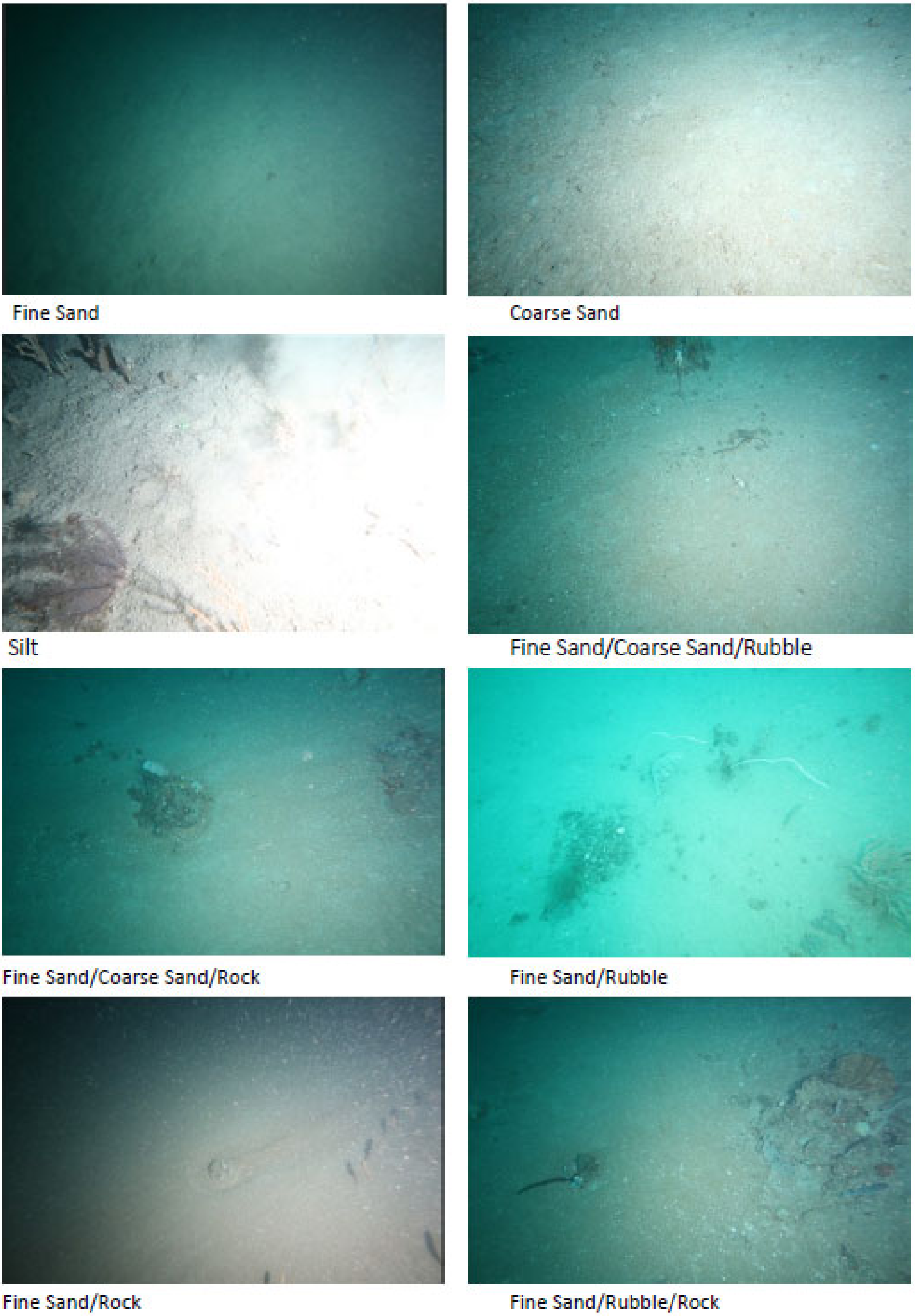

Figure 32. Examples of substrate categories from the NWS. Note: images are not from the survey area.

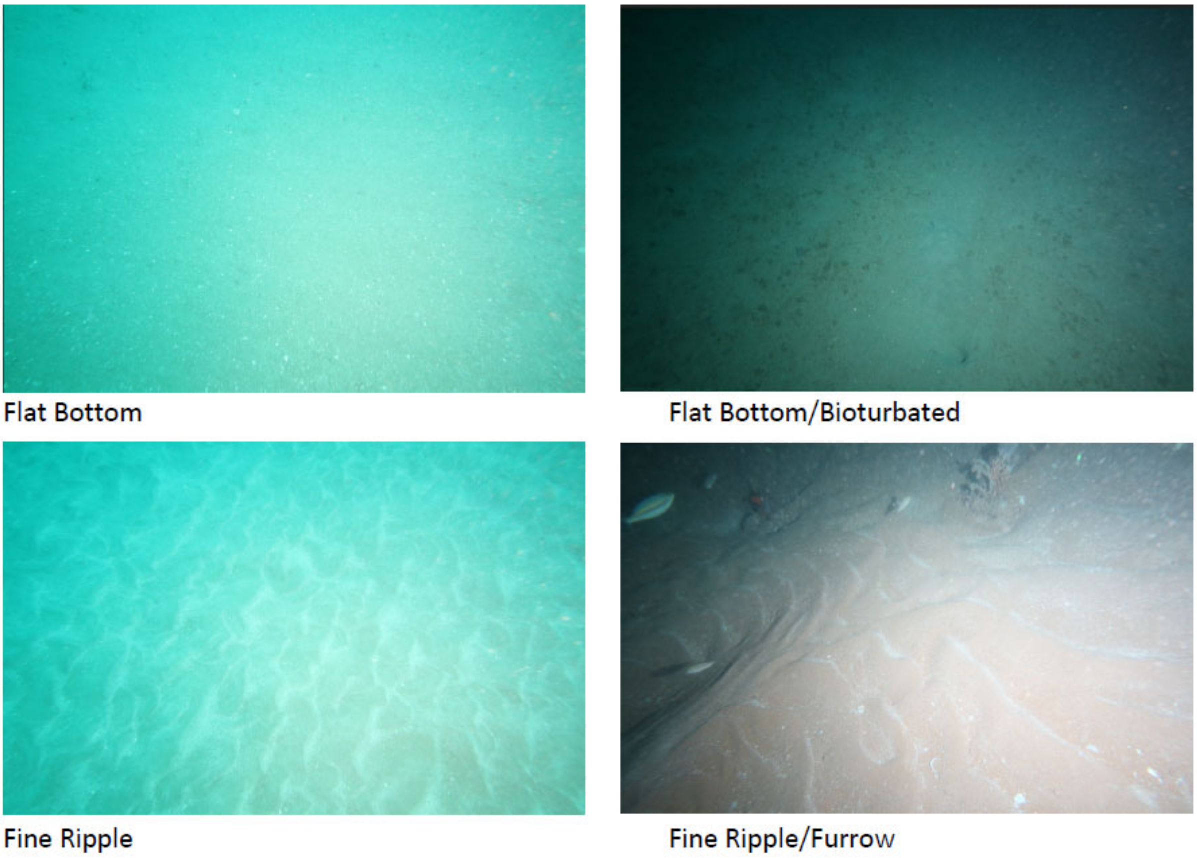

Figure 33. Classification of different soft bottom topography categories from the NWS. Note: images are not from the survey area.

3.3.2 Substrate and topography at historical survey sites

Data was selected for historical survey sites that fell within the survey area, or within 10 km of the boundary of the area. This was done to bolster the small number of sites that fell within some of the ecotypes determined for the area. The number of sites surveyed within each ecotype varied from two (ecotype 1) to nine (ecotype 5) (See Chapter 2 for description of ecotypes). Ecotypes 6 and 7 fell outside of the survey area. Substrate was dominated by fine sand across all sites (Figure 34, Figure 36). All ecotypes, except ecotype 2, showed a small proportion of coarse sand. Rubble and rock occurred to a very minor extent in ecotypes 3, 4 and 5.

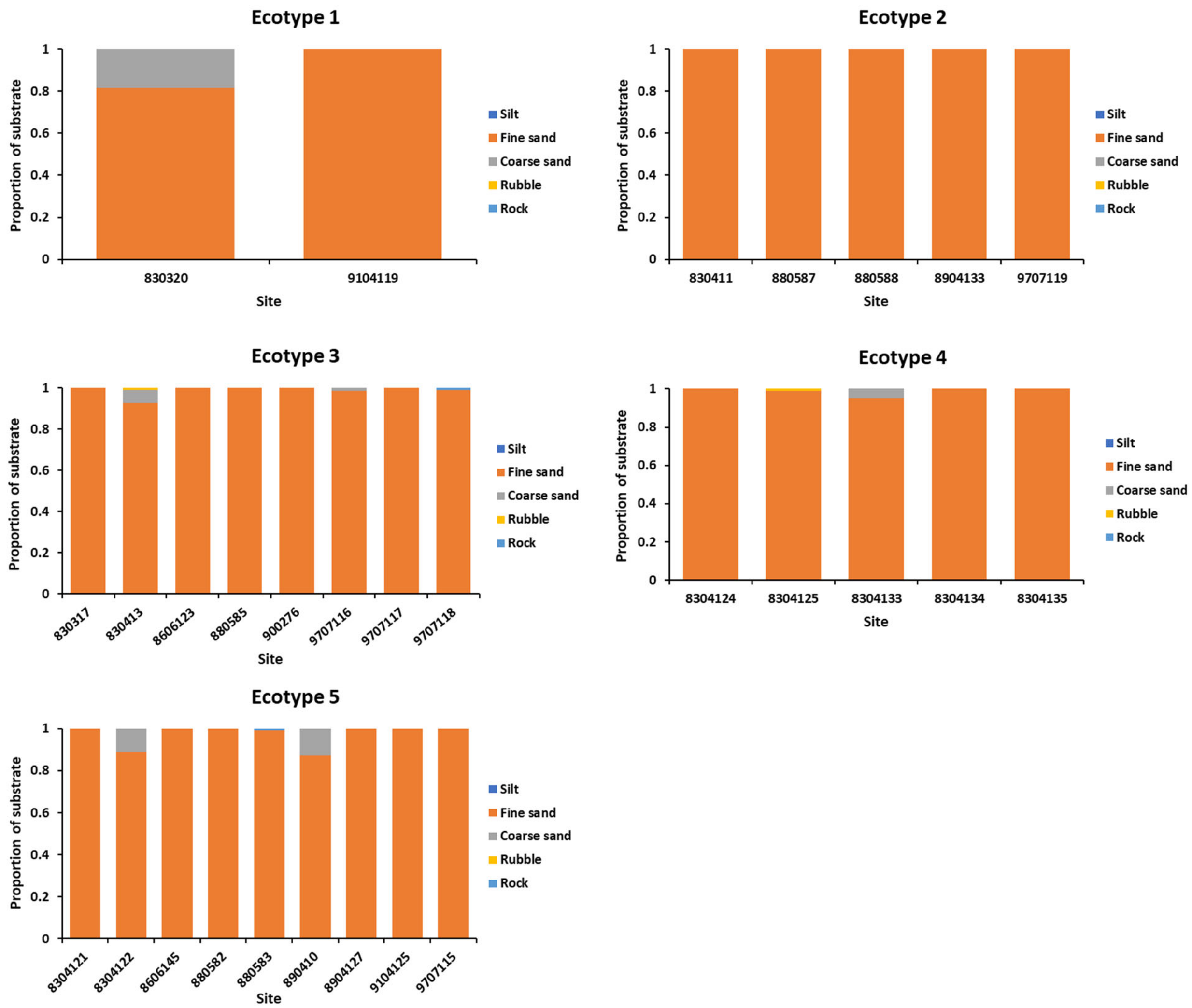

Figure 34. Proportion of substrate type by ecotype for each site surveyed within the survey area during historical trawls during 1982 - 1997. Site number is in format: year, voyage number, site number (e.g. 830320 – site 20, third voyage of 1983).

Topography was dominated by flat bottom and fine ripples across the five ecotypes (Figure 35, Figure 37). Ecotypes 3 and 5 showed a very small proportion of more structured habitat (ridge, furrow, large ripples).

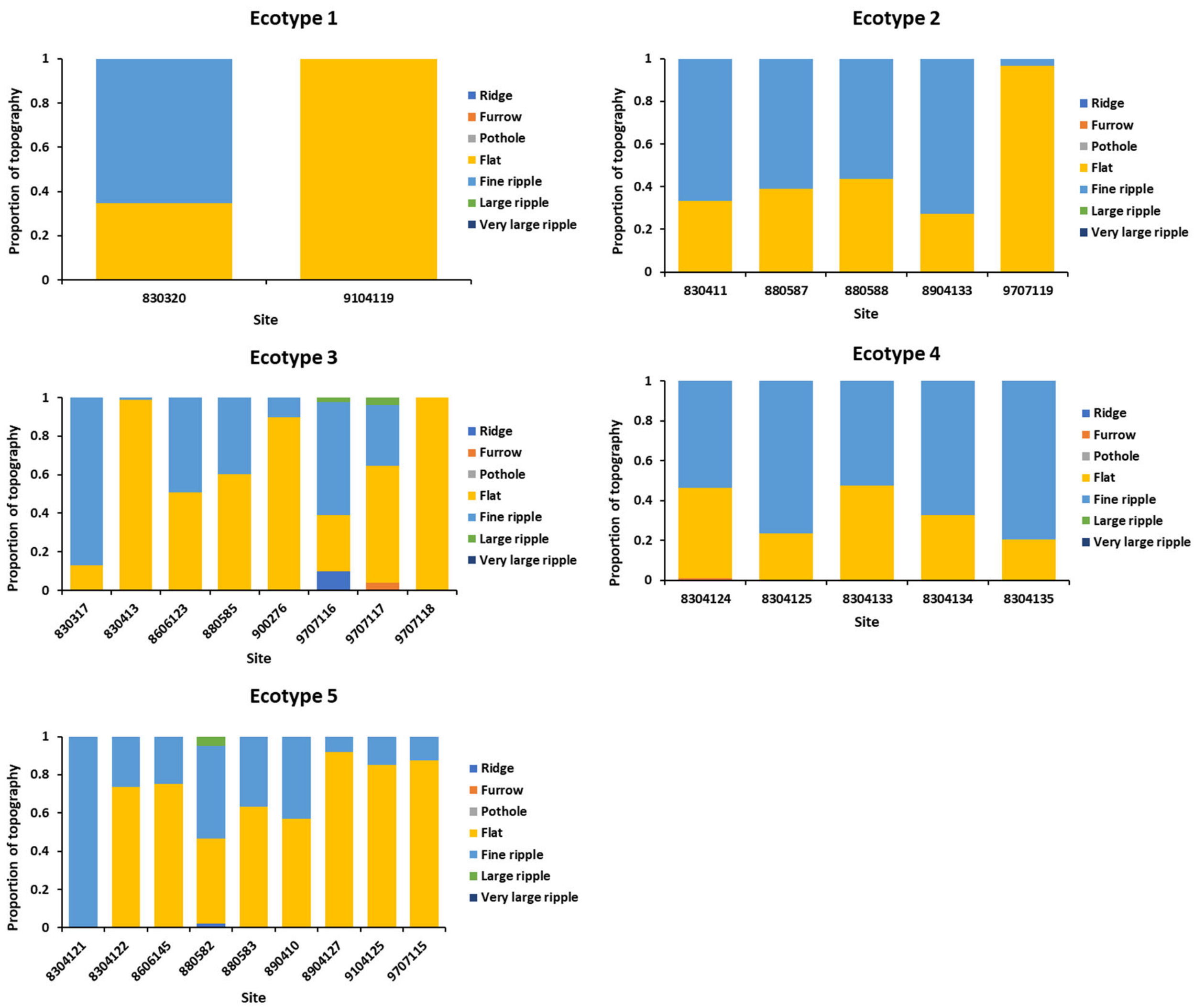

Figure 35. Proportion of substrate type by ecotype for each site surveyed within the survey area during historical trawls during 1982 - 1997. Site number is in format: year, voyage number, site number (e.g. 830320 – site 20, third voyage of 1983).

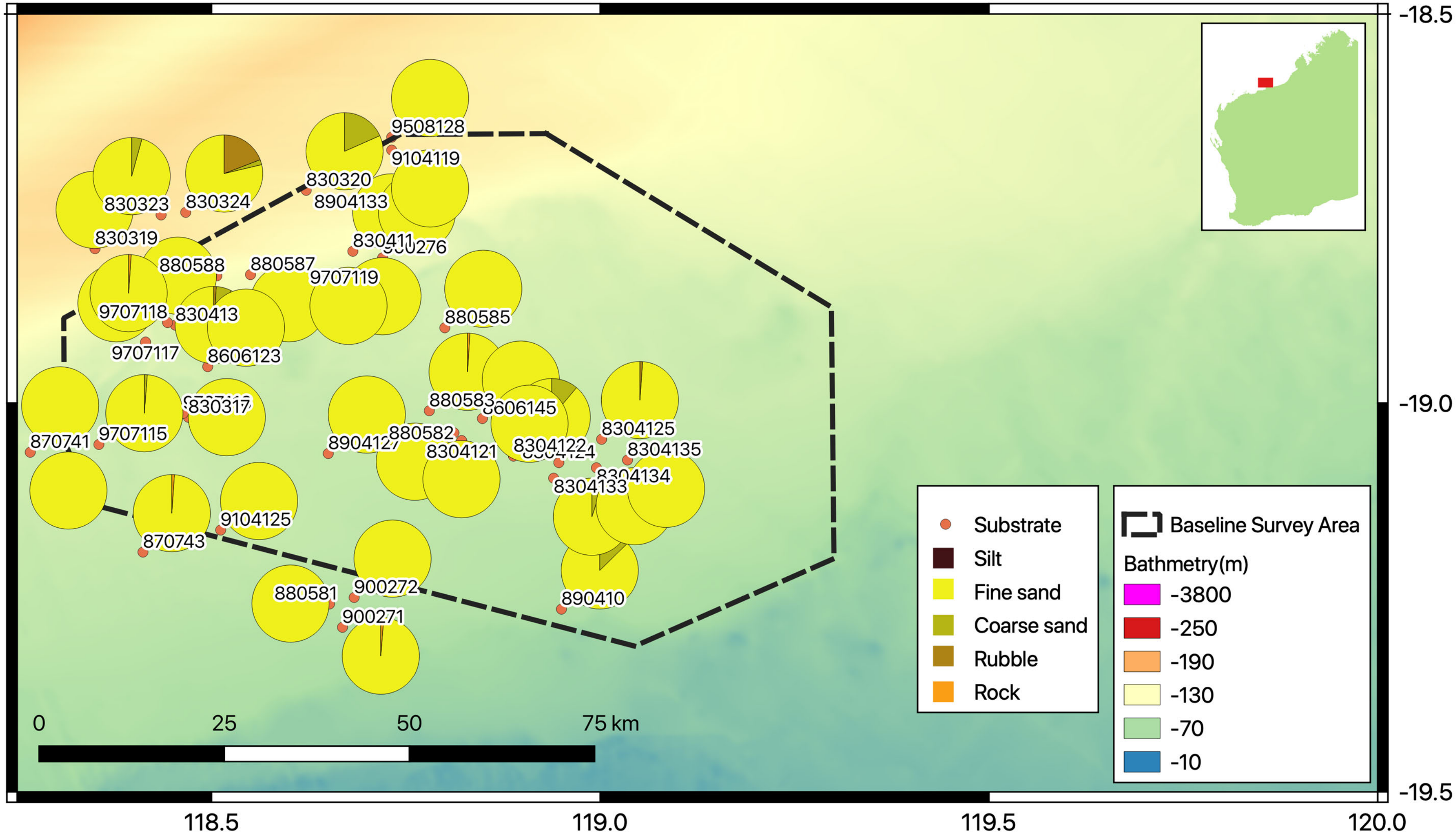

Figure 36. Proportion of substrate type at each of the historical stations in and around the survey area (black dashed line).

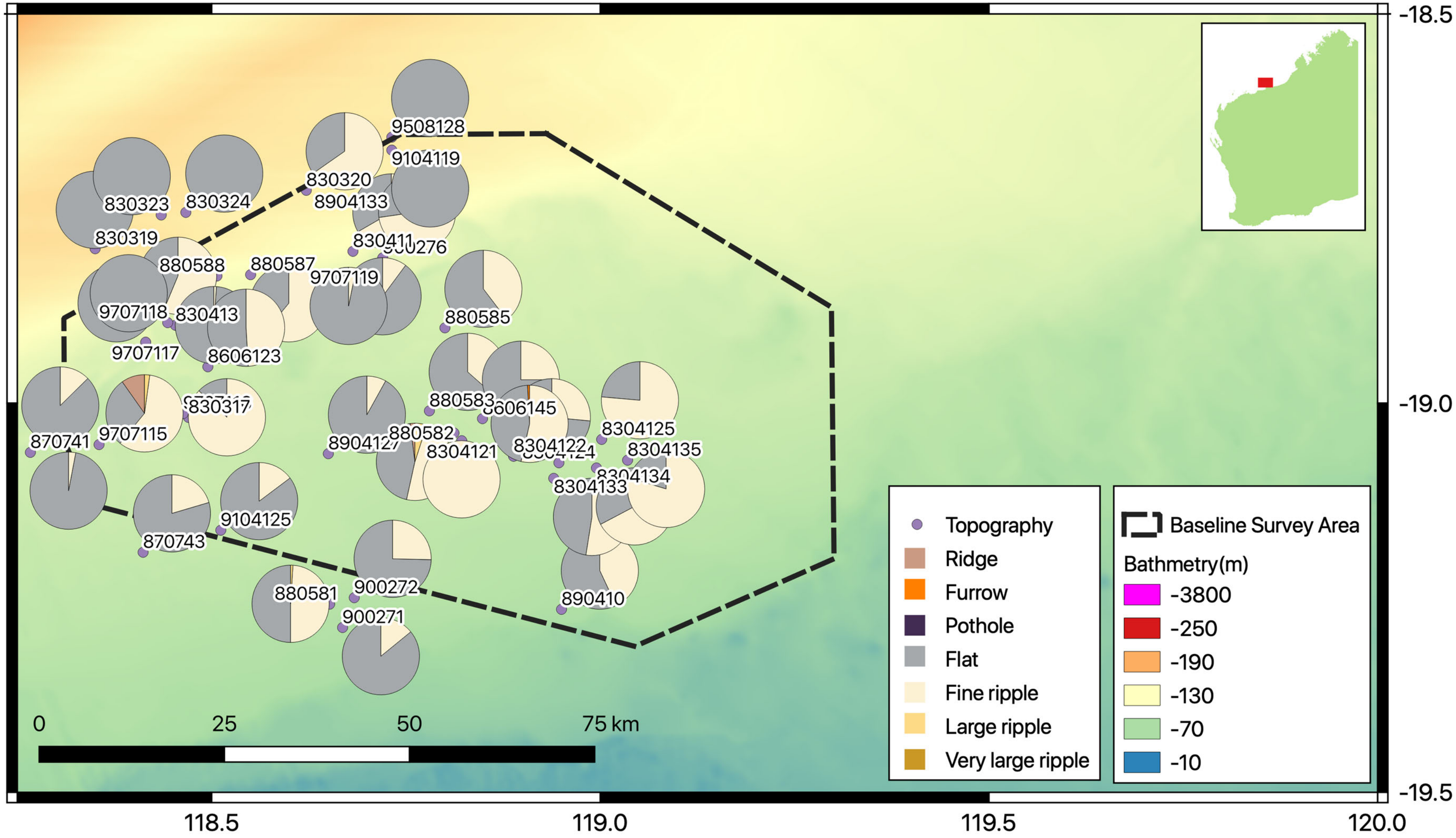

Figure 37. Proportion of topography type at each of the historical stations in and around the survey area (black dashed line).

3.3.3 Substrate and topography at 2019 survey sites

For the most recent survey (RPS 2020) the greatest proportion of seabed at most stations in most ecotypes was categorised as “silt/sandy mud” (Figure 38, Figure 39) compared to “fine sand” in the historical surveys (Figure 34). This almost certainly represents a slightly different emphasis in interpretation rather than any change in the seabed over time. Consistent with the historical surveys, the December 2019 survey showed greater structure and variability in the seabed at sites in ecotypes 3, 4 and 5.

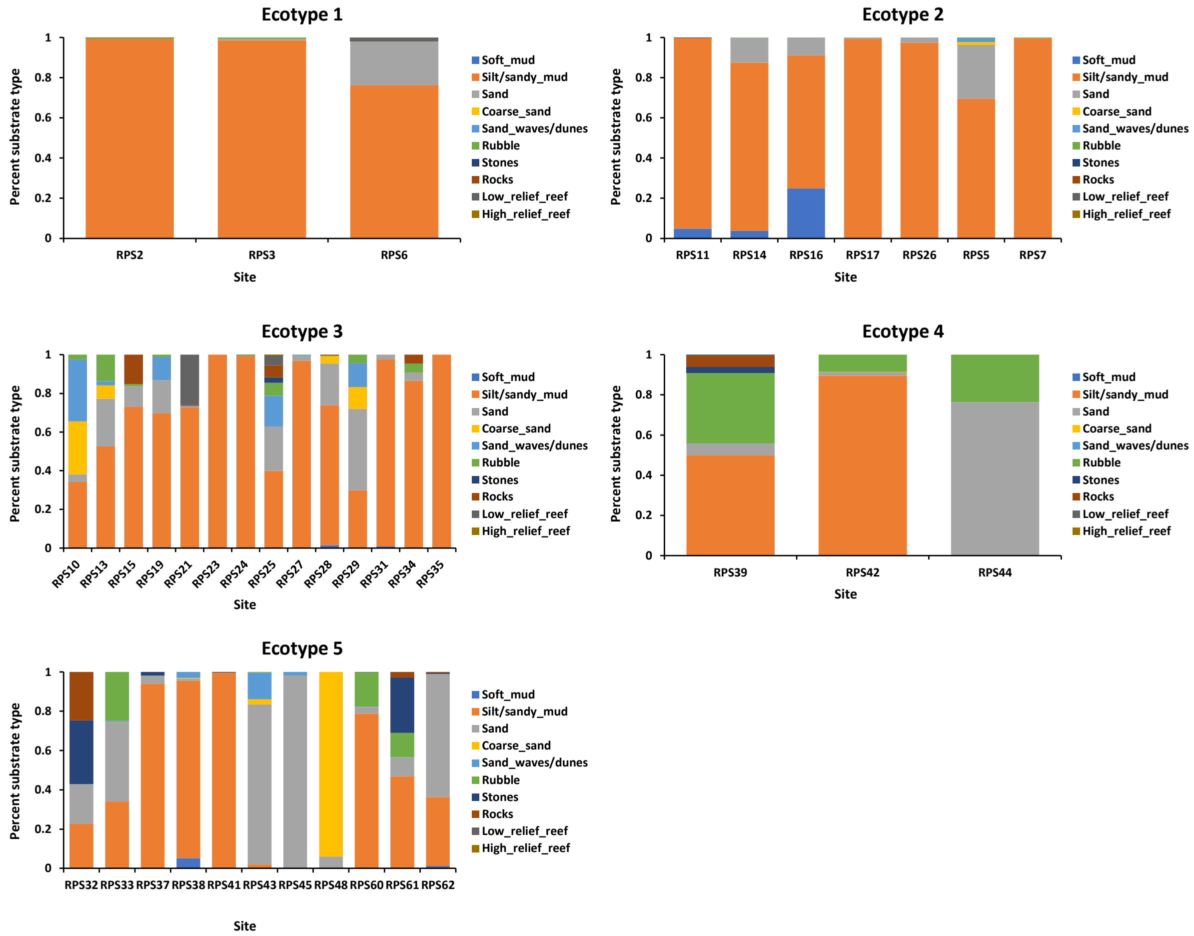

Figure 38. Proportion of substrate type by ecotype for each site surveyed within the survey area during December 2019.

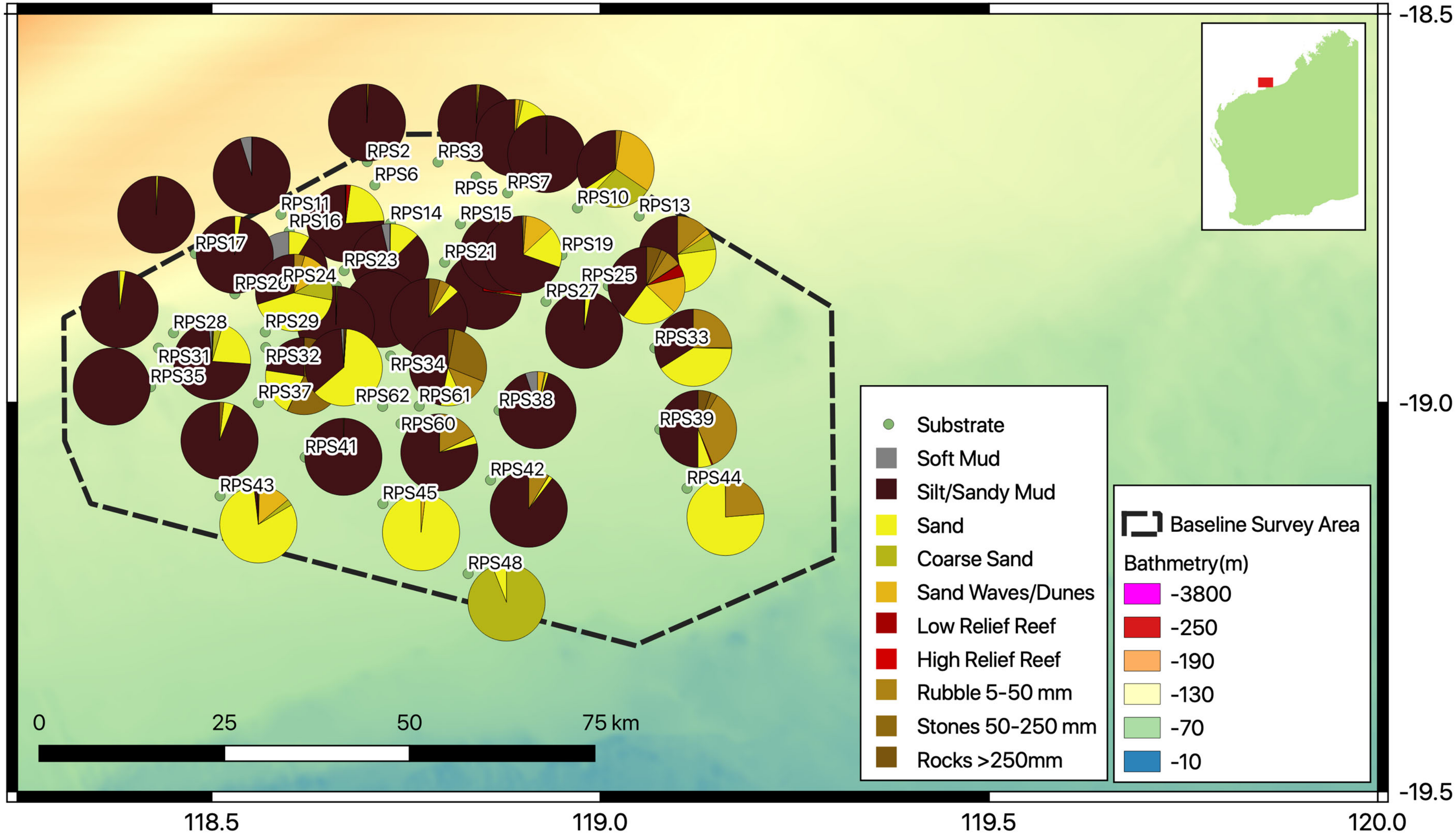

Figure 39. Proportion of substrate type for each site surveyed within the survey area (black dashed line) during December 2019.

3.3.4 Benthic biota at historical sites

A large proportion of all sites in all ecotypes was dominated by the "no biota" category when biohabitat was scored for the seabed imagery (Figure 40, Figure 41), indicating that habitat forming filter-feeders and other biota were not detected. This is consistent with the substrate being scored as mostly flat sandy habitat (Figure 34). The sites within ecotypes 1 and 2 had less than 20% and 10% filter-feeder biohabitat respectively (Figure 40). Sites in ecotype 3 associated with the ancient coastline had between 10 and 65% filter-feeder biohabitat with most sites having significant cover of whips and hydroids along with smaller proportions of soft corals and gorgonians. Ecotype 4 sites had between 20% and 45% filter-feeder biohabitat cover with sponges, seapens and whips being most important while ecotype 5 sites had the highest proportion of filter-feeder biohabitat cover (30% – 65%) with sponges, hydroids, whips and seapens being the most important.

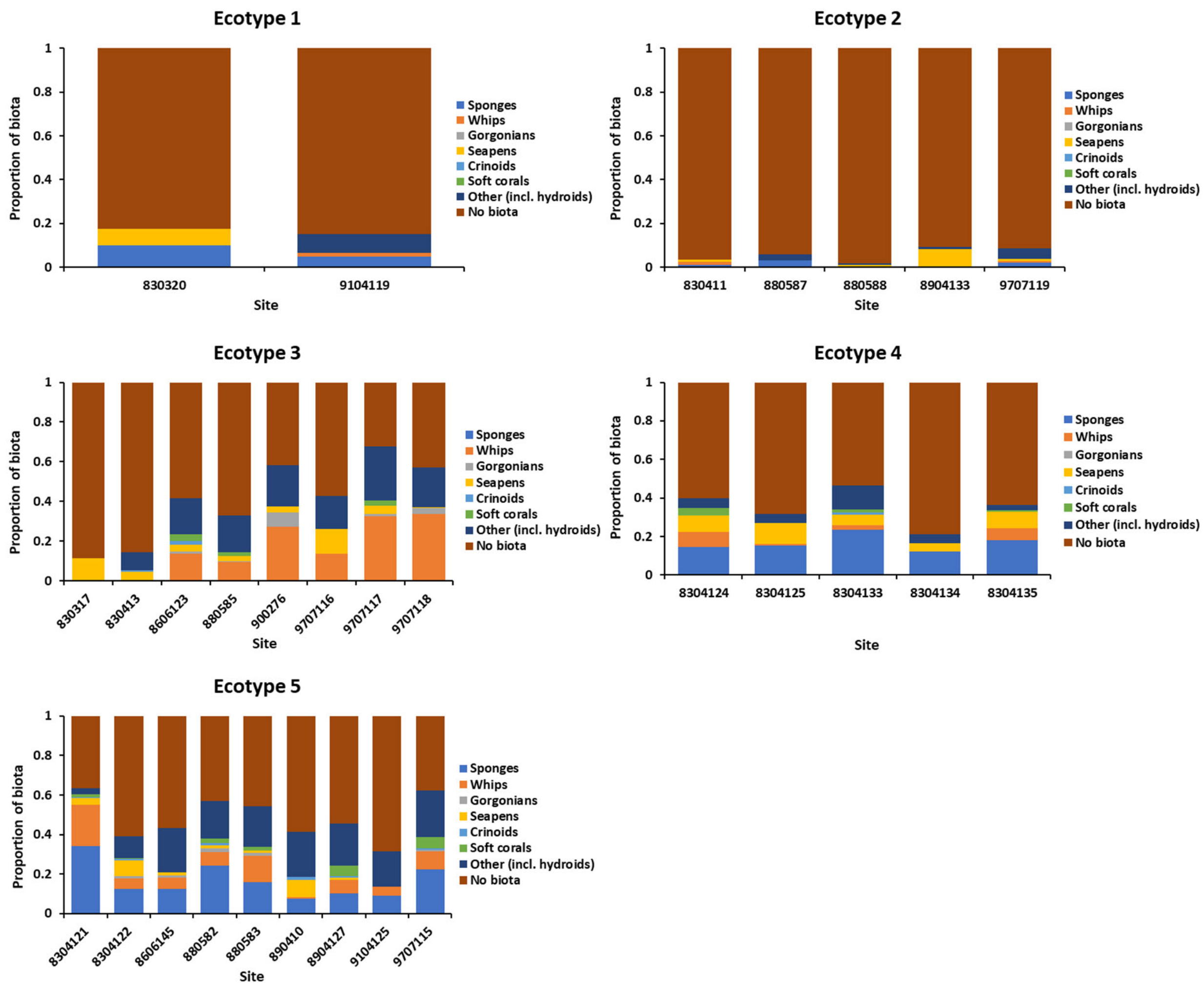

Figure 40. Proportion of biota types in seabed images along trawl lines for CSIRO 1982 – 1997 survey sites in ecotypes 1 - 6. Maroon = no biota present in the images. "Other" includes all other epibenthic organisms that could not be accurately allocated to these specified groups.

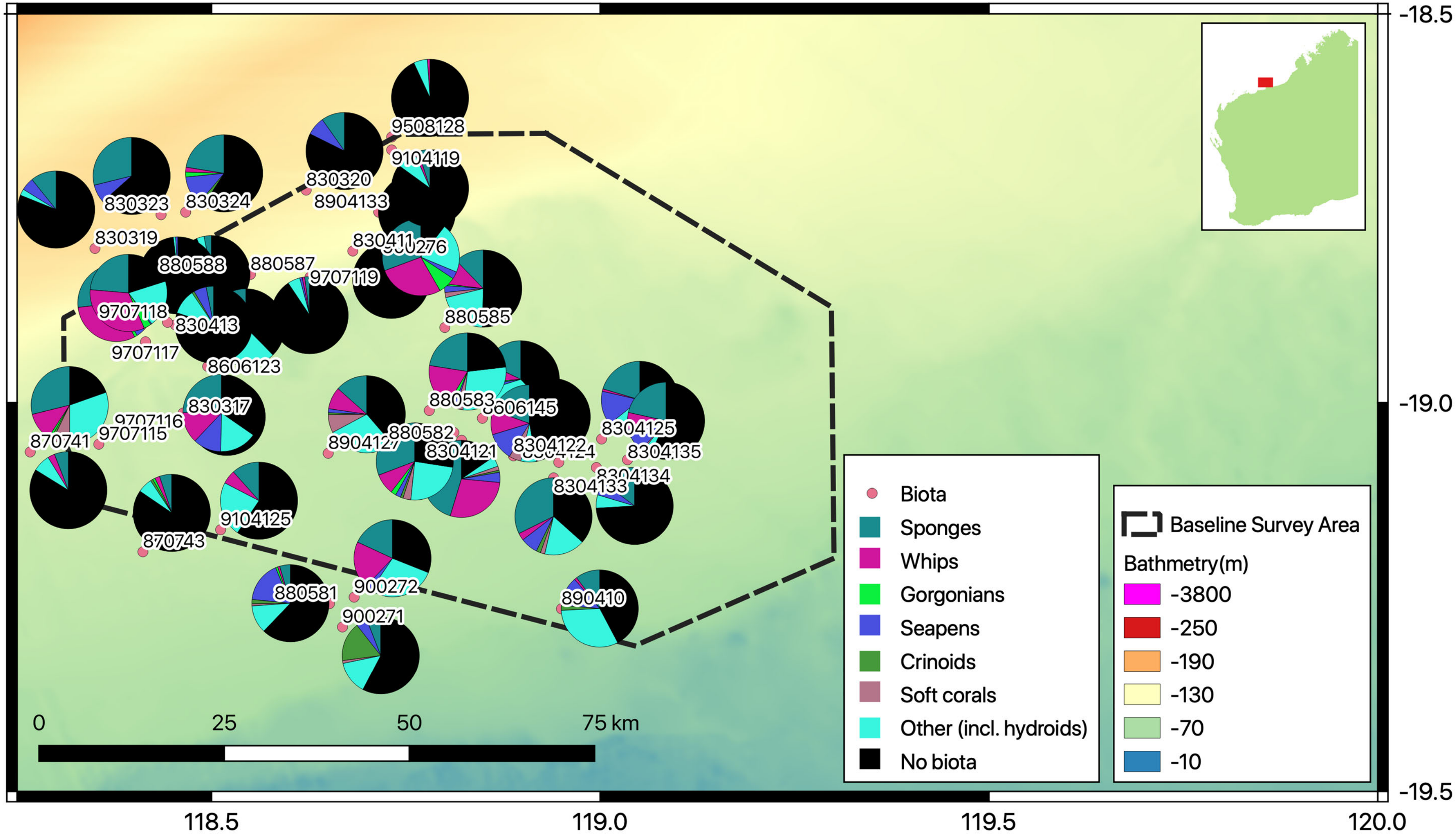

Figure 41. Proportion of biota type at each station in and around the survey area (black dashed line).

3.3.5 Benthic biota at 2019 sites

A high proportion (30% – 100%) of all sites in all ecotypes had either no obvious bioturbated biohabitat or worm tube sedimentary habitat (Figure 42, Figure 44). These are analogous to the "no biohabitat" category from historical surveys. The proportion of each benthic habitat type in December 2019 was scored from high-definition video footage in real time while for the 1982–1997 historical surveys this was done post-voyage from still images (photographic slides). Sites in the deepest and most offshore ecotype (1) were categorised by an almost complete absence of filter-feeder biohabitat (Figure 42) and animals associated with soft sediment habits, mostly seapens, free-living crinoids and anemones (Figure 43). Sites in ecotype 2 were very similar to ecotype 1 except that most sites had small proportions of sponges and soft corals present (Figure 42) and a more diverse array of free-living animals (Figure 43). Most sites within ecotype 3, associated with the ancient coastline KEF, also had low proportions of filter-feeder biohabitat, except for worm tube sediments, but several sites had significant coverage (four sites with more than 40%) of sponge, gorgonian, soft coral and whip biohabitat (Figure 42). Animals scored from sites in ecotype 3 included large numbers of hydroids and sea pens (Figure 43). Sites in ecotype 4 also had large proportions (ca. 40%) of sponge, whip, soft coral and gorgonian filter-feeder biohabitat (Figure 42) and site RPS44 had very high abundances (> 100) of anemones and free-living crinoids (Figure 43). Within ecotype 5, there were seven sites with > 35% filter-feeder biohabitat (predominantly sponge, whip, soft coral and gorgonians) with the dominant biota being seapens, crinoids, hydroids and ascidians (Figure 43). Ecotype 5 was the only ecotype that exhibited a notable number of ascidians.

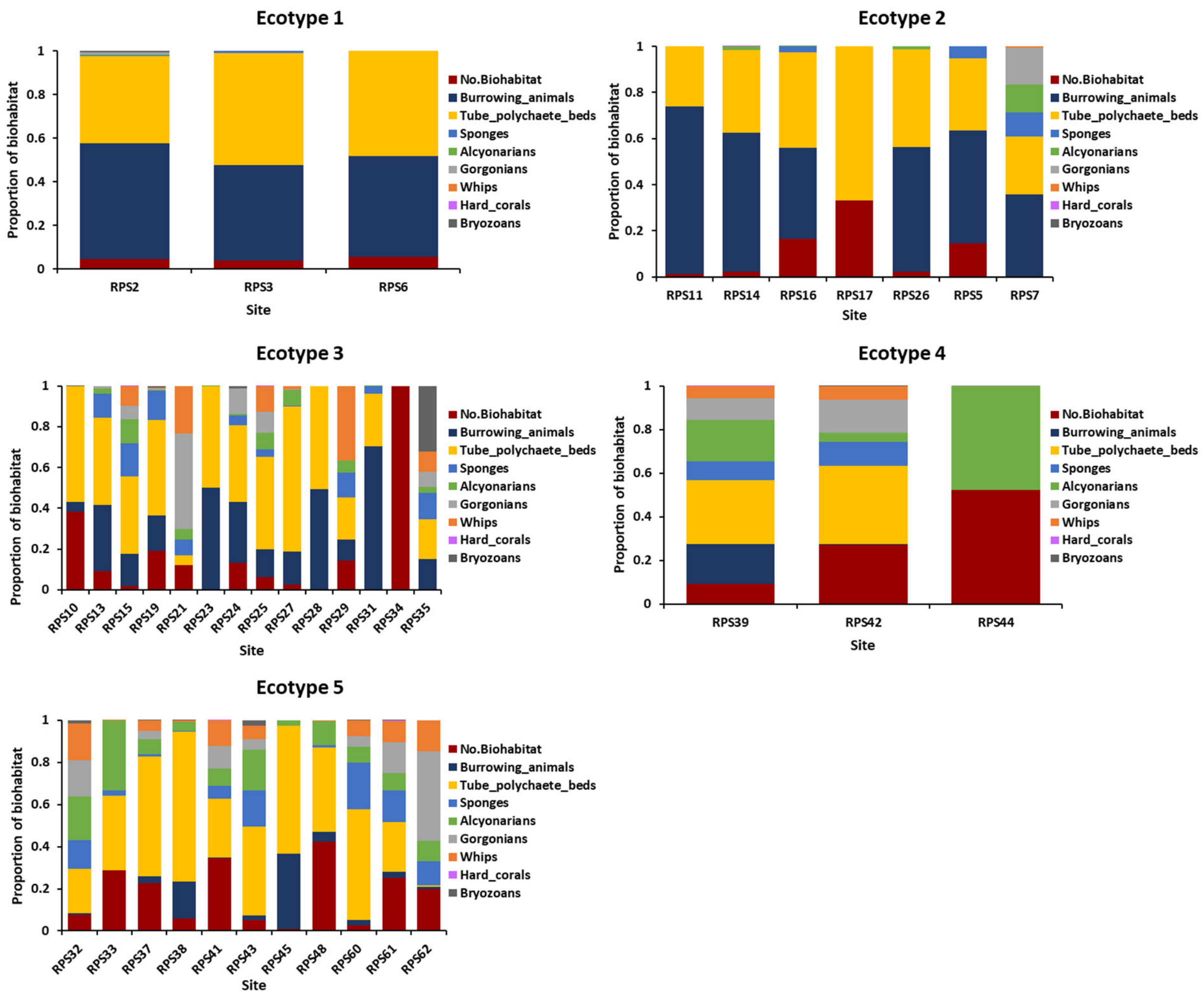

Figure 42. Proportion of each biohabitat type in seabed videos along ROV transects for December 2019 survey sites in each ecotype.

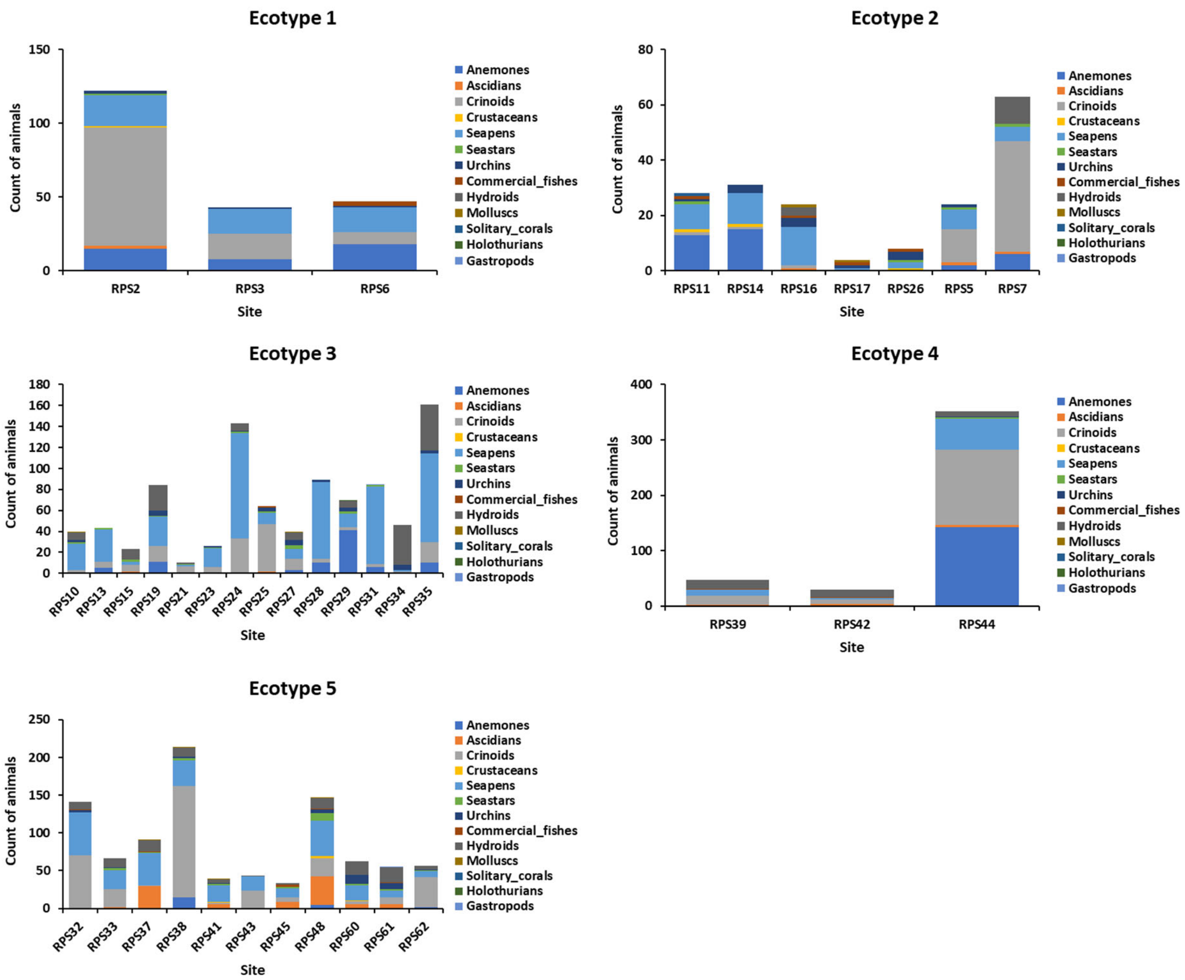

Figure 43. Number of animal events in seabed videos along ROV transects for December 2019 survey sites in each ecotype.

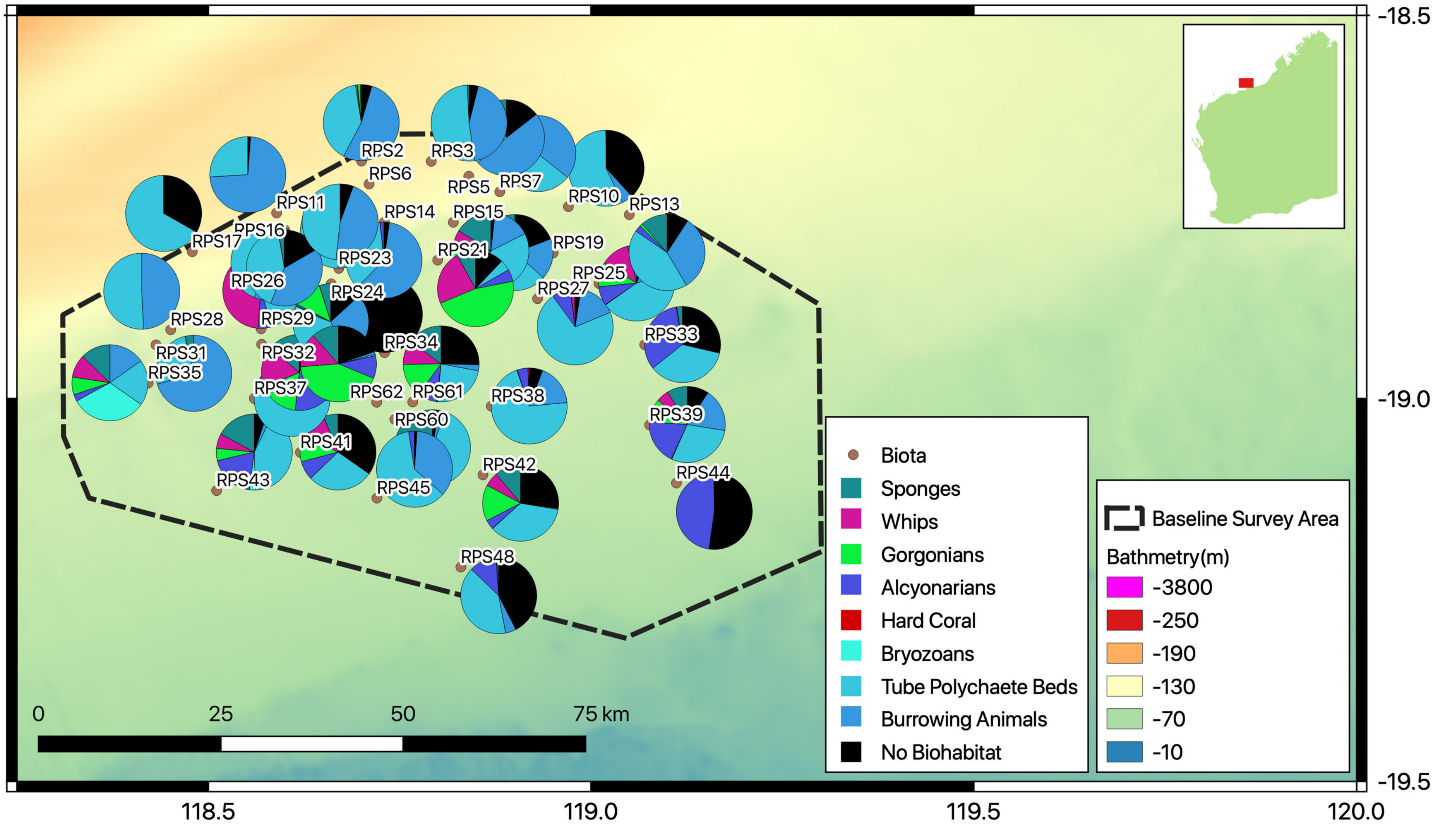

Figure 44. Proportion of biohabitat type at each of the December 2019 survey sites in the survey area (black dashed line).

4 Fish species diversity in the Dorado Survey Area

4.1 Data sources

A total of 4700 fish records, collected from 1967 to 1997, were downloaded from ALA records (Figure 45) for the survey area. Individual records were interrogated for identification accuracy using the CSIRO Australian National Fish Collection (ANFC) database, the Codes for Aquatic Australian Biota (CAAB) Database (Rees et al. 2020), the Australian Faunal Directory online (hereafter AFD online [Hoese et al. 2005]) and various other sources including online information and regional guide books. Dubious records (e.g. species significantly outside of their known range) and records not identifiable to species were excluded if not verifiable from an associated preserved specimen or image. Records to genus level were included only when the genus had been confirmed from the area and no other species of that genus were already recorded from the ALA records.

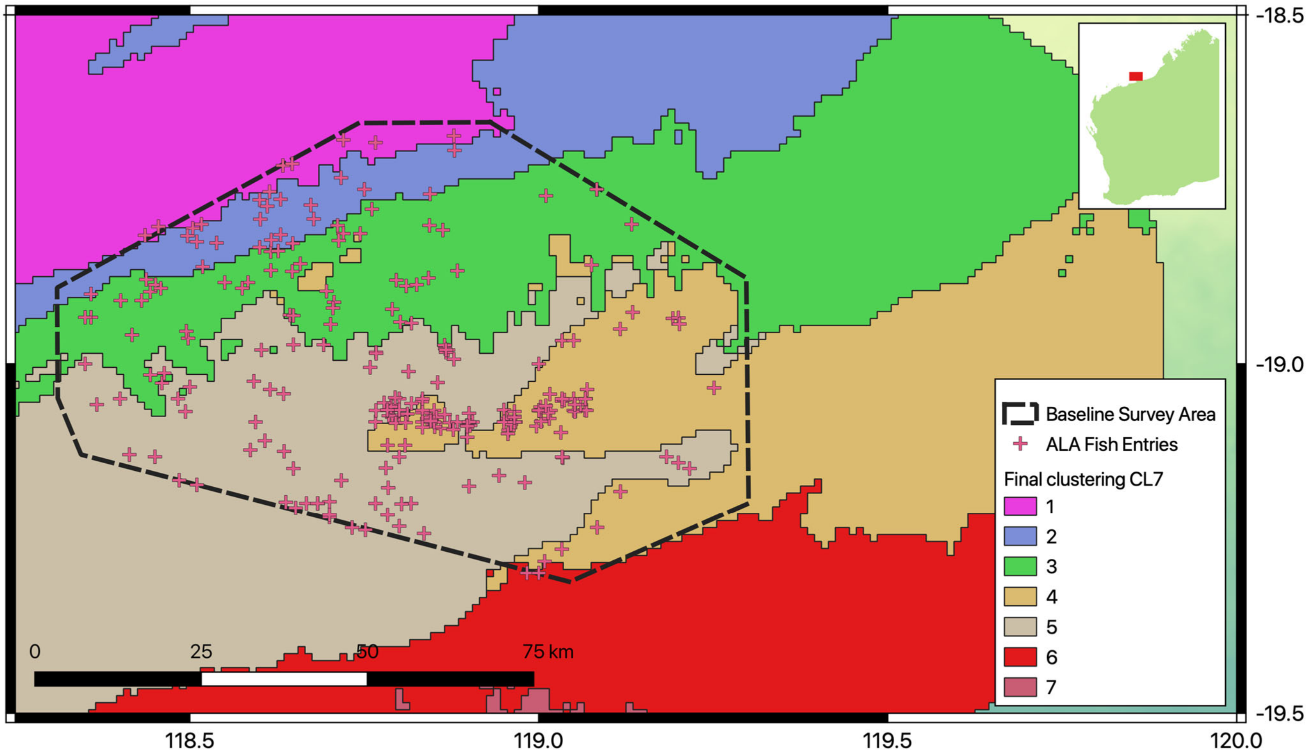

Figure 45. Locations of sample sites within the survey area (black dashed line) for fish biodiversity data records held in the ALA.

4.2 Fish diversity in the Dorado Survey Area compared with the broader NWS Province

After 782 records were excluded, 3917 records comprised of 359 fish species were confirmed as valid records for the survey area (Appendix B). All taxa had previously been recorded from the NWS Province (Hoese et al. 2005), although some names vary slightly between Appendix B and the AFD online (Hoese et al. 2005) due to the latter list including only described species or needing minor name updates. Consistency of names can be assured by matching distributions and voucher specimens from CAAB (Rees et al. 2020) and ANFC with names and CAAB codes used in AFD online (Hoese et al. 2005).

The SBRUV survey undertaken by RPS (2019) recorded 54 fish species, 36 of which were previously recorded through ALA records, 11 that were not recorded through ALA records, and 7 that could not be matched to ALA records due to lack of species identity (Appendix B). The 11 additional species not previously recorded from ALA records comprised mostly highly mobile species that are attracted to baits, such as sharks (four spp.), trevallies (two spp.) and other bony fishes from five different families (Appendix B). A total of 370 fish species have now been recorded from the survey area, equating to approximately 24% of the 1568 fish species (Hoese et al. 2005) known from the NWS Province as defined by the Integrated Marine and Coastal Regionalisation of Australia (IMCRA 1996).

Nine of the 11 newly recorded fish species for the survey area found during the RPS survey have previously been recorded to the north and south of the survey area, possibly suggesting inadequate prior sampling, rather than range extensions as the reason for not previously being detected. However, two species recorded during the RPS survey are either range extensions or dubiously identified from the video survey. If identified correctly, the Samsonfish, *Seriola hippos*, record would be a > 600 km range extension to the north of its currently documented northern limit near Exmouth Gulf. The Tille Trevally, *Caranx tille*, has not definitively been identified from inshore Western Australian waters, although a tentative identification of a juvenile from Port Hedland exists at CSIRO ANFC. These two NWS records would be a > 2500 km range extension to the southwest of the species Australian distribution, currently confirmed from Townsville westwards to the Arafura Sea ((Hoese et al. 2005) and also Christmas Island (Allen et al. 2007).

The NWS Province covers a large distributional area (238 759 km^2; latitude range approximately 14°00–22°30’S and longitude range approximately 114–125°E) and depth range from the intertidal zone to 200 m (DEWHA 2008). As such, higher diversity is to be expected than in the significantly smaller survey area that incorporates a depth range of about 50-150 m and area of 5512 km^2 (or 2.3% of the area of the NWS Province). Of significance in relation to the survey area, is the lack of offshore islands containing shallow subtidal and intertidal habitats and associated fish diversity. The broader NWS Province contains the Montebello Islands where 456 fish species in 75 families were recorded by Allen (2000), predominantly using visual census but supplemented by the ichthyocide rotenone for cryptic species. The ten most diverse fish families recorded by Allen (2000) accounted for 54% of the total fauna, namely Gobiidae (46 species versus 11 in the survey area), Labridae (39 vs. 11), Pomacentridae (37 vs. 3), Blenniidae (28 vs. 0), Apogonidae (22 vs. 7), Serranidae (19 vs. 15), Chaetodontidae (17 vs. 6), Carangidae (16 vs. 24), Lutjanidae (14 vs. 15) and Acanthuridae (11 vs. 1). The most diverse families in the survey area were Carangidae (24), Lutjanidae and Serranidae (15), Scorpaenidae (14), Nemipteridae and Carcharhinidae (12), Lethrinidae and Gobiidae (11 each), and Tetraodontidae (10 each). Within the survey area, comparable numbers to the most diverse families recorded by Allen (2000) were only achieved for families Serranidae, Carangidae and Lutjanidae. These families are represented by medium to large fishes that are usually either reef-dependent and easily sighted during visual surveys and/or readily trawled due to schooling behaviour.

Fish species diversity in the survey area is limited by the lack of shallow (< 50 m) inshore habitats and islands. For example, Moore et al. (2014) recorded 281 fish species from a much narrower depth range (0–30 m) around Broome to the north-east while Allen (2000) recorded 456 species around the Montebello Islands to the south-west of the survey area. Similarly, the maximum depth range of the survey area (c. 150 m) is significantly shallower than the continental shelf break (c. 200 m), where another unique assemblage of species typically occurs (e.g. see Last et al. 2005). Clearly, a diverse suite of collecting techniques mentioned in the above surveys provides the most comprehensive picture of the fish fauna in any given area.

4.3 Threatened, Endangered and Protected Species (TEPS)

4.3.1 Elasmobranchs

Of the elasmobranch fishes recorded from the survey area, only the Scalloped Hammerhead, *Sphyrna lewini*, is currently listed by the EPBC Act, where it has been listed as Endangered and Conservation Dependent since 2018. The occurrence of the species in the survey area is from three individuals recorded during CSIRO surveys in August 1983. From records on the ALA, it has been recorded both northwards and southwards of this area on numerous occasions since the 1960s, but data on its abundances are lacking from available sources searched for this study. Although the species can be confused with the Great Hammerhead, *Sphyrna mokarran*, which was also recorded during the SBRUV survey (RPS 2019), CSIRO shark experts at the time were likely aware of the two species and it is assumed that identification was correct.

It is unknown if the survey area contains any significant feeding, breeding or migratory habitat for the Scalloped Hammerhead. Although the species has a cosmopolitan distribution within tropical and warm temperate seas (including northern Australia), African and Indo-West Pacific populations may be distinct (Last & Stevens 2009). Large population declines have been recorded in some areas due to exploitation (Last & Stevens 2009) and despite the Endangered and Conservation Dependent listings under the EPBC Act, there is concern about the level of protection being inadequate in Australian waters (Rayns 2019). The species has a heightened conservation concern through an IUCN Redlist listing of Critically Endangered (Rigby et al. 2019b).

Another elasmobranch that occurs in the survey area is the Whitespotted Guitarfish, *Rhynchobatus australiae.* There are 10 records from the survey area obtained during CSIRO NWS surveys between 1980–1997 with the species also recorded during the SBRUV survey (RPS 2019). It is listed as Critically Endangered by the IUCN (Kyne et al. 2019).

The Silky Shark, *Carcharhinus falciformis*, is listed in the EPBC Act as migratory, subject to the Bonn Convention (Convention of the Conservation of Migratory Species of Wild Animals), and is listed as Vulnerable by the IUCN (Rigby et al. 2017). The Oceanic Whitetip Shark, *Carcharhinus longimanus*, is listed as Critically Endangered by the IUCN (Rigby et al. 2019a). Both species have been recorded from the survey area, during CSIRO NWS studies in 1980-1997 and Soviet Fishery Data in 1973, respectively.

All abovementioned elasmobranchs are likely afforded reasonable protection in the NWS area, including within the survey area, due to a lack of targeted commercial fishing practices for these species in these waters. While the NWS area is a small part of each of the species distributional ranges, they potentially offer important refuges for breeding, feeding and migration, although data on critical habitats for each of these species is not well defined in the literature.

4.3.2 Syngnathiformes

All Australian members of Syngnathidae and Solenostomidae are declared under s248 of the EPBC Act. The three relevant syngnathid species known from the survey area are Western Spiny Seahorse, *Hippocampus angustus,* Gunther's Pipehorse, *Solegnathus lettiensis* (*S. guentheri* is sometimes used for the same species in Australia), and Pallid Pipehorse, *Solegnathus* sp. 2 (Kuiter 2000) (*S. hardwickii* is also used for the same species in Australia). Because the taxonomy of some of these species is not fully resolved, there is some uncertainty about their distributions. However, the wide breadth of their distributions in northern Australia and the presumed lack of targeted fishing indicates there are suitable and widespread habitats to maintain populations.

5 Invertebrate species diversity

5.1 Data sources

Records of seven phyla of marine invertebrates were downloaded from the Atlas of Living Australia (Figure 46) with the purpose of determining what data on biodiversity existed for the survey area and how this compared with what is known for the broader area of the North West Shelf Province. These data can only be regarded as a guide of the recorded invertebrate biodiversity of the area as the area as a whole is poorly surveyed, not all Australian museums upload all records for all phyla (particularly older records) onto the ALA, and for some phyla (e.g. sponges, bryozoa), the taxonomy is not well known. However, the approach taken here compares like with like for recorded biodiversity for these phyla on the NWS.

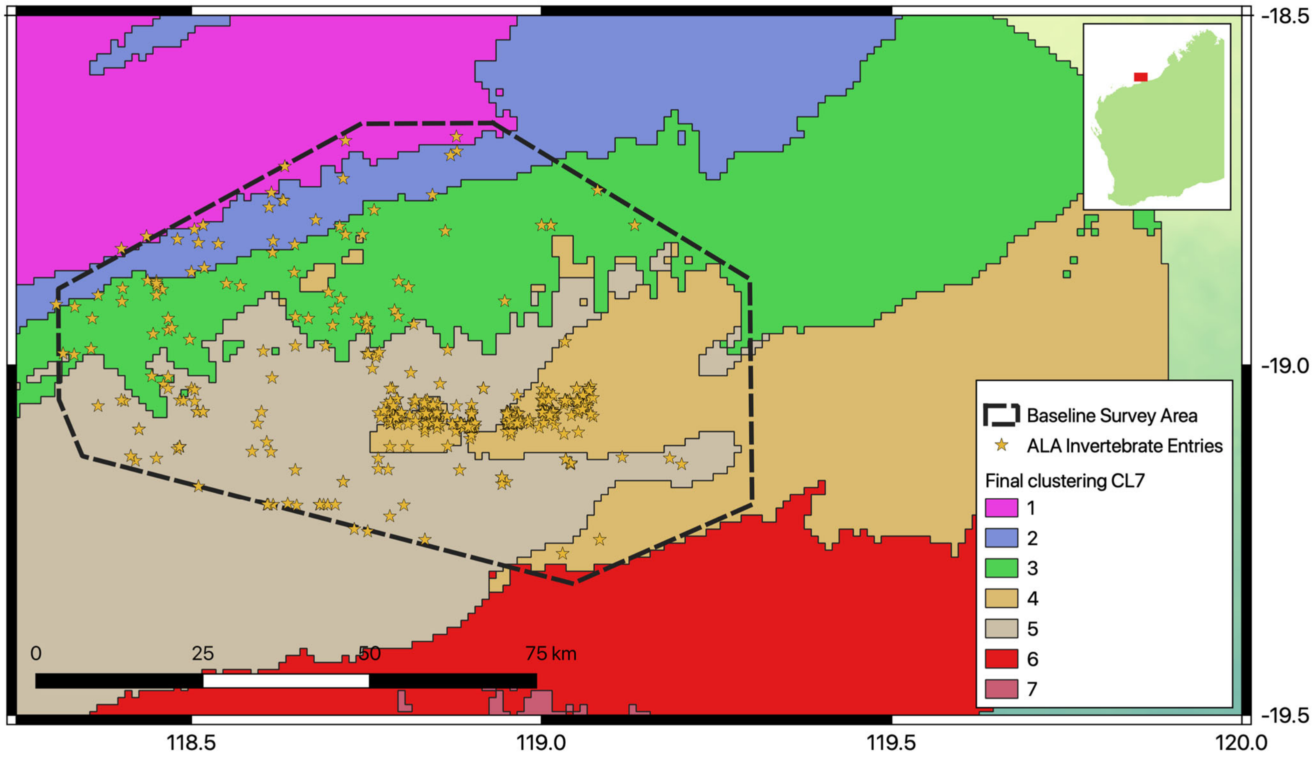

Figure 46. Locations of sample sites within the survey area (black dashed line) for marine invertebrate biodiversity data records held in the ALA.

5.2 Invertebrate species recorded from the Dorado Survey Area

Tables C.1 to C.7 in Appendix C set out the species recorded from the survey area for seven key phyla:

Porifera (sponges)

- 87 species recorded, all demosponges. This is likely to be a significant underestimate due, in part, to a large proportion of Australian sponges being undescribed. The ALA only records species with formal names (158 for the entire NWS Province) and although the high diversity of NWS sponges is gradually being documented (Hooper et al. 2002; Fromont 2004; Fromont et al. 2006; 2016) many uniquely identified and catalogued species lack a formal name. For example, a recent survey of the Dampier and Montebello Marine Parks found a total of 153 species of which 80 could not be named (Keesing 2019). Hooper et al. (2002) estimated there were 344 sponge species on the NWS with as many as 37% endemic.

Cnidaria (hydroids, soft corals, hard corals, whips, fans, seapens, zoanthids)

- 72 species recorded, comprising 45 Alcyonacea (17 soft corals of various types, 22 fans and gorgonians, six whips), two black corals, five hard corals (all solitary corals), three sea pens, three zoanthids and 14 hydroids. This is a similar diversity to that recorded from the Dampier and Montebello Marine Parks (46 species of Alcyonacea, Keesing 2019).

Bryozoa (lace corals)

- Three species recorded. This is certainly a large underestimate given bryozoa are not regularly sampled and the taxonomy is poorly known.

Annelida (polychaete worms)

- 23 species recorded

Mollusca (bivalves, gastropods, scaphopods, cephalopods)

- 208 species recorded, comprising 55 bivalves, 124 Gastropods, 11 scaphopods and 18 species of cephalopods which included two squid, 13 cuttlefish and three octopus. This is a relatively high diversity for a small area, especially when one considers that it lacks in shallow water and intertidal habitats where molluscs are abundant. A recent survey of the deeper (> 30 m) habitats of the Dampier and Montebello Marine Parks found 90 species of molluscs (Keesing 2019) while other surveys of similar areas on the NWS which included the shallow habits recorded over 600 species (Wells et al. 2000; 2003; Slack-Smith and Bryce 1996; 2004).

Echinodermata (starfish, crinoids [sea lilies], basket stars, brittle stars, sea cucumbers, sea urchins)

- 76 species recorded, comprising 18 starfish, 19 crinoids, 15 brittle stars, seven basket stars, three sea cucumbers and 14 echinoids. This group is also likely to be under-sampled especially for sea cucumbers. Keesing (2019) recorded 30 species of crinoids, seven basket stars and 26 brittle stars from the areas of the Dampier and Montebello Marine Parks.

Arthropoda (crustaceans and sea spiders, excludes small, mostly planktonic taxa such as maxillopods and ostracods)

- 253 species recorded, comprising 174 decapods (crabs and shrimps), 17 amphipods, 12 cumaceans, 28 isopods, seven stomatopods, four tanaids and 11 sea spiders. This is a similar diversity to that recorded from the Dampier and Montebello Marine Parks (154 species of decapods, [Keesing 2019]).

5.3 Comparison of invertebrate species diversity with the broader NWS region

Among the seven phyla of marine invertebrates examined, there were a total of 722 species recorded from the survey area, representing 18% of species recorded from the NWS Province as a whole (Table 13). Overlap between the survey area and the whole NWS Province varied between 9% for bryozoa and 55% for sponges, however for the better sampled taxa of molluscs, echinoderms and arthropods this overlap was between 12 and 24%.

Species recorded from the survey area but not recorded elsewhere in the NWS Province ranged from 9% of echinoderms to 22% of cnidarians (Table 13). Overall, 15% of species of marine invertebrates examined and recorded from the NWS Province were recorded only from the survey area (Table 13). Although the survey area made up just 2.3 % of the area of the NW Province, no firm conclusion can be made regarding differences in biodiversity between the survey and surrounding areas due to a sparsity of biodiversity data from this area, poor taxonomic knowledge of some animal groups, and incomplete ALA records. Data for fishes, a group that has been relatively much better sampled and for which the taxonomy is very mature, showed no differentiation between the survey area and surrounding areas. Thus, of the 370 species recorded from the survey area, only two species had not been recorded elsewhere in the NWS Province and it is possible these species represent errors in identification (see Chapter 4).

Table 13. Comparison of marine invertebrate diversity in the survey area with that of the broader area of the NWS Province (IMCRA – Integrated Marine and Coastal Regionalisation of Australia).

Phyla	Count of species recorded in Northwest IMCRA Province	Count of species recorded in survey area	Percentage of NWS species represented in survey area	Count of species in survey area that were not recorded elsewhere on NWS	Percentage of species in survey area that were not recorded elsewhere on NWS
PORIFERA	158	87	55	9	10
CNIDARIA	337	72	21	16	22
BRYOZOA	33	3	9	0	0
ANNELIDA	218	23	11	3	13
MOLLUSCA	1728	208	12	21	10
ECHINODERMATA	431	76	18	7	9
ARTHROPODA	1059	253	24	53	21
TOTALS	3964	722	18	109	15

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Appendix A Data tables giving site locations referred to in this report

A.1 Data tables giving survey site locations referred to in this report

In various parts of the report maps and graphs refer to sample sites. The tables below provide the GPS coordinates for each site.

Apx Table A.1 Sites sampled during the December 2019 survey of the survey area. Mid points of ROV transect are given. Assigned ecotype at each site is given. There were no sites in ecotypes 6 or 7 which fall outside the survey area.

Site	latitude (deg)	longitude (deg)	Ecotype
RPS2	-18.6901	118.7001	1
RPS3	-18.6905	118.7911	1
RPS5	-18.7099	118.8402	2
RPS6	-18.7201	118.7098	1
RPS7	-18.7302	118.8806	2
RPS10	-18.7496	118.9703	3
RPS11	-18.7579	118.5891	2
RPS13	-18.7601	119.0498	3
RPS14	-18.7700	118.7299	2
RPS15	-18.7701	118.8199	3
RPS16	-18.7801	118.5997	2
RPS17	-18.8085	118.4789	2
RPS19	-18.8100	118.9503	3
RPS21	-18.8195	118.7996	3
RPS23	-18.8303	118.6703	3
RPS24	-18.8504	118.6604	3
RPS25	-18.8499	119.0101	3
RPS26	-18.8601	118.5298	2
RPS27	-18.8698	118.9300	3
RPS28	-18.9103	118.4508	3
RPS29	-18.9091	118.5689	3
RPS31	-18.9300	118.4314	3
RPS32	-18.9293	118.5695	5
RPS33	-18.9299	119.0700	5
RPS34	-18.9402	118.7301	3
RPS35	-18.9798	118.4213	3
RPS37	-19.0000	118.5599	5
RPS38	-19.0101	118.8695	5
RPS39	-19.0345	119.0764	4
RPS41	-19.0703	118.6202	5
RPS42	-19.0997	118.8586	4
RPS43	-19.1201	118.5107	5
RPS44	-19.1103	119.1114	4
RPS45	-19.1300	118.7201	5
RPS48	-19.2201	118.8298	5
RPS60	-19.0273	118.7435	5
RPS61	-19.0046	118.7669	5
RPS62	-19.0049	118.7198	5

Apx Table A.2 GPS co-ordinates for CSIRO 1982–1997 historical survey sites in and around the survey area. Start point is given. Most trawls are about 2 km long. Assigned ecotype is also given. There are no sites in ecotypes 6 and 7.

Site	Start Lat (deg)	Start Long (deg)	Ecotype
830317	-19.0183	118.4700	3
830319	-18.8017	118.3500	1
830320	-18.7267	118.6217	1
830323	-18.7583	118.4350	1
830324	-18.7550	118.4667	1
830411	-18.8050	118.6817	2
830413	-18.9000	118.4533	3
870741	-19.0633	118.2667	5
870743	-19.1917	118.4117	5
880581	-19.2583	118.6517	5
880582	-19.0383	118.8117	5
880583	-19.0100	118.7800	5
880585	-18.9033	118.8000	3
880587	-18.8350	118.5500	2
880588	-18.8367	118.5067	2
890410	-19.2650	118.9500	5
900271	-19.2883	118.6683	5
900272	-19.2500	118.6833	5
900276	-18.8133	118.7200	3
8304121	-19.0483	118.8217	5
8304122	-19.0683	118.8883	5
8304124	-19.0767	118.9467	4
8304125	-19.0467	119.0017	4
8304133	-19.0967	118.9400	4
8304134	-19.0833	118.9950	4
8304135	-19.0733	119.0350	4
8606123	-18.9533	118.4950	3
8606145	-19.0200	118.8483	5
8904127	-19.0650	118.6500	5
8904133	-18.7550	118.7150	2
9104119	-18.6750	118.7317	1
9104125	-19.1633	118.5117	5
9508128	-18.6583	118.7317	1
9707115	-19.0533	118.3550	5
9707116	-19.0133	118.4633	3
9707117	-18.9217	118.4150	3
9707118	-18.8967	118.4433	3
9707119	-18.8383	118.6267	2

Appendix B Fish biodiversity table

Apx Table B. 1. Table of fish records from the survey area from ALA records and 2018 RPS SBRUV survey with the following notes: 1a previously recorded in ALA, 1b not previously recorded in survey area 1c identification uncertain and cannot be matched to previous records. Overlap with 2017 Montebello and Dampier Marine Parks survey (Keesing 2019) also shown.

ALA records survey area	Montebello & Dampier MP 2017 survey	RPS SBRUV 2018 survey presence	CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	COMMENTS
			ELASMOBRANCHII				
1	No		Hexanchiformes	Hexanchidae	*Hexanchus nakamurai*	Teng, 1962	
1	No		Heterodontiformes	Heterodontidae	*Heterodontus zebra*	(Gray, 1831)	
1	1		Orectolobiformes	Hemiscylliidae	*Chiloscyllium punctatum*	Müller & Henle, 1838	
1	No		Orectolobiformes	Ginglymostomatidae	*Nebrius ferrugineus*	(Lesson, 1830)	
1	1		Orectolobiformes	Stegostomatidae	*Stegostoma fasciatum*	(Hermann, 1783)	*Stegostoma tigrinum* used by some workers
1	1		Carcharhiniformes	Scyliorhinidae	*Atelomycterus fasciatus*	Compagno & Stevens, 1993	
1	No		Carcharhiniformes	Scyliorhinidae	*Halaelurus sellus*	White, Last & Stevens, 2007	
No	No	1b	Carcharhiniformes	Triakidae	*Hemitriakis falcata*	Compagno & Stevens, 1993	
No	No	1b	Carcharhiniformes	Carcharhinidae	*Carcharhinus albimarginatus*	(Rüppell, 1837)	
1	No		Carcharhiniformes	Carcharhinidae	*Carcharhinus amblyrhynchos*	(Bleeker, 1856)	
1	1	1a	Carcharhiniformes	Carcharhinidae	*Carcharhinus coatesi*	(Whitley, 1939)	
1	No		Carcharhiniformes	Carcharhinidae	*Carcharhinus falciformis*	(Müller & Henle, 1839)	
1	No		Carcharhiniformes	Carcharhinidae	*Carcharhinus longimanus*	(Poey 1861)	
1	No		Carcharhiniformes	Carcharhinidae	*Carcharhinus obscurus*	(Lesueur, 1818)	

1	1	1a	Carcharhiniformes	Carcharhinidae	*Carcharhinus plumbeus*	(Nardo, 1827)	
1	No	1a	Carcharhiniformes	Carcharhinidae	*Carcharhinus sorrah*	(Müller & Henle, 1839)	
1	No		Carcharhiniformes	Carcharhinidae	*Carcharhinus tilstoni*	(Whitley, 1950)	
?	?	1c	Carcharhiniformes	Carcharhinidae	*Carcharhinus* spp.		
No	No	1b	Carcharhiniformes	Carcharhinidae	*Galeocerdo cuvieri*	(Péron & Lesueur, 1822)	
1	1	1a	Carcharhiniformes	Carcharhinidae	*Loxodon macrorhinus*	Müller & Henle, 1839	
1	1		Carcharhiniformes	Carcharhinidae	*Rhizoprionodon acutus*	(Rüppell, 1837)	
1	1		Carcharhiniformes	Hemigaleidae	*Hemigaleus australiensis*	White, Last & Compagno, 2005	
1	No		Carcharhiniformes	Sphyrnidae	*Eusphyra blochii*	(Cuvier, 1816)	
1	No	1a	Carcharhiniformes	Sphyrnidae	*Sphyrna lewini*	(Griffith & Smith, 1834)	
No	No	1b	Carcharhiniformes	Sphyrnidae	*Sphyrna mokarran*	(Rüppell, 1837)	
1	1	1a	Rhinopristiformes	Rhinidae	*Rhynchobatus australiae*	Whitley, 1939	
1	1		Rhinopristiformes	Rhinobatidae	*Rhinobatos sainsburyi*	Last, 2004	
1	No		Torpediniformes	Narcinidae	*Narcine westraliensis*	McKay, 1966	
1	1		Myliobatiformes	Dasyatidae	*Himantura australis*	Last, White & Naylor, 2016	
1	1		Myliobatiformes	Dasyatidae	*Maculabatis astra*	(Last, Manjaji-Matsumoto & Pogonoski, 2008)	
1	1		Myliobatiformes	Dasyatidae	*Neotrygon australiae*	Last, White & Séret, 2016	
1	1		Myliobatiformes	Dasyatidae	*Neotrygon leylandi*	(Last, 1987)	
1	1		Myliobatiformes	Dasyatidae	*Pateobatis fai*	(Jordan & Seale, 1906)	
1	1		Myliobatiformes	Gymnuridae	*Gymnura australis*	(Ramsay & Ogilby, 1886)	
			ACTINOPTERYGII				
1	1		Anguilliformes	Muraenidae	*Gymnothorax cribroris* cf.	Whitley, 1932	
1	1		Anguilliformes	Muraenidae	*Gymnothorax mccoskeri*	Smith & Böhlke, 1997	
1	1		Anguilliformes	Muraenidae	*Gymnothorax pseudothyrsoideus*	(Bleeker, 1852)	
1	No		Anguilliformes	Congridae	*Oxyconger leptognathus*	(Bleeker 1858)	
1	No		Anguilliformes	Ophichthidae	*Ichthyapus vulturus*	(Weber & de Beaufort, 1916)	
1	1		Clupeiformes	Clupeidae	*Amblygaster sirm*	(Walbaum, 1792)	
1	No		Clupeiformes	Clupeidae	*Dussumieria elopsoides*	Bleeker, 1849	
1	No		Clupeiformes	Engraulidae	*Stolephorus indicus*	(Hasselt, 1823)	
1	1		Aulopiformes	Synodontidae	*Saurida filamentosa* cf.	Ogilby, 1910	

1	1		Aulopiformes	Synodontidae	*Saurida grandisquamis*	(Günther, 1864)	
No	No	1b	Aulopiformes	Synodontidae	*Saurida longimanus*	Norman, 1939	
1	1		Aulopiformes	Synodontidae	*Saurida micropectoralis* cf.	Macleay 1881	In ALA as *Saurida argentea*
1	1	1a	Aulopiformes	Synodontidae	*Saurida undosquamis*	(Richardson, 1848)	
1	1		Aulopiformes	Synodontidae	*Synodus hoshinonis*	Tanaka, 1917	
1	1	1a	Aulopiformes	Synodontidae	*Synodus indicus*	(Day, 1873)	
1	No		Aulopiformes	Synodontidae	*Synodus macrops*	Tanaka, 1917	
1	1		Aulopiformes	Synodontidae	*Synodus sageneus*	Waite, 1905	
1	1	1a	Aulopiformes	Synodontidae	*Trachinocephalus trachinus*	(Temminck & Schlegel, 1846)	In ALA as *Trachinocephalus myops*
1	No		Siluriformes	Ariidae	*Netuma bilineata*	(Valenciennes, 1840)	
1	1	1a	Siluriformes	Ariidae	*Netuma thalassina* cf.	(Rüppell, 1837)	
1	1		Siluriformes	Plotosidae	*Euristhmus sandrae*	Murdy & Ferraris, 2006	
1	No		Batrachoidiformes	Batrachoididae	*Batrachomoeus occidentalis*	Hutchins, 1976	
1	1		Lophiiformes	Lophiidae	*Lophiomus setigerus*	(Vahl, 1797)	
1	No		Lophiiformes	Antennariidae	*Antennarius pictus*	(Shaw & Nodder, 1794)	
1	1		Lophiiformes	Ogcocephalidae	*Halieutaea indica*	Annandale & Jenkins, 1910	
1	No		Beloniformes	Exocoetidae	*Cheilopogon spilopterus*	(Valenciennes, 1847)	
1	No		Beloniformes	Exocoetidae	*Cheilopogon suttoni*	(Whitley & Colefax, 1938)	
1	No		Beloniformes	Exocoetidae	*Cypselurus poecilopterus*	(Valenciennes, 1847)	
1	No		Beloniformes	Exocoetidae	*Euleptorhamphus viridis*	(Hasselt, 1823)	
1	No		Beloniformes	Exocoetidae	*Hirundichthys oxycephalus*	(Bleeker, 1852)	
1	No		Beryciformes	Monocentridae	*Monocentris japonica*	(Houttuyn, 1782)	
1	1		Beryciformes	Holocentridae	*Myripristis botche*	Cuvier, 1829	
1	No		Beryciformes	Holocentridae	*Myripristis murdjan*	(Forsskål, 1775)	
1	1		Beryciformes	Holocentridae	*Sargocentron rubrum*	(Forsskål, 1775)	
1	No		Zeiformes	Zeidae	*Zenopsis nebulosa*	(Temminck & Schlegel, 1845)	
1	1		Lampriformes	Veliferidae	*Velifer hypselopterus* cf.	Bleeker 1879	
1	1	1a	Syngnathiformes	Fistulariidae	*Fistularia commersonii*	Rüppell, 1838	
1	1		Syngnathiformes	Fistulariidae	*Fistularia petimba*	Lacépède, 1803	

1	?		Syngnathiformes	Centriscidae	*Centriscus scutatus*	Linnaeus, 1758	Doubt as to the ALA record ident. - may be *Centriscus cristatus*, but no preserved specimen exists
1	1		Syngnathiformes	Syngnathidae	*Hippocampus angustus*	Günther, 1870	
1	No		Syngnathiformes	Syngnathidae	*Solegnathus lettiensis*	Bleeker, 1860	
1	1		Syngnathiformes	Syngnathidae	*Solegnathus* sp. 2 (cf *hardwicki*)	[of Kuiter, 2000]	ALA records as *Solegnathus hardwicki*, species name not resolved
1	1		Syngnathiformes	Dactylopteridae	*Dactyloptena macracanthus*	(Bleeker, 1854)	
1	1		Syngnathiformes	Dactylopteridae	*Dactyloptena orientalis*	(Cuvier, 1829)	
1	1		Syngnathiformes	Dactylopteridae	*Dactyloptena papilio*	Ogilby, 1910	
1	No		Syngnathiformes	Dactylopteridae	*Dactyloptena peterseni*	(Nyström, 1887)	
1	1		Syngnathiformes	Pegasidae	*Eurypegasus draconis*	(Linnaeus, 1766)	
1	1		Scorpaeniformes	Apistidae	*Apistus carinatus*	(Bloch & Schneider, 1801)	
1	1		Scorpaeniformes	Scorpaenidae	*Dendrochirus brachypterus*	(Cuvier, 1829)	
1	No		Scorpaeniformes	Scorpaenidae	*Dendrochirus zebra*	(Cuvier, 1829)	
1	No		Scorpaeniformes	Scorpaenidae	*Parapterois heterurus*	(Bleeker, 1856)	
1	1		Scorpaeniformes	Scorpaenidae	*Pterois russelii*	Bennett, 1831	
1	No		Scorpaeniformes	Scorpaenidae	*Pterois volitans*	(Linnaeus, 1758)	
1	No		Scorpaeniformes	Scorpaenidae	*Neomerinthe amplisquamiceps*	(Fowler, 1938)	
1	1		Scorpaeniformes	Scorpaenidae	*Pteroidichthys amboinensis*	Bleeker, 1856	
1	1		Scorpaeniformes	Scorpaenidae	*Pteroidichthys noronhai*	(Fowler, 1938)	
1	?		Scorpaeniformes	Scorpaenidae	*Scorpaena* sp.		In ALA as *Scorpaena neglecta* which could be *Scorpaena onaria* or an undescribed species
1	1		Scorpaeniformes	Scorpaenidae	*Scorpaenodes smithi*	Eschmeyer & Rama-Rao, 1972	
1	No		Scorpaeniformes	Scorpaenidae	*Scorpaenopsis furneauxi*	Whitley, 1959	
1	No		Scorpaeniformes	Scorpaenidae	*Scorpaenopsis macrochir*	Ogilby, 1910	
1	1		Scorpaeniformes	Scorpaenidae	*Scorpaenopsis neglecta*	Heckel, 1837	
1	1		Scorpaeniformes	Scorpaenidae	*Scorpaenopsis venosa*	(Cuvier, 1829)	
1	1		Scorpaeniformes	Tetrarogidae	*Cottapistus cottoides*	(Linnaeus, 1758)	
1	1		Scorpaeniformes	Tetrarogidae	*Richardsonicthys leucogaster*	(Richardson, 1848)	
1	1		Scorpaeniformes	Synanceiidae	*Erosa erosa*	(Langsdorf, 1829)	
1	1		Scorpaeniformes	Synanceiidae	*Inimicus sinensis*	(Valenciennes, 1833)	

1	?		Scorpaeniformes	Synanceiidae	*Minous trachycephalus*	(Bleeker, 1854)	ALA records as *Minous trachycephalus* could also refer to *Minous roseus*
1	No		Scorpaeniformes	Triglidae	*Lepidotrigla argus*	Ogilby, 1910	
1	No		Scorpaeniformes	Triglidae	*Lepidotrigla bispinosa* cf.	[of Gomon]	
1	1		Scorpaeniformes	Triglidae	*Lepidotrigla japonica* cf.	[of Gomon]	
1	No		Scorpaeniformes	Triglidae	*Lepidotrigla russelli*	Del Cerro & Lloris, 1995	
1	No		Scorpaeniformes	Triglidae	*Lepidotrigla* sp. 2	[of Sainsbury et al 1985]	
1	No		Scorpaeniformes	Triglidae	*Pterygotrigla elicryste*	Richards, Yato & Last, 2003	
1	No		Scorpaeniformes	Aploactinidae	*Adventor elongatus*	(Whitley, 1952)	
1	No		Scorpaeniformes	Aploactinidae	*Aploactis aspera*	(Richardson, 1844)	
1	No		Scorpaeniformes	Platycephalidae	*Onigocia macrocephala*	(Weber, 1913)	
1	No		Scorpaeniformes	Platycephalidae	*Onigocia spinosa*	(Temminck & Schlegel, 1843)	
1	1		Scorpaeniformes	Platycephalidae	*Rogadius patriciae*	Knapp, 1987	
1	No		Scorpaeniformes	Platycephalidae	*Rogadius pristiger*	(Cuvier, 1829)	
1	1		Scorpaeniformes	Platycephalidae	*Rogadius tuberculatus*	(Cuvier, 1829)	
1	No		Scorpaeniformes	Platycephalidae	*Thysanophrys celebica*	(Bleeker, 1854)	
1	1		Scorpaeniformes	Platycephalidae	*Thysanophrys chiltonae*	Schultz, 1966	
?	?	1c	Scorpaeniformes	Platycephalidae	Platycephalidae unknown spp.		
1	No		Scorpaeniformes	Hoplichthyidae	*Hoplichthys citrinus*	Gilbert, 1905	
1	No		Perciformes	Acropomatidae	*Acropoma* sp.		in ALA as *Acropoma japonicum*, now likely *A. leobergi*
1	No		Perciformes	Serranidae	*Caprodon schlegelii*	(Günther, 1859)	
1	No		Perciformes	Serranidae	*Chelidoperca* sp.		
1	1		Perciformes	Serranidae	*Diploprion bifasciatum*	Cuvier, 1828	
1	1	1a	Perciformes	Serranidae	*Epinephelus amblycephalus*	(Bleeker, 1857)	
1	1	1a	Perciformes	Serranidae	*Epinephelus areolatus*	(Forsskål, 1775)	
1	1		Perciformes	Serranidae	*Epinephelus bilobatus*	Randall & Allen, 1987	In ALA as *Epinephelus maculatus*, which is not reliably recorded from inshore coastal WA
1	1		Perciformes	Serranidae	*Epinephelus coioides*	(Hamilton, 1822)	
1	No		Perciformes	Serranidae	*Epinephelus fuscoguttatus*	(Forsskål, 1775)	
1	No		Perciformes	Serranidae	*Epinephelus heniochus*	Fowler, 1904	
1	No		Perciformes	Serranidae	*Epinephelus latifasciatus*	(Temminck & Schlegel, 1843)	

No	No	1b	Perciformes	Serranidae	*Epinephelus malabaricus*	(Bloch & Schneider, 1801)	
1	1		Perciformes	Serranidae	*Epinephelus multinotatus*	(Peters, 1876)	
1	1		Perciformes	Serranidae	*Epinephelus sexfasciatus*	(Valenciennes, 1828)	
1	1		Perciformes	Serranidae	*Plectropomus maculatus*	(Bloch, 1790)	
1	No		Perciformes	Serranidae	*Pseudanthias* sp.		Listed in ALA as *Pseudanthias fasciatus* which possibly refers to *Pseudanthias gibbosus* in AFD online
1	1		Perciformes	Pseudochromidae	*Congrogadus spinifer*	(Borodin, 1933)	
1	1		Perciformes	Pseudochromidae	*Pseudochromis howsoni*	Allen, 1995	
1	1		Perciformes	Pseudochromidae	*Pseudochromis quinquedentatus*	McCulloch, 1926	
1	1		Perciformes	Glaucosomatidae	*Glaucosoma buergeri*	Richardson, 1845	
1	1		Perciformes	Glaucosomatidae	*Glaucosoma magnificum*	(Ogilby, 1915)	
1	1	1a	Perciformes	Terapontidae	*Terapon jarbua*	(Forsskål, 1775)	
1	1	1a	Perciformes	Priacanthidae	*Priacanthus hamrur*	(Forsskål, 1775)	
1	No		Perciformes	Priacanthidae	*Priacanthus macracanthus*	Cuvier, 1829	
1	1		Perciformes	Priacanthidae	*Priacanthus tayenus*	Richardson, 1846	
1	1		Perciformes	Apogonidae	*Apogonichthyoides atripes*	(Ogilby, 1911)	
1	1		Perciformes	Apogonidae	*Jaydia argyrogaster*	(Weber, 1909)	
1	1		Perciformes	Apogonidae	*Ostorhinchus cavitensis*	(Jordan & Seale, 1907)	
1	1		Perciformes	Apogonidae	*Ostorhinchus fasciatus*	(White, 1790)	
1	1		Perciformes	Apogonidae	*Ostorhinchus semilineatus*	(Temminck & Schlegel, 1843)	
1	1		Perciformes	Apogonidae	*Ostorhinchus septemstriatus*	(Günther, 1880)	
1	1		Perciformes	Apogonidae	*Rhabdamia gracilis*	(Bleeker, 1856)	
1	No		Perciformes	Sillaginidae	*Sillago analis*	Whitley, 1943	
1	1	1a	Perciformes	Rachycentridae	*Rachycentron canadum*	(Linnaeus, 1766)	
1	1	1a	Perciformes	Echeneidae	*Echeneis naucrates*	Linnaeus, 1758	
1	1		Perciformes	Carangidae	*Alectis ciliaris*	(Bloch, 1787)	
1	1		Perciformes	Carangidae	*Alepes apercna*	Grant, 1987	
1	1		Perciformes	Carangidae	*Atule mate*	(Cuvier, 1833)	
1	1	1a	Perciformes	Carangidae	*Carangoides caeruleopinnatus*	(Rüppell, 1830)	
1	1	1a	Perciformes	Carangidae	*Carangoides chrysophrys*	(Cuvier, 1833)	
1	1		Perciformes	Carangidae	*Carangoides equula*	(Temminck & Schlegel, 1844)	

1	1		Perciformes	Carangidae	*Carangoides fulvoguttatus*	(Forsskål, 1775)	
1	1		Perciformes	Carangidae	*Carangoides gymnostethus*	(Cuvier, 1833)	
1	1	1a	Perciformes	Carangidae	*Carangoides malabaricus*	(Bloch & Schneider, 1801)	
1	No		Perciformes	Carangidae	*Carangoides talamparoides*	Bleeker, 1852	
?	?	1c	Perciformes	Carangidae	*Carangoides* sp 10.		Juvenile
?	?	1c	Perciformes	Carangidae	*Carangoides* spp.		
1	No		Perciformes	Carangidae	*Caranx bucculentus*	Alleyne & Macleay, 1877	
1	1	1a	Perciformes	Carangidae	*Caranx ignobilis*	(Forsskål, 1775)	
No	No	1b	Perciformes	Carangidae	*Caranx tille*	Cuvier, 1833	Range extension or misidentification?
?	?	1c	Perciformes	Carangidae	*Decapterus* spp.		
1	1		Perciformes	Carangidae	*Decapterus macrosoma*	Bleeker, 1851	
1	1		Perciformes	Carangidae	*Decapterus russelli*	(Rüppell, 1830)	
1	1		Perciformes	Carangidae	*Gnathanodon speciosus*	(Forsskål, 1775)	
1	1		Perciformes	Carangidae	*Parastromateus niger*	(Bloch, 1795)	
1	No		Perciformes	Carangidae	*Selar boops*	(Cuvier, 1833)	
1	1		Perciformes	Carangidae	*Selar crumenophthalmus*	(Bloch, 1793)	
1	1		Perciformes	Carangidae	*Selaroides leptolepis*	(Cuvier, 1833)	
1	No	1a	Perciformes	Carangidae	*Seriola dumerili*	(Risso, 1810)	
No	No	1b	Perciformes	Carangidae	*Seriola hippos*	Günther, 1876	Range extension or misidentification?
1	1		Perciformes	Carangidae	*Seriolina nigrofasciata*	(Rüppell, 1829)	
1	No		Perciformes	Carangidae	*Uraspis uraspis*	(Günther, 1860)	
1	No		Perciformes	Menidae	*Mene maculata*	(Bloch & Schneider, 1801)	
1	1		Perciformes	Leiognathidae	*Equulites elongatus*	(Günther, 1874)	
1	No		Perciformes	Leiognathidae	*Eubleekeria splendens*	(Cuvier, 1829)	
1	1		Perciformes	Leiognathidae	*Photopectoralis bindus*	(Valenciennes, 1835)	
1	1		Perciformes	Bramidae	*Brama pauciradiata*	Fujita & Last, 1995	
1	1		Perciformes	Caesionidae	*Dipterygonotus balteatus*	(Valenciennes, 1830)	
1	1		Perciformes	Caesionidae	*Pterocaesio chrysozona*	(Cuvier, 1830)	
1	No		Perciformes	Caesionidae	*Pterocaesio digramma*	(Bleeker, 1865)	
1	1		Perciformes	Lutjanidae	*Lutjanus argentimaculatus*	(Forsskål, 1775)	

1	1		Perciformes	Lutjanidae	*Lutjanus erythropterus*	Bloch, 1790	
1	No		Perciformes	Lutjanidae	*Lutjanus kasmira*	(Forsskål, 1775)	
1	1		Perciformes	Lutjanidae	*Lutjanus lemniscatus*	(Valenciennes, 1828)	
1	1		Perciformes	Lutjanidae	*Lutjanus lutjanus*	Bloch, 1790	
1	1	1a	Perciformes	Lutjanidae	*Lutjanus malabaricus*	(Bloch & Schneider, 1801)	
1	1	1a	Perciformes	Lutjanidae	*Lutjanus russellii*	(Bleeker, 1849)	in ALA as '*Lutjanus* sp. [in Yearsley, Last and Ward]'
1	1	1a	Perciformes	Lutjanidae	*Lutjanus sebae*	(Cuvier, 1828)	
1	1	1a	Perciformes	Lutjanidae	*Lutjanus vitta*	(Quoy & Gaimard, 1824)	
1	No		Perciformes	Lutjanidae	*Pristipomoides argyrogrammicus*	(Valenciennes, 1831)	
1	No		Perciformes	Lutjanidae	*Pristipomoides filamentosus*	(Valenciennes, 1830)	
1	1	1a	Perciformes	Lutjanidae	*Pristipomoides multidens*	(Day, 1871)	
No	No	1b	Perciformes	Lutjanidae	*Pristipomoides sieboldii*	(Bleeker, 1857)	
1	1		Perciformes	Lutjanidae	*Pristipomoides typus*	Bleeker, 1852	
1	1		Perciformes	Lutjanidae	*Symphorus nematophorus*	(Bleeker, 1860)	
1	No		Perciformes	Nemipteridae	*Nemipterus bathybius*	Snyder, 1911	
1	1		Perciformes	Nemipteridae	*Nemipterus celebicus*	(Bleeker, 1854)	
1	1		Perciformes	Nemipteridae	*Nemipterus furcosus*	(Valenciennes, 1830)	
1	No		Perciformes	Nemipteridae	*Nemipterus isacanthus*	(Bleeker, 1873)	
1	1		Perciformes	Nemipteridae	*Nemipterus nematopus*	(Bleeker, 1851)	
1	1		Perciformes	Nemipteridae	*Nemipterus peronii*	(Valenciennes, 1830)	
1	1		Perciformes	Nemipteridae	*Nemipterus virgatus*	Houttuyn, 1782)	
1	1		Perciformes	Nemipteridae	*Nemipterus zysron*	(Bleeker, 1856)	
?	?	1c	Perciformes	Nemipteridae	*Nemipterus* spp.		
1	1		Perciformes	Nemipteridae	*Parascolopsis tanyactis*	Russell, 1986	
1	1		Perciformes	Nemipteridae	*Pentapodus nagasakiensis*	(Tanaka, 1915)	
1	1		Perciformes	Nemipteridae	*Pentapodus porosus*	(Valenciennes, 1830)	
1	1		Perciformes	Nemipteridae	*Scolopsis monogramma*	(Kuhl & van Hasselt, 1830)	
1	No		Perciformes	Gerreidae	*Gerres filamentosus*	Cuvier, 1829	
1	1		Perciformes	Gerreidae	*Pentaprion longimanus*	(Cantor, 1850)	
1	No		Perciformes	Hapalogenyidae	*Hapalogenys dampieriensis*	Iwatsuki & Russell, 2006	

1	1		Perciformes	Haemulidae	*Diagramma pictum*	(Thunberg, 1792)	
1	No		Perciformes	Haemulidae	*Pomadasys argenteus*	(Forsskål, 1775)	
1	1		Perciformes	Haemulidae	*Pomadasys kaakan*	(Cuvier, 1830)	
1	1		Perciformes	Lethrinidae	*Gymnocranius elongatus*	Senta, 1973	
1	1	1a	Perciformes	Lethrinidae	*Gymnocranius grandoculis*	(Valenciennes, 1830)	
1	1		Perciformes	Lethrinidae	*Lethrinus laticaudis*	Alleyne & Macleay, 1877	
1	1	1a	Perciformes	Lethrinidae	*Lethrinus lentjan*	(Lacépède, 1802)	
1	No		Perciformes	Lethrinidae	*Lethrinus microdon*	Valenciennes, 1830	
1	No		Perciformes	Lethrinidae	*Lethrinus miniatus*	(Forster, 1801)	
1	1		Perciformes	Lethrinidae	*Lethrinus nebulosus*	(Forsskål, 1775)	
1	1		Perciformes	Lethrinidae	*Lethrinus olivaceus*	Valenciennes, 1830	
1	1		Perciformes	Lethrinidae	*Lethrinus punctulatus*	Macleay, 1878	In ALA as *Lethrinus* sp [Carpenter]; excluded from AFD online
1	1		Perciformes	Lethrinidae	*Lethrinus variegatus*	Valenciennes, 1830	
1	No		Perciformes	Lethrinidae	*Monotaxis grandoculis*	(Forsskål, 1775)	
1	1	1a	Perciformes	Sparidae	*Argyrops bleekeri*	Oshima, 1927	Previously recorded as *Argyrops spinifer*, which is now restricted to the Western Indian Ocean
1	No		Perciformes	Sparidae	*Dentex spariformis*	Ogilby, 1910	
1	1		Perciformes	Mullidae	*Parupeneus chrysopleuron*	(Temminck & Schlegel, 1843)	
1	1		Perciformes	Mullidae	*Parupeneus heptacanthus*	(Lacépède, 1802)	
1	1		Perciformes	Mullidae	*Parupeneus indicus*	(Shaw, 1803)	
1	1		Perciformes	Mullidae	*Upeneus guttatus*	(Day, 1868)	
1	1	1a	Perciformes	Mullidae	*Upeneus moluccensis* cf.	(Bleeker, 1855)	
1	No		Perciformes	Mullidae	*Upeneus sulphureus*	Cuvier, 1829	
1	No		Perciformes	Mullidae	*Upeneus torres*	Uiblein & Gledhill, 2014	
1	1		Perciformes	Mullidae	*Upeneus tragula* cf.	Richardson, 1846	
1	1		Perciformes	Ephippidae	*Platax batavianus*	Cuvier, 1831	
1	No		Perciformes	Ephippidae	*Platax orbicularis*	(Forsskål, 1775)	
1	1		Perciformes	Ephippidae	*Platax teira*	(Forsskål, 1775)	
1	No		Perciformes	Ephippidae	*Zabidius novemaculeatus*	(McCulloch, 1916)	
1	No		Perciformes	Chaetodontidae	*Chaetodon auriga*	Forsskål, 1775	

1	1		Perciformes	Chaetodontidae	*Coradion altivelis*	McCulloch, 1916	
1	1		Perciformes	Chaetodontidae	*Coradion chrysozonus*	(Cuvier, 1831)	
1	1		Perciformes	Chaetodontidae	*Heniochus acuminatus*	(Linnaeus, 1758)	
1	1		Perciformes	Chaetodontidae	*Heniochus diphreutes*	Jordan, 1903	
1	1		Perciformes	Chaetodontidae	*Parachaetodon ocellatus*	(Cuvier, 1831)	
1	1		Perciformes	Pomacanthidae	*Chaetodontoplus duboulayi*	(Günther, 1867)	
1	1		Perciformes	Pomacanthidae	*Chaetodontoplus personifer*	(McCulloch, 1914)	
1	1		Perciformes	Pomacanthidae	*Pomacanthus imperator*	(Bloch, 1787)	
1	1		Perciformes	Pomacentridae	*Chromis fumea*	(Tanaka, 1917)	
1	1		Perciformes	Pomacentridae	*Neopomacentrus cyanomos*	(Bleeker, 1856)	In ALA (Soviet data) as *Pomacentrus cianomus*
1	1		Perciformes	Pomacentridae	*Pristotis obtusirostris*	(Günther, 1862)	
1	No		Perciformes	Pentacerotidae	*Histiopterus typus*	Temminck & Schlegel, 1844	
1	1		Perciformes	Cirrhitidae	*Cirrhitichthys aprinus* cf.	(Cuvier, 1829)	
1	No		Perciformes	Sphyraenidae	*Sphyraena acutipinnis*	Day, 1876	
1	No		Perciformes	Sphyraenidae	*Sphyraena barracuda*	(Edwards, 1771)	
1	1	1a	Perciformes	Sphyraenidae	*Sphyraena forsteri*	Cuvier, 1829	
1	1		Perciformes	Sphyraenidae	*Sphyraena jello*	Cuvier, 1829	
1	No		Perciformes	Sphyraenidae	*Sphyraena pinguis*	Günther, 1874	
1	1		Perciformes	Sphyraenidae	*Sphyraena putnamae*	Jordan & Seale, 1905	
No	No	1b	Perciformes	Sphyraenidae	*Sphyraena qenie*	Klunzinger, 1870	
1	?		Perciformes	Labridae - Labrinae	*Anampses* sp.		
1	1	1a	Perciformes	Labridae - Labrinae	*Bodianus solatus*	Gomon, 2006	
1	1		Perciformes	Labridae - Labrinae	*Choerodon cauteroma*	Gomon & Allen, 1987	
1	1		Perciformes	Labridae - Labrinae	*Choerodon cephalotes*	(Castelnau, 1875)	
1	1		Perciformes	Labridae - Labrinae	*Choerodon monostigma*	Ogilby, 1910	
1	1		Perciformes	Labridae - Labrinae	*Choerodon sugillatum*	Gomon, 1987	
1	No		Perciformes	Labridae - Labrinae	*Choerodon zamboangae*	(Seale & Bean, 1907)	
1	No		Perciformes	Labridae - Labrinae	*Halichoeres melanurus*	(Bleeker, 1851)	
1	No		Perciformes	Labridae - Labrinae	*Iniistius dea*	(Temminck & Schlegel, 1846)	
1	1		Perciformes	Labridae - Labrinae	*Iniistius opalus*	Fukui 2018	In ALA as *Iniistius jacksonensis*, which is endemic to eastern Australia

1	1		Perciformes	Labridae - Labrinae	*Suezichthys soelae*	Russell, 1985	
1	No		Perciformes	Labridae - Scarinae	*Chlorurus spilurus*	(Valenciennes, 1840)	
1	1		Perciformes	Labridae - Scarinae	*Scarus ghobban*	Forsskål, 1775	
1	No		Perciformes	Labridae - Scarinae	*Scarus rivulatus*	Valenciennes, 1840	
1	1		Perciformes	Pinguipedidae	*Parapercis alboguttata*	(Günther, 1872)	
1	No		Perciformes	Pinguipedidae	*Parapercis diplospilus*	Gomon, 1981	
1	1		Perciformes	Pinguipedidae	*Parapercis nebulosa*	(Quoy & Gaimard, 1825)	
1	1		Perciformes	Pinguipedidae	*Parapercis xanthozona*	(Bleeker, 1849)	
1	No		Perciformes	Pinguipedidae	*Ryukyupercis gushikeni*	(Yoshino, 1975)	
1	No		Perciformes	Hemerocoetidae	*Acanthaphritis barbata*	(Okamura & Kishida, 1963)	
1	No		Perciformes	Trichonotidae	*Trichonotus* sp.		
1	1		Perciformes	Uranoscopidae	*Ichthyscopus insperatus*	Mees, 1960	
1	1		Perciformes	Uranoscopidae	*Uranoscopus cognatus*	Cantor, 1849	
1	No		Perciformes	Uranoscopidae	*Uranoscopus* sp. 1 [of Sainsbury]		
1	No		Perciformes	Champsodontidae	*Champsodon guentheri*	Regan, 1908	
1	1		Perciformes	Champsodontidae	*Champsodon vorax* cf.	Günther, 1867	
1	No		Perciformes	Schindleriidae	*Schindleria praematura*	(Schindler, 1931)	
1	?		Perciformes	Ammodytidae	*Bleekeria mitsukurii*	Jordan & Evermann, 1902	*Bleekeria* specimen from 2017 NW Shelf voyage lost, ID can't be confirmed
1	?		Perciformes	Ammodytidae	*Bleekeria viridianguilla*	(Fowler, 1931)	*Bleekeria* specimen from 2017 NW Shelf voyage lost, ID can't be confirmed
1	No		Perciformes	Callionymidae	*Calliurichthys afilum*	(Fricke, 2000)	
1	No		Perciformes	Callionymidae	*Calliurichthys grossi*	(Ogilby, 1910)	
1	1		Perciformes	Callionymidae	*Dactylopus dactylopus*	(Valenciennes, 1837)	
1	No		Perciformes	Callionymidae	*Orbonymus rameus*	(McCulloch, 1926)	
1	No		Perciformes	Callionymidae	*Repomucenus filamentosus*	(Valenciennes, 1837)	
1	No		Perciformes	Draconettidae	*Centrodraco insolitus*	(McKay, 1971)	
1	1		Perciformes	Gobiidae	*Bathygobius* sp.	(Hoese, in preparation.)	
1	No		Perciformes	Gobiidae	*Bryaninops loki*	Larson, 1985	
1	No		Perciformes	Gobiidae	*Lobulogobius morrigu*	Larson, 1983	

1	No		Perciformes	Gobiidae	*Lobulogobius omanensis*	Koumans, 1944	
1	No		Perciformes	Gobiidae	*Pleurosicya annandalei*	Hornell & Fowler, 1922	
1	1		Perciformes	Gobiidae	*Pleurosicya boldinghi*	Weber, 1913	
1	No		Perciformes	Gobiidae	*Pleurosicya elongata*	Larson, 1990	
1	No		Perciformes	Gobiidae	*Pleurosicya mossambica*	Smith, 1959	
1	1		Perciformes	Gobiidae	*Priolepis profunda*	(Weber, 1909)	
1	No		Perciformes	Gobiidae	*Sueviota lachneri*	Winterbottom & Hoese, 1988	
1	No		Perciformes	Gobiidae	*Valenciennea wardii*	(Playfair, 1866)	
1	1		Perciformes	Acanthuridae	*Acanthurus grammoptilus*	Richardson, 1843	
1	1		Perciformes	Siganidae	*Siganus fuscescens*	(Houttuyn, 1782)	
1	1		Perciformes	Scombridae	*Rastrelliger kanagurta*	(Cuvier, 1816)	
No	No	1b	Perciformes	Scombridae	*Scomberomorus* spp.		
1	No		Perciformes	Trichiuridae	*Tentoriceps cristatus*	(Klunzinger, 1884)	
1	1		Perciformes	Trichiuridae	*Trichiurus lepturus* cf.	Linnaeus, 1758	
1	No		Perciformes	Istiophoridae	*Kajikia audax*	(Philippi, 1887)	
1	No		Perciformes	Centrolophidae	*Psenopsis humerosa*	Munro, 1958	
1	No		Perciformes	Nomeidae	*Cubiceps baxteri*	McCulloch, 1923	
1	No		Perciformes	Ariommatidae	*Ariomma indicum*	(Day, 1870)	
1	1		Pleuronectiformes	Psettodidae	*Psettodes erumei*	(Bloch & Schneider, 1801)	
1	No		Pleuronectiformes	Citharidae	*Brachypleura novaezeelandiae*	Günther, 1862	
1	No		Pleuronectiformes	Bothidae	*Arnoglossus elongatus*	Weber, 1913	
1	No		Pleuronectiformes	Bothidae	*Arnoglossus waitei*	Norman, 1926	
1	No		Pleuronectiformes	Bothidae	*Bothus myriaster*	Temminck & Schlegel, 1846	
1	1		Pleuronectiformes	Bothidae	*Crossorhombus azureus*	(Alcock, 1889)	
1	1		Pleuronectiformes	Bothidae	*Engyprosopon grandisquama*	(Temminck & Schlegel, 1846)	
1	No		Pleuronectiformes	Bothidae	*Engyprosopon maldivensis*	(Regan, 1908)	
1	1		Pleuronectiformes	Bothidae	*Grammatobothus pennatus*	(Ogilby, 1913)	
1	1		Pleuronectiformes	Bothidae	*Grammatobothus polyophthalmus*	(Bleeker, 1866)	
1	No		Pleuronectiformes	Bothidae	*Psettina gigantea*	Amaoka, 1963	
?	?	1c	Pleuronectiformes	Bothidae	Bothidae unknown spp.		
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	(Hamilton, 1822)	

1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus diplospilus*	Norman, 1926	
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus dupliciocellatus*	Regan, 1905	
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus elevatus*	Ogilby, 1912	
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus jenynsii*	(Bleeker, 1855)	
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus quinquocellatus*	Weber & de Beaufort, 1929	
1	1		Pleuronectiformes	Paralichthyidae	*Pseudorhombus spinosus*	McCulloch, 1914	
1	1		Pleuronectiformes	Pleuronectidae	*Samaris cristatus*	Gray, 1831	
1	No		Pleuronectiformes	Soleidae	*Zebrias quagga*	(Kaup, 1858)	
1	No		Pleuronectiformes	Cynoglossidae	*Cynoglossus kopsii*	(Bleeker, 1851)	
1	No		Pleuronectiformes	Cynoglossidae	*Cynoglossus maccullochi*	Norman, 1926	
1	No		Pleuronectiformes	Cynoglossidae	*Paraplagusia bilineata*	(Bloch, 1787)	
1	1		Tetraodontiformes	Triacanthidae	*Trixiphichthys weberi*	(Chaudhuri, 1910)	
1	1	1a	Tetraodontiformes	Balistidae	*Abalistes stellatus*	(Anonymous, 1798)	
1	1		Tetraodontiformes	Balistidae	*Pseudobalistes fuscus*	(Bloch & Schneider, 1801)	
1	1		Tetraodontiformes	Balistidae	*Sufflamen fraenatum*	(Latreille, 1804)	
1	1		Tetraodontiformes	Balistidae	*Xanthichthys lineopunctatus*	(Hollard, 1854)	
1	1		Tetraodontiformes	Monacanthidae	*Aluterus monoceros*	(Linnaeus, 1758)	
1	1		Tetraodontiformes	Monacanthidae	*Eubalichthys caeruleoguttatus*	Hutchins, 1977	
1	No		Tetraodontiformes	Monacanthidae	*Paramonacanthus filicauda*	(Günther, 1880)	
1	1		Tetraodontiformes	Monacanthidae	*Paramonacanthus oblongus*	(Schlegel, 1850)	
1	1		Tetraodontiformes	Monacanthidae	*Pseudomonacanthus peroni*	(Hollard, 1854)	
1	1		Tetraodontiformes	Ostraciidae	*Lactoria diaphana*	(Bloch & Schneider, 1801)	
1	1		Tetraodontiformes	Ostraciidae	*Ostracion nasus*	Bloch, 1785	
1	1		Tetraodontiformes	Ostraciidae	*Ostracion rhinorhynchus*	Bleeker, 1852	
1	1		Tetraodontiformes	Ostraciidae	*Tetrosomus gibbosus*	(Linnaeus, 1758)	
1	No		Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	(Bloch & Schneider, 1801)	
1	No	1a	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	(Anonymous, 1798)	
1	1		Tetraodontiformes	Tetraodontidae	*Canthigaster rivulata*	(Temminck & Schlegel, 1850)	
1	No		Tetraodontiformes	Tetraodontidae	*Lagocephalus inermis*	(Temminck & Schlegel, 1847)	
1	1	1a	Tetraodontiformes	Tetraodontidae	*Lagocephalus lunaris*	(Bloch & Schneider, 1801)	

1	1		Tetraodontiformes	Tetraodontidae	*Lagocephalus sceleratus*	(Gmelin, 1789)	
1	1		Tetraodontiformes	Tetraodontidae	*Torquigener pallimaculatus*	Hardy, 1983	
1	1		Tetraodontiformes	Tetraodontidae	*Torquigener parcuspinus*	Hardy, 1983	
1	No		Tetraodontiformes	Tetraodontidae	*Torquigener tuberculiferus*	(Ogilby, 1912)	
1	No		Tetraodontiformes	Tetraodontidae	*Tylerius spinosissimus*	(Regan, 1908)	
1	1		Tetraodontiformes	Diodontidae	*Cyclichthys orbicularis*	(Bloch, 1785)	
1	No		Tetraodontiformes	Diodontidae	*Cyclichthys spilostylus*	(Leis & Randall, 1982)	
1	1		Tetraodontiformes	Diodontidae	*Diodon holocanthus*	Linnaeus, 1758	
1	1		Tetraodontiformes	Diodontidae	*Lophodiodon calori*	(Bianconi, 1854)	
1	1		Tetraodontiformes	Diodontidae	*Tragulichthys jaculiferus*	(Cuvier, 1818)	

Appendix C Invertebrate diversity tables

Apx Table C 1. Table of Porifera (sponge) records from the survey area from ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
DEMOSPONGIAE				
Agelasida	Agelasidae	*Amphinomia sulphurea*	Hooper, 1991	
Axinellida	Axinellidae	*Axinella aruensis*	(Hentschel, 1912)	
Axinellida	Axinellidae	*Phakellia carduus*	(Lamarck, 1814)	
Axinellida	Axinellidae	*Phakellia dendyi*	Bergquist, 1970	
Axinellida	Axinellidae	*Phakellia tropicalis*	Alvarez & Hooper, 2009	*
Axinellida	Axinellidae	*Reniochalina stalagmitis*	Lendenfeld, 1888	
Axinellida	Raspailiidae	*Ceratopsion axifera*	(Hentschel, 1912)	
Axinellida	Raspailiidae	*Echinodictyum cancellatum*	(Lamarck, 1814)	
Axinellida	Raspailiidae	*Echinodictyum clathrioides*	Hentschel, 1911	
Axinellida	Raspailiidae	*Echinodictyum conulosum*	Kieschnick, 1898	
Axinellida	Raspailiidae	*Echinodictyum mesenterinum*	(Lamarck, 1814)	
Axinellida	Raspailiidae	*Echinodictyum rugosum*	Ridley & Dendy, 1886	*
Axinellida	Raspailiidae	*Ectyoplasia tabula*	(Lamarck, 1814)	
Axinellida	Raspailiidae	*Endectyon thurstoni*	(Dendy, 1887)	
Axinellida	Raspailiidae	*Raspailia compressa*	Bergquist, 1970	*
Axinellida	Raspailiidae	*Raspailia elegans*	(Lendenfeld, 1887)	
Axinellida	Raspailiidae	*Raspailia wardi*	Hooper, 1991	

Axinellida	Raspailiidae	*Thrinacophora cervicornis*	Ridley & Dendy, 1886	
Axinellida	Raspailiidae	*Trikentrion flabelliforme*	Carter, 1882	
Axinellida	Stelligeridae	*Higginsia mixta*	Hentschel, 1912	
Biemnida	Biemnidae	*Biemna saucia*	Hooper, Capon & Hodder, 1991	*
Biemnida	Biemnidae	*Sigmaxinella soelae*	Hooper, 1984	
Bubarida	Dictyonellidae	*Acanthella cavernosa*	Dendy, 1922	
Bubarida	Dictyonellidae	*Acanthella dendyi*	Bergquist, 1970	
Bubarida	Dictyonellidae	*Phakettia euctimena*	(Hentschel, 1912)	
Clionaida	Clionaidae	*Spheciospongia vagabunda*	(Ridley, 1884)	
Clionaida	Spirastrellidae	*Spirastrella* sp.		
Dictyoceratida	Irciniidae	*Ircinia* sp.		
Dictyoceratida	Irciniidae	*Psammocinia* sp.		
Dictyoceratida	Spongiidae	*Coscinoderma* sp.		
Dictyoceratida	Spongiidae	*Hippospongia* sp.		
Dictyoceratida	Spongiidae	*Hyattella intestinalis*	(Lamarck, 1814)	
Dictyoceratida	Spongiidae	*Spongia* sp.		
Dictyoceratida	Thorectidae	*Aplysinopsis* sp.		
Dictyoceratida	Thorectidae	*Carteriospongia* sp.		
Dictyoceratida	Thorectidae	*Dactylospongia* sp.		
Dictyoceratida	Thorectidae	*Fasciospongia* sp.		
Dictyoceratida	Thorectidae	*Hyrtios* sp.		
Dictyoceratida	Thorectidae	*Luffariella* sp.		
Dictyoceratida	Thorectidae	*Phyllospongia* sp.		
Dictyoceratida	Thorectidae	*Thorectandra excavatus*	(Ridley, 1884)	
Haplosclerida	Callyspongiidae	*Callyspongia schulzei*	(Kieschnick, 1900)	
Haplosclerida	Chalinidae	*Haliclona* sp.		
Haplosclerida	Niphatidae	*Amphimedon* sp.		
Haplosclerida	Niphatidae	*Cribrochalina* sp.		
Haplosclerida	Niphatidae	*Niphates* sp.		
Haplosclerida	Petrosiidae	*Acanthostrongylophora ashmorica*	Hooper, 1984	
Haplosclerida	Petrosiidae	*Petrosia* sp.		

Haplosclerida	Petrosiidae	*Xestospongia* sp.		
Haplosclerida	Phloeodictyidae	*Oceanapia* sp.		
Haplosclerida	Phloeodictyidae	*Siphonodictyon* sp.		
Poecilosclerida	Coelosphaeridae	*Coelosphaera* sp.		
Poecilosclerida	Crellidae	*Crella spinulata*	(Hentschel, 1911)	
Poecilosclerida	Desmacididae	*Desmacidon* sp.		
Poecilosclerida	Desmacididae	*Desmapsamma* sp.		
Poecilosclerida	Iotrochotidae	*Iotrochota baculifera*	Ridley, 1884	
Poecilosclerida	Microcionidae	*Clathria abietina*	(Lamarck, 1814)	
Poecilosclerida	Microcionidae	*Clathria cactiformis*	(Lamarck, 1814)	
Poecilosclerida	Microcionidae	*Clathria coppingeri*	(Ridley, 1884)	
Poecilosclerida	Microcionidae	*Clathria lendenfeldi*	Ridley & Dendy, 1886	
Poecilosclerida	Microcionidae	*Clathria major*	Hentschel, 1912	
Poecilosclerida	Microcionidae	*Clathria procera*	(Ridley, 1884)	
Poecilosclerida	Microcionidae	*Clathria spinifera*	(Lindgren, 1897)	
Poecilosclerida	Myxillidae	*Psammochela psammodes*	(Hentschel, 1911)	
Suberitida	Halichondriidae	*Ciocalypta* sp.		
Suberitida	Halichondriidae	*Halichondria* sp.		
Suberitida	Halichondriidae	*Hymeniacidon* sp.		
Suberitida	Halichondriidae	*Spongosorites* sp.		*
Suberitida	Suberitidae	*Caulospongia amplexa*	Fromont, 1998	
Suberitida	Suberitidae	*Caulospongia perfoliata*	(Lamarck, 1814)	
Suberitida	Suberitidae	*Caulospongia plicata*	Saville Kent, 1871	
Suberitida	Suberitidae	*Homaxinella* sp.		*
Suberitida	Suberitidae	*Plicatellopsis* sp.		*
Suberitida	Suberitidae	*Suberites* sp.		
Tethyida	Hemiasterellidae	*Axos flabelliformis*	Carter, 1879	
Tethyida	Tethyidae	*Xenospongia patelliformis*	Gray, 1858	
Tetractinellida	Ancorinidae	*Disyringa dissimilis*	(Ridley, 1884)	
Tetractinellida	Ancorinidae	*Stelletta clavosa*	Ridley, 1884	

Tetractinellida	Geodiidae	*Geodia* sp.		
Tetractinellida	Tetillidae	*Cinachyra* sp.		
Tetractinellida	Tetillidae	*Cinachyrella australiensis*	(Carter, 1886)	
Tetractinellida	Tetillidae	*Cinachyrella enigmatica*	(Burton, 1934)	*
Tetractinellida	Tetillidae	*Craniella* sp.		
Verongiida	Aplysinellidae	*Aplysinella* sp.		*
Verongiida	Aplysinellidae	*Suberea ianthelliformis*	(Lendenfeld, 1888)	
Verongiida	Ianthellidae	*Ianthella basta*	(Pallas, 1766)	
Verongiida	Ianthellidae	*Ianthella flabelliformis*	(Pallas, 1766)	

Apx Table C 2. Table of Cnidaria (soft corals, hard corals, hydroids, seapens and zooanthids) records from the survey area ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
ANTHOZOA				
Alcyonacea	Acanthogorgiidae	*Acanthogorgia* sp.		
Alcyonacea	Acanthogorgiidae	*Anthogorgia* sp.		
Alcyonacea	Alcyoniidae	*Eleutherobia rubra*	(Brundin, 1896)	*
Alcyonacea	Alcyoniidae	*Lobophytum* sp.		
Alcyonacea	Alcyoniidae	*Sarcophyton* sp.		
Alcyonacea	Alcyoniidae	*Sinularia* sp.		
Alcyonacea	Anthothelidae	*Alertigorgia orientalis*	(Ridley, 1884)	
Alcyonacea	Anthothelidae	*Solenocaulon* sp.		
Alcyonacea	Clavulariidae	*Carijoa* sp.		
Alcyonacea	Ellisellidae	*Ctenocella pectinata*	(Pallas, 1766)	
Alcyonacea	Ellisellidae	*Dichotella* sp.		
Alcyonacea	Ellisellidae	*Ellisella* sp.		
Alcyonacea	Ellisellidae	*Junceella* sp.		
Alcyonacea	Ellisellidae	*Verrucella* sp.		

Alcyonacea	Ellisellidae	*Viminella* sp.		
Alcyonacea	Isididae	*Mopsea encrinula*	(Lamarck, 1815)	*
Alcyonacea	Melithaeidae	*Acabaria* sp.		
Alcyonacea	Melithaeidae	*Melithaea* sp.		
Alcyonacea	Melithaeidae	*Mopsella* sp.		
Alcyonacea	Nephtheidae	*Chromonephthea megasclera*	Van Ofwegen, 2005	
Alcyonacea	Nephtheidae	*Chromonephthea rubra*	(Kükenthal, 1910)	*
Alcyonacea	Nephtheidae	*Dendronephthya* sp.		
Alcyonacea	Nephtheidae	*Nephthea* sp.		
Alcyonacea	Nephtheidae	*Scleronephthya* sp.		
Alcyonacea	Nephtheidae	*Stereonephthya* sp.		
Alcyonacea	Nephtheidae	*Umbellulifera* sp.		
Alcyonacea	Nidaliidae	*Chironephthya* sp.		
Alcyonacea	Nidaliidae	*Nephthyigorgia* sp.		
Alcyonacea	Nidaliidae	*Siphonogorgia* sp.		
Alcyonacea	Paralcyoniidae	*Studeriotes* sp.		
Alcyonacea	Parisididae	*Parisis* sp.		
Alcyonacea	Plexauridae	*Astrogorgia* sp.		
Alcyonacea	Plexauridae	*Bebryce* sp.		
Alcyonacea	Plexauridae	*Dentomuricea* sp.		*
Alcyonacea	Plexauridae	*Echinogorgia* sp.		
Alcyonacea	Plexauridae	*Echinomuricea* sp.		
Alcyonacea	Plexauridae	*Euplexaura* sp.		
Alcyonacea	Plexauridae	*Menella* sp.		
Alcyonacea	Plexauridae	*Paramuricea* sp.		*
Alcyonacea	Plexauridae	*Paraplexaura* sp.		
Alcyonacea	Plexauridae	*Pseudothesea* sp.		*
Alcyonacea	Plexauridae	*Villogorgia* sp.		
Alcyonacea	Primnoidae	*Callogorgia* sp.		
Alcyonacea	Primnoidae	*Plumarella penna*	(Lamarck, 1815)	

Alcyonacea	Subergorgiidae	*Subergorgia suberosa*	(Pallas, 1766)	
Antipatharia	Antipathidae	*Antipathes* sp.		
Antipatharia	Antipathidae	*Cirrhipathes* sp.		
Pennatulacea	Pennatulidae	*Pteroeides* sp.		
Pennatulacea	Veretillidae	*Lituaria* sp.		*
Pennatulacea	Virgulariidae	*Scytalium martensii*	Kölliker, 1870	
Scleractinia	Caryophylliidae	*Polycyathus* sp.		
Scleractinia	Flabellidae	*Truncatoflabellum aculeatum*	(Milne Edwards & Haime, 1848)	
Scleractinia	Flabellidae	*Truncatoflabellum angiostomum*	(Folkeson, 1919)	
Scleractinia	Flabellidae	*Truncatoflabellum veroni*	Cairns, 1998	
Scleractinia	Rhizangiidae	*Culicia australiensis*	Hoffmeister, 1933	
Zoanthidea	Epizoanthidae	*Epizoanthus* sp.		
Zoanthidea	Parazoanthidae	*Parazoanthus* sp.		
Zoanthidea	Sphenopidae	*Sphenopus* sp.		
HYDROZOA				
Leptothecata	Aglaopheniidae	*Aglaophenia cupressina*	Lamouroux, 1816	
Leptothecata	Aglaopheniidae	*Gymnangium hians*	(Busk, 1852)	*
Leptothecata	Aglaopheniidae	*Gymnangium longicorne*	(Busk, 1852)	*
Leptothecata	Aglaopheniidae	*Lytocarpia angulosa*	(Lamarck, 1816)	
Leptothecata	Aglaopheniidae	*Macrorhynchia phoenicea*	(Busk, 1852)	
Leptothecata	Lafoeidae	*Filellum* sp.		*
Leptothecata	Lafoeidae	*Zygophylax* sp.		*
Leptothecata	Plumulariidae	*Nemertesia* sp.		*
Leptothecata	Plumulariidae	*Plumularia badia*	Kirchenpauer, 1876	
Leptothecata	Plumulariidae	*Polyplumaria bedoti*	(Billard, 1911)	*
Leptothecata	Plumulariidae	*Polyplumaria cornuta*	(Bale, 1884)	*
Leptothecata	Sertulariidae	*Diphasia mutulata*	(Busk, 1852)	*
Leptothecata	Sertulariidae	*Salacia tetracythara*	Lamouroux, 1816	*
Leptothecata	Thyroscyphidae	*Thyroscyphus torresii*	(Busk, 1852)	

Apx Table C 3. Table of Bryozoa records from the survey area from ALA records . (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
GYMNOLAEMATA				
Cheilostomata	Adeonidae	*Adeonella* sp.		
Cheilostomata	Flustridae	*Retiflustra* sp.		
Cheilostomata	Phidoloporidae	*Triphyllozoon arcuatum*	(MacGillivray, 1889)	

Apx Table C 4. Table of Annelid (Polychaete) records from the survey area from ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
POLYCHAETA				
Amphinomida	Amphinomidae	*Chloeia flava*	(Pallas, 1766)	
Phyllodocida	Nephtyidae	*Aglaophamus foliocirrata*	Rainer & Kaly, 1988	
Phyllodocida	Nephtyidae	*Aglaophamus victoriae*	Rainer & Kaly, 1988	
Phyllodocida	Nephtyidae	*Inermonephtys tetrophthalmos*	Rainer & Kaly, 1988	
Phyllodocida	Nephtyidae	*Micronephthys* sp.		
Phyllodocida	Nereididae	*Neanthes cricognatha*	(Ehlers, 1904)	
Phyllodocida	Nereididae	*Nicon* sp.		
Phyllodocida	Phyllodocidae	*Eteone platycephala*	Augener, 1913	
Phyllodocida	Phyllodocidae	*Eulalia* sp.		
Phyllodocida	Phyllodocidae	*Eumida trifasciata*	Eibye-Jacobsen, 1991	
Phyllodocida	Polynoidae	*Paralepidonotus indicus*	(Kinberg, 1856)	*
Phyllodocida	Sigalionidae	*Euthalenessa fimbriata*	(McIntosh, 1885)	*
Sabellida	Serpulidae	*Protula* sp.		

Sabellida	Serpulidae	*Serpula jukesii*	Baird, 1865	
Sabellida	Serpulidae	*Spirobranchus latiscapus*	(Marenzeller, 1885)	*
Terebellida	Polycirridae	*Amaeana apheles*	(Hutchings, 1974)	
Terebellida	Polycirridae	*Amaeana trilobata*	(Sars, 1863)	
Terebellida	Polycirridae	*Lysilla bilobata*	Hutchings & Glasby, 1986	
Terebellida	Terebellidae	*Lanice bidewa*	Hutchings & Glasby, 1988	
Terebellida	Terebellidae	*Loimia ingens*	(Grube, 1878)	
Terebellida	Terebellidae	*Pista curtiuncata*	Hartmann-Schröder, 1981	
Terebellida	Terebellidae	*Pista trunca*	Hutchings, 1977	
Terebellida	Trichobranchidae	*Trichobranchus torulosus*	Hutchings & Peart, 2000	

Apx Table C 5. Table of Mollusc records from the survey area from ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NSW Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
BIVALVIA				
Adapedonta	Hiatellidae	*Hiatella australis*	(Lamarck, 1818)	
Arcida	Arcidae	*Barbatia* sp.		
Arcida	Cucullaeidae	*Cucullaea labiata*	(Lightfoot, 1786)	
Arcida	Glycymerididae	*Glycymeris tenuicostata*	(Reeve, 1843)	
Arcida	Limopsidae	*Limopsis multistriata*	(Forsskål, 1775)	
Cardiida	Cardiidae	*Acrosterigma attenuatum*	(Sowerby, 1841)	
Cardiida	Cardiidae	*Acrosterigma transcendens*	(Melvill & Standen, 1899)	*
Cardiida	Cardiidae	*Afrocardium richardi*	(Audouin, 1826)	
Cardiida	Cardiidae	*Lunulicardia retusa*	(Linnaeus, 1767)	
Cardiida	Cardiidae	*Nemocardium bechei*	(Reeve, 1852)	*
Cardiida	Cardiidae	*Nemocardium probatum*	(Iredale, 1927)	
Cardiida	Cardiidae	*Vasticardium elongatum*	(Bruguière, 1789)	*

Cardiida	Galeommatidae	*Galeomma* sp.		*
Cardiida	Lasaeidae	*Rochefortia* sp.		
Cardiida	Mactridae	*Mactra iridescens*	Habe, 1958	
Cardiida	Psammobiidae	*Gari pulcherrima*	(Deshayes, 1855)	
Cardiida	Semelidae	*Theora nasuta*	Hedley, 1909	
Cardiida	Veneridae	*Antigona lamellaris*	Schumacher, 1817	
Cardiida	Veneridae	*Placamen retroversum*	(Deshayes, 1853)	
Carditida	Carditidae	*Cardita crassicosta*	Lamarck, 1819	
Carditida	Carditidae	*Centrocardita squamigera*	(Deshayes, 1832)	
Carditida	Condylocardiidae	*Warrana pellucida*	Middelfart, 2002	
Limida	Limidae	*Ctenoides annulata*	(Lamarck, 1819)	
Limida	Limidae	*Lima vulgaris*	(Link, 1807)	
Limida	Limidae	*Limea parvula*	Verco, 1908	
Limida	Limidae	*Limea torresiana*	(Smith, 1885)	
Lucinida	Lucinidae	*Divaricella irpex*	(E.A. Smith, 1885)	
Lucinida	Lucinidae	*Plicolucina flabellata*	Glover, Taylor & Slack-Smith, 2003	
Ostreida	Gryphaeidae	*Hyotissa* sp.		
Ostreida	Ostreidae	*Booneostrea subucula*	(Jousseaume in Lamy, 1925)	
Ostreida	Ostreidae	*Dendostrea folium*	(Linnaeus, 1758)	
Ostreida	Ostreidae	*Nicaisolopha tridacnaeformis*	(Cox, 1927)	*
Ostreida	Pteriidae	*Electroma physoides*	(Lamarck, 1819)	
Ostreida	Pteriidae	*Pteria* sp.		
Ostreida	Pteriidae	*Vulsella vulsella*	(Linnaeus, 1758)	
Pectinida	Pectinidae	*Amusium balloti*	(Bernardi, 1861)	
Pectinida	Pectinidae	*Annachlamys flabellata*	(Lamarck, 1819)	
Pectinida	Pectinidae	*Complicachlamys wardiana*	Iredale, 1939	
Pectinida	Pectinidae	*Cryptopecten nux*	(Reeve, 1853)	
Pectinida	Pectinidae	*Decatopecten strangei*	(Reeve, 1852)	
Pectinida	Pectinidae	*Glorichlamys quadrilirata*	(Lischke, 1870)	

Pectinida	Pectinidae	*Mimachlamys scabricostata*	(Sowerby, 1915)	
Pectinida	Pectinidae	*Pecten dijkstrai*	Duncan & Wilson, 2012	
Pectinida	Pectinidae	*Scaeochlamys livida*	(Lamarck, 1819)	
Pectinida	Pectinidae	*Semipallium dringi*	(Reeve, 1853)	
Pectinida	Pectinidae	*Serratovola pallula*	Dijkstra, 1998	
Pectinida	Pectinidae	*Ylistrum balloti*	Bernardi, 1861	
Pectinida	Plicatulidae	*Plicatula muricata*	Sowerby, 1873	
Pectinida	Propeamussiidae	*Parvamussium cristatellum*	(Dautzenberg & Bavay, 1912)	
Pectinida	Propeamussiidae	*Parvamussium retiolum*	Dijkstra, 1995	
Pectinida	Propeamussiidae	*Parvamussium scitulum*	(Smith, 1885)	
Pectinida	Spondylidae	*Spondylus sinensis*	Schreibers, 1793	
Pectinida	Spondylidae	*Spondylus victoriae*	Sowerby, 1860	
Trigoniida	Trigoniidae	*Neotrigonia* sp.		
Anomalodesmata	Verticordiidae	*Spinosipella deshayesiana*	(Fischer, 1862)	
CEPHALOPODA				
Octopoda	Argonautidae	*Argonauta hians*	Lightfoot, 1786	
Octopoda	Octopodidae	*Amphioctopus exannulatus*	(Norman, 1993)	
Octopoda	Octopodidae	*Octopus cyanea*	Gray, 1849	*
Sepiida	Sepiadariidae	*Sepiadarium auritum*	Robson, 1914	
Sepiida	Sepiadariidae	*Sepiadarium kochii*	Steenstrup, 1881	
Sepiida	Sepiadariidae	*Sepioloidea lineolata*	(Quoy & Gaimard, 1832)	*
Sepiida	Sepiidae	*Metasepia pfefferi*	(Hoyle, 1885)	
Sepiida	Sepiidae	*Sepia cottoni*	Adam, 1979	
Sepiida	Sepiidae	*Sepia elliptica*	Hoyle, 1885	
Sepiida	Sepiidae	*Sepia irvingi*	Meyer, 1909	
Sepiida	Sepiidae	*Sepia novaehollandiae*	Hoyle, 1909	*
Sepiida	Sepiidae	*Sepia papuensis*	Hoyle, 1885	
Sepiida	Sepiidae	*Sepia pharaonis*	Ehrenberg, 1831	
Sepiida	Sepiidae	*Sepia rhoda*	(Iredale, 1954)	
Sepiida	Sepiidae	*Sepia smithi*	Hoyle, 1885	
Sepiolida	Sepiolidae	*Euprymna* sp.		

Teuthida	Loliginidae	*Loligo* sp.		
Teuthida	Loliginidae	*Uroteuthis edulis*	(Hoyle, 1885)	
SCAPHOPODA				
Dentaliida	Calliodentaliidae	*Calliodentalium crocinum*	(Dall, 1907)	*
Dentaliida	Dentaliidae	*Dentalium aprinum*	Linnaeus, 1767	
Dentaliida	Dentaliidae	*Dentalium exmouthensis*	Lamprell & Healy, 1998	
Dentaliida	Dentaliidae	*Dentalium formosum*	Adams & Reeve, 1850	
Dentaliida	Dentaliidae	*Striodentalium thetidis*	(Hedley, 1903)	
Dentaliida	Fustiariidae	*Fustiaria caesura*	(Colman, 1958)	*
Dentaliida	Fustiariidae	*Fustiaria stenoschiza*	(Pilsbry & Sharp, 1897)	
Dentaliida	Laevidentaliidae	*Laevidentalium erectum*	(Sowerby, 1860)	*
Dentaliida	Laevidentaliidae	*Laevidentalium lubricatum*	(Sowerby, 1860)	
Dentaliida	Laevidentaliidae	*Laevidentalium marshae*	Lamprell & Healy, 1998	
Gadilida	Gadilidae	*Dischides prionotus*	(Watson, 1879)	
GASTROPODA				
Cephalaspidea	Philinidae	*Philine* sp.		
Cerithimorpha	Dialidae	*Paradiala* sp.		
Cerithimorpha	Siliquariidae	*Tenagodus* sp.		
Cerithimorpha	Turritellidae	*Archimediella fastigiata*	(Adams & Reeve, 1850)	
Cerithimorpha	Turritellidae	*Haustator cingulifera*	(Sowerby, 1825)	
Hypsogastropoda	Atlantidae	*Atlanta peronii*	Lesueur, 1817	
Hypsogastropoda	Borsoniidae	*Tomopleura* sp.		
Hypsogastropoda	Bursidae	*Bufonaria margaritula*	(Deshayes, 1832)	
Hypsogastropoda	Bursidae	*Bufonaria rana*	(Linnaeus, 1758)	
Hypsogastropoda	Bursidae	*Bursa granularis*	(Röding, 1798)	
Hypsogastropoda	Cancellariidae	*Trigonostoma thysthlon*	Petit & Harasewych, 1987	*
Hypsogastropoda	Cancellariidae	*Tritonoharpa antiquata*	(Reeve, 1844)	
Hypsogastropoda	Capulidae	*Capulus danieli*	(Crosse, 1858)	
Hypsogastropoda	Cassidae	*Semicassis angasi*	(Iredale, 1927)	
Hypsogastropoda	Cassidae	*Semicassis bisulcata*	(Schubert & Wagner, 1829)	

Hypsogastropoda	Clathurellidae	*Etrema spurca*	(Hinds, 1843)	
Hypsogastropoda	Clavatulidae	*Turricula nelliae*	(E.A. Smith, 1877)	
Hypsogastropoda	Columbellidae	*Mitrella merita*	(Brazier, 1877)	
Hypsogastropoda	Columbellidae	*Zafra succinea*	(Hervier, 1899)	
Hypsogastropoda	Conidae	*Conasprella longurionis*	(Kiener, 1850)	
Hypsogastropoda	Conidae	*Conus dampierensis*	Filmer & Coomans, 1985	
Hypsogastropoda	Conidae	*Conus trigonus*	Reeve, 1848	
Hypsogastropoda	Conidae	*Conus voluminalis*	Reeve, 1843	
Hypsogastropoda	Costellariidae	*Vexillum modestum*	(Reeve, 1845)	
Hypsogastropoda	Cymatiidae	*Cymatium pfeifferianum*	(Reeve, 1844)	
Hypsogastropoda	Cymatiidae	*Gyrineum lacunatum*	(Mighels, 1845)	
Hypsogastropoda	Cymatiidae	*Gyrineum pulchellum*	(Sowerby, 1825)	
Hypsogastropoda	Cymatiidae	*Monoplex comptus*	(Adams, 1855)	
Hypsogastropoda	Cymatiidae	*Ranularia sinensis*	(Reeve, 1844)	
Hypsogastropoda	Cymatiidae	*Turritriton labiosus*	(Wood, 1828)	
Hypsogastropoda	Cypraeidae	*Contradusta walkeri*	(Sowerby, 1832)	
Hypsogastropoda	Cypraeidae	*Erronea subviridis*	(Reeve, 1835)	
Hypsogastropoda	Cystiscidae	*Cystiscus angasi*	(Crosse, 1870)	
Hypsogastropoda	Cystiscidae	*Cystiscus melwardi*	(Laseron, 1957)	
Hypsogastropoda	Cystiscidae	*Gibberula compressa*	(Laseron, 1957)	
Hypsogastropoda	Drilliidae	*Conopleura striata*	Hinds, 1844	*
Hypsogastropoda	Enophoridae	*Onustus indicus*	(Gmelin, 1791)	
Hypsogastropoda	Enophoridae	*Stellaria chinensis*	(Philippi, 1841)	
Hypsogastropoda	Enophoridae	*Xenophora solarioides*	(Reeve, 1845)	
Hypsogastropoda	Epitoniidae	*Eglisia tricarinata*	Adams & Reeve, 1850	
Hypsogastropoda	Eratoidae	*Alaerato angistoma*	G.B. Sowerby II, 1832	*
Hypsogastropoda	Eratoidae	*Eratoena corrugata*	(Hinds, 1844)	
Hypsogastropoda	Fasciolariidae	*Fusinus colus*	(Linnaeus, 1758)	
Hypsogastropoda	Ficidae	*Ficus subintermedia*	(Orbigny, 1852)	
Hypsogastropoda	Harpidae	*Harpa articularis*	Lamarck, 1822	
Hypsogastropoda	Harpidae	*Morum* sp.		

Hypsogastropoda	Hipponicidae	*Cheilea* sp.		
Hypsogastropoda	Hipponicidae	*Hipponix* sp.		
Hypsogastropoda	Hipponicidae	*Malluvium devotus*	(Hedley, 1904)	
Hypsogastropoda	Mangeliidae	*Pseudorhaphitoma* sp.		
Hypsogastropoda	Marginellidae	*Dentimargo arvina*	(Laseron, 1957)	
Hypsogastropoda	Marginellidae	*Dentimargo tropica*	(Laseron, 1957)	
Hypsogastropoda	Marginellidae	*Dentimargo walkeri*	(Smith, 1899)	
Hypsogastropoda	Marginellidae	*Mesoginella brachia*	(Watson, 1886)	
Hypsogastropoda	Marginellidae	*Protoginella lavigata*	(Brazier, 1876)	
Hypsogastropoda	Marginellidae	*Volvarina rex*	(Laseron, 1957)	
Hypsogastropoda	Mitridae	*Imbricaria interlirata*	(Reeve, 1844)	
Hypsogastropoda	Mitridae	*Scabricola melvilli*	G.B. Sowerby II, 1882	
Hypsogastropoda	Muricidae	*Chicoreus cervicornis*	(Lamarck, 1822)	
Hypsogastropoda	Muricidae	*Ergalatax contracta*	(Reeve, 1846)	
Hypsogastropoda	Muricidae	*Favartia* sp.		*
Hypsogastropoda	Muricidae	*Murex acanthostephes*	Watson, 1883	
Hypsogastropoda	Muricidae	*Murex pecten*	Lightfoot, 1786	
Hypsogastropoda	Muricidae	*Orania* sp.		
Hypsogastropoda	Muricidae	*Pterochelus acanthopterus*	(Lamarck, 1816)	
Hypsogastropoda	Muricidae	*Pterynotus alatus*	(Röding, 1798)	
Hypsogastropoda	Muricidae	*Vokesimurex multiplicatus*	(Sowerby, 1895)	
Hypsogastropoda	Nassariidae	*Cyllene pulchella*	Adams & Reeve, 1850	
Hypsogastropoda	Nassariidae	*Nassaria acuminata*	(Reeve, 1844)	
Hypsogastropoda	Nassariidae	*Nassarius albescens*	(Dunker, 1846)	
Hypsogastropoda	Nassariidae	*Nassarius splendidulus*	(Dunker, 1846)	
Hypsogastropoda	Nassariidae	*Nassarius subtranslucidus*	(Smith, 1903)	
Hypsogastropoda	Nassariidae	*Phos sculptilis*	Watson, 1886	
Hypsogastropoda	Nassariidae	*Phos senticosus*	(Linnaeus, 1758)	
Hypsogastropoda	Naticidae	*Eunaticina* sp.		
Hypsogastropoda	Naticidae	*Glyphepithema alapapilionis*	(Röding, 1798)	

Hypsogastropoda	Naticidae	*Mammilla simiae*	(Deshayes, 1838)	
Hypsogastropoda	Naticidae	*Neverita peselephanti*	(Link, 1807)	
Hypsogastropoda	Naticidae	*Polinices flemingianus*	(Récluz, 1844)	
Hypsogastropoda	Naticidae	*Tanea euzona*	(Récluz, 1844)	
Hypsogastropoda	Naticidae	*Tanea luculenta*	(Iredale, 1929)	*
Hypsogastropoda	Olividae	*Ancillista cingulata*	(Sowerby, 1830)	
Hypsogastropoda	Olividae	*Ancillista muscae*	(Pilsbry, 1926)	
Hypsogastropoda	Olividae	*Oliva australis*	Duclos, 1835	
Hypsogastropoda	Personidae	*Distorsio reticularis*	(Linnaeus, 1758)	
Hypsogastropoda	Pseudomelatomidae	*Inquisitor lassulus*	Hedley, 1922	
Hypsogastropoda	Pseudomelatomidae	*Inquisitor odhneri*	Wells, 1994	
Hypsogastropoda	Ranellidae	*Reticutriton pfeifferianus*	Reeve, 1844	
Hypsogastropoda	Raphitomidae	*Daphnella* sp.		
Hypsogastropoda	Seraphsidae	*Terebellum terebellum*	(Linnaeus, 1758)	
Hypsogastropoda	Strombidae	*Doxander campbelli*	Griffith & Pidgeon, 1834	
Hypsogastropoda	Terebridae	*Duplicaria australis*	(Smith, 1873)	
Hypsogastropoda	Terebridae	*Hastula* sp.		
Hypsogastropoda	Terebridae	*Hastulopsis conspersa*	(Hinds, 1844)	
Hypsogastropoda	Terebridae	*Terebra amanda*	Hinds, 1844	
Hypsogastropoda	Terebridae	*Terebra trismacaria*	Melvill, 1917	
Hypsogastropoda	Terebridae	*Triplostephanus triseriatus*	(Gray, 1834)	
Hypsogastropoda	Tonnidae	*Tonna* sp.		
Hypsogastropoda	Triviidae	*Cleotrivia* sp.		*
Hypsogastropoda	Triviidae	*Dolichupis producta*	(Gaskoin, 1836)	
Hypsogastropoda	Triviidae	*Trivirostra hyalina*	Schilder, 1933	*
Hypsogastropoda	Triviidae	*Trivirostra oryza*	(Lamarck, 1811)	
Hypsogastropoda	Turbinellidae	*Syrinx aruanus*	(Linnaeus, 1758)	
Hypsogastropoda	Turbinellidae	*Tudivasum inerme*	(Angas, 1878)	
Hypsogastropoda	Turridae	*Gemmula diomedea*	Powell, 1964	
Hypsogastropoda	Turridae	*Gemmula hastula*	Reeve, 1843	
Hypsogastropoda	Turridae	*Gemmula monilifera*	(Pease, 1861)	

Hypsogastropoda	Turridae	*Lophiotoma indica*	(Röding, 1798)	
Hypsogastropoda	Volutidae	*Amoria damonii*	Gray, 1864	
Hypsogastropoda	Volutidae	*Amoria ellioti*	(Sowerby, 1864)	
Hypsogastropoda	Volutidae	*Amoria praetexta*	(Reeve, 1849)	
Hypsogastropoda	Volutidae	*Cymbiola nivosa*	(Lamarck, 1804)	
Lepetellida	Fissurellidae	*Diodora jukesii*	(Reeve, 1850)	
Lepetellida	Fissurellidae	*Diodora ticaonica*	(Reeve, 1850)	
Lepetellida	Fissurellidae	*Emarginula incisura*	A. Adams, 1852	
Nudibranchia	Arminidae	*Dermatobranchus* sp.		
Nudibranchia	Tritoniidae	*Tritonia* sp.		
Pleurobranchida	Pleurobranchidae	*Pleurobranchaea brockii*	Bergh, 1897	*
Pteropoda	Cavoliniidae	*Diacavolinia longirostris*	(Blainville, 1821)	
Pteropoda	Limacinidae	*Limacina bulimoides*	(d'Orbigny, 1836)	
Seguenziida	Chilodontaidae	*Hybochelus cancellatus*	(Krauss, 1848)	
Trochida	Calliostomatidae	*Laetifautor monilis*	(Reeve, 1863)	
Trochida	Solariellidae	*Solariella* sp.		*
Heterostropha	Mathildidae	*Mathilda* sp.		*

Apx Table C 6. Table of Echinoderm records from the survey area from ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	*SCIENTIFIC_NAME*	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
ASTEROIDEA				
Forcipulatida	Zoroasteridae	*Pholidaster squamatus*	Sladen, 1889	
Paxillosida	Astropectinidae	*Astropecten polyacanthus*	Müller & Troschel, 1842	
Paxillosida	Astropectinidae	*Astropecten zebra*	Sladen, 1883	
Paxillosida	Luidiidae	*Luidia maculata*	Müller & Troschel, 1842	
Spinulosida	Echinasteridae	*Echinaster stereosomus*	Fisher, 1913	
Spinulosida	Echinasteridae	*Metrodira subulata*	Gray, 1840	
Valvatida	Goniasteridae	*Anthenoides dubius*	H.L. Clark, 1938	
Valvatida	Goniasteridae	*Mediaster* sp.		
Valvatida	Goniasteridae	*Milteliphaster regenerator*	(Döderlein, 1922)	
Valvatida	Goniasteridae	*Rosaster nannus*	Fisher, 1913	*
Valvatida	Goniasteridae	*Stellaster equestris*	(Retzius, 1805)	
Valvatida	Ophidiasteridae	*Hacelia helicosticha*	(Sladen, 1889)	
Valvatida	Ophidiasteridae	*Heteronardoa carinata*	(Koehler, 1910)	
Valvatida	Ophidiasteridae	*Tamaria* sp.		
Valvatida	Oreasteridae	*Anthenea pentagonula*	(Lamarck, 1816)	
Valvatida	Oreasteridae	*Goniodiscaster granuliferus*	(Gray, 1847)	
Valvatida	Oreasteridae	*Pentaceraster gracilis*	(Lütken, 1871)	
Velatida	Pterasteridae	*Euretaster insignis*	(Sladen, 1882)	
CRINOIDEA				
Comatulida	Asterometridae	*Pterometra trichopoda*	(A.H. Clark, 1908)	
Comatulida	Calometridae	*Neometra conaminis*	A.H. Clark, 1914	
Comatulida	Calometridae	*Neometra diana*	(A.H. Clark, 1912)	
Comatulida	Comatulidae	*Capillaster multiradiata*	(Linnaeus, 1758)	
Comatulida	Comatulidae	*Capillaster sentosa*	(Carpenter, 1888)	
Comatulida	Comatulidae	*Clarkcomanthus alternans*	(Carpenter, 1881)	

Comatulida	Comatulidae	*Comanthus briareus*	(Bell, 1882)	
Comatulida	Comatulidae	*Comaster multifidus*	(Müller, 1841)	
Comatulida	Comatulidae	*Comaster schlegelii*	(Carpenter, 1881)	
Comatulida	Comatulidae	*Comatula pectinata*	(Linnaeus, 1758)	
Comatulida	Comatulidae	*Comatula purpurea*	Mï¿½ller, 1843	
Comatulida	Comatulidae	*Comatula rotalaria*	(Lamarck, 1816)	
Comatulida	Comatulidae	*Comatula solaris*	Lamarck, 1816	
Comatulida	Comatulidae	*Phanogenia multibrachiatus*	(Carpenter, 1888)	*
Comatulida	Himerometridae	*Amphimetra tessellata*	(Müller, 1841)	
Comatulida	Himerometridae	*Heterometra crenulata*	(Carpenter, 1882)	
Comatulida	Zygometridae	*Zygometra andromeda*	A.H. Clark, 1912	
Comatulida	Zygometridae	*Zygometra comata*	A.H. Clark, 1911	
Comatulida	Zygometridae	*Zygometra microdiscus*	(Bell, 1882)	
ECHINOIDEA				
Camarodonta	Temnopleuridae	*Salmaciella dussumieri*	(L. Agassiz, 1846)	
Camarodonta	Temnopleuridae	*Salmacis belli*	Döderlein, 1902	
Camarodonta	Temnopleuridae	*Temnopleurus* sp.		
Cidaroida	Cidaridae	*Prionocidaris baculosa*	(Lamarck, 1816)	
Cidaroida	Cidaridae	*Prionocidaris bispinosa*	(Lamarck, 1816)	
Clypeasteroida	Echinocyamidae	*Echinocyamus crispus*	Mazzetti, 1894	
Clypeasteroida	Echinocyamidae	*Echinocyamus provectus*	De Meijere, 1904	*
Clypeasteroida	Fibulariidae	*Fibularia cribrellum*	De Meijere, 1904	
Clypeasteroida	Fibulariidae	*Fibularia ovulum*	Lamarck, 1816	
Clypeasteroida	Fibulariidae	*Fibulariella acuta*	Yoshiwara, 1898	
Clypeasteroida	Fibulariidae	*Fibulariella oblonga*	Gray, 1851	
Clypeasteroida	Laganidae	*Peronella lesueuri*	(Valenciennes, 1841)	
Echinothurioida	Echinothuriidae	*Asthenosoma intermedium*	H.L. Clark, 1938	*
Echinothurioida	Echinothuriidae	*Asthenosoma varium*	Grube, 1868	
HOLOTHUROIDEA				
Dendrochirotida	Cucumariidae	*Loisettea amphictena*	Rowe & Pawson, 1985	

Dendrochirotida	Cucumariidae	*Plesiocolochirus dispar*	(Lampert, 1889)	*
Dendrochirotida	Cucumariidae	*Plesiocolochirus spinosus*	(Quoy & Gaimard, 1833)	*
OPHIUROIDEA				
Euryalida	Euryalidae	*Astrobrachion adhaerens*	(Studer, 1884)	
Euryalida	Euryalidae	*Astroceras pergamena*	Lyman, 1879	*
Euryalida	Euryalidae	*Euryale aspera*	(Lamarck, 1816)	
Euryalida	Gorgonocephalidae	*Astroboa nigrofurcata*	Döderlein, 1927	
Euryalida	Gorgonocephalidae	*Astroboa nuda*	(Lyman, 1874)	
Euryalida	Gorgonocephalidae	*Astroglymma sculptum*	(Döderlein, 1896)	
Euryalida	Gorgonocephalidae	*Astroglymna sculptum*	Dï¿½derlein, 1896	
Ophiurida	Ophiacanthidae	*Ophiacantha dallasi*	(Duncan, 1879)	
Ophiurida	Ophiactidae	*Ophiactis macrolepidota*	Marktanner-Turneretscher, 1887	
Ophiurida	Ophiactidae	*Ophiactis savignyi*	(Müller & Troschel, 1842)	
Ophiurida	Ophiodermatidae	*Ophiochasma stellata*	(Ljungman, 1867)	
Ophiurida	Ophiodermatidae	*Ophiopsammus yoldii*	(Lütken, 1856)	
Ophiurida	Ophiolepididae	*Ophiolepis unicolor*	H.L. Clark, 1938	
Ophiurida	Ophiotrichidae	*Macrophiothrix megapoma*	H.L. Clark, 1938	
Ophiurida	Ophiotrichidae	*Macrophiothrix obtusa*	(Koehler, 1905)	
Ophiurida	Ophiotrichidae	*Ophiogymna elegans*	Ljungman, 1866	
Ophiurida	Ophiotrichidae	*Ophiogymna pellicula*	(Duncan, 1887)	
Ophiurida	Ophiotrichidae	*Ophiogymna pulchella*	(Koehler, 1905)	
Ophiurida	Ophiotrichidae	*Ophiomaza cacaotica*	Lyman, 1871	
Ophiurida	Ophiotrichidae	*Ophiothela danae*	Verrill, 1869	
Ophiurida	Ophiotrichidae	*Ophiothrix melanosticta*	Grube, 1868	
Ophiurida	Ophiuridae	*Dictenophiura stellata*	(Studer, 1882)	

Apx Table C 7. Table of Arthropod (Crustacean and sea spider) records from the survey area from ALA records. (*denotes taxa recorded in the survey area and not recorded elsewhere in the IMCRA NWS Province)

CLASS/ORDER	FAMILY	SCIENTIFIC_NAME	AUTHORITY	Not recorded elsewhere in IMCRA NWS Province
MALACOSTRACA				
Amphipoda	Amaryllididae	*Bamarooka dinjerra*	Lowry & Stoddart, 2002	
Amphipoda	Caprellidae	*Metaprotella sandalensis*	Mayer, 1898	
Amphipoda	Caprellidae	*Metaproto novaehollandiae*	(Haswell, 1879)	*
Amphipoda	Caprellidae	*Protella similis*	Mayer, 1903	
Amphipoda	Caprellidae	*Pseudoprotella soela*	Guerra-Garcia, 2004	
Amphipoda	Endevouridae	*Endevoura inusitata*	Lowry & Hughes, 2015	
Amphipoda	Ischyroceridae	*Ambicholestes minutus*	Just, 1998	*
Amphipoda	Ischyroceridae	*Cerapus* sp.		
Amphipoda	Lysianassidae	*Photosella miersi*	(Stebbing, 1888)	*
Amphipoda	Lysianassidae	*Photosella mucronata*	(Pirlot, 1936)	
Amphipoda	Lysianassidae	*Waldeckia enoei*	Stephensen, 1931	
Amphipoda	Phoxocephalidae	*Birubius jirrandus*	J.L. Barnard & Drummond, 1978	
Amphipoda	Phoxocephalidae	*Birubius lowannus*	J.L. Barnard & Drummond, 1978	
Amphipoda	Synopiidae	*Pseudotiron* sp.		
Amphipoda	Synopiidae	*Tiron* sp.		
Amphipoda	Uristidae	*Ichnopus tenuicornis*	(Haswell, 1879)	
Amphipoda	Uristidae	*Ichnopus wardi*	Lowry & Stoddart, 1992	
Cumacea	Bodotriidae	*Cyclaspis* sp.		
Cumacea	Bodotriidae	*Glyphocuma* sp.		
Cumacea	Bodotriidae	*Pomacuma* sp.		
Cumacea	Bodotriidae	*Zenocuma* sp.		
Cumacea	Gynodiastylidae	*Allodiastylis* sp.		
Cumacea	Gynodiastylidae	*Gynodiastylis insolitaseta*	Gerken, 2001	

Cumacea	Gynodiastylidae	*Gynodiastylis nordaustraliana*	Bacescu, 1991	*
Cumacea	Gynodiastylidae	*Litogynodiastylis ornata*	(Hale, 1946)	
Cumacea	Lampropidae	*Hemilamprops latus*	Hale, 1946	*
Cumacea	Nannastacidae	*Campylaspis aspera*	Hale, 1945	*
Cumacea	Nannastacidae	*Campylaspis pileus*	(Foxon, 1932)	*
Cumacea	Nannastacidae	*Campylaspis wardi*	Bacescu, 1991	
Decapoda	Albuneidae	*Albunea* sp.		
Decapoda	Albuneidae	*Austrolepidopa caledonia*	Boyko & Harvey, 1999	
Decapoda	Albuneidae	*Austrolepidopa trigonops*	Efford & Haig, 1968	
Decapoda	Albuneidae	*Paralbunea dayriti*	(Serène & Umali, 1965)	
Decapoda	Albuneidae	*Stemonopa insignis*	Efford & Haig, 1968	
Decapoda	Alpheidae	*Alpheus edwardsii*	(Audouin, 1827)	
Decapoda	Alpheidae	*Alpheus eulimene*	de Man, 1909	*
Decapoda	Alpheidae	*Alpheus pareuchirus*	Coutière, 1905	*
Decapoda	Alpheidae	*Synalpheus dorae*	Bruce, 1988	
Decapoda	Alpheidae	*Synalpheus iocasta*	De Man, 1909	
Decapoda	Alpheidae	*Synalpheus neomeris*	(de Man, 1897)	
Decapoda	Alpheidae	*Synalpheus neptunus*	(Dana, 1852)	*
Decapoda	Alpheidae	*Synalpheus pococki*	Coutière, 1898	
Decapoda	Alpheidae	*Synalpheus quadriarticulatus*	Banner & Banner, 1975	*
Decapoda	Alpheidae	*Synalpheus stimpsonii*	(De Man, 1888)	
Decapoda	Alpheidae	*Synalpheus streptodactylus*	Coutière, 1905	
Decapoda	Anchistioididae	*Anchistioides* sp.		
Decapoda	Anthidae	*Actaea carcharias*	White, 1848	
Decapoda	Anthidae	*Actaea hystrix*	Miers, 1886	
Decapoda	Anthidae	*Actaea tuberculosa*	(Miers, 1884)	
Decapoda	Anthidae	*Actaeodes* sp.		
Decapoda	Anthidae	*Atergatopsis tweediei*	(Ward, 1934)	
Decapoda	Anthidae	*Banareia inconspicua*	Miers, 1884	*
Decapoda	Anthidae	*Hypocolpus maculatus*	(Haswell, 1882)	
Decapoda	Anthidae	*Liomera cinctimana*	(White, 1847)	

Decapoda	Anthidae	*Medaeops granulosus*	(Haswell, 1882)	
Decapoda	Anthidae	*Neoxanthops* sp.		
Decapoda	Anthidae	*Paraetisus globulus*	Ward, 1933	
Decapoda	Aristeidae	*Aristeus virilis*	(Spence Bate, 1881)	*
Decapoda	Axiidae	*Axiopsis consobrina*	de Man, 1905	*
Decapoda	Axiidae	*Spongiaxius brucei*	(Sakai, 1986)	*
Decapoda	Calappidae	*Calappa capellonis*	Laurie, 1906	
Decapoda	Calappidae	*Calappa philargius*	(Linnaeus, 1758)	
Decapoda	Calappidae	*Calappa woodmasoni*	Alcock, 1896	
Decapoda	Callianassidae	*Callianassa acutirostella*	(Sakai, 1988)	*
Decapoda	Callianassidae	*Callianassa parvula*	Sakai, 1988	*
Decapoda	Chlorotocellidae	*Chlorotocella gracilis*	Balss, 1914	
Decapoda	Corystidae	*Gomeza bicornis*	Gray, 1831	
Decapoda	Corystidae	*Jonas leuteanus*	Ward, 1933	
Decapoda	Crangonidae	*Aegaeon* sp.		
Decapoda	Crangonidae	*Philocheras angustirostris*	(De Man, 1918)	
Decapoda	Crangonidae	*Philocheras brucei*	Komai, 2004	
Decapoda	Crangonidae	*Philocheras incisus*	(Kemp, 1916)	
Decapoda	Crangonidae	*Philocheras lowisi*	(Kemp, 1916)	
Decapoda	Crangonidae	*Philocheras plebs*	(Kemp, 1916)	
Decapoda	Diogenidae	*Dardanus callichela*	Cook, 1989	
Decapoda	Dromiidae	*Cryptodromia* sp.		
Decapoda	Dromiidae	*Desmodromia tranterae*	McLay, 2001	
Decapoda	Dromiidae	*Lauridromia dehaani*	Rathbun, 1923	
Decapoda	Epialtidae	*Acanthophrys* sp.		
Decapoda	Epialtidae	*Hyastenus convexus*	Miers, 1884	
Decapoda	Epialtidae	*Naxioides* sp.		
Decapoda	Epialtidae	*Phalangipus* sp.		
Decapoda	Galatheidae	*Allogalathea elegans*	(Adams & White, 1848)	
Decapoda	Galatheidae	*Allogalathea longimana*	Cabezas, Macpherson & Machordom, 2011	

Decapoda	Galatheidae	*Galathea* sp.		
Decapoda	Glyphocrangonidae	*Glyphocrangon* sp.		*
Decapoda	Hippolytidae	*Tozeuma armatum*	Paulson, 1875	
Decapoda	Hippolytidae	*Tozeuma tomentosum*	(Baker, 1904)	
Decapoda	Homolidae	*Paromolopsis boasi*	Wood-Mason in Wood-Mason & Alcock, 1891	*
Decapoda	Inachidae	*Achaeus* sp.		
Decapoda	Inachidae	*Oncinopus angustifrons*	Takeda & Myake, 1969	
Decapoda	Inachidae	*Oncinopus kathae*	Davie, 2011	
Decapoda	Leucosiidae	*Alox ornatum*	(Ihle, 1918)	*
Decapoda	Leucosiidae	*Ixa* sp.		
Decapoda	Leucosiidae	*Leucosia* sp.		
Decapoda	Leucosiidae	*Myra affinis*	Bell, 1855	
Decapoda	Leucosiidae	*Myra eudactylus*	(Bell, 1855)	
Decapoda	Leucosiidae	*Myrine kessleri*	(Paulson, 1875)	
Decapoda	Leucosiidae	*Oreophorus* sp.		
Decapoda	Leucosiidae	*Urnalana pulchella*	(Bell, 1855)	
Decapoda	Leucosiidae	*Urnalana whitei*	(Bell, 1855)	
Decapoda	Lyreididae	*Lyreidus* sp.		*
Decapoda	Lysmatidae	*Lysmata multiscissa*	(Nobili, 1904)	*
Decapoda	Majidae	*Entomonyx sp.*		
Decapoda	Matutidae	*Izanami curtispina*	Sakai, 1961	
Decapoda	Matutidae	*Izanami inermis*	(Miers, 1884)	
Decapoda	Matutidae	*Matuta* sp.		
Decapoda	Nephropidae	*Metanephrops* sp.		*
Decapoda	Ogyrididae	*Ogyrides* sp.		*
Decapoda	Palaemonidae	*Ancylomenes kuboi*	Bruce, 2010	*
Decapoda	Palaemonidae	*Ancylomenes magnificus*	(Bruce, 1979)	
Decapoda	Palaemonidae	*Ancylomenes okunoi*	Bruce, 2010	
Decapoda	Palaemonidae	*Ancylomenes speciosus*	(Okuno, 2004)	
Decapoda	Palaemonidae	*Ancylomenes tosaensis*	(Kubo, 1951)	
Decapoda	Palaemonidae	*Carinopontonia paucipes*	Bruce, 1988	*

Decapoda	Palaemonidae	*Chernocaris placunae*	Johnson, 1967	*
Decapoda	Palaemonidae	*Cuapetes andamanensis*	(Kemp, 1922)	
Decapoda	Palaemonidae	*Cuapetes grandis*	(Stimpson, 1860)	
Decapoda	Palaemonidae	*Cuapetes nilandensis*	(Borradaile, 1915)	
Decapoda	Palaemonidae	*Dasycaris* sp.		*
Decapoda	Palaemonidae	*Lipkemenes lanipes*	(Kemp, 1922)	
Decapoda	Palaemonidae	*Manipontonia psamathe*	(de Man, 1902)	
Decapoda	Palaemonidae	*Miopontonia yongei*	Bruce, 1985	
Decapoda	Palaemonidae	*Palaemonella pottsi*	(Borradaile, 1915)	
Decapoda	Palaemonidae	*Palaemonella rotumana*	(Borradaile, 1898)	
Decapoda	Palaemonidae	*Periclimenaeus pachydentatus*	Bruce, 1969	
Decapoda	Palaemonidae	*Periclimenes affinis*	(Zehntner, 1894)	
Decapoda	Palaemonidae	*Periclimenes incertus*	Borradaile, 1915	
Decapoda	Palaemonidae	*Periclimenes pectiniferus*	Holthuis, 1952	
Decapoda	Palaemonidae	*Phyllognathia ceratophthalma*	(Balss, 1913)	
Decapoda	Palaemonidae	*Pontoniopsis comanthi*	Borradaile, 1915	
Decapoda	Palaemonidae	*Urocaridella urocaridella*	(Holthuis, 1950)	
Decapoda	Palicidae	*Neopalicus jukesii*	(White, 1847)	
Decapoda	Pandalidae	*Heterocarpus woodmasoni*	Alcock, 1901	
Decapoda	Pandalidae	*Plesionika pumila*	Chace, 1985	
Decapoda	Pandalidae	*Thalassocaris* sp.		
Decapoda	Parapaguridae	*Parapagurus* sp.		*
Decapoda	Parthenopidae	*Aulacolambrus hoplonotus*	(Adams & White, 1848)	*
Decapoda	Parthenopidae	*Cryptopodia dorsalis*	White & Adams, 1847	
Decapoda	Parthenopidae	*Cryptopodia pan*	Laurie, 1906	
Decapoda	Parthenopidae	*Parthenope chondrodes*	Davie & Turner, 1994	
Decapoda	Parthenopidae	*Parthenope longimanus*	(Linnaeus, 1758)	
Decapoda	Pasiphaeidae	*Leptochela japonica*	Hayashi & Miyake, 1969	*
Decapoda	Pasiphaeidae	*Leptochela robusta*	Stimpson, 1860	
Decapoda	Pasiphaeidae	*Leptochela soelae*	Hanamura, 1987	

Decapoda	Penaeidae	*Metapenaeopsis gallensis*	(Pearson, 1905)	
Decapoda	Penaeidae	*Metapenaeopsis mannarensis*	de Bruin, 1965	
Decapoda	Penaeidae	*Metapenaeopsis mogiensis*	Crosnier, 1991	
Decapoda	Penaeidae	*Metapenaeopsis toloensis*	Hall, 1962	
Decapoda	Penaeidae	*Metapenaeopsis wellsi*	Racek, 1967	
Decapoda	Penaeidae	*Penaeopsis eduardoi*	Pérez Farfante, 1977	
Decapoda	Pilumnidae	*Bathypilumnus pugilator*	(A. Milne Edwards, 1873)	
Decapoda	Pilumnidae	*Caecopilumnus* sp.		
Decapoda	Pilumnidae	*Eumedonus niger*	H. Milne Edwards, 1834	
Decapoda	Pilumnidae	*Harrovia elegans*	De Man, 1887	
Decapoda	Pilumnidae	*Harrovia tuberculata*	Haswell, 1880	*
Decapoda	Pilumnidae	*Heteropilumnus longisetum*	Davie & Humpherys, 1997	
Decapoda	Pilumnidae	*Pilumnus semilanatus*	Miers, 1884	
Decapoda	Pilumnidae	*Zebrida adamsi*	White, 1847	
Decapoda	Pilumnidae	*Zebrida longispina*	Haswell, 1880	*
Decapoda	Polybiidae	*Brusinia brucei*	Stevcic, 1991	
Decapoda	Porcellanidae	*Aliaporcellana suluensis*	(Dana, 1852)	
Decapoda	Porcellanidae	*Aliaporcellana telestophila*	Johnson, 1958	
Decapoda	Porcellanidae	*Lissoporcellana furcillata*	Haig, 1965	
Decapoda	Porcellanidae	*Lissoporcellana miyakei*	Haig, 1981	*
Decapoda	Porcellanidae	*Lissoporcellana quadrilobata*	(Miers, 1884)	
Decapoda	Porcellanidae	*Pachycheles sculptus*	(H. Milne Edwards, 1837)	
Decapoda	Porcellanidae	*Petrolisthes militaris*	(Heller, 1862)	
Decapoda	Porcellanidae	*Polyonyx biunguiculatus*	(Dana, 1852)	
Decapoda	Portunidae	*Charybdis* sp.		
Decapoda	Portunidae	*Cycloachelous orbitosinus*	(Rathbun, 1911)	
Decapoda	Portunidae	*Lissocarcinus laevis*	Miers, 1886	
Decapoda	Portunidae	*Lupocyclus inaequalis*	(Walker, 1887)	
Decapoda	Portunidae	*Lupocyclus philippinensis*	Semper, 1880	
Decapoda	Portunidae	*Lupocyclus rotundatus*	Adams & White, 1849	
Decapoda	Portunidae	*Lupocyclus tugelae*	Barnard, 1950	

Decapoda	Portunidae	*Podophthalmus nacreus*	Alcock, 1899	
Decapoda	Portunidae	*Portunus gracilimanus*	Stimpson, 1858	
Decapoda	Portunidae	*Portunus granulatus*	H. Milne Edwards, 1834	
Decapoda	Portunidae	*Portunus longispinosus*	Dana, 1852	
Decapoda	Portunidae	*Portunus rugosus*	A. Milne Edwards, 1861	
Decapoda	Portunidae	*Portunus tuberculosus*	A. Milne Edwards, 1861	
Decapoda	Portunidae	*Thalamita sexlobata*	Miers, 1886	
Decapoda	Portunidae	*Thalamita spinifera*	Borradaile, 1902	
Decapoda	Raninidae	*Cosmonotus grayi*	Adams & White, 1848	
Decapoda	Raninidae	*Notopus dorsipes*	(Linnaeus, 1758)	
Decapoda	Raninidae	*Notosceles serratifrons*	(Henderson, 1893)	
Decapoda	Raninidae	*Umalia trirufomaculata*	(Davie & Short, 1989)	
Decapoda	Rhynchocinetidae	*Rhynchocinetes* sp.		*
Decapoda	Scyllaridae	*Scyllarus* sp.		
Decapoda	Scyllaridae	*Thenus australiensis*	Burton & Davie, 2007	
Decapoda	Sergestidae	*Sicyonella inermis*	(Paulson, 1875)	*
Decapoda	Sicyoniidae	*Sicyonia lancifer*	(Olivier, 1811)	
Decapoda	Sicyoniidae	*Sicyonia ocellata*	Stimpson, 1860	*
Decapoda	Solenoceridae	*Haliporoides sibogae*	de Man, 1907	*
Decapoda	Solenoceridae	*Solenocera rathbuni*	Ramadan, 1938	
Decapoda	Stenopodidae	*Odontozona ensifera*	Dana, 1852	
Decapoda	Stenopodidae	*Stenopus hispidus*	(Olivier, 1811)	
Decapoda	Stylodactylidae	*Neostylodactylus amarynthis*	(de Man, 1902)	
Decapoda	Stylodactylidae	*Neostylodactylus investigatoris*	(Kemp, 1925)	*
Decapoda	Thalassocarididae	*Chlorotocoides spinicauda*	De Man, 1902	
Decapoda	Trapeziidae	*Quadrella coronata*	Dana, 1852	
Decapoda	Xanthidae	*Pseudactaea corallina*	Alcock, 1898	
Isopoda	Anthuridae	*Haliophasma beaufortia*	Poore & Lew Ton, 1988	
Isopoda	Anthuridae	*Haliophasma blandfordia*	Poore & Lew Ton, 1988	
Isopoda	Arcturidae	*Astacilla lewtonae*	King, 2003	

Isopoda	Arcturidae	*Neastacilla inaequispinosa*	(Guiler, 1949)	
Isopoda	Arcturidae	*Neastacilla lawadi*	King, 2003	
Isopoda	Austrarcturellidae	*Austrarcturella aphelura*	Poore & Bardsley, 1992	
Isopoda	Austrarcturellidae	*Austrarcturella pictila*	Poore & Bardsley, 1992	
Isopoda	Bopyridae	*Eophrixus* sp.		*
Isopoda	Bopyridae	*Pseudione* sp.		*
Isopoda	Chaetiliidae	*Stegidotea latipoda*	Poore, 1990	*
Isopoda	Cirolanidae	*Cartetolana integra*	(Miers, 1884)	
Isopoda	Cirolanidae	*Cirolana* sp.		
Isopoda	Cirolanidae	*Natatolana angula*	Bruce, 1986	
Isopoda	Cirolanidae	*Natatolana buzwilsoni*	Keable, 2006	
Isopoda	Cirolanidae	*Natatolana thalme*	Bruce, 1986	
Isopoda	Cirolanidae	*Natatolana vieta*	(Hale, 1925)	*
Isopoda	Cymothoidae	*Anilocra longicauda*	Schioedte & Meinert, 1881	
Isopoda	Cymothoidae	*Anilocra soelae*	Bruce, 1987	
Isopoda	Cymothoidae	*Ceratothoa* sp.		*
Isopoda	Gnathiidae	*Gnathia falcipenis*	Holdich & Harrison, 1980	*
Isopoda	Idoteidae	*Lyidotea nodata*	Hale, 1929	
Isopoda	Sphaeromatidae	*Agostodina munta*	Bruce, 1994	
Isopoda	Sphaeromatidae	*Chitonopsis* sp.		*
Isopoda	Sphaeromatidae	*Cilicaea* sp.		
Isopoda	Sphaeromatidae	*Paracassidina bakeri*	Bruce, 1994	
Isopoda	Sphaeromatidae	*Paracassidina dama*	Bruce, 1994	
Isopoda	Sphaeromatidae	*Paracassidina incompta*	Bruce, 1994	
Isopoda	Stenetriidae	*Stenetrium* sp.		
Stomatopoda	Odontodactylidae	*Odontodactylus japonicus*	(De Haan, 1844)	
Stomatopoda	Protosquillidae	*Chorisquilla convoluta*	Ahyong, 2001	
Stomatopoda	Protosquillidae	*Haptosquilla tuberosa*	(Pocock, 1893)	
Stomatopoda	Squillidae	*Alimopsoides tuberculatus*	Moosa, 1991	
Stomatopoda	Squillidae	*Busquilla plantei*	Manning, 1978	*
Stomatopoda	Squillidae	*Oratosquillina manningi*	Ahyong, Chan & Liao, 2000	

Stomatopoda	Squillidae	*Oratosquillina quinquedentata*	(Brooks, 1886)	
Tanaidacea	Apseudidae	*Apseudes* sp.		
Tanaidacea	Kalliapseudidae	*Transkalliapseudes spinulata*	Drumm & Heard, 2006	
Tanaidacea	Metapseudidae	*Julmarichardia gutui*	Ritger & Heard, 2007	*
Tanaidacea	Numbakullidae	*Numbakulla pymaeus*	Gutu & Heard, 2002	*
PYCNOGONIDA				
Pantopoda	Ammotheidae	*Achelia assimilis*	(Haswell, 1884)	
Pantopoda	Ammotheidae	*Achelia nana*	(Loman, 1908)	
Pantopoda	Ammotheidae	*Nymphopsis acinacispinatus*	Williams, 1933	*
Pantopoda	Ascorhynchidae	*Ascorhynchus* sp.		
Pantopoda	Callipallenidae	*Parapallene nierstraszi*	Loman, 1908	
Pantopoda	Callipallenidae	*Propallene* sp.		*
Pantopoda	Callipallenidae	*Pseudopallene zamboangae*	Stock, 1953	
Pantopoda	Nymphonidae	*Nymphon molleri*	Clark, 1963	*
Pantopoda	Nymphonidae	*Nymphon rottnesti*	Child, 1975	
Pantopoda	Pallenopsidae	*Pallenopsis cidaribatus*	Child, 1975	
Pantopoda	Phoxichilidiidae	*Anoplodactylus simplex*	Clark, 1963	*

Appendix D Digital Elevation Model (DEM) – detailed bathymetric model of the Santos Dorado development and surrounding areas

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DEM Production Report

Project: Santos Dorado Seabed Characterisation & Habitat Mapping

Compiled By: Chris Berry (GSM Group)

Compiled for: CSIRO Oceans and Atmosphere

Report No: OD-204222_DR2019_01

Revision History:

Revision	Description of change	Author	Date
0	First Issue	C. Berry	02-12-2019

Contents

Figures

1 Executive summary

CSIRO's Geophysical Survey & Mapping (GSM) team was contacted by John Keesing (Oceans & Atmosphere, CSIRO) on 31 October 2019 to prepare a Digital Elevation Model (DEM) for use in the Santos Dorado seabed habitat mapping project (R-14272). The DEM was to be utilized by CSIRO scientists to produce a seabed habitat map, description and regional evaluation which was to be included in Santos' Offshore Petroleum Proposal (OPP). The Dorado site is located approx. 160km North of Port Hedland, Western Australia.

The DEM of the Dorado site was created through combining bathymetry data from several sources. These sources included:

- Santos - Client issued data
- CSIRO - Data Trawler Archives
- Geoscience Australia - AusSeabed Marine Data Discovery
- Geoscience Australia - Australian Bathymetry and Topography Grid 2009

The bathymetry datasets of variable resolution and datums were combined to produce a model of uniform resolution and datum. The final DEM products were produced at a resolution of 0.001° on a horizontal datum of WGS84 (Geographic) & vertical datum of Mean Sea Level (MSL).

CARIS Base Editor was used to combine these datasets with Fledermaus being used for supplementary visualisation and analysis. The resolution of the final DEM was limited by the low resolution of the supplied and resourced bathymetry data covering the site.

Deliverables associated with the DEM included:

- XYZ file (*.xyz)
- Geotiff file (RGB)
- Geotiff file (Floating Point)
- Fledermaus scene file (*.scene)

Data caveat: *Third party bathymetry data has been utilised in the creation of the above-mentioned DEM. The low resolution of data sets limits the resolution of the final DEM and its associated products.*

2 Site Location

2.1 Site Location Overview

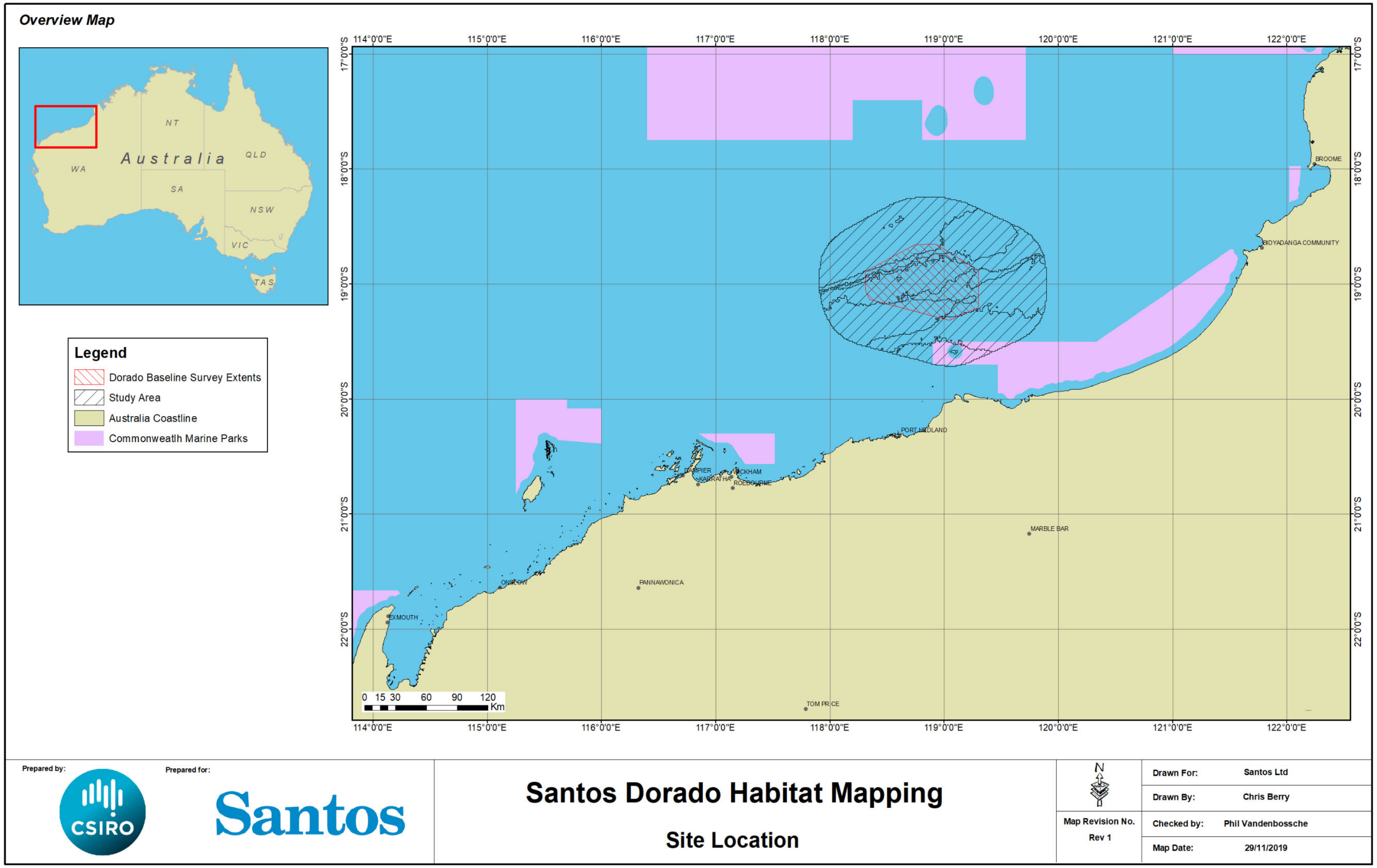

Figure 47: General site locality map

3 Bathymetry Data Sources

Bathymetry datasets were compiled from several sources for use in creation of the DEM. These datasets ensured the complete coverage of the Santos Dorado site while also providing redundancy through comparison of overlapping datasets. The datasets and their associated metadata are described below.

3.1 Santos Supplied Datasets

Table 14. Santos Supplied Bathymetry Metadata

DATASET	FILE TYPE	RESOLUTION	COORDINATE SYSTEM	VERTICAL DATUM	FILE SIZE (MB)
Capreolous 3D	*.xyz	200m	UTM Z50S GDA94	MSL	9.3
Bilby 3D	*.xyz	100m	UTM Z50S WGS84	MSL	65.2
Keraudren 3D	*.xyz	100m	UTM Z50S GDA2020	MSL	9.7

3.2 CSIRO Data Trawler Archives

Table 15. CSIRO Data Trawler Bathymetry Metadata

DATASET	FILE TYPE	RESOLUTION	COORDINATE SYSTEM	VERTICAL DATUM	FILE SIZE (MB)
2017_V05	*.GSF	5m	UTM Z50S WGS84	MSL (AusGeoid09)	461.4

3.3 Geoscience Australia- AusSeabed Marine Discovery Portal

Table 16. Geoscience Australia AusSeabed Bathymetry Metadata

DATASET	FILE TYPE	RESOLUTION	COORDINATE SYSTEM	VERTICAL DATUM	FILE SIZE (MB)
GA2012 (SE50a)	*.xyz	50m	UTM Z50S WGS84	-	266.3

3.4 Geoscience Australia- Australian Bathymetry & Topographic Grid 2009

Table 17. Geoscience Australia Aus. Bathy. & Topo. 2009 Bathymetry Metadata

DATASET	FILE TYPE	RESOLUTION	COORDINATE SYSTEM	VERTICAL DATUM	FILE SIZE (MB)
GA2012 (SE50)	*.xyz	50m	UTM Z50S WGS84	-	157.1

4 Bathymetry Data Sources

4.1 Bathymetry Data Sources Overview

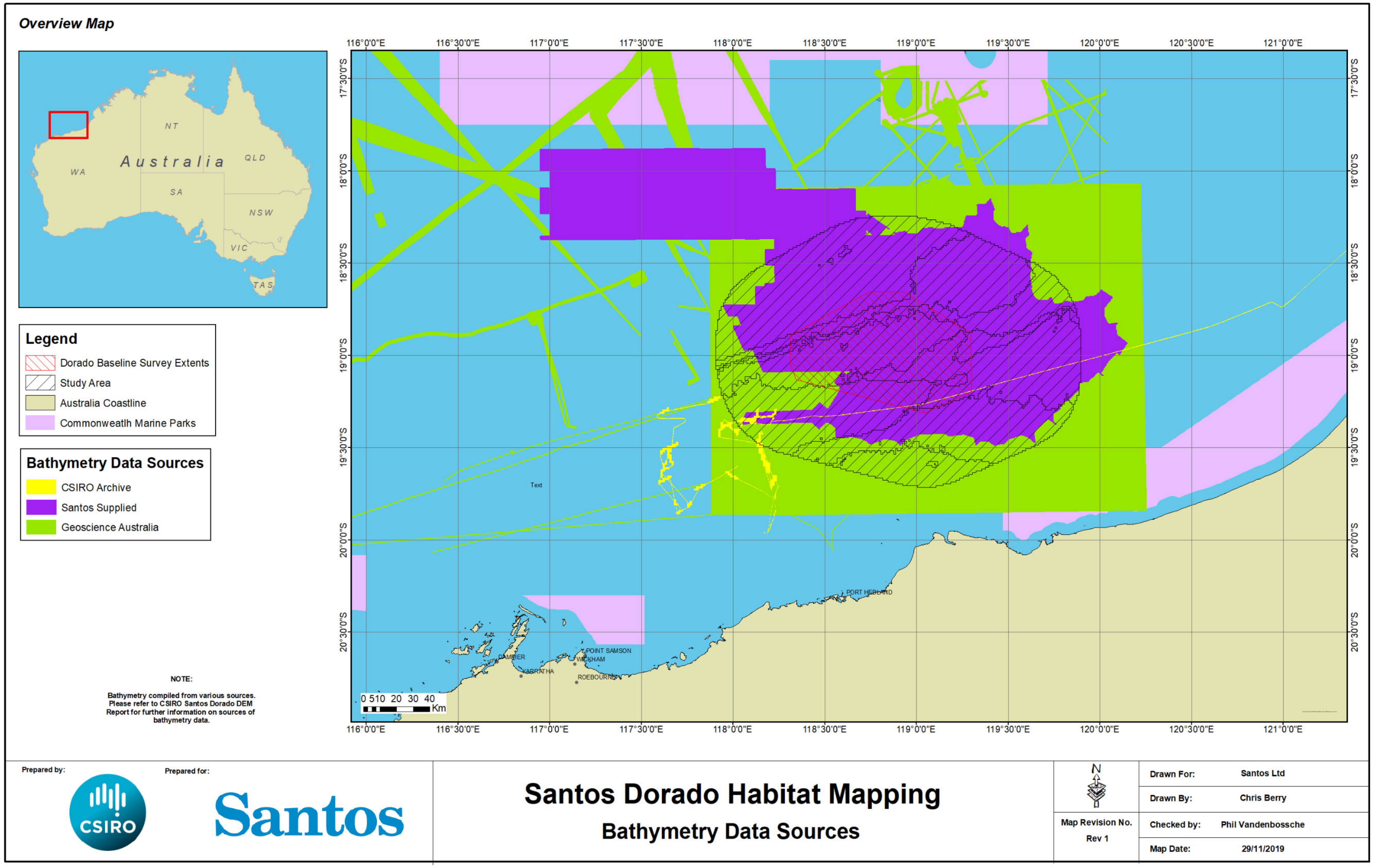

Figure 48. Bathymetry Data Source Overview

5 Data Processing

5.1 Workflow

The workflow for combining the sourced data and producing deliverables was as follows:

- Import datasets to Fledermaus software on common horizontal datum for visual analysis
- Calculate differences in vertical datums through performing surface difference calculations
- Shift data to a common vertical datum
- Import shifted data to CARIS Base Editor for re-gridding
- Re-grid data preserving the highest resolution datasets and utilising lower resolution data to fill gaps in the model
- Confirm resolution is fit for purpose with habitat mapping science staff
- Produce deliverable products including *.xyz, *.tif (Image and Floating Point) and *.scene files

5.2 Methodology

5.1.1 Initial Visualisation

Bathymetry datasets were initially imported into the QPS Fledermaus (Version 7.8.8) software package to allow for visualisation and analysis. Each dataset was imported on a common horizontal datum of WGS84 (Geographic).

5.1.2 Vertical Datum Analysis

In order to address slight differences in the vertical datums of each data set, which could be attributed to differences in resolutions and processing methods, the datasets were vertically shifted to a common datum. The required vertical datum, Mean Sea Level (MSL), was adopted from the CSIRO 2017_V05 (2017_V05) dataset. This data was chosen to provide the vertical datum as the data acquisition and processing methods were known to be robust, while the data was of a high resolution (5m Resolution data acquired by RV Investigator in 2017, reduced to Mean Sea Level (MSL) datum utilising GPS Tides reduced to the Ausgeoid09 (MSL)).

The median difference between each dataset compared to the 2017_V05 data was established through differential surface comparisons in the Fledermaus software. These surface comparisons provided a value to vertically shift each dataset. The vertical shift of each dataset maybe seen below in Table 5.

Table 18. Summary of Vertical Datum Shifts

DATASET	VERTICAL SHIFT (M)
Capreolous 3D	0.56
Bilby 3D	0.56
Keraudren 3D	0.56
GA2012 (SE50a)	2.2
GA2009 (Aus. Bathy. & Topo 2009)	1.48

5.1.3 Re-gridding

CARIS Base Editor (Version 5.3.12) software was utilised for re-gridding datasets. The re-gridding Smethod involved preserving the highest resolution data utilising the lower resolution data to fill gaps in the model. A weighted mean average method was utilised for creating the final model. The data was combined and re-gridded at various resolutions with the optimal result providing maximum detail while avoiding any disruption to the completeness of the DEM. Once an acceptable resolution was established this was confirmed as being fit for purpose with CSIRO Habitat Mapping Science Staff.

6 Combined Digital Elevation Model

6.1 Santos Dorado Combined DEM Overview

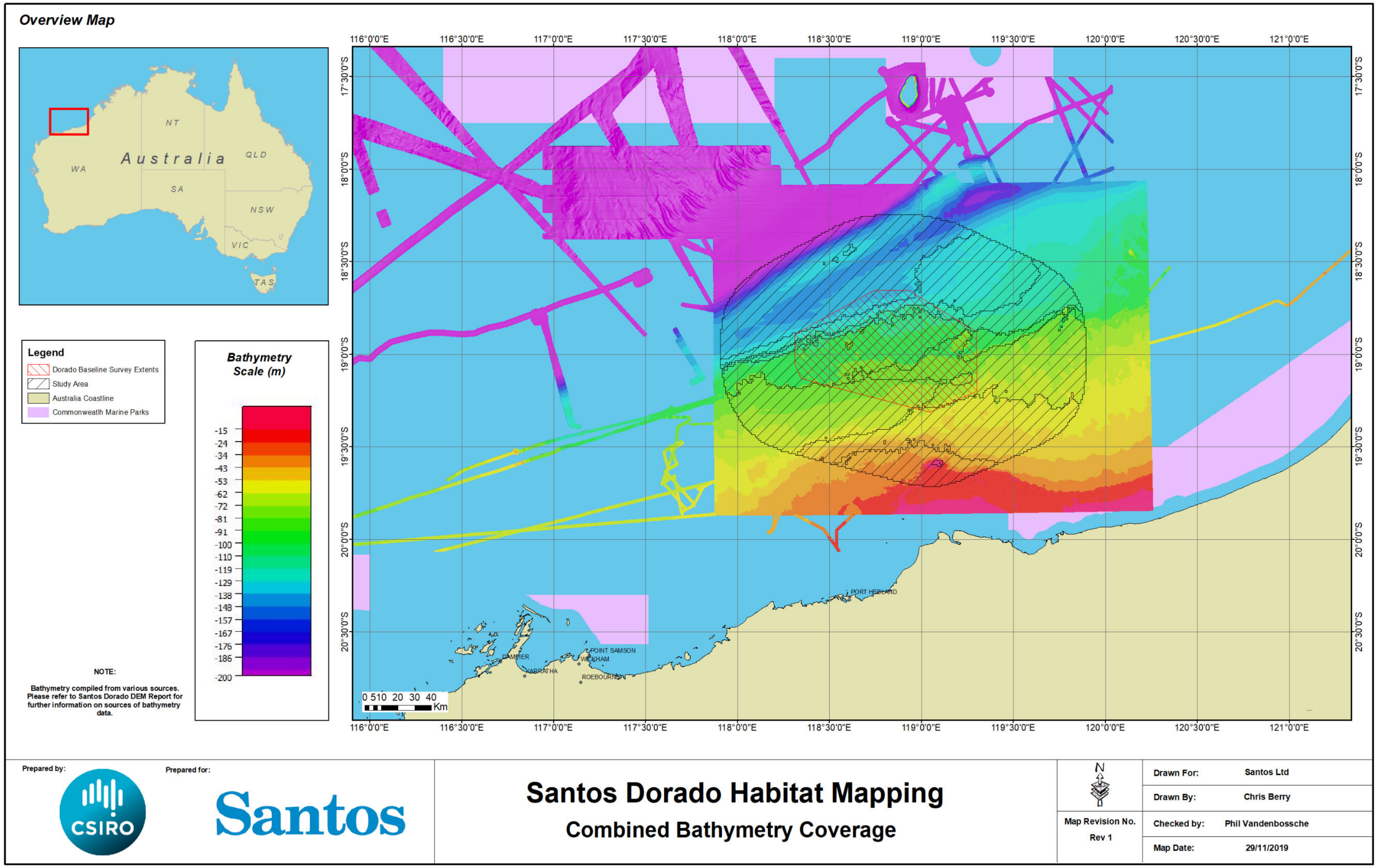

Figure 3. Santos Dorado Combined DEM.

7 DEM Product Parameters

The compiled datasets were of varying coordinate reference systems and datums (See Tables 1-4). These datasets were each transformed to a common coordinate reference system and vertical datum. As directed by CSIRO Habitat Mapping Science Staff the DEM products are presented in a horizontal datum of WGS84 (Geographic) and vertical datum of Mean Sea Level (MSL). The final resolution of the combined DEM was established as 0.001° (~ 100m),

Table 19. DEM Parameters

DIGITAL ELEVATION MODEL (DEM) PARAMETERS	
Horizontal Datum	WGS84 (Geographic)
Vertical Datum	Mean Sea Level (MSL)
Resolution	0.001°

8 Deliverables

A summary of the digital products delivered is as follows:

Table 20. Summary of Deliverables

FILE NAME	FILE TYPE	FILE SIZE (MB)
Santos Dorado_DEM_WGS84_GEO_001_191202.tiff	GeoTiff	12.8
Santos Dorado_DEM_WGS84_GEO_001_191202_Floating.tif	Floating point GeoTiff	23.5
Santos Dorado_DEM_WGS84_GEO_001_191202.scene	Fledermaus Scene	394.4
Santos Dorado_DEM_WGS84_GEO_001_191202.xyz	XYZ	246.1
Santos Dorado_DEM Production Report_Dec2019_Rev1	*.docx	3.1

NOTE: The Fledermaus scene product may be viewed in Fledermaus iView4d. This application is part of the Fledermaus 7.8 package and has been supplied with the deliverables.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

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FOR FURTHER INFORMATION

CSIRO Oceans & Atmosphere
Dr John Keesing
t +61 8 93336500
e john.keesing@csiro.au

Attachment 4 Sediment Quality

SEDIMENT QUALITY SURVEY REPORT

Dorado Oil Development, December 2020

EEN19234.001
Sediment quality survey report
Rev 0
25 May 2020

rpsgroup.com

Approval for issue

J. Fitzpatrick		25 May 2020

Prepared by:

RPS

Garnet Hooper
Principal Marine Scientist

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
E garnet.hooper@rpsgroup.com.au

Prepared for:

Santos WA Energy Ltd

Sonja Mavrick
HSE Team Lead Dorado Development

Level 7, 100 St Georges Terrace
Perth WA 6000

T +61 8 6218 7100
E sonja.mavrick@santos.com

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ACRONYMS AND ABBREVIATIONS

Acronym or abbreviation	Full name
AS/NZS	Australian Standard/New Zealand Standard
BSL	Below sea level
BTEXN	Benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene
CoC	Chain of custody (form)
DMS	Degrees minutes seconds
Dry wt	Dry weight
Dup	Duplicate
FPSO	Floating production storage and offtake
g/G (Folk)	Gravel or gravelly
GPS	Global positioning system
ISQG	Interim sediment quality guideline
KEF	Key ecological feature
LOR	Limit of reporting
m/M (Folk)	Mud or muddy
MAFRL	Marine and Freshwater Research Laboratory at Murdoch University
n-MDS	Non-metric Multi-Dimensional Scaling
NATA	National Association of Testing Authorities
NORM	Naturally occurring radiative material
OPP	Offshore project proposal
PAH	Polycyclic aromatic hydrocarbons
PCA	Principal components analysis
PSD	Particle size distribution
ROV	Remotely-operated vehicle
s/S (Folk)	Sand or sandy
SIMPROF	Similarity profile analysis
TBT	Tributyltin
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TPH	Total petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
TSS	Total suspended solids
WGS84	World geodetic system 1984
WHP	Wellhead platform
°C	Degrees Celsius
µm	Micrometres

EXECUTIVE SUMMARY

Santos is planning the Dorado Oil Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 130 km north of Port Hedland. The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority. The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk.

A key component of the marine environmental characterisation studies being undertaken to inform the development and OPP is a sediment quality survey that was undertaken from 15 to 20 December 2019.

Fifteen sediment quality sampling sites were distributed across the study area to provide coverage of the proposed field development, allow consideration of sites where previous oil and gas drilling activities had been undertaken (i.e. Roc-1), the ancient coastline Key Ecological Feature (KEF) and provide representative data across CSIRO's preliminary ecotypes for the area.

Sediment samples were collected from each site for the analysis of contaminants (metals/metalloids, hydrocarbons, naturally-occurring radioactive materials), nutrients (total Kjeldahl nitrogen, total phosphorous and total organic carbon) and particle size distributions. Fourteen of the fifteen sites were successfully sampled, ranging in depth from 62 m to 137 m below sea level (BSL). All sediment samples were collected, handled, preserved, and delivered to the analytical laboratories within specified holding times for all analytes.

Key conclusions from the sediment quality survey include:

- Arsenic was the only metal/metalloid in the sediments sampled from the survey area which exceeded its ANZG (2018) ISQG-Low trigger value, and this only occurred at one site (Site 13).
- The concentrations of arsenic, chromium and iron had a negative (inverse) relationship with sediment silt content, with declining metal concentrations up to 20 % silt, then concentrations remained relatively consistent with increasing silt content to ~32 % silt. Silt content was also related to water depth, though the trend was increasing sediment silt content with increased depth. The pattern of decreasing metals and metalloids with increasing silt content observed in the present study is contrary to the common trend of metals being associated with smaller particle grain sizes (Martincic et al. 1990). This is an important point for the interpretation of any future survey programs, as the concentrations of these metals/metalloids may naturally occur at up to three or more times higher in the vicinity of the proposed wellhead platform location than in the finer sediments in the deeper waters to the north. DEC (2006) found that total arsenic concentrations were relatively high across the region (with a median concentration of 36 mg/kg recorded for one site off Onslow), and exceeded the recommended sediment quality guideline at some of the essentially unimpacted locations sampled. These exceedances were considered to be natural by DEC (2006), and likely to be related to the local geology. Higher total arsenic concentrations in shallower water (with less silt content) in the southern sampling locations may therefore be due to effects of the underlying geology.
- Tributyltin concentrations were below the limit of reporting at all sites.
- Oil and grease concentrations ranged from 220 mg/kg at site 11, to 1900 mg/kg at site 15. The concentration at site 15 was significantly higher than all other sites. The second highest value (~ 450 mg/kg) was recorded at site 1 and in duplicate 2 taken from site 6. The source of the high concentration of oil and grease in the sample from site 15 was not determined in this study, as total recoverable hydrocarbons (TRH) were below limits of detection in this sample.
- Total petroleum hydrocarbons (TPH), TRH and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) concentrations were below the laboratory LOR at all sites within the survey area. Consequently, no analysis of polycyclic aromatic hydrocarbons (PAHs) was required.
- The combined concentration of radium^{226}, radium^{228} and thorium^{228} ('combined NORMs') was below the guideline value of 35 Bq/kg at all sites, even when considering upper confidence limits.
- Nutrients (nitrogen, phosphorus) and organic carbon are released as by-products of the decay of organic matter. Total Kjeldahl nitrogen (TKN) concentrations exhibited low variability, but were generally marginally higher at sites along the northern and western edges of the survey area. Nutrient concentrations were found to be comparable with other studies from offshore environments in northern Australia. There was no discernible spatial pattern in total phosphorus concentrations or correlation with

depth. Total organic carbon concentrations also exhibited limited variation, and closely corresponded with TKN concentrations, with the highest levels recorded at the siltier sites along the northern and western edges of the survey area.

- The survey area was characterised by a gradual transition in sediment coarseness, with the coarsest sediments (highest gravel component and lowest silt component) at the southern and south-eastern sites, and siltier sediments in the northern sites. This distribution generally related to water depth, with the deepest northern sites generally having a greater silt component than the shallower southern sites. The silt component of sediments at Roc-1 (~20.3 %) was comparable with particle size data previously collected at the Roc-1 location (NGI 2017). Folk sediment classifications were useful in identifying trends in sediment types across the study area, and highlighted the relative consistency in the broad sediment types recorded (ranging from slightly gravelly muddy sand to gravelly sand).

1 INTRODUCTION

1.1 Background

Santos is planning the Dorado Oil Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 130 km north of Port Hedland. The Dorado Project will target the Dorado oil field with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading facility (FPSO). There is also potential for future development of the surrounding reservoirs. These may be developed by drilling additional subsea production wells and tied back to the WHP via flowlines. The locations of the wells, and associated areas of seabed disturbance, will be guided by ongoing exploration work and are not known currently. Given the uncertainty in the location of seabed disturbing activities, Santos has taken the approach of describing sediment types such that development in any part of the Dorado Project Area can be assessed accordingly when the locations are better defined.

The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority. The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk. A program of environmental studies was required to characterise the benthic habitats, macrofaunal and infaunal communities, water and sediment quality within the Dorado survey area. This report provides the outcomes of the sediment quality survey conducted between 15 and 20 December 2019.

The sediment quality survey was intended to provide information on the physico-chemical characteristics of the sediments within the Dorado Project Area. The outcomes will inform the assessment of potential environmental impacts and risks to sediment quality from the Dorado project. Outcomes may also be used to inform the design of any potential future environmental monitoring for the Dorado Project. Infaunal samples were collected during the sediment quality field survey, but the outcomes will be reported in the Dorado benthic habitats survey report (RPS 2020).

1.2 Objectives

This sediment quality survey is a key component of the Dorado marine environmental characterisation studies program.

The specific objectives of the Dorado sediment quality survey were to:

- Characterise the physico-chemical characteristics of the marine sediments within the Dorado survey area.
- Compare the existing condition of the sediments with relevant sediment quality guidelines (e.g. ANZG 2018).

1.3 Summary of survey operations

The Dorado sediment characterisation survey was undertaken between 15 and 20 December 2019. Sediment quality sampling (and infauna sampling for the benthic habitat study) was undertaken over a four-day period spanning 16 to 19 December 2019. The water depths of the sites at which sediments were surveyed ranged from 62 to 137 m below sea level (BSL). Fifteen locations were sampled within the survey boundary (see Figure 2-1), with Site 7 located at the Roc-1 well location to identify potential impacts from historic drilling campaigns in the area. Particle size distribution (PSD) and contaminant samples were retrieved from fourteen sites, while infauna samples were collected from five sites across the target area. Site 12 was abandoned following repeated unsuccessful sampling attempts; review of the vessel echosounder indicated a hard seabed at this site (insufficient sediment to sample). A summary of the sample types obtained from each sampling site is presented in Appendix A.

2 METHODS

2.1 Sampling sites

An array of fifteen pre-determined sampling sites provided coverage across the Dorado survey area, extending from the Dorado Project Area into and beyond the ‘ancient coastline at 125 m water depth’ key ecological feature (KEF) (DEWHA 2008) (Figure 2-1, Table 2-1). Sites were also distributed to provide representative samples across a range of CSIRO preliminary ecotypes (Keesing et al. 2020).

Water depths at sampling sites ranged from 62 to 137 m. Site 4 was located within the ancient coastline KEF and Site 7 was located at the previous Roc-1 well location.

Table 2-1: Sample site coordinates

Sample site	Latitude* (DMS)	Longitude* (DMS)	X* (UTM Z50K - metres)	Y* (UTM Z50K - metres)	Depth (m)
SP1	19° 06' 39.632" S	118° 30' 48.920" E	659214	7886201	91
SP2	19° 04' 55.110" S	118° 23' 26.506" E	646310	7889522	88
SP3	18° 55' 35.947" S	118° 23' 16.184" E	646144	7906714	87
SP4	18° 50' 37.097" S	118° 30' 59.652" E	659782	7915790	120
SP5	18° 40' 18.793" S	118° 52' 11.219" E	697205	7934446	137
SP6	18° 47' 49.020" S	118° 49' 33.751" E	692449	7920651	105
SP7	18° 52' 49.030" S	118° 49' 28.600" E	692203	7911428	97
SP8	19° 01' 35.083" S	118° 44' 40.884" E	683622	7895339	87
SP9	19° 05' 37.086" S	118° 51' 11.639" E	694970	7887780	88
SP10	19° 11' 06.421" S	118° 46' 58.228" E	687459	7877731	81
SP11	19° 17' 42.212" S	119° 02' 16.080" E	714133	7865266	62
SP12	19° 08' 24.576" S	119° 03' 06.145" E	715797	7882397	80
SP13	19° 03' 27.565" S	119° 06' 29.592" E	721853	7891460	86
SP14	18° 51' 15.941" S	119° 08' 49.297" E	726212	7913909	93
SP15	18° 46' 30.623" S	119° 03' 15.689" E	716547	7922799	111

*Note: Datum used was WGS84.

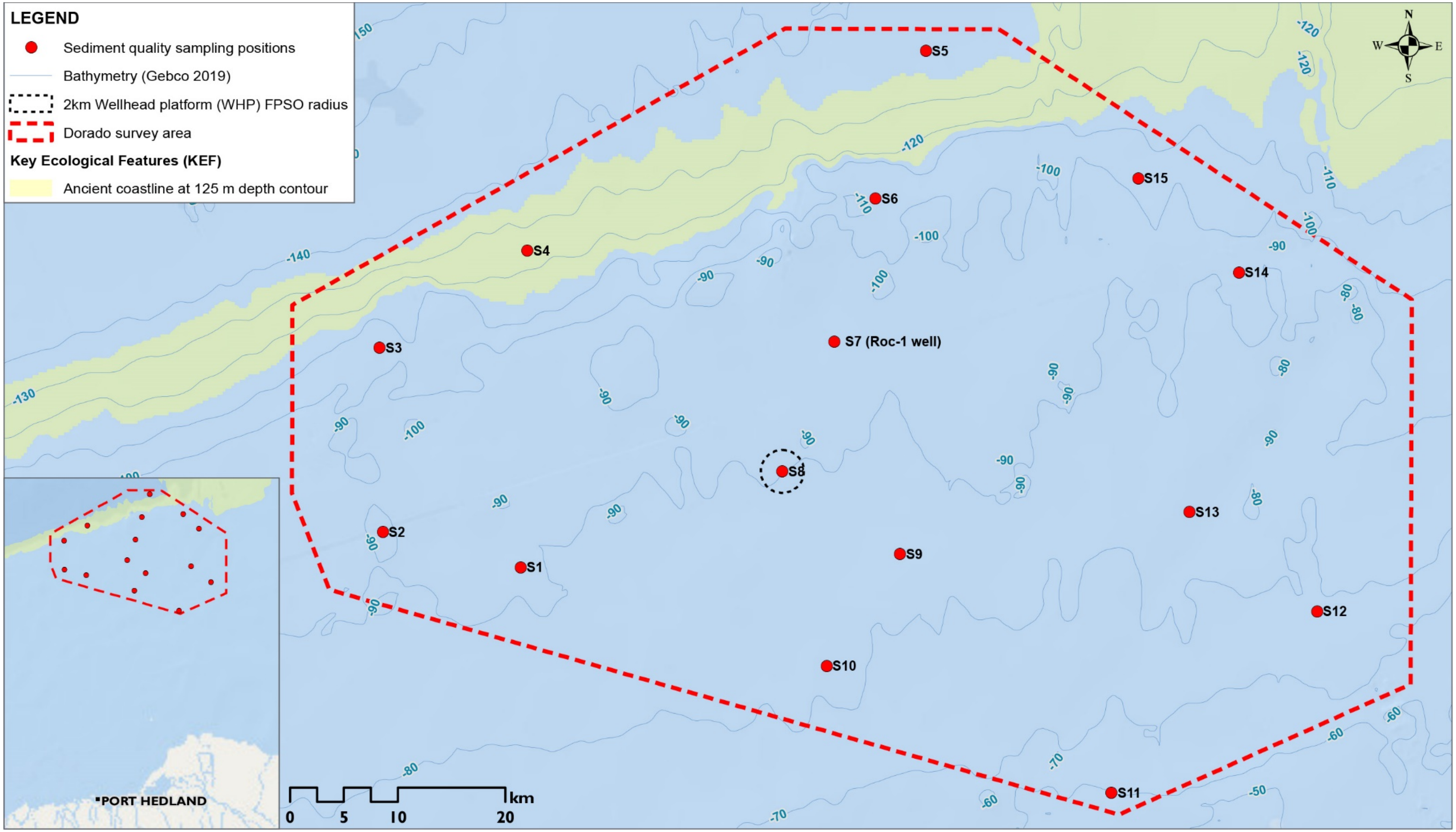

Figure 2-1: Sediment quality sampling positions

2.2 Timing

Sediment and infauna sampling was undertaken overnight, from 16 to 19 December 2019, during the Austral summer.

2.3 Quality control

The field survey was conducted in accordance with the agreed Sampling Analysis and Quality Plan (SAQP) for the survey (RPS 2019). The SAQP was approved by Santos prior to mobilisation and covered the planned survey sites, methods, schedule, analytes and data handling. The key elements for survey quality control relate to sample and data integrity and chain-of-custody tracking of samples.

2.4 Sediment sampling

2.4.1 Grab samples

Sediments were sampled using a 0.25 m^2 van Veen grab (Figure 2-2) that was deployed from the stern A-frame of the Jetwave Maddison. Prior to deployment at each site, the internal surface of the grab was cleaned with Decon 90™ to prevent between-site contamination of samples. Once deployed, the grab was lowered to the seabed, and allowed to settle. The grab was then retrieved to the deck. A qualitative description of the sample was recorded, including conspicuous biota, sediment type, and any features (e.g. smell, anthropogenic material, conspicuous layers or hydrocarbons).

Of the grab sample samples collected at each site:

- One was collected for contaminants, nutrients and particle size distribution (PSD).
- A second grab collected for infauna (as part of the benthic habitat study).

The following information was recorded on grab sample logs sheets when the samples hit the seabed, irrespective of whether the sample was successful or not:

- Site number
- GPS waypoint number
- Date and time
- Water depth (below sounder, which was mounted ~1.8 m BSL).

Upon retrieval to the deck, the following information was also recorded for each attempt (see Appendix A):

- Successful (Y/N)?
- Volume of sample collected (either proportion of grab or estimated volume in litres)
- Sediment description
- Sediment features
- Conspicuous fauna
- Sample type(s) collected from sample (where relevant)
- A photograph of the sample, with a photo slate in view showing project number, site number and date (e.g. Figure 2-3).

Where sample volumes were insufficient to provide sufficient sediment, the attempt was rejected. Due to the need to return contaminant samples to the laboratory within sample holding times, sampling effort per site had to be constrained to a maximum of six sampling attempts at each site. Where repeated failures to obtain sufficient sediment occurred, a process (described below) was applied to prioritise samples collected.

Figure 2-2: van Veen grab sampler being deployed during the study

2.4.2 Sampling process

The process for sample collection required prioritisation of different sample types. The following rationale was applied, as per the SAQP:

1. Contaminants and nutrients. These were priority for collection as information pertaining to sediment contaminants and nutrients could not be derived by the other sampling methods used in the Dorado environmental characterisation surveys (i.e. ROV imagery and water quality sampling)
2. Particle size distribution was a lower priority than contaminants sampling, as broad sediment descriptions may be defined from subsea imagery. These samples were taken after contaminants and nutrients samples had been collected.
3. Infauna. Infauna samples required to support the benthic habitat survey scope (RPS 2020) were collected during the sediment survey as they require the same sampling equipment.

Figure 2-3: van Veen grab (0.25 m²) with infauna sediment sample from Site 1

2.4.3 Sample processing, preservation and storage

Contaminants samples were taken from the surface layer of sediment (upper 2–5 cm) at each sampling site where possible. Full contamination risk mitigation protocols and were implemented during sampling, which included careful assessment of sampling areas and use of clean gloves each time samples were collected.

Surficial sediment within the grab was carefully removed and transferred to a glass bowl using plastic sampling utensils pre-cleaned with Decon 90™. Sediment within 5 mm of the sides of the grab were not analysed to minimise risk of contamination.

The collected sediment was then homogenised in a glass bowl before being transferred to sample jars. Two 70 ml samples were collected for metals, nutrients and total organic carbon (TOC); a 150 ml sample collected for hydrocarbons and tributyl tin (TBT); and a 250 ml sample collected for naturally occurring radiative materials (NORMs). These samples were processed on board by filling the jars to the neck whilst leaving sufficient air to allow for expansion when frozen. Since contaminants sampling did not require the full amount of collected sediment, a 300–500 g sub-sample for PSD analysis was obtained and placed in a plastic ziplock bag and chilled to ~4 °C. Samples for contaminants and PSD were collected at 14 of the 15 sampling sites, with no successful samples collected from Site 12.

Infauna samples were collected from five sites – 3, 4, 5, 8 and 13 (Figure 2-1). Infauna samples were photographed with a slate identifying the sample site name and date, before being sieved using a 1 mm box sieve. Samples were carefully transferred to a sample bag and preserved in 80 % ethanol. The results of taxonomic analysis of these samples are summarised in the benthic habitat survey report.

All samples were clearly labelled with the following information:

- Sample type: i.e. contaminants/nutrients type(s), PSD or infauna

- Sample ID: Site number (i.e. S1)
- Date of sampling
- The job number: EEN19234.001.

2.4.4 Storage and transport

All samples were preserved and handled in accordance with the requirements of the Australian and New Zealand Standards (AS/NZS 5667.12:1999 Water quality – sampling guidance on sampling of bottom sediments) and the National Association of Testing Authorities (NATA) accredited laboratories. Given the survey location is remote, the preservation techniques were selected to achieve maximum holding times for each parameter and samples stored in accordance with the laboratory requirements until delivery within the required holding times (see Appendix B).

Sample storage and transport were in accordance with the information provided in Table B.1 of Appendix B. Samples for chemical analysis were chilled immediately and frozen as soon as possible. Frozen samples were packed into eskies to ensure that they remained frozen until received by the laboratory.

Infauna samples preserved in ~80% ethanol needed to be kept cool but did not require refrigeration or freezing. Further information pertaining to infauna analysis and interpretation can be found in the Dorado benthic habitat survey report (RPS 2020).

All samples were transported with chain of custody (CoC) forms that detailed the sample identifications, sample type, date and time of sampling, and the analyses required.

2.5 Sample analysis

The analytes, corresponding limits of reporting (LOR) and guideline values are presented in Table B.1 of Appendix B. All analyses were undertaken using standard methods at NATA-accredited laboratories (see Table B.2 in Appendix B).

PSD analysis was undertaken using a combination of laser diffraction and sieving, with the results combined to provide a full PSD curve:

- Laser diffraction of particles sized from 0.022 µm to 1 mm
- Wet/dry sieving of sediments for the following sizes: <500 µm, 500 µm, 1 mm, 2 mm, 4 mm, 8 mm and >16 mm.

The following chemical geophysical parameters were analysed from contaminants samples:

- Heavy metals/metalloids (Al, As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Ni, Pb, Zn)
- Total recoverable hydrocarbons (TRH) (C6-C40)
- Oil and grease
- NORMs (radium^{226}, radium^{228} and thorium^{228})
- Nutrients (total Kjeldahl nitrogen [TKN] and total phosphorus [TP])
- Total organic carbon (TOC)
- Tributyltin (TBT).

2.6 Data analysis

Sediment analyte concentrations were compared to relevant guideline levels (see Appendix B). Where relevant (i.e. for TBT and hydrocarbons), results above limits of detection were normalised to 1% carbon prior for comparison with guideline levels.

The PSD data for each sample was described in terms of the Folk sediment classification, skewness, kurtosis and sorting. This information is useful for sediment mapping and to identify relationships between physical sediment characteristics and contaminant concentrations or biological assemblages.

Multivariate analysis of sediment quality data was undertaken using the Plymouth Routines In Multivariate Ecological Research (PRIMER) v7 software (Clarke & Gorley 2015).After transformation and normalisation of contaminants and PSD data, resemblance matrices were derived using Euclidean distance. The ‘Cluster’ routine with similarity profile (SIMPROF) permutational tests were used to identify groupings of samples based on survey data. Non-metric multi-dimensional scaling (n-MDS) was used to represent the relative distribution of sample data in 2-dimensional space to identify relationships between sample sites. The principal components analysis (PCA) routine was used to determine the effect of sediment components on the distribution of sample sites.

2.7 Quality control procedures

The following quality control process was undertaken to quantify potential sample contamination that could have occurred during collection, handling, storage or transport. Low analyte concentration water provided by the laboratories were used in two tests:

- Field blank: low analyte water was poured into a sample container in the field during sampling, but with no filtering or additional handling. Water was used rather than inert sediment as it was considered to be a more sensitive test. Field blanks test for any contamination of samples during sample collection.
- Transport blank: low analyte water was poured into a sample container at the end of field sampling, with no filtering or additional handling. Water was used rather than inert sediment as it was considered to be a more sensitive test. Transport blanks test for any contamination of samples during transport and storage.

The following duplicate sediment samples were also collected to determine potential variability in analysis:

- Duplicate 1 (a replicate sample collected for QA/QC purposes; collected at Site 7)
- Duplicate 2 (collected at Site 6).

In addition, the following protocols to mitigate for contamination risk were put in place:

- Sterile, Decon 90™ cleaned latex gloves were worn when handling sediments samples, with a new pair of gloves worn for each grab sample. Gloves, bowls and sampling utensils were cleaned with Decon 90 ™ between sampling attempts.
- The internal surfaces of the grab sampler were thoroughly cleaned with Decon 90 ™ between sampling sites to prevent between-site contamination.
- The sample processing area was located far from potential sources of contamination (e.g. the A-frame and vessel exhaust fumes). No smoking was allowed in or near the sampling or processing area.
- The insides of sample jars and bags did not contact potentially contaminated surfaces.
- Once sealed, contaminants and PSD samples were transferred to eskies with ice blocks to keep samples chilled until they could be transferred to a fridge or freezer (in line with sample storage requirements).

Procedural and record keeping quality control measures implemented included:

- Global positioning systems (GPS) waypoints were recorded for all sampling attempts when the grab reached the seabed.
- Water depths, dates, samples collected, times and in situ observations were recorded in field logs.
- Appropriate CoC forms to accompany samples were completed for each laboratory. These indicated the sample ID, the type of sample, the date of sampling and the analysis required.
- Any changes to the field procedures were documented.

3 RESULTS

3.1 Sediment quality

Sediment survey logs, showing sampling data for all sampling attempts (e.g. date, geographic position, sample descriptions) can be found in Appendix A. Photographs of sediment samples can be found in Appendix C. A summary of samples collected is presented in Table 3-1. PSD and contaminant samples were successfully retrieved from fourteen sites, while infauna samples were collected from five sites across the survey area. Site 12 was abandoned following repeated failed sampling attempts (insufficient sediment to sample). Review of the vessel's echosounder indicated a hard seabed at this site.

Table 3-1: Samples obtained at each sampling site.

Site	Longitude (S)	Latitude (E)	Sample type		
			Contaminants[1]	PSD[2]	Infauna
1	19° 06' 39.632"	118° 30' 48.920"	✓	✓	
2	19° 04' 55.110"	118° 23' 26.506"	✓	✓	
3	18° 55' 35.947"	118° 23' 16.184"	✓	✓	✓
4	18° 50' 37.097"	118° 30' 59.652"	✓	✓	✓
5	18° 40' 18.793"	118° 52' 11.219"	✓	✓	✓
6	18° 47' 49.020"	118° 49' 33.751"	✓	✓	
7	18° 52' 49.030"	118° 49' 28.600"	✓	✓	
8	19° 01' 35.083"	118° 44' 40.884"	✓	✓	✓
9	19° 05' 37.086"	118° 51' 11.639"	✓	✓	
10	19° 11' 06.421"	118° 46' 58.228"	✓	✓	
11	19° 17' 42.212"	119° 02' 16.080"	✓	✓	
12	19° 08' 24.576"	119° 03' 6.145"	No sample		
13	19° 03' 27.565"	119° 06' 29.592"	✓	✓	✓
14	18° 51' 15.941"	119° 08' 49.297"	✓	✓	
15	18° 46' 30.623"	119° 03' 15.689"	✓	✓	

1 Organics, metals, hydrocarbons and NORMs

2 Particle size distribution

3.1.1 Metals and metalloids

Of the total metals/metalloids in the sediments sampled from the Dorado survey area, only arsenic was recorded at concentrations above the ANZG (2018) ISQG-Low trigger value (Table 3-2). Total arsenic concentrations were recorded above the ISQG-Low trigger value at only one site (Site 13), with a concentration of 21 mg kg^{-1} dry weight (dry wt). This marginally exceeded the ISQG-low trigger value of 20 mg kg^{-1} dry wt. Arsenic levels at all other sites ranged from 5 to 17 mg kg^{-1} dry wt and thus did not exceed the ISQG-Low trigger value.

Nickel concentrations were well below the ISQG-Low trigger value (21 mg kg^{-1} dry wt) at all sites. Both arsenic and chromium were generally 2–3 times greater in the shallow water sites (60–80 m) than in the deeper water sediments (90–120 m). Similarly, concentrations of iron also tended to decline with site depth, decreasing from approximately 4000 mg kg^{-1} dry weight at the shallowest sites (Sites 9–11) to approximately 2000 mg/kg at the deepest (Sites 4 and 5).

To determine potential correlations between metals concentrations and particle size distributions (which was also found to be related to depth), the concentrations of total arsenic, total chromium (Figure 3-1) and total iron (Figure 3-2) were plotted against sediment silt content. Trendlines were used to identify relationships between analyte concentration and silt content, with R^2 values used to identify the strength of the relationship (i.e. how well the trendline fitted the scatterplot data). In all cases, analyte concentrations declined with increasing silt content to ~20 % silt, then remained relatively consistent with increasing silt content. Trendlines were considered representative of the data (R^2= >0.8). Total arsenic showed the greatest decline between ~1.6 % silt and ~20.3 %, with a 74 % reduction in concentration (21 mg/kg to 5 mg/kg). Total iron showed a 52 % reduction (4700 mg/kg to 2300 mg/kg) and total chromium showed a 45 % loss (20 mg/kg to 11 mg/kg). Potential relationships between analyte concentrations and sand/gravel were also investigated, but potential relationships were found to be much weaker (maximum R^2= <0.5 and <0.2, respectively).

Total concentrations of lead and zinc showed little variation between sites and were well below the ANZG (2018) ISQG-Low trigger values for each (50 mg/kg dry weight and 200 mg kg^{-1} dry weight, respectively). Total cadmium concentrations ranged from 0.1 to 0.3 mg kg^{-1} dry weight at all sites, well below the ANZG (2018) ISQG-low reliability trigger value of 1.5 mg kg^{-1} dry wt.

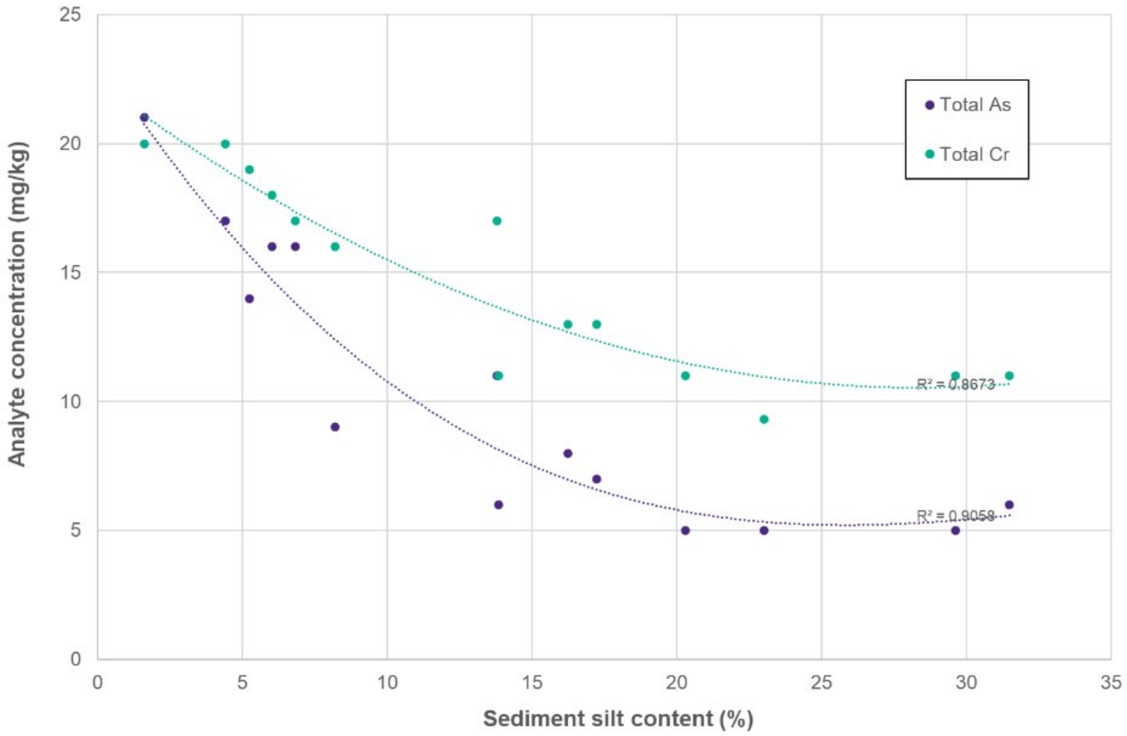

Figure 3-1: Total arsenic (As) and chromium (Cr) concentrations (mg/kg) against sediment silt content (%)

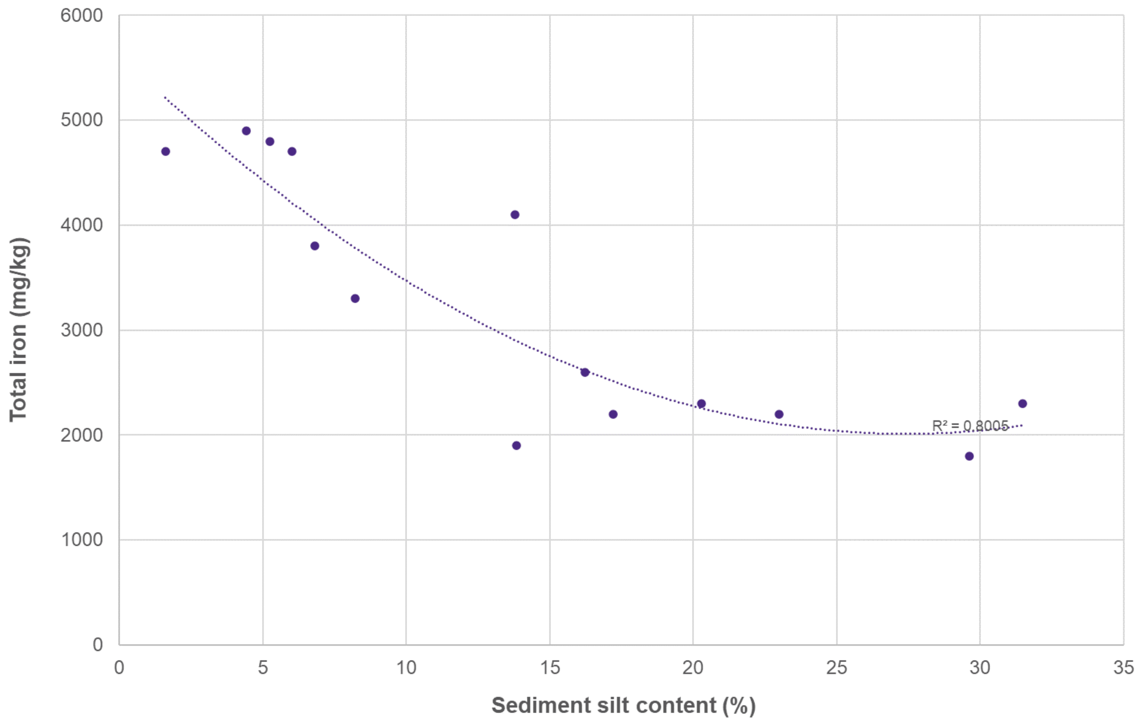

Figure 3-2: Total iron (Fe) content (mg/kg) against sediment silt content (%)

Table 3-2: Total metal and metalloid concentrations

Analyte	Aluminium	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Nickel	Lead	Zinc	Mercury
Units	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
Limit of reporting	<20	<2	<0.2	<0.1	<0.2	<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01
Guideline[a]	N/A	20	N/A	1.5	80	1.0	65	N/A	21	50	200	0.15
Site												
S1	1600	9	8.6	0.2	16	1.6	2.2	3300	3.3	2	4.5	<0.01
S2	2100	11	10	0.2	17	1.6	3.9	4100	4.1	2	5.3	<0.01
S3	1800	6	10	0.3	11	1.6	2.7	2300	4.0	1	5.1	<0.01
S4	1700	5	14	0.2	11	1.6	2.8	1800	4.3	<1	5.1	<0.01
S5	1500	5	11	0.2	9.3	1.3	2.8	2200	3.8	1	4.7	<0.01
S6	1700	7	10	0.2	13	1.6	2.4	2200	3.4	1	5.1	<0.01
S7	1300	5	17	0.3	11	1.1	2.0	2300	2.7	<1	3.4	<0.01
S8	1400	16	15	0.3	18	1.4	1.7	4700	3.2	2	3.7	<0.01
S9	1600	14	9.8	0.2	19	1.4	2.1	4800	3.6	2	4.2	<0.01
S10	1500	17	8.5	0.3	20	1.5	1.8	4900	3.2	2	3.9	<0.01
S11	1500	16	8.4	0.1	17	1.4	1.2	3800	2.3	1	3.3	<0.01
S13	1400	**21**	8.4	0.1	20	1.5	1.8	4700	3.1	2	4.0	<0.01
S14	1400	8	9.1	0.2	13	1.1	1.9	2600	2.5	<1	3.6	<0.01
S15	1200	6	9.3	0.2	11	1.2	1.8	1900	2.8	1	3.8	<0.01
Dup1 (Site 7)	1400	6	19	0.2	11	1.1	2.0	2300	2.6	1	3.5	<0.01
Dup2 (Site 6)	1800	6	11	0.3	12	1.5	2.5	2100	3.4	1	5.2	<0.01

a See Table B.1 of Appendix B for information on guidelines. Exceedances of guideline values are indicated by values in bold

3.1.2 Tributyltin

Tributyltin concentrations at all sites were below the limit of reporting (LOR) (Table 3-3) and thus well below the ANZG (2018) ISQG-low reliability trigger value of 9 µg Sn kg^{-1}.

Table 3-3: Tributyltin concentrations

Parameter	Tributyltin
Units	µg Sn kg^{-1}
Limit of reporting	<0.5
Guideline[a]	9
Site	
S1	<0.5
S2	<0.5
S3	<0.5
S4	<0.5
S5	<0.5
S6	<0.5
S7	<0.5
S8	<0.5
S9	<0.5
S10	<0.5
S11	<0.5
S13	<0.5
S14	<0.5
S15	<0.5
Dup1 (Site 7)	<0.5
Dup2 (Site 6)	<0.5

a See Appendix B for information on guidelines.

3.1.3 Hydrocarbons

Oil and grease concentrations ranged from 220 mg/kg at site 11, to 1900 mg/kg at site 15 (Table 3-4). The concentration at site 15 was significantly higher than at all other sites – 450 mg/kg was the second highest value recorded (at site 1 and in duplicate 2 taken from site 6). As total organic carbon (TOC) in the Dorado sediments was very low (0.3-0.5 %), oil and grease concentrations ranged from 520 mg/kg to 4,750 mg/kg when normalised to 1% total organic carbon. There is no guideline value for oil and grease in sediments.

Total petroleum hydrocarbons (TPH), total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) concentrations were below the laboratory LOR at all sites within the survey area (Table 3-4). Consequently, no analysis of polycyclic aromatic hydrocarbons (PAHs) was required.

Table 3-4: Oil and grease, total petroleum hydrocarbons, total recoverable hydrocarbons and BTEXN (in mg kg^{-1} dry wt)

Compound	LOR	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S13	S14	S15	Dup1	Dup2
Moisture content (%)	1	28.1	26.8	28	29.2	33.4	44.9	27.7	28.6	27.3	22	27.6	29.9	29.3	30.2	26.4	48
Oil and grease	100	450	390	330	300	260	420	290	310	290	340	220	310	350	1900	320	450
TPH																	
C6–C9 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
C10 - C14 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
C15 - C28 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
C29 - C36 fraction	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sum C10 - C36 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
TRH																	
C6-C10 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
C6-C10 fraction minus BTEX	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
>C10-C16 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
>C10-C16 fraction minus naphthalene	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
>C16-C34 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
>C34-C40 fraction	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sum C10-C40 fraction	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
BTEXN																	
Benzene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
meta- and para-xylene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-xylene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total xylenes	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sum of BTEX	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

3.1.4 Naturally occurring radioactive materials

All NORMs samples, with the exception of radium^{228} in the duplicate 2 sample, were above laboratory limits of reporting (LORs). Due to the nature of radionuclides and the methods used to measure them, limits of reporting are determined for each measurement. This means that measurements can be obtained for some samples that are below the limit of reporting for others, even for the same radionuclide (e.g. see the results for radium^{228} in Table 3-5). Where results are considered statistically robust, data with confidence limits are provided.

The combined value for radium^{226}, radium^{228} and thorium^{228} ('combined NORMs') were below the guideline value of 35 Bq/kg at all sites, even when considering upper confidence limits.

Table 3-5: Naturally-occurring radioactive materials (NORMs)

Parameter	Radium^{226}	Radium^{228}	Thorium^{228}	Combined NORMs
Units	Bq/kg	Bq/kg	Bq/kg	Bq/kg
Guideline	(see combined NORMs)			35 Bq/kg combined
Site				
S1	8.08 ± 0.99	3.56 ±1.18	3.16 ±0.57	**14.80**
S2	9.43 ± 1.22	1.87 ±0.94	8.91 ±1.27	**20.21**
S3	7.16 ± 0.88	3.22 ±0.93	6.51 ±0.92	**16.89**
S4	8.98 ± 1.05	1.89 ±1.03	8.27 ±1.02	**19.14**
S5	9.54 ± 0.94	1.48 ±0.64	5.58 ±0.71	**16.60**
S6	7.13 ±0.90	7.13 ±0.90	5.12 ±0.84	**19.38**
S7	9.03 ±0.91	9.03 ±0.91	5.02 ±0.68	**23.05**
S8	9.81 ±1.15	9.81 ±1.15	2.78 ±0.54	**22.40**
S9	8.61 ±1.23	8.61 ±1.23	4.88 ±0.89	**22.10**
S10	7.71 ±0.98	7.71 ±0.98	3.28 ±0.67	**18.70**
S11	6.81 ±0.99	2.12 ±0.97	3.51 ±0.61	**12.44**
S13	7.80 ±0.80	1.85 ±0.63	2.82 ±0.46	**12.47**
S14	8.04 ±0.84	1.69 ±0.84	2.61 ±0.50	**12.34**
S15	7.68 ±0.82	2.10 ±0.91	1.99 ±0.42	**11.77**
Dup1 (Site 7)	7.98 ±0.86	1.45 ±0.64	3.51 ±0.56	**12.94**
Dup2 (Site 6)	6.35 ±1.18	<6.70	6.33 ±1.15	**19.38**

3.1.5 Nutrients

Total Kjeldahl nitrogen (TKN) concentrations exhibited low variability, ranging from 0.3 mg N g^{-1} (Sites 1, 8, 10, 11, 13 and 15) to 0.5 mg N g^{-1} (Sites 2–5) (Table 3-6). TKN concentrations were generally greatest at sites along the northern and western edges of the survey area, although the difference was slight.

Total phosphorus (TP) concentrations ranged from 0.47 mg P g^{-1} at S11 to 1.0 mg P g^{-1} at Site 15. The minor variation in TP concentrations between sites did not exhibit any discernible spatial pattern or correlation with depth.

Total organic carbon (TOC) concentrations also exhibited limited variation, ranging from 0.3% at Sites 8, 10, 11 and 13 to 0.5% at Sites 2–5. TOC levels closely corresponded with TKN concentrations, with the highest levels recorded at sites along the northern and western edges of the survey area.

There are no ANZG (2018) trigger values for sediment nutrient concentrations.

Table 3-6: Sediment concentrations of total Kjeldahl nitrogen (TKN), total phosphorus (TP) and total organic carbon (TOC)

Parameter	TKN	TP	TOC
Units	mg N g^{-1}	mg P g^{-1}	% C
Limit of reporting	<0.1	<0.5	<0.2
Guideline	N/A	N/A	N/A
Site			
S1	0.3	0.92	0.4
S2	0.5	0.88	0.5
S3	0.5	0.74	0.5
S4	0.5	0.71	0.5
S5	0.5	0.82	0.5
S6	0.4	0.70	0.4
S7	0.4	0.63	0.4
S8	0.3	0.65	0.3
S9	0.4	0.70	0.4
S10	0.3	0.62	0.3
S11	0.3	0.47	0.3
S13	0.3	0.76	0.3
S14	0.4	0.61	0.4
S15	0.3	1.0	0.4
Dup1 (Site 7)	0.4	0.63	0.4
Dup2 (Site 6)	0.5	0.73	0.4

3.1.6 Multivariate analysis of sediment quality data

Data for metals/metalloids and nutrients were combined and normalised for multivariate analysis. Data that were consistently or wholly below the laboratory LOR or minimum reporting limit (i.e. TBT, TPH, TRH, BTEXN) were excluded from the analysis. Analysis using PRIMER v7 was based on Euclidean distance resemblance. Cluster analysis with SIMPROF identified three significant groups and one outlier (Site 2) (Figure 3-3):

1. Group A consisted of site 15 only.
2. Group B consisted of three samples (Sites 14, 7 and duplicate 1), which included the previous Roc-1 drilling location (Site 7 and duplicate 1). The grouping of these sites was predominantly driven by oil and grease, barium, TP and cadmium concentrations.
3. Group C corresponded to Site 2 only.
4. Group D corresponded to four north-western deep sites (Sites 3 to 6, and includes duplicate 2 which was taken at site 6). The grouping of these sites was predominantly driven by cadmium, barium, nickel, aluminium and TKN concentrations.
5. Group E corresponded to the six southern survey area sites (Sites 1, 8, 9, 10, 11 and 13). The grouping of these sites was predominantly driven by TP, barium, nickel, copper, lead and zinc concentrations.

These groupings are also shown in a n-MDS ordination plot showing relative similarity between sites and groups (Figure 3-4).

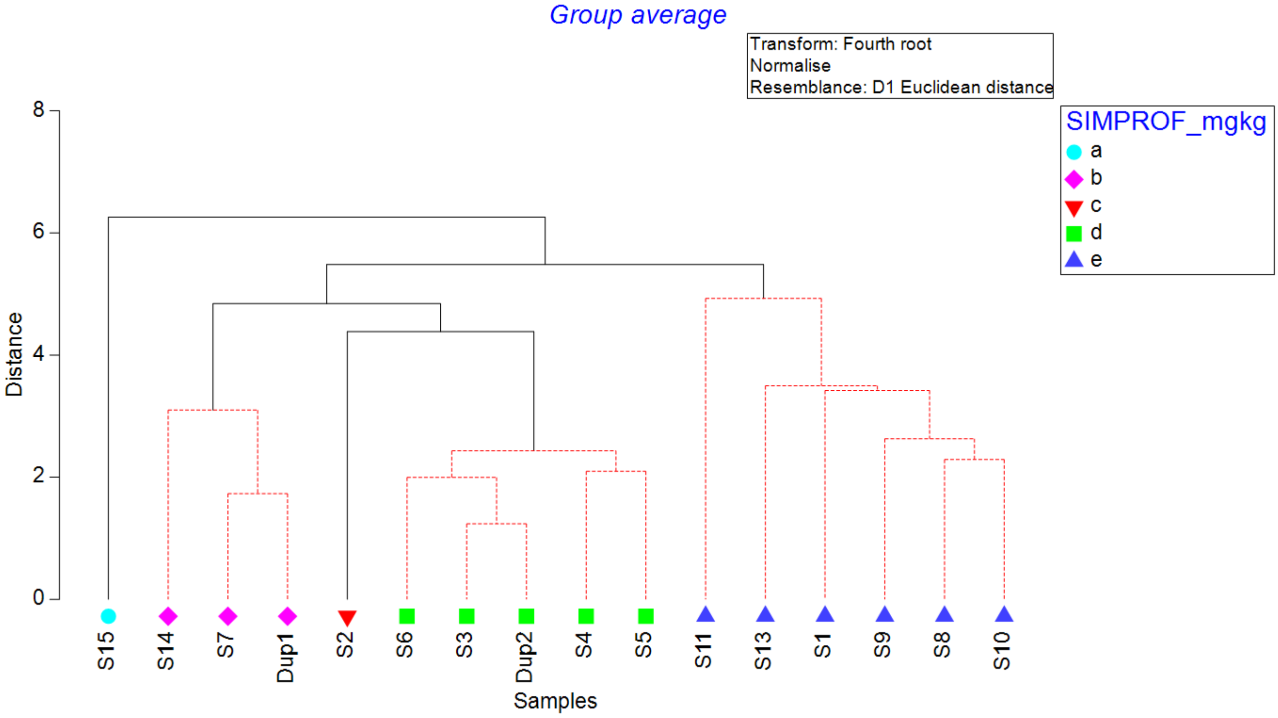

Figure 3-3: Cluster analysis of sites based on contaminants and nutrients. Red lines indicate significant SIMPROF groups

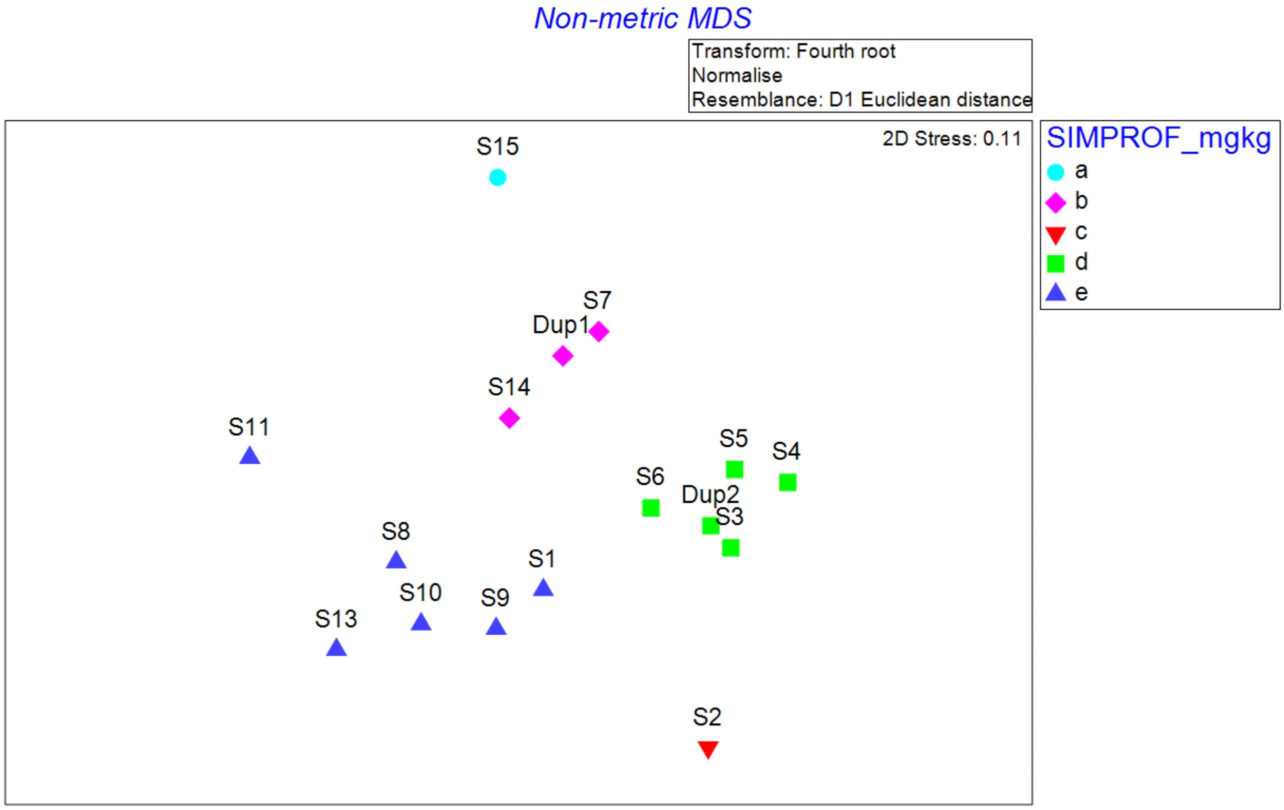

Figure 3-4: n-MDS ordination plot of sites based on contaminants and nutrients

3.1.7 Particle size distributions

Laboratory PSD results can be found in Appendix D. Prior to statistical analysis, data were analysed to characterise sediment samples in terms of Folk sediment classification, sorting, skewness and kurtosis (Table 3-7, Figure 3-5).

Folk sediment classifications provide a high-level description of sediment characteristics. The description is provided in the form of a code, which is made of abbreviations for principal sediment components. The code describes the sediment starting with the least characteristic component and finishing with the most characteristic component (which is capitalised), where:

m/M = muddy/Mud (which is synonymous with silt/clay)

s/S = sandy/Sand

g/G = gravelly or Gravel

() = slightly

For example:

(m)sG = slightly muddy sandy Gravel

gmS = gravelly muddy Sand

The sediment samples in the survey area ranged from slightly gravelly muddy sand ((g)mS) at the northern (deepest) section of the survey area (Sites 4, 6 and 15), to gravelly sand (gS) at Sites 8 to 11 (Figure 3-5). Sites in the northern (deeper) section of the survey area tended to consist of muddier sediment that became slightly coarser towards the shallower south-eastern section (gravelly sand as opposed to gravelly muddy sand). Sediments were characterised by finer particles in a northerly (offshore) direction within the survey area, increasing from ~5% silt at southern sites to ~20% silt at northern sites (Table 3-7). The proportion of sand ranged between 60 and 90% across sites, but there was no obvious spatial pattern to the variation. The central southern sites (Sites 8 to 10) had the highest proportion of gravel, with between 10 and 19% (Table 3-7). No sample was obtained from Site 12, potentially due to hard substrate at this site.

Table 3-7: Sediment sample particle size characteristics

Site	% silt/ clay (<63 µm)	% sand (0.063–2 mm)	% gravel (2–>16 mm)	Sorting	Skewness	Kurtosis	Folk
S1	8.21	89.56	2.23	Poorly sorted	Coarse skewed	Very leptokurtic	(g)S
S2	13.8	76.68	9.52	Very poorly sorted	Symmetrical	Leptokurtic	gmS
S3	31.48	63.3	5.22	Very poorly sorted	Fine skewed	Leptokurtic	gmS
S4	29.62	69.55	0.83	Poorly sorted	Coarse skewed	Platykurtic	(g)mS
S5	23	70.97	6.03	Very poorly sorted	Symmetrical	Leptokurtic	gmS
S6	17.22	81.77	1.01	Poorly sorted	Strongly coarse skewed	Mesokurtic	(g)mS
S7	20.29	73.56	6.15	Very poorly sorted	Symmetrical	Mesokurtic	gmS
S8	6.02	80.49	13.49	Very poorly sorted	Fine skewed	Very leptokurtic	gS
S9	5.25	75.03	19.72	Very poorly sorted	Strongly fine skewed	Leptokurtic	gS
S10	4.42	85.39	10.19	Poorly sorted	Fine skewed	Very leptokurtic	gS
S11	6.82	84.32	8.86	Poorly sorted	Symmetrical	Leptokurtic	gS
S13	1.61	96.7	1.69	Moderately sorted	Symmetrical	Leptokurtic	(g)S
S14	16.23	74.39	9.38	Very poorly sorted	Symmetrical	Leptokurtic	gmS
S15	13.85	82.27	3.88	Poorly sorted	Symmetrical	Leptokurtic	(g)mS

Sorting is a classification used to describe the distribution of grain sizes within samples. Well-sorted sediments comprise similarly-sized particles, whereas poorly sorted sediments comprise a wide range of different-sized particles. Sorting, therefore, has implications for both the physico-chemical characteristics of sediments (e.g. sediment oxygenation based on impacts to pore water flow) and the biological characteristics of sediments (e.g. energy required to move through sediments). Sediments in the study area ranged from moderately sorted at Site 13 in the eastern part of the survey area, to very poorly sorted through the central area (Sites 2, 3, 7, 8, 9 and 14) and at the deepest site (Site 5). Sediments at all other sites were poorly sorted (Table 3-7).

Skewness and kurtosis describe the shape of the particle size distribution curve, relative to the bell-shaped normal curve. Skewness describes a shift in the curve to the left (finer end of the size scale, hence 'fine skewed') or to the right (coarser particle sizes or 'coarse skewed'). Kurtosis describes the relative contribution of all particle sizes. A leptokurtic curve (which appears 'sharp' or 'pointed') is characteristic of a sediment sample that is highly dominated by a small number of similar size classes. A platykurtic curve ('plate-like') describes a sediment sample that has a relatively even representation of particle sizes across the full size range. Sediments in the survey area ranged from strongly fine skewed and leptokurtic at Site 9 to strongly coarse skewed and mesokurtic at Site 6 (Table 3-7).

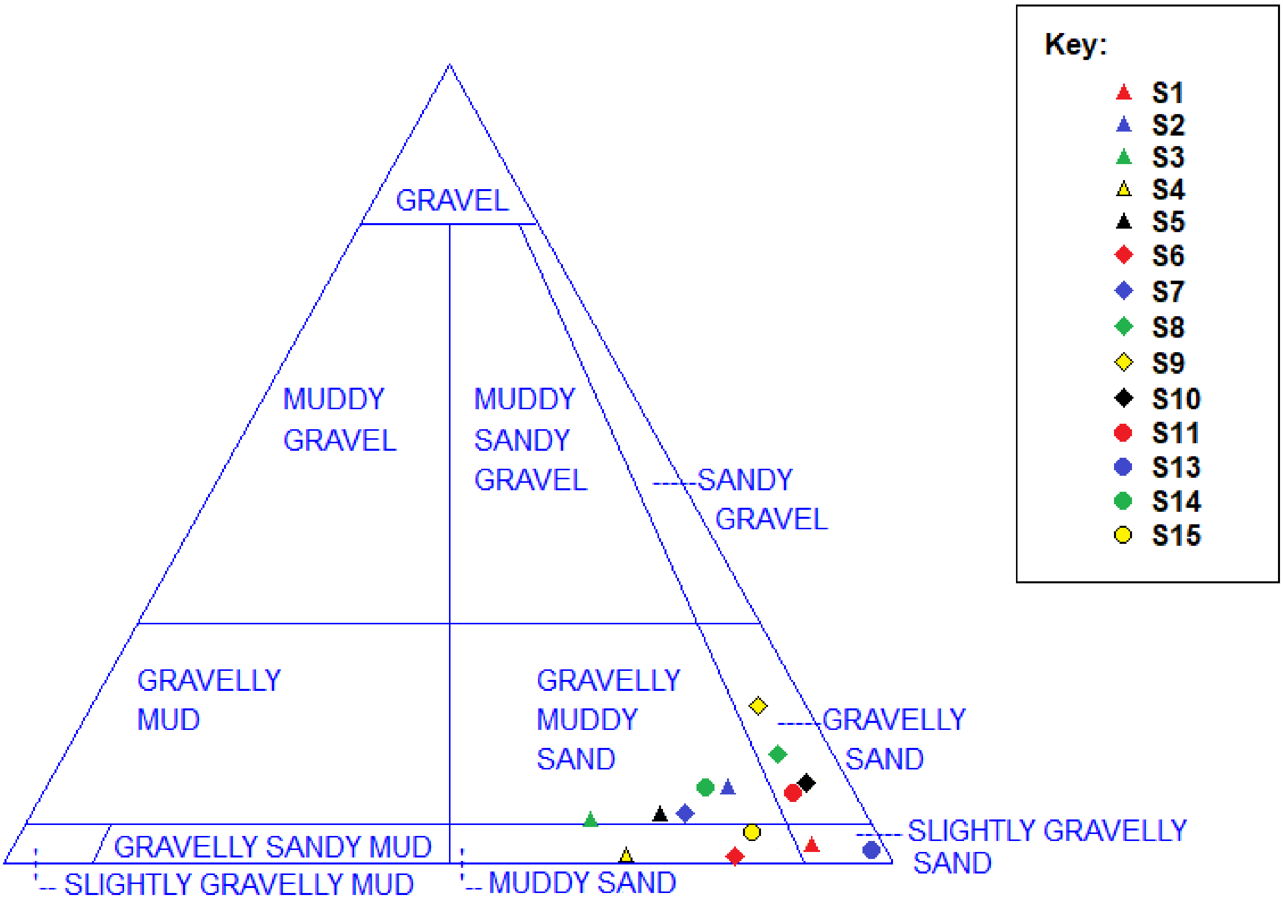

Figure 3-5: Folk classification ternary plot of Dorado sediments

Cluster analysis of PSD data identified six main groups of sediments and two outliers (Figure 3-6). When applying Folk sediment classifications, these groups could be classified into coarser groups (slightly gravelly sand and gravelly sand; Sites 1, 8, 9, 10, 11 and 13) and finer sediments (slightly gravelly muddy sand and gravelly muddy sand). Principal component analysis (PCA; Figure 3-7) showed the effect of the contribution of different size classes on the distribution of samples and their Folk classifications. The size classifications used in the analysis and interpretation of particle size data are described in Table 3-8.

Clay, silt and very fine sand (4 µm, 63 µm and 125 µm) were primarily responsible for change in sediment type along the PC1 axis, with increased contribution of fines with decreasing PC1 value (i.e. from right to left). This explained the distribution of the muddy sands on the left hand side of the plot (i.e. they all had negative PC1 values). The coarser slightly gravelly sands and gravelly sands were distributed to the right of the plot. Coarse and very coarse sands (i.e. 500 µm and 1000 µm) were responsible for the distribution of sites along a diagonal vector towards the top right of the plot (i.e. a positive PC1 and positive PC2 trajectory). The sites classified as slightly gravelly sands (sites 1 and 13) were distributed along this trajectory. The medium sands (250 µm) and coarser grain sizes (granules to coarse pebbles, i.e. 2000 to >16,000 µm) vectors roughly equated to a negative PC2 trajectory, i.e. they had an increasing contribution with decreasing PC2 value. This means that the sediments with a greater contribution of coarser grain sizes (i.e. the 'gravelly', rather than 'slightly gravelly' classifications) were distributed in the lower have of the plot. The outcome is that sites with slightly gravelly sediments are in the top left of the figure (sites 4, 6 and 15), the sites with slightly gravelly sands are in the top right (sites 1 and 13); the sites with gravelly muddy sands are in the bottom left (sites 2, 3, 5, 7 and 14), and the sites with gravelly sands in the bottom right (sites 8, 9, 10 and 11).

Table 3-8: Hierarchy of sediment size classes, after Wentworth (1922)

Principal sediment component	Subclass	Size range (to nearest µm)
Clay		<4 µm
Silt		4-62 µm
Sand	Very fine	63-124 µm
	Fine	125-249 µm
	Medium	250-499 µm
	Coarse	500-999 µm
	Very coarse	1000-1999 µm
Pebbles	Granules to very fine	2000-3999
	Fine	4000-7999
	Medium	8000-15,999
	Coarse	>16,000

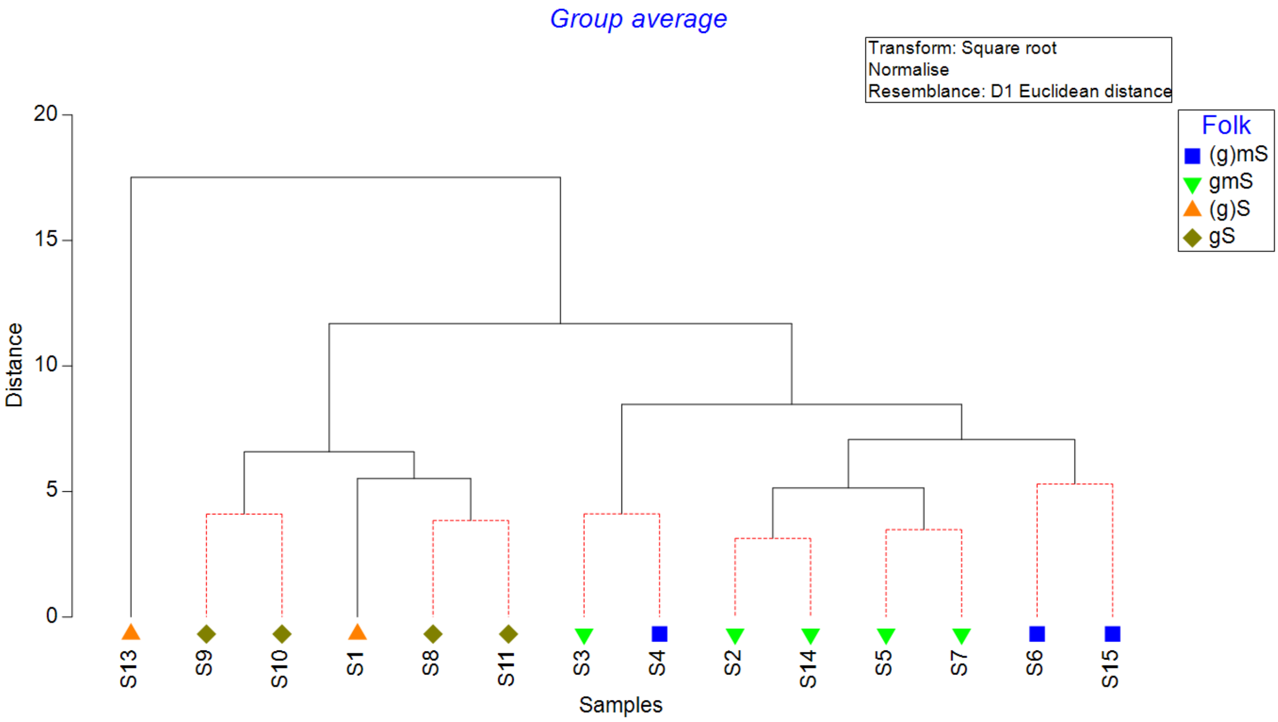

Figure 3-6: Grouping of sites based on sediment particle size characteristics. Colours represent folk groupings, and red lines represent significant SIMPROF groups

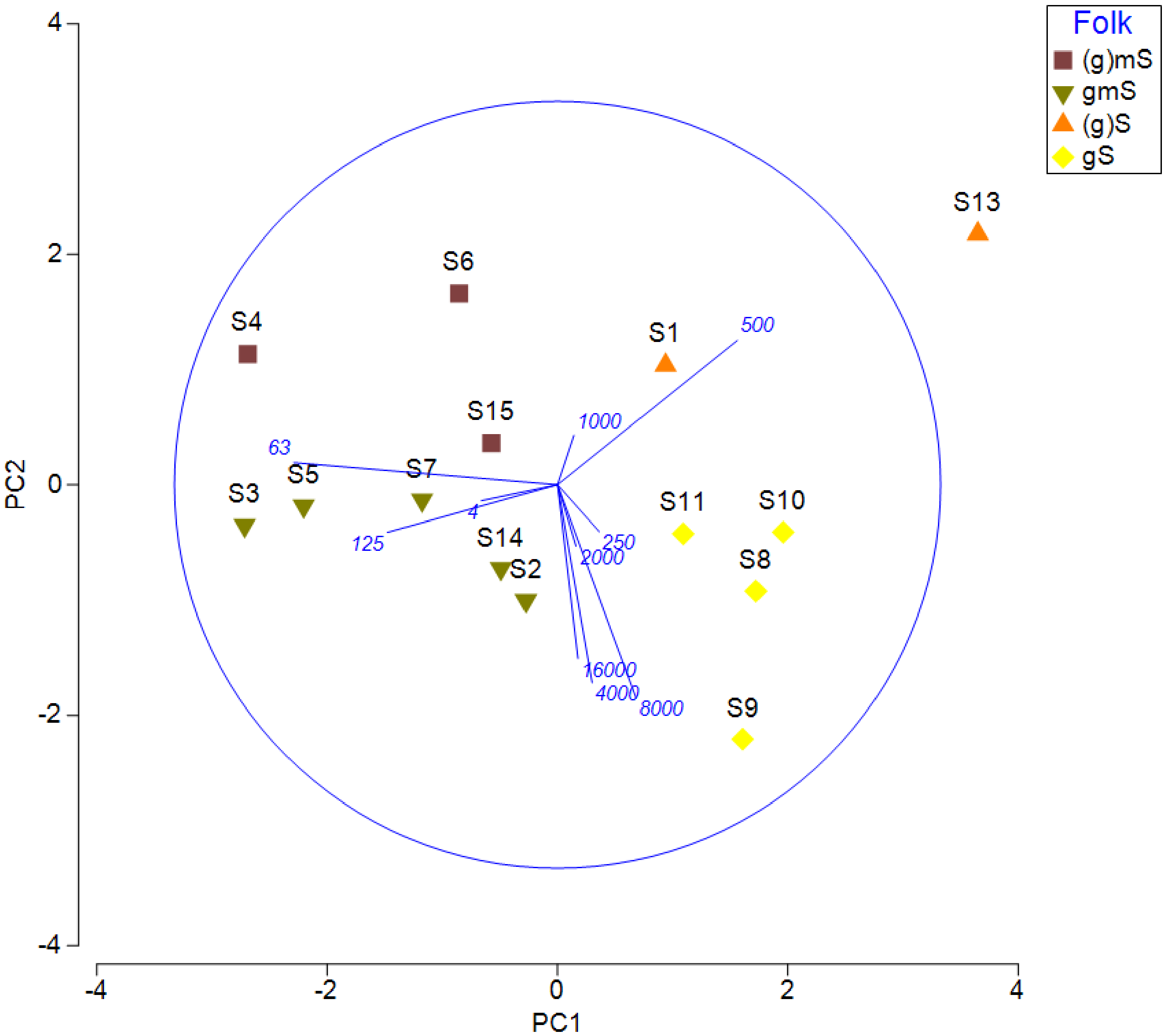

Figure 3-7: Principal component analysis (PCA) plot showing the relative effect of sediment particle size classes on the distribution of sample sites and Folk classifications

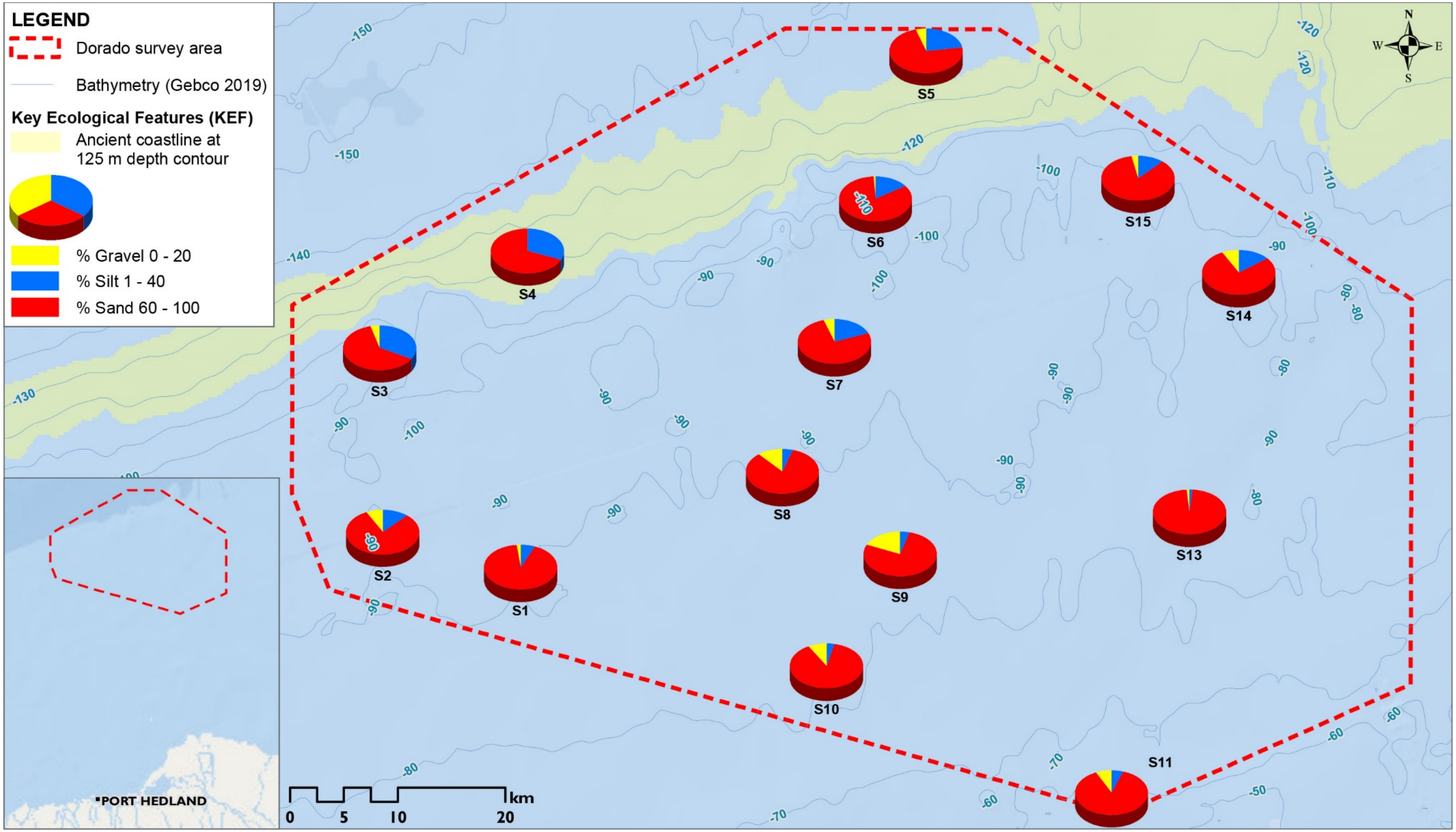

Figure 3-8: Proportion of silt, sand and gravel at sampling locations throughout the study area

3.2 Quality control samples

Results from laboratory analysis of the transport blank and field blank showed that samples were below limits of detection for all analytes. This confirms that no contamination was introduced during transport of the samples or during the process of collecting them on the vessel.

Multivariate analysis identified that duplicate samples taken as sites 7 (duplicate 1) and site 6 (duplicate 2) were not significantly different in terms of their contaminants and nutrients composition to the sites samples (see section 3.1.6). This confirms that the samples were sufficiently repeatable and therefore representative of the sampling sites.

These results demonstrated that QA/QC procedures implemented to mitigate risk of sample contamination were effective.

4 DISCUSSION

The present survey provided data characterising sediment quality (physico-chemical characteristics) within the Dorado study area. Water depths of sampling sites ranged from 56 m at the most southern site to 137 m at the most northern site. Sediments were specifically sampled in the ancient coastline KEF (Site 4) to determine if this was a unique sediment type in the area.

Site 7 was located at the previous Roc-1 drilling location to test for potential impacts from historic drilling campaigns in the area. Roc-1 was drilled in late 2015 – early 2016; four years prior to the current survey. Although drilling had been undertaken at Site 7 (Roc-1) no impacts on sediment quality from these activities were detected, apart from a slightly higher barium concentration. The higher barium concentrations probably reflect the presence of drilling mud components (barite) in the sediment matrix. No petroleum hydrocarbons or heavy metal exceedances were detected at the Roc-1 drilling site. The multi-variate analyses showed that the physical characteristics of the sediments at Site 7 were similar to those at surrounding sites.

Of the total metals/metalloids in the sediments sampled from the survey area, only arsenic exceeded the ANZG (2018) ISQG-Low trigger value and only at one site (Site 13).

Concentrations of the metals and metalloids total arsenic, total chromium and total iron showed a negative (inverse) relationship with site depth and sediment silt content, with declining analyte concentrations up to 20 % silt, then concentrations remained relatively consistent with increasing silt content to ~32 % silt. Silt content was also related to water depth, increasing with increased depth. The pattern of decreasing metals and metalloids with increasing silt content observed in the present study is contrary to the common trend of metals being associated with smaller particle grain sizes (Martincic et al. 1990). This is an important point for the interpretation of any future survey programs, as the concentrations of these metals/metalloids may naturally occur at up to three or more times higher in the vicinity of the proposed wellhead platform location than in the finer sediments in the deeper waters to the north. DEC (2006) found that total arsenic concentrations were relatively high across the region (with a median concentration of 36 mg/kg recorded for one site off Onslow), and exceeded the recommended sediment quality guideline at some of the essentially unimpacted locations sampled. These exceedances were considered to be natural by DEC (2006), and likely to be related to the local geology. Higher total arsenic concentrations in shallower water (with less silt content) in the southern sampling locations may therefore be due to effects of the underlying geology.

With the exception of cadmium (and barium, which is not represented in DEC 2006), all metals and metalloid concentrations were equal to or less than the estimated natural background concentrations for Pilbara coastal marine sediments (DEC 2006).

Nickel was recorded at concentrations below guideline at all sites, despite the fact that nickel tends to be strongly associated with organic molecules (Wenziker et al. 2006) and is commonly found in high concentrations in Australian sediments (Commonwealth of Australia 2009).

Tributyltin and hydrocarbon concentrations at all sites were below the limit of reporting at all sites. Similar results have been recorded in other studies of sediment quality in offshore areas in northern Australia (e.g. ConocoPhillips 2018).

Oil and grease ranged from 220 mg/kg at site 11, to 1900 mg/kg at site 15. The result for site 15 was significantly higher than all other sites – 450 mg/kg was the second highest value recorded (at site 1 and in duplicate 2 taken from site 6). Site 15 is one of the northern deep-water sites not previously exposed to drilling. Total recoverable hydrocarbons (TRH) were below limits of detection at this site, making identification of the source difficult - even potential grease contamination from the winch wire is unlikely due to the absence of TRH.

Total petroleum hydrocarbons (TPH), total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) concentrations were below the laboratory LOR at all sites within the survey area. Consequently, no analysis of polycyclic aromatic hydrocarbons (PAHs) was required.

The combined value for radium^{226}, radium^{228} and thorium^{228} (‘combined NORMs’) were below the guideline value of 35 Bq/kg at all sites, even when considering upper confidence limits.

Nutrients (nitrogen, phosphorus and organic carbon) are released in the decay of organic matter. Total Kjeldahl nitrogen (TKN) concentrations exhibited low variability, but were generally marginally higher at sites along the northern and western edges of the survey area. They were comparable to levels recorded from other offshore surveys in Northern Australia (e.g. ConocoPhillips 2018), though total organic carbon concentrations were considered to be low. There was no discernible spatial pattern in total phosphorus or correlation with depth. Total organic carbon concentrations also exhibited limited variation, and closely corresponded with TKN concentrations, with the highest levels recorded at the siltier sites along the northern and western edges of the survey area.

The survey area was characterised by a gradual transition in sediment coarseness, with the coarsest sediments (greatest gravel component and least silt component) at the southern and south-eastern sites, and higher silt content in the northern sites. This distribution generally related to water depth, with the deepest northern sites (Sites 2, 3, 4, 5, 6, 7, 14 and 15) generally having a greater silt component than the southern sites (Sites 1, 8, 9, 10, 11 and 12). Site 13 was distinct as it has a low contribution of both silt and gravel, and has the highest contribution of sand.

The relative increase in silt component with increased depth is a common feature in offshore areas (e.g. ConocoPhillips 2018, Shell 2018), due to a reduction in near-seabed current speeds, which may be insufficient to resuspend finer particle sizes than at shallower sites and/or result in increased deposition of finer material, as the increased fine content with increased water depth is a common occurrence in the offshore marine environment. The silt component of sediments at Roc-1 (~20.3 %) were comparable with particle size data previously collected at the Roc-1 location (NGI 2017). Silt content at Roc-1 (20.3 %) was greater than the other 'central' sites (i.e. sites 1,2, 8 and 14) with silt content of 8.2, 13.8, 6.0 and 16.2 %, respectively, though this variability was within the range of sediment silt content at sites in other depth ranges and therefore cannot be directly attributed to historic drilling activities at site 7 (Roc-1). Folk sediment classifications were useful in identifying trends in sediment types across the study area and showed there was low variability in the sediment types across the survey area, which only ranged from slightly gravelly muddy sand to gravelly sand. Offshore sediments are often dominated by sands and muddy sands, with varying contributions of gravel (which can be biogenic in origin, e.g. shell fragments).

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Appendix A
Sediment survey sampling summary and field log sheets

APPENDIX A: SEDIMENT SURVEY SAMPLING SUMMARY AND FIELD LOG SHEETS

Table A-1: Log sheet records of sediment survey grab sampling. Site number, GPS waypoint number, date and time and water depth were recorded for every grab sample attempt where the grab hit the seafloor. Upon successful retrieval to the deck, the following information was also recorded: volume of the grab sample (sample size), sediment composition, sediment features, conspicuous flora/fauna, type of sample taken, i.e. fauna, particle size distribution (PSD) and its volume, or contaminants

Site	Waypoint name	Date	Time	Depth (m)	Successful?	Sample no.	Sample size	Composition	Features	Conspicuous flora/fauna	Fauna replicate	PSD vol (cm^3)	Contaminants	Notes
1	130	17/12/2019	04:48	87	N									
1	126	17/12/2019	03:49	89	Y	1						300	OMHN	
1	125	17/12/2019	03:36	90	N									Sounder is 1.8 m below waterline
1	127	17/12/2019	04:11	98	N									
1	124	17/12/2019	03:22	99	N									
1	128	17/12/2019	04:23	100	N									
1	129	17/12/2019	04:36	100	N									
2	119	17/12/2019	01:13	80	N									
2	118	17/12/2019	00:52	85	Y	1	1/3					300		
2	121	17/12/2019	01:47	86	Y	2	1/3	Silty, fine to medium, encrusting calcareous biogenic material		Hydroids, worm tubes, gorgonian, bryzoan			OMHN	
2	120	17/12/2019	01:26	90	N		1/6							
2	122	17/12/2019	01:59	100	N									
2	123	17/12/2019	02:14	104	N									No fauna taken at site 2
3	116	16/12/2019	23:03	85	Y	1	1/2	Silty fine sand				300	OMHN	
3	117	16/12/2019	23:23	98	Y	2	1/2	Silty fine sand			1			
4	108	16/12/2019	19:49	118	N									
4	110	16/12/2019	20:08	118	Y	1	1/3	Silty fine sand			1		OMHN	
4	111	16/12/2019	20:32	118	N		1/5							
4	112	16/12/2019	20:53	118	N									
4	113	16/12/2019	21:07	118	N									Grab did not release/go off at sea floor
4	114	16/12/2019	21:16	118	Y	2	1/5					300		
4	115	16/12/2019	21:35	118	N									
5	184	19/12/2019	02:15	135	N		Scraping							
5	185	19/12/2019	02:40	135	N		Scraping							
5	186	19/12/2019	03:00	135	Y	1		Fine muddy silty sand				300	OMHN	
5	187	19/12/2019	03:26	135	N		Scraping							
5	189	19/12/2019	04:00	135	Y	2	1/5	Silty, fine			1			Waypoint 188: grab did not close
6	182	19/12/2019	00:32	98	N									
6	183	19/12/2019	00:54	98	N									
6	179	18/12/2019	23:38	103	Y	1						300	OMHN	
6	180	19/12/2019	00:01	103	N									
6	181	19/12/2019	00:12	103	N									
7	171	18/12/2019	21:38	95	Y	1	~10L	Light brown fine silty/clay sand		Small hydroids		300	OMHN	
7	173	18/12/2019	21:56	95	N									
7	174	18/12/2019	22:12	95	N									
7	175	18/12/2019	22:19	97	N									Ignore waypoints 176 + 177
7	178	18/12/2019	22:42	97	Y	2							OMHN (Duplicate 1)	
8	168	18/12/2019	19:37	85	N									
8	169	18/12/2019	19:46	85	Y	1		Medium silty sand with shell in		Mantis shrimp (see photo)		300	OMHN	

Site	Waypoint name	Date	Time	Depth (m)	Successful?	Sample no.	Sample size	Composition	Features	Conspicuous flora/fauna	Fauna replicate	PSD vol (cm^3)	Contaminants	Notes
8	170	18/12/2019	20:05	85	Y	2	1/2				1			Fauna sample split between two bags
9	163	18/12/2019	17:25	83	N									
9	165	18/12/2019	18:00	83	Y	2	300 ml	Shell & sand				150		
9	166	18/12/2019	18:15	84	Y	3	Scraping	Sand				150		
9	167	18/12/2019	16:30	84	N									
9	164	18/12/2019	17:40	86	Y	1	Small	Fine-medium sand		Small crab		150	OMHN	
10	161	18/12/2019	16:10	78	N		Empty							Grab changed to spare due to bending damage
10	158	18/12/2019	15:14	79	N		Scraping							
10	159	18/12/2019	15:20	79	N		Empty							
10	160	18/12/2019	15:58	79	N		Empty							
10	162	18/12/2019	16:25	79	Y	1	2L	Medium fine sand, shell grit					OMHN	
11	150	18/12/2019	04:30	54	N		Scraping							
11	149	18/12/2019	03:59	60	Y	1	~15 litres	Silty medium sand	Tubes	Brittlestars, heart urchin (as prior)		300	OMHN	
11	152	18/12/2019	04:52	60	N									
11	151	18/12/2019	04:41	61	N									
11	147	18/12/2019	03:34	63	N									
11	148	18/12/2019	03:48	63	N		Scraping							
12	146	18/12/2019	02:09	76	N									Sounder shows very hard ground
12	144	18/12/2019	01:32	77	N									
12	142	18/12/2019	01:01	81	N		Scraping							
12	143	18/12/2019	01:16	81	N		Scraping							
12	145	18/12/2019	01:52	82	N		Scraping							
13	139	17/12/2019	23:18	84	Y	1						300	OMHN	
13	140	17/12/2019	23:44	84	N		Scraping							
13	141	17/12/2019	23:51	84	Y	2					1			Fauna sample split between three bags
14	136	17/12/2019	20:23	91	N		Scraping							
14	137	17/12/2019	20:33	91	N									
14	138	17/12/2019	20:43	91	Y	1		Medium-fine silty sand with shell gravel	Burrows, tubes, casts	Heart urchin (~5-10 cm, yellow/green - see photo)		300	OMHN	
14	-	17/12/2019	21:19	92	N									Sample unsuccessful - position not recorded.
15	134	17/12/2019	19:13	105	N									
15	135	17/12/2019	19:23	105	N		Scraping							
15	131	17/12/2019	18:21	109	N		Empty							Ground at site 15 looks hard on sounder
15	132	17/12/2019	18:41	109	N		Scraping	Sandy						Tiny amount of sand
15	133	17/12/2019	18:52	109	Y	1	1/4	Medium course sand + gravel				300	OMHN	

Appendix B
Details of laboratory analysis

APPENDIX B: DETAILS OF LABORATORY ANALYSIS

Table B-1: Analyte laboratory limits of reporting (LOR), guideline values, storage/preservation and holding times

Analyte (unit)	LOR	Guideline value	Storage medium	Preservation method	Holding time
Aluminium (mg kg^{-1} dry wt)	<20	N/A	Glass jar	Frozen	180 days
Arsenic (mg kg^{-1} dry wt)	<2	20[1]	Glass jar	Frozen	180 days
Barium (mg kg^{-1} dry wt)	<0.2	N/A	Glass jar	Frozen	180 days
Cadmium (mg kg^{-1} dry wt)	<0.1	1.5[1]	Glass jar	Frozen	180 days
Cobalt (mg kg^{-1} dry wt)	<0.2	1.0[2]	Glass jar	Frozen	180 days
Chromium (mg kg^{-1} dry wt)	<0.2	80[1]	Glass jar	Frozen	180 days
Copper (mg kg^{-1} dry wt)	<0.2	65[1]	Glass jar	Frozen	180 days
Iron (mg kg^{-1} dry wt)	<5	N/A	Glass jar	Frozen	180 days
Nickel (mg kg^{-1} dry wt)	<0.7	21[1]	Glass jar	Frozen	180 days
Lead (mg kg^{-1} dry wt)	<1	50[1]	Glass jar	Frozen	180 days
Zinc (mg kg^{-1} dry wt)	<0.5	200[1]	Glass jar	Frozen	180 days
Mercury (mg kg^{-1} dry wt)	<0.01	0.15[1]	Glass jar	Frozen	28 days
Tributyltin (µg Sn kg^{-1} dry wt)[a]	<0.5	9.0[1]	Glass jar	Frozen	56 days
TRH (C_{10}-C_{36}) (mg kg^{-1} dry wt)[a]	<5	280[1]	Glass jar	Frozen	14 days
Oil and grease (mg kg^{-1} dry wt)	<100	N/A	Glass jar	Frozen	14 days
Radium[226] bq kg^{-1} dry wt)	<500	35,000 (sum of gross alpha and gross beta)[3]	Glass jar	Frozen	14 days
Radium[228] (bq kg^{-1} dry wt)	<500		Glass jar	Frozen	14 days
Thorium[228] bq kg^{-1} dry wt)	<500		Glass jar	Frozen	14 days
Total Kjeldahl nitrogen (mg N kg^{-1} dry wt)	<0.1	N/A	Glass jar	Frozen	14 days
Total phosphorus (mg P kg^{-1} dry wt)	<0.05	N/A	Glass jar	Frozen	14 days
Total organic carbon (% C)	<0.1	N/A	Glass jar	Frozen	14 days
Particle size distribution	N/A	N/A	Plastic ziplock bag	Chilled to ~4 °C	N/A
Infauna	N/A	N/A	Plastic ziplock bag	80 % ethanol	N/A

[a] Normalised to 1 % TOC.

[1] Simpson et al. (2013).

[2] ANZECC & ARMCANZ (2000) low reliability trigger value.

[3] National Assessment Guidelines for Dredging (2009) screening level (interim sediment quality guideline trigger value).

Table B-2: Laboratories used for sediment and infauna analysis

Analyte	Laboratory
Heavy metals/metalloids (Al, As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Ni, Pb, Zn)	Marine and Freshwater Laboratory (MAFRL)
Hydrocarbons (TRH, BTEXN)	Australian Laboratory Services (ALS)
Oil and grease	ALS
Tributyltin (TBT)	ALS
NORMs (radium[226], radium[228] and thorium[228])	SGS
Nutrients (total Kjeldahl nitrogen [TKN] and total phosphorus [TP])	MAFRL
Total organic carbon (TOC)	MAFRL
Tributyltin (TBT)	MAFRL
Particle size distribution (PSD)	MAFRL
Infauna sorting and taxonomy	Benthic Australia

Appendix C
Photographs of grab samples

APPENDIX C: PHOTOGRAPHS OF GRAB SAMPLES

Figure C-1: Sediment sampled at Site 1 in CSIRO ecotype 4

Figure C-2: Silty, fine to medium sediments with encrusting biogenic material from Site 2 in CSIRO ecotype 4

Figure C-3: Silty fine sand sediment from Site 3 in CSIRO ecotype 3

Figure C-4: Silty fine sand sediment from Site 4 in CSIRO ecotype 2

Figure C-5: Silty fine mud/sand sediment from Site 5 in CSIRO ecotype 1

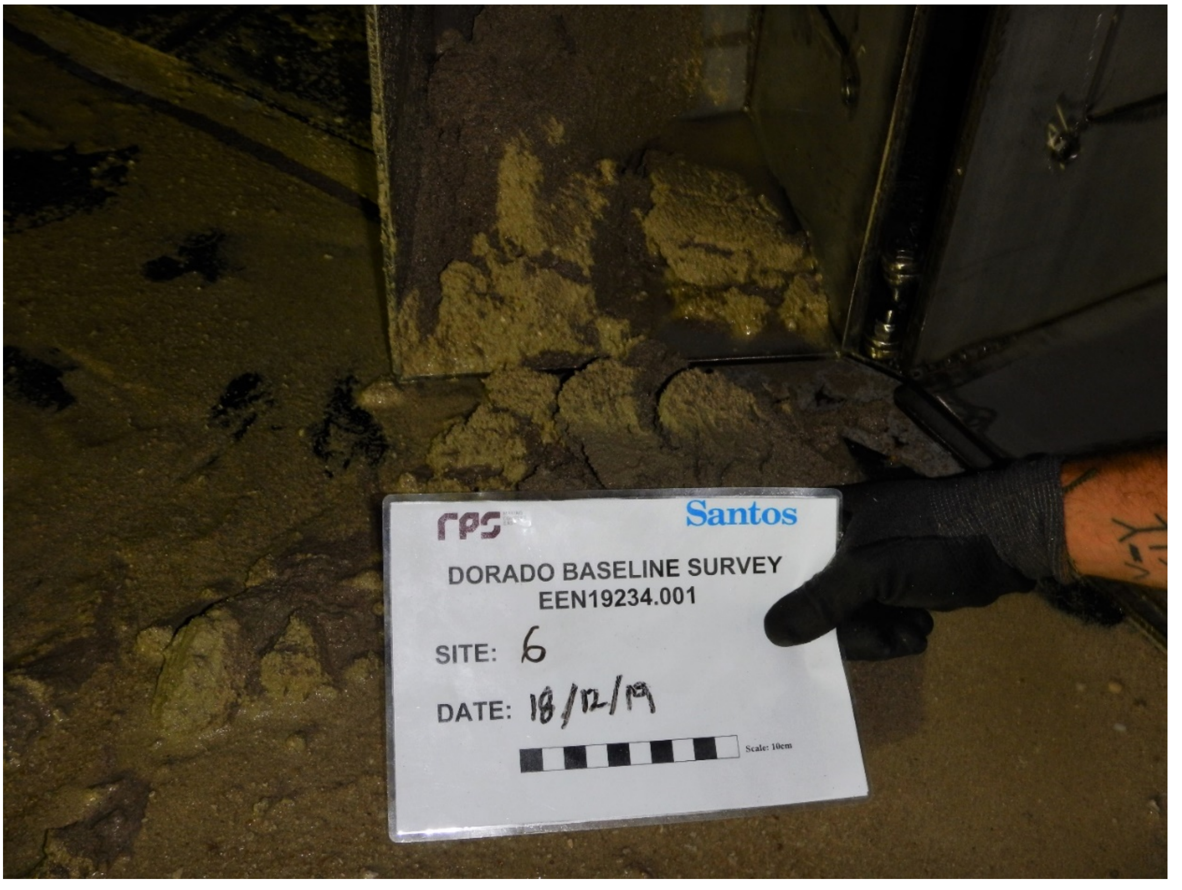

Figure C-6: Fine-grained sand sediment from Site 6 in CSIRO ecotype 3

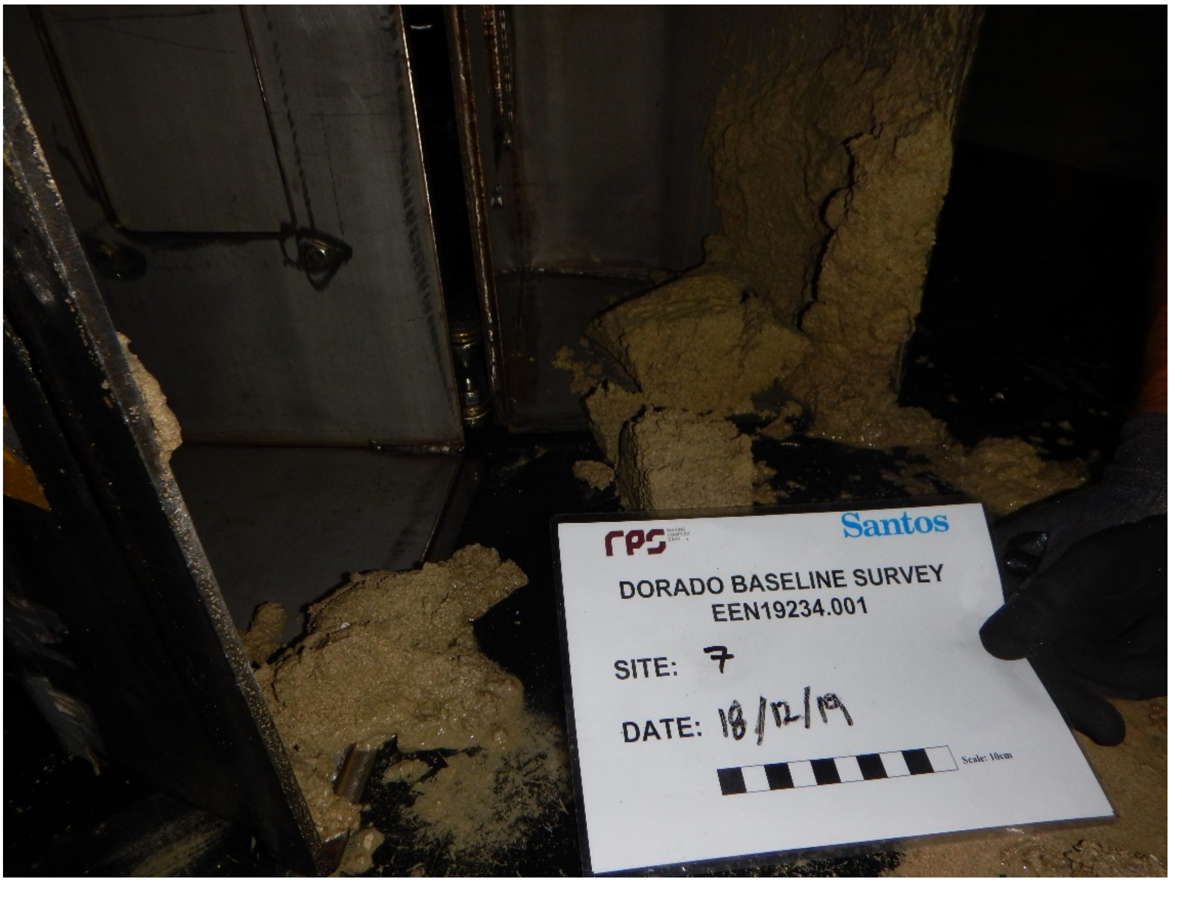

Figure C-7: Fine, silty clay/sand sediment from Site 7 in CSIRO ecotype 4

Figure C-8: Medium silty sand sediment with shell gravel from Site 8 in CSIRO ecotype 4

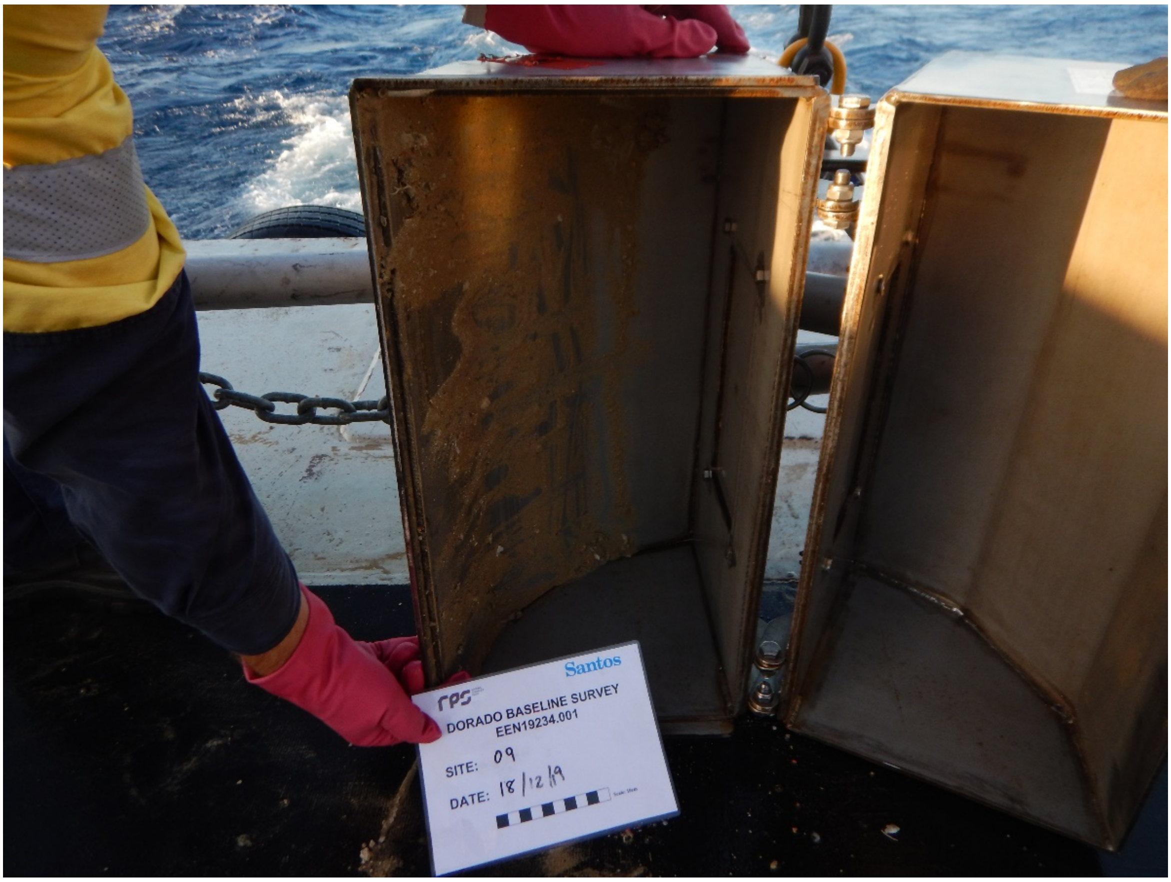

Figure C-9: Fine-to-medium shell and sand sediment from Site 9 in CSIRO ecotype 5

Figure C-10: Medium-fine sand and shell grit sediment from Site 10 in CSIRO ecotype 6

Figure C-11: Silty, medium sand sediment from Site 11 in CSIRO ecotype 7

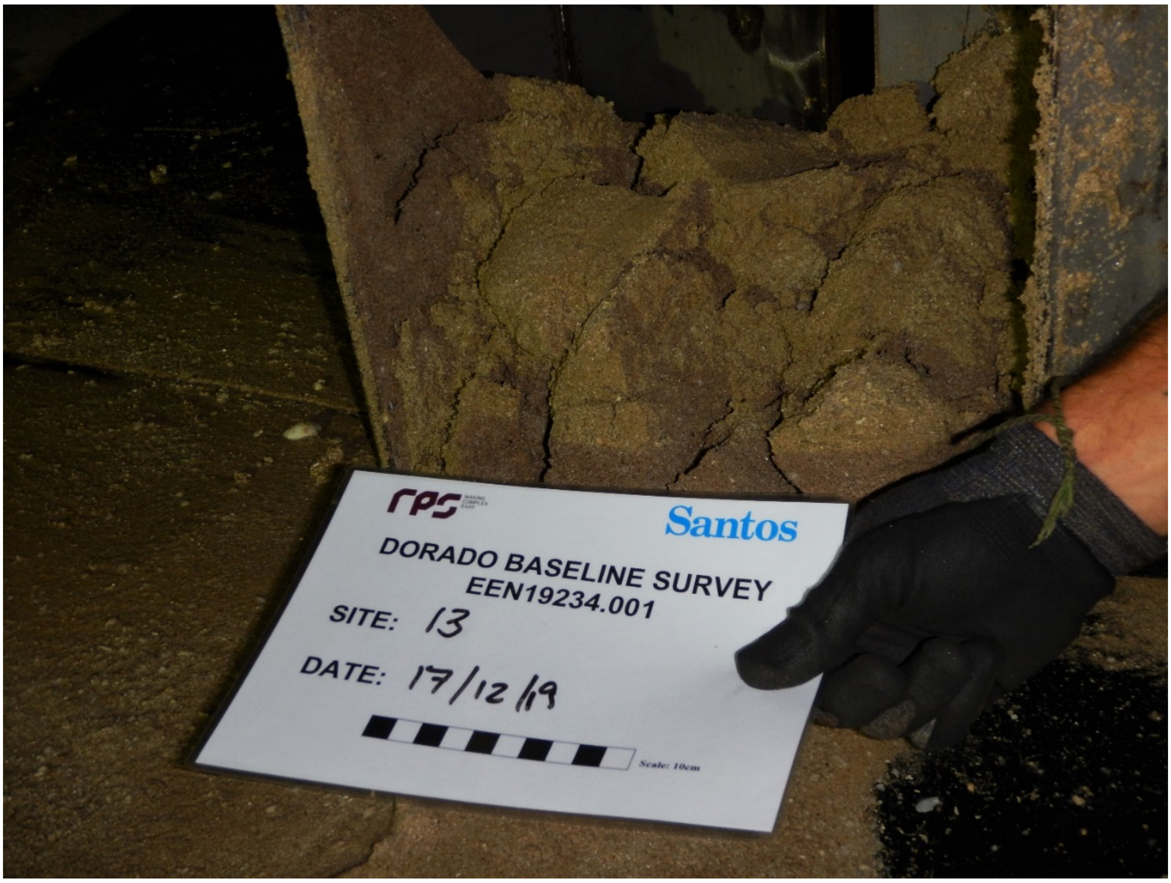

Figure C-12: Sediment from Site 13, in CSIRO ecotype 5

Figure C-13: Medium-coarse sand and gravel sediment from Site 15 in CSIRO ecotype 3

Appendix D
Analytical laboratory reports

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1913671**	Page	: 1 of 11
Client	: **RPS Australia West Pty Ltd**	Laboratory	: Environmental Division Perth
Contact	: GARNET HOOPER	Contact	: Rhiannon Steere
Address	: PO BOX 170 WEST PERTH WA 6872	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: 08 9211 1131	Telephone	: 08 9406 1306
Project	: Santos	Date Samples Received	: 23-Dec-2019 07:00
Order number	: ----	Date Analysis Commenced	: 24-Dec-2019
C-O-C number	: RPS19-2	Issue Date	: 13-Jan-2020 15:59
Sampler	: ----		
Site	: Dorado		
Quote number	: EP/954/19		
No. of samples received	: 16		
No. of samples analysed	: 16		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Diana Mesa	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
ShukHui Li	Client Services - Technical Manager	WRG Subcontracting, Wangara, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP090 Organotin: Sample 'S1' shows poor surrogate recovery due to matrix interference. Confirmed by re-extraction and re-analysis.
- Oil and Grease Analysis (CM067) is conducted by ALS Scoresby NATA accreditation no. 992, site no. 989.. NATA accreditation does not cover performance of this method.

Analytical Results

Sub-Matrix: **SEDIMENT** (Matrix: **SOIL**)			*Client sample ID*	**S1**	**S2**	**S3**	**S4**	**S5**
			Client sampling date / time	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	19-Dec-2019 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1913671-001**	**EP1913671-002**	**EP1913671-003**	**EP1913671-004**	**EP1913671-005**
				Result	Result	Result	Result	Result
CM067: Oil and Grease								
Oil and Grease	----	100	mg/kg	**450**	**390**	**330**	**300**	**260**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**28.1**	**26.8**	**28.0**	**29.2**	**33.4**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**86.3**	**104**	**108**	**113**	**108**
Toluene-D8	2037-26-5	0.2	%	**72.5**	**70.1**	**84.0**	**71.9**	**82.1**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	S1	S2	S3	S4	S5
			Client sampling date / time	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	19-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913671-001	EP1913671-002	EP1913671-003	EP1913671-004	EP1913671-005
				Result	Result	Result	Result	Result
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.2	%	71.1	80.0	82.6	84.0	80.5
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	34.3	71.1	71.1	72.9	111

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	S6	S7	S8	S9	S10
			Client sampling date / time	19-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913671-006	EP1913671-007	EP1913671-008	EP1913671-009	EP1913671-010
				Result	Result	Result	Result	Result
CM067: Oil and Grease								
Oil and Grease	----	100	mg/kg	**420**	**290**	**310**	**290**	**340**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**44.9**	**27.7**	**28.6**	**27.3**	**22.0**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**104**	**88.2**	**92.0**	**93.1**	**96.2**
Toluene-D8	2037-26-5	0.2	%	**82.8**	**71.1**	**74.3**	**75.3**	**77.1**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	S6	S7	S8	S9	S10
			Client sampling date / time	19-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913671-006	EP1913671-007	EP1913671-008	EP1913671-009	EP1913671-010
				Result	Result	Result	Result	Result
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.2	%	**79.0**	**78.8**	**70.1**	**72.8**	**73.2**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**104**	**118**	**121**	**96.0**	**124**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	S11	S13	S14	S15	DUP1
			Client sampling date / time	18-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913671-011	EP1913671-012	EP1913671-013	EP1913671-014	EP1913671-015
				Result	Result	Result	Result	Result
CM067: Oil and Grease								
Oil and Grease	----	100	mg/kg	**220**	**310**	**350**	**1900**	**320**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**27.6**	**29.9**	**29.3**	**30.2**	**26.4**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**91.5**	**107**	**101**	**99.2**	**110**
Toluene-D8	2037-26-5	0.2	%	**71.5**	**81.3**	**80.0**	**77.8**	**72.8**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	S11	S13	S14	S15	DUP1
			Client sampling date / time	18-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913671-011	EP1913671-012	EP1913671-013	EP1913671-014	EP1913671-015
				Result	Result	Result	Result	Result
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.2	%	70.1	80.7	78.0	76.1	86.6
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	81.8	131	80.0	110	98.4

Analytical Results

Sub-Matrix: SEDIMENT
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	DUP2	----	----	----	----
			Client sampling date / time	18-Dec-2019 00:00	----	----	----	----
				EP1913671-016	--------	--------	--------	--------
				Result	----	----	----	----
CM067: Oil and Grease								
Oil and Grease	----	100	mg/kg	**450**	----	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**48.0**	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	----	----	----	----
>C16 - C34 Fraction	----	3	mg/kg	<3	----	----	----	----
>C34 - C40 Fraction	----	5	mg/kg	<5	----	----	----	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	----	----	----	----
C10 - C14 Fraction	----	3	mg/kg	<3	----	----	----	----
C15 - C28 Fraction	----	3	mg/kg	<3	----	----	----	----
C29 - C36 Fraction	----	5	mg/kg	<5	----	----	----	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	----	----	----	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	----	----	----	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	----	----	----	----
Toluene	108-88-3	0.2	mg/kg	<0.2	----	----	----	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	----	----	----	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	----	----	----	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	----	----	----	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	----	----	----	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	----	----	----	----
EP090: Organotin Compounds								
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	----	----	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**101**	----	----	----	----
Toluene-D8	2037-26-5	0.2	%	**80.5**	----	----	----	----

Analytical Results

Sub-Matrix: **SEDIMENT** (Matrix: **SOIL)**			Client sample ID	**DUP2**	----	----	----	----
			Client sampling date / time	18-Dec-2019 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	**EP1913671-016**	--------	--------	--------	--------
				Result	----	----	----	----
EP080-SD: TPH(V)/BTEX Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.2	%	**78.0**	----	----	----	----
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**116**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SEDIMENT**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	70	130
Toluene-D8	2037-26-5	70	130
4-Bromofluorobenzene	460-00-4	70	130
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EP1913671**	Page	: 1 of 5
Client	: **RPS Australia West Pty Ltd**	Laboratory	: Environmental Division Perth
Contact	: GARNET HOOPER	Contact	: Rhiannon Steere
Address	: PO BOX 170 WEST PERTH WA 6872	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: 08 9211 1131	Telephone	: 08 9406 1306
Project	: Santos	Date Samples Received	: 23-Dec-2019
Order number	: ----	Date Analysis Commenced	: 24-Dec-2019
C-O-C number	: RPS19-2	Issue Date	: 13-Jan-2020
Sampler	: ----		
Site	: Dorado		
Quote number	: EP/954/19		
No. of samples received	: 16		
No. of samples analysed	: 16		

NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Diana Mesa	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
ShukHui Li	Client Services - Technical Manager	WRG Subcontracting, Wangara, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 2789576)									
EP1913671-001	S1	EA055: Moisture Content	----	0.1	%	28.1	28.6	1.84	0% - 20%
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 2789580)									
EP1913671-012	S13	EA055: Moisture Content	----	0.1	%	29.9	30.2	0.769	0% - 20%
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 2789583)									
EP1913660-025	Anonymous	EA055: Moisture Content	----	0.1	%	<0.1	<0.1	0.00	No Limit
EP1913671-015	DUP1	EA055: Moisture Content	----	0.1	%	26.4	27.0	1.95	0% - 20%
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 2791067)									
EP1913625-002	Anonymous	EA055: Moisture Content	----	0.1	%	6.5	6.7	2.32	No Limit
EP1913664-003	Anonymous	EA055: Moisture Content	----	0.1	%	1.0	1.6	45.3	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 2784115)									
EP1913671-001	S1	EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP1913671-011	S11	EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 2784118)									
EP1913671-001	S1	EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	<3	0.00	0% - 3%
EP1913671-011	S11	EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	<3	0.00	0% - 3%
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 2784115)									
EP1913671-001	S1	EP071-SD: >C10 - C16 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 2784115) - continued									
EP1913671-001	S1	EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP1913671-011	S11	EP071-SD: >C10 - C16 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<5	<5	0.00	No Limit
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 2784118)									
EP1913671-001	S1	EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	0.00	0% - 3%
EP1913671-011	S11	EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	0.00	0% - 3%
EP080-SD: BTEXN (QC Lot: 2784118)									
EP1913671-001	S1	EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.5	<0.5	0.00	0% - .2%
		EP080-SD: Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
EP1913671-011	S11	EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.5	<0.5	0.00	0% - .2%
		EP080-SD: Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
		EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	0.00	0% - .2%
EP090: Organotin Compounds (QC Lot: 2786538)									
EM1922007-003	Anonymous	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.00	No Limit
EP1913671-007	S7	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2784115)								
EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<3	252 mg/kg	84.3	75.9	145
EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<3	634 mg/kg	76.3	70.9	140
EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<5	99 mg/kg	69.4	60.2	132
EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2784118)								
EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	32 mg/kg	81.0	70.0	130
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 2784115)								
EP071-SD: >C10 - C16 Fraction	----	3	mg/kg	<3	404 mg/kg	83.4	76.1	147
EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<3	567 mg/kg	70.2	63.4	132
EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<5	33 mg/kg	74.1	54.9	130
EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 2784118)								
EP080-SD: C6 - C10 Fraction	C6_C10	3	mg/kg	<3	37 mg/kg	85.7	70.0	130
EP080-SD: BTEXN (QCLot: 2784118)								
EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	2 mg/kg	108	70.0	130
EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	2 mg/kg	76.2	70.0	130
EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	2 mg/kg	85.9	70.0	130
EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	4 mg/kg	94.0	70.0	130
EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	2 mg/kg	94.6	70.0	130
EP080-SD: Total Xylenes	----	0.2	mg/kg	<0.2	----	----	----	----
EP080-SD: Sum of BTEX	----	0.2	mg/kg	<0.2	----	----	----	----
EP080-SD: Naphthalene	91-20-3	0.2	mg/kg	<0.2	0.5 mg/kg	83.6	70.0	130
EP090: Organotin Compounds (QCLot: 2786538)								
EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	1.25 µgSn/kg	58.1	52.0	139

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2784115)							
EP1913671-002	S2	EP071-SD: C10 - C14 Fraction	----	252 mg/kg	93.2	70.0	130
		EP071-SD: C15 - C28 Fraction	----	634 mg/kg	83.2	70.0	130
		EP071-SD: C29 - C36 Fraction	----	99 mg/kg	77.8	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2784118)							
EP1913671-002	S2	EP080-SD: C6 - C9 Fraction	----	32 mg/kg	71.8	70.0	130
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 2784115)							
EP1913671-002	S2	EP071-SD: >C10 - C16 Fraction	----	404 mg/kg	91.6	70.0	130
		EP071-SD: >C16 - C34 Fraction	----	567 mg/kg	76.8	70.0	130
		EP071-SD: >C34 - C40 Fraction	----	33 mg/kg	86.0	70.0	130
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 2784118)							
EP1913671-002	S2	EP080-SD: C6 - C10 Fraction	C6_C10	37 mg/kg	70.3	70.0	130
EP080-SD: BTEXN (QCLot: 2784118)							
EP1913671-002	S2	EP080-SD: Benzene	71-43-2	2 mg/kg	98.7	70.0	130
		EP080-SD: Toluene	108-88-3	2 mg/kg	80.5	70.0	130
EP090: Organotin Compounds (QCLot: 2786538)							
EM1922007-006	Anonymous	EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	57.7	20.0	130

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EP1913671**	Page	: 1 of 6
Client	: **RPS Australia West Pty Ltd**	Laboratory	: Environmental Division Perth
Contact	: GARNET HOOPER	Telephone	: 08 9406 1306
Project	: Santos	Date Samples Received	: 23-Dec-2019
Site	: Dorado	Issue Date	: 13-Jan-2020
Sampler	: ----	No. of samples received	: 16
Order number	: ----	No. of samples analysed	: 16

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **Surrogate recovery outliers exist for all regular sample matrices - please see following pages for full details.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Regular Sample Surrogates

Sub-Matrix: **SEDIMENT**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Samples Submitted							
EP090S: Organotin Surrogate	EP1913671-001	S1	**Tripropyltin**	----	34.3 %	35.0-130 %	**Recovery less than lower data quality objective**
EP090S: Organotin Surrogate	EP1913671-012	S13	**Tripropyltin**	----	131 %	35.0-130 %	**Recovery greater than upper data quality objective**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)			*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA055: Moisture Content (Dried @ 105-110°C)								
Soil Glass Jar - Unpreserved (EA055)								
S1, S3,	S2, S4	**16-Dec-2019**	----	----	----	**30-Dec-2019**	30-Dec-2019	✓
Soil Glass Jar - Unpreserved (EA055)								
S13, S15	S14,	**17-Dec-2019**	----	----	----	**30-Dec-2019**	31-Dec-2019	✓
Soil Glass Jar - Unpreserved (EA055)								
S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	----	----	----	**30-Dec-2019**	01-Jan-2020	✓
Soil Glass Jar - Unpreserved (EA055)								
S5,	S6	**19-Dec-2019**	----	----	----	**31-Dec-2019**	02-Jan-2020	✓

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
Soil Glass Jar - Unpreserved (EP071-SD)								
S1, S3,	S2, S4	**16-Dec-2019**	**24-Dec-2019**	30-Dec-2019	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S13, S15	S14,	**17-Dec-2019**	**24-Dec-2019**	31-Dec-2019	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**24-Dec-2019**	01-Jan-2020	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S5,	S6	**19-Dec-2019**	**24-Dec-2019**	02-Jan-2020	✓	**08-Jan-2020**	02-Feb-2020	✓
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
Soil Glass Jar - Unpreserved (EP071-SD)								
S1, S3,	S2, S4	**16-Dec-2019**	**24-Dec-2019**	30-Dec-2019	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD)								
S1, S3,	S2, S4	**16-Dec-2019**	**27-Dec-2019**	30-Dec-2019	✓	**27-Dec-2019**	30-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S13, S15	S14,	**17-Dec-2019**	**24-Dec-2019**	31-Dec-2019	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD)								
S13, S15	S14,	**17-Dec-2019**	**27-Dec-2019**	31-Dec-2019	✓	**27-Dec-2019**	31-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**24-Dec-2019**	01-Jan-2020	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD)								
S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**27-Dec-2019**	01-Jan-2020	✓	**27-Dec-2019**	01-Jan-2020	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
S5,	S6	**19-Dec-2019**	**24-Dec-2019**	02-Jan-2020	✓	**08-Jan-2020**	02-Feb-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD)								
S5,	S6	**19-Dec-2019**	**27-Dec-2019**	02-Jan-2020	✓	**27-Dec-2019**	02-Jan-2020	✓

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
Soil Glass Jar - Unpreserved (EP080-SD) S1, S3,	S2, S4	**16-Dec-2019**	**27-Dec-2019**	30-Dec-2019	✓	**27-Dec-2019**	30-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP080-SD) S13, S15	S14,	**17-Dec-2019**	**27-Dec-2019**	31-Dec-2019	✓	**27-Dec-2019**	31-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP080-SD) S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**27-Dec-2019**	01-Jan-2020	✓	**27-Dec-2019**	01-Jan-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD) S5,	S6	**19-Dec-2019**	**27-Dec-2019**	02-Jan-2020	✓	**27-Dec-2019**	02-Jan-2020	✓
EP080-SD: BTEXN								
Soil Glass Jar - Unpreserved (EP080-SD) S1, S3,	S2, S4	**16-Dec-2019**	**27-Dec-2019**	30-Dec-2019	✓	**27-Dec-2019**	30-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP080-SD) S13, S15	S14,	**17-Dec-2019**	**27-Dec-2019**	31-Dec-2019	✓	**27-Dec-2019**	31-Dec-2019	✓
Soil Glass Jar - Unpreserved (EP080-SD) S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**27-Dec-2019**	01-Jan-2020	✓	**27-Dec-2019**	01-Jan-2020	✓
Soil Glass Jar - Unpreserved (EP080-SD) S5,	S6	**19-Dec-2019**	**27-Dec-2019**	02-Jan-2020	✓	**27-Dec-2019**	02-Jan-2020	✓
EP090: Organotin Compounds								
Soil Glass Jar - Frozen on receipt (EP090) S1, S3,	S2, S4	**16-Dec-2019**	**27-Dec-2019**	10-Feb-2020	✓	**30-Dec-2019**	05-Feb-2020	✓
Soil Glass Jar - Frozen on receipt (EP090) S13, S15	S14,	**17-Dec-2019**	**27-Dec-2019**	11-Feb-2020	✓	**30-Dec-2019**	05-Feb-2020	✓
Soil Glass Jar - Frozen on receipt (EP090) S7, S9, S11, DUP2	S8, S10, DUP1,	**18-Dec-2019**	**27-Dec-2019**	12-Feb-2020	✓	**30-Dec-2019**	05-Feb-2020	✓
Soil Glass Jar - Frozen on receipt (EP090) S5,	S6	**19-Dec-2019**	**27-Dec-2019**	13-Feb-2020	✓	**30-Dec-2019**	05-Feb-2020	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Moisture Content	EA055	6	38	**15.79**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Organotin Analysis	EP090	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Oil and Grease	CM067	SOIL	Oil & Grease analysis subcontracted to ALS Scoresby. NATA accreditation does not cover performance of this service.
Moisture Content	EA055	SOIL	In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 105-110 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 6.1 and Table 1 (14 day holding time).
TPH - Semivolatile Fraction	EP071-SD	SOIL	In house: Referenced to USEPA SW 846 - 8270D. Extracts are analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (2013) Schedule B(3) (Method 504)
TRH Volatiles/BTEX in Sediments	EP080-SD	SOIL	In house: Referenced to USEPA SW 846 - 8260B Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.
Organotin Analysis	EP090	SOIL	In house: Referenced to USEPA SW 846 - 8270D Prepared sample extracts are analysed by GC/MS coupled with high volume injection, and quanitified against an established calibration curve.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Methanolic Extraction of Soils for Purge and Trap	ORG16	SOIL	In house: Referenced to USEPA SW 846 - 5030A. 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
Tumbler Extraction of Solids for LVI (Non-concentrating)	ORG17D	SOIL	In house: 10g of sample, Na2SO4 and surrogate are extracted with 50mL 1:1 DCM/Acetone by end over end tumbling. An aliquot is concentrated by nitrogen blowdown to a reduced volume for analysis if required.
Organotin Sample Preparation	ORG35	SOIL	In house: 20g sample is spiked with surrogate and leached in a methanol:acetic acid:UHP water mix and vacuum filtered. Reagents and solvents are added to the sample and the mixture tumbled. The butyltin compounds are simultaneously derivatised and extracted. The extract is further extracted with petroleum ether. The resultant extracts are combined and concentrated for analysis.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

SEDIMENT DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 6/03/2020
Date Received: 21/12/2019
Our Reference: RPS19-2 v2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg
Reporting Limit		**<20**	**<2**	**<0.2**	**<0.1**	**<0.2**	**<0.2**	**<0.2**	**<5**	**<0.7**	**<1**
Analysis Date		**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**
File		**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**
S1	16/12/2019	1600	9	8.6	0.2	1.6	16	2.2	3300	3.3	2
S2	16/12/2019	2100	11	10	0.2	1.6	17	3.9	4100	4.1	2
S3	16/12/2019	1800	6	10	0.3	1.6	11	2.7	2300	4.0	1
S4	16/12/2019	1700	5	14	0.2	1.6	11	2.8	1800	4.3	<1
S5	19/12/2019	1500	5	11	0.2	1.3	9.3	2.8	2200	3.8	1
S6	19/12/2019	1700	7	10	0.2	1.6	13	2.4	2200	3.4	1
S7	18/12/2019	1300	5	17	0.3	1.1	11	2.0	2300	2.7	<1
S8	18/12/2019	1400	16	15	0.3	1.4	18	1.7	4700	3.2	2
S9	18/12/2019	1600	14	9.8	0.2	1.4	19	2.1	4800	3.6	2
S10	18/12/2019	1500	17	8.5	0.3	1.5	20	1.8	4900	3.2	2
S11	18/12/2019	1500	16	8.4	0.1	1.4	17	1.2	3800	2.3	1
S13	17/12/2019	1400	21	8.4	0.1	1.5	20	1.8	4700	3.1	2
S14	17/12/2019	1400	8	9.1	0.2	1.1	13	1.9	2600	2.5	<1
S15	17/12/2019	1200	6	9.3	0.2	1.2	11	1.8	1900	2.8	1
Dupicate 1	18/12/2019	1400	6	19	0.2	1.1	11	2.0	2300	2.6	1
Duplicate 2	18/12/2019	1800	6	11	0.3	1.5	12	2.5	2100	3.4	1

Note: Results expressed as dry weight basis
This report replaces RPS19-1 issued on the 24/01/2020 change is the addition of Co

Signatory: Jamie Woodward
Date: 6/03/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

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SEDIMENT DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 6/03/2020
Date Received: 21/12/2019
Our Reference: RPS19-2 v2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg
Reporting Limit		**<20**	**<2**	**<0.2**	**<0.1**	**<0.2**	**<0.2**	**<0.2**	**<5**	**<0.7**	**<1**
Analysis Date		**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**	**17/01/2020**
File		**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**	**20011701**
QA/QC Data	**Acceptance Criteria**										
Duplicate % Difference	<20%	2%	8%	1%	1%	4%	1%	2%	1%	5%	2%
Standard Addition Recovery	80-120%	106%	118%	101%	99%	99%	101%	112%	high sample	97%	102%
Blank	<RL	<20	<2	<0.2	<0.1	<0.2	<0.2	<0.2	<5	<0.7	<1
Control Recovery	80-120%	108%	107%	104%	102%	102%	102%	97%	101%	104%	103%

Note: Where high sample reported for Standard Addition Recovery dilution and/or other element recovery used to determine sample recovery

Signatory: Jamie Woodward
Date: 6/03/2020

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SEDIMENT DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 6/03/2020
Date Received: 21/12/2019
Our Reference: RPS19-2 v2
Your Reference: EEN19234.001

METHOD	Sampling	ICP002	ICP007	2600	4500	6200
SAMPLE CODE	Date	Total Ext Zn	Total Ext Hg	TKN	TOTAL P	TOC
		mg/kg	mg/kg	mg.N/g	mg.P/g	% C
Reporting Limit		<0.5	<0.01	<0.1	<0.05	<0.1
Analysis Date		17/01/2020	23/01/2020	24/01/2020		23/01/2020
File		20011701	20012302	20012401		20012301
S1	16/12/2019	4.5	<0.01	0.3	0.92	0.4
S2	16/12/2019	5.3	<0.01	0.5	0.88	0.5
S3	16/12/2019	5.1	<0.01	0.5	0.74	0.5
S4	16/12/2019	5.1	<0.01	0.5	0.71	0.5
S5	19/12/2019	4.7	<0.01	0.5	0.82	0.5
S6	19/12/2019	5.1	<0.01	0.4	0.70	0.4
S7	18/12/2019	3.4	<0.01	0.4	0.63	0.4
S8	18/12/2019	3.7	<0.01	0.3	0.65	0.3
S9	18/12/2019	4.2	<0.01	0.4	0.70	0.4
S10	18/12/2019	3.9	<0.01	0.3	0.62	0.3
S11	18/12/2019	3.3	<0.01	0.3	0.47	0.3
S13	17/12/2019	4.0	<0.01	0.3	0.76	0.3
S14	17/12/2019	3.6	<0.01	0.4	0.61	0.4
S15	17/12/2019	3.8	<0.01	0.3	1.0	0.4
Dupicate 1	18/12/2019	3.5	<0.01	0.4	0.63	0.4
Duplicate 2	18/12/2019	5.2	<0.01	0.5	0.73	0.4

Note: For results for compliance purposes uncertainity of measurement (MU) will sometimes affect the interpretation whether the result passes or fails the compliance limit.
Tables for measurement uncertainity are available online at www.mafrl.murdoch.edu.au

Signatory: Jamie Woodward
Date: 6/03/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

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SEDIMENT DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 6/03/2020
Date Received: 21/12/2019
Our Reference: RPS19-2 v2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C
Reporting Limit		**<0.5**	**<0.01**	**<0.1**	**<0.05**	**<0.1**
Analysis Date		**17/01/2020**	**23/01/2020**	**24/01/2020**		**23/01/2020**
File		**20011701**	**20012302**	**20012401**		**20012301**
QA/QC Data	**Acceptance Criteria**					
Duplicate % Difference	<20%	1%	9%	4%	1%	2%
Standard Addition Recovery	80-120%	99%	100%	91%	102%	
Blank	<RL	<0.5	<0.01	<0.1	<0.05	<0.1
Control Recovery	80-120%	107%	96%	101%	103%	97%

Signatory: Jamie Woodward
Date: 6/03/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S1
Sampling Date:	16/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.58**
Very Fine Silt % (4-8µm)	0.92
Fine Silt % (8-16µm)	1.43
Medium Silt % (16-31µm)	2.40
Course Silt % (31-63µm)	3.40
Total Silt (4-63µm)	**8.15**
Very Fine sand % (63-125µm)	7.34
Fine sand % (125-250µm)	30.89
Medium sand % (250-500µm)	35.42
Coarse sand % (500-1000µm)	10.61
Very Coarse sand % (1000-2000µm)	4.78
Total Sand (63-2000µm)	**89.04**
Total Gravels (>2000µm)	**2.23**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.61
1000	4.78
2000	1.72
4000	0.32
8000	0.20
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	263.46
Minimum settling velocity of 50% of particles (mm s^1)	57.24
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	79.62
Minimum settling velocity of 90% of particles (mm s^1)	5.23
Time for 90% of particles to settle over 1 m (hours)	0.053

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, shell and plant material present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S2
Sampling Date:	16/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.16**
Very Fine Silt % (4-8µm)	1.28
Fine Silt % (8-16µm)	2.24
Medium Silt % (16-31µm)	4.14
Course Silt % (31-63µm)	5.95
Total Silt (4-63µm)	**13.61**
Very Fine sand % (63-125µm)	10.74
Fine sand % (125-250µm)	26.96
Medium sand % (250-500µm)	20.33
Coarse sand % (500-1000µm)	10.51
Very Coarse sand % (1000-2000µm)	7.16
Total Sand (63-2000µm)	**75.71**
Total Gravels (>2000µm)	**9.52**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.51
1000	7.16
2000	5.37
4000	3.30
8000	0.85
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	236.46
Minimum settling velocity of 50% of particles (mm s^1)	46.11
Time for 50% of particles to settle over 1 m (hours)	0.006
D10 (µm)	35.85
Minimum settling velocity of 90% of particles (mm s^1)	1.06
Time for 90% of particles to settle over 1 m (hours)	0.262

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock, coral and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Marine and Freshwater
Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S3
Sampling Date:	16/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.98**
Very Fine Silt % (4-8µm)	2.12
Fine Silt % (8-16µm)	4.50
Medium Silt % (16-31µm)	9.76
Course Silt % (31-63µm)	15.66
Total Silt (4-63µm)	**32.04**
Very Fine sand % (63-125µm)	16.38
Fine sand % (125-250µm)	19.68
Medium sand % (250-500µm)	15.04
Coarse sand % (500-1000µm)	7.16
Very Coarse sand % (1000-2000µm)	2.49
Total Sand (63-2000µm)	**60.76**
Total Gravels (>2000µm)	**5.22**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.16
1000	2.49
2000	1.22
4000	1.15
8000	2.85
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	123.15
Minimum settling velocity of 50% of particles (mm s^1)	12.51
Time for 50% of particles to settle over 1 m (hours)	0.022
D10 (µm)	18.21
Minimum settling velocity of 90% of particles (mm s^1)	0.27
Time for 90% of particles to settle over 1 m (hours)	1.015

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell and plant material present.

Signatory: Jamie Woodward
Date: 20/01/2020

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PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S4
Sampling Date:	16/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.86**
Very Fine Silt % (4-8µm)	2.03
Fine Silt % (8-16µm)	4.20
Medium Silt % (16-31µm)	9.51
Course Silt % (31-63µm)	14.22
Total Silt (4-63µm)	**29.96**
Very Fine sand % (63-125µm)	16.01
Fine sand % (125-250µm)	24.84
Medium sand % (250-500µm)	17.49
Coarse sand % (500-1000µm)	6.50
Very Coarse sand % (1000-2000µm)	2.52
Total Sand (63-2000µm)	**67.36**
Total Gravels (>2000µm)	**0.83**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.50
1000	2.52
2000	0.83
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	134.07
Minimum settling velocity of 50% of particles (mm s^1)	14.82
Time for 50% of particles to settle over 1 m (hours)	0.019
D10 (µm)	19.11
Minimum settling velocity of 90% of particles (mm s^1)	0.30
Time for 90% of particles to settle over 1 m (hours)	0.922

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S5
Sampling Date:	19/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.51**
Very Fine Silt % (4-8µm)	1.68
Fine Silt % (8-16µm)	3.49
Medium Silt % (16-31µm)	7.31
Course Silt % (31-63µm)	10.87
Total Silt (4-63µm)	**23.35**
Very Fine sand % (63-125µm)	17.14
Fine sand % (125-250µm)	25.18
Medium sand % (250-500µm)	14.13
Coarse sand % (500-1000µm)	7.62
Very Coarse sand % (1000-2000µm)	5.04
Total Sand (63-2000µm)	**69.12**
Total Gravels (>2000µm)	**6.03**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.62
1000	5.04
2000	5.82
4000	0.21
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	155.73
Minimum settling velocity of 50% of particles (mm s^1)	20.00
Time for 50% of particles to settle over 1 m (hours)	0.014
D10 (µm)	22.68
Minimum settling velocity of 90% of particles (mm s^1)	0.42
Time for 90% of particles to settle over 1 m (hours)	0.655

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

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PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S6
Sampling Date:	19/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.02**
Very Fine Silt % (4-8µm)	1.52
Fine Silt % (8-16µm)	2.81
Medium Silt % (16-31µm)	4.82
Course Silt % (31-63µm)	8.71
Total Silt (4-63µm)	**17.86**
Very Fine sand % (63-125µm)	12.25
Fine sand % (125-250µm)	17.87
Medium sand % (250-500µm)	30.33
Coarse sand % (500-1000µm)	15.62
Very Coarse sand % (1000-2000µm)	4.04
Total Sand (63-2000µm)	**80.11**
Total Gravels (>2000µm)	**1.01**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.62
1000	4.04
2000	0.93
4000	0.08
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	257.03
Minimum settling velocity of 50% of particles (mm s^1)	54.48
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	30.42
Minimum settling velocity of 90% of particles (mm s^1)	0.76
Time for 90% of particles to settle over 1 m (hours)	0.364

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, shell and coral present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S7
Sampling Date:	18/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.47**
Very Fine Silt % (4-8µm)	1.62
Fine Silt % (8-16µm)	3.14
Medium Silt % (16-31µm)	6.30
Course Silt % (31-63µm)	9.19
Total Silt (4-63µm)	**20.25**
Very Fine sand % (63-125µm)	11.73
Fine sand % (125-250µm)	24.36
Medium sand % (250-500µm)	19.33
Coarse sand % (500-1000µm)	11.32
Very Coarse sand % (1000-2000µm)	5.40
Total Sand (63-2000µm)	**72.14**
Total Gravels (>2000µm)	**6.15**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.32
1000	5.40
2000	4.19
4000	1.95
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	205.20
Minimum settling velocity of 50% of particles (mm s^1)	34.72
Time for 50% of particles to settle over 1 m (hours)	0.008
D10 (µm)	24.85
Minimum settling velocity of 90% of particles (mm s^1)	0.51
Time for 90% of particles to settle over 1 m (hours)	0.546

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S8
Sampling Date:	18/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	13/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.30**
Very Fine Silt % (4-8µm)	0.62
Fine Silt % (8-16µm)	0.99
Medium Silt % (16-31µm)	1.68
Course Silt % (31-63µm)	2.92
Total Silt (4-63µm)	**6.22**
Very Fine sand % (63-125µm)	5.52
Fine sand % (125-250µm)	23.04
Medium sand % (250-500µm)	33.01
Coarse sand % (500-1000µm)	12.86
Very Coarse sand % (1000-2000µm)	5.56
Total Sand (63-2000µm)	**79.99**
Total Gravels (>2000µm)	**13.49**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.86
1000	5.56
2000	6.29
4000	4.58
8000	2.62
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	333.76
Minimum settling velocity of 50% of particles (mm s^1)	91.85
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	106.96
Minimum settling velocity of 90% of particles (mm s^1)	9.43
Time for 90% of particles to settle over 1 m (hours)	0.029

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S9
Sampling Date:	18/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.33**
Very Fine Silt % (4-8µm)	0.64
Fine Silt % (8-16µm)	0.79
Medium Silt % (16-31µm)	1.55
Course Silt % (31-63µm)	2.18
Total Silt (4-63µm)	**5.16**
Very Fine sand % (63-125µm)	6.70
Fine sand % (125-250µm)	32.22
Medium sand % (250-500µm)	24.54
Coarse sand % (500-1000µm)	5.85
Very Coarse sand % (1000-2000µm)	5.48
Total Sand (63-2000µm)	**74.79**
Total Gravels (>2000µm)	**19.72**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.85
1000	5.48
2000	8.47
4000	7.30
8000	3.95
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	278.22
Minimum settling velocity of 50% of particles (mm s^1)	63.83
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	113.56
Minimum settling velocity of 90% of particles (mm s^1)	10.63
Time for 90% of particles to settle over 1 m (hours)	0.026

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

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Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S10
Sampling Date:	18/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.29**
Very Fine Silt % (4-8µm)	0.64
Fine Silt % (8-16µm)	0.70
Medium Silt % (16-31µm)	1.29
Course Silt % (31-63µm)	1.59
Total Silt (4-63µm)	**4.22**
Very Fine sand % (63-125µm)	5.45
Fine sand % (125-250µm)	36.10
Medium sand % (250-500µm)	32.32
Coarse sand % (500-1000µm)	6.21
Very Coarse sand % (1000-2000µm)	5.22
Total Sand (63-2000µm)	**85.30**
Total Gravels (>2000µm)	**10.19**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.21
1000	5.22
2000	6.54
4000	3.65
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	266.17
Minimum settling velocity of 50% of particles (mm s^1)	58.42
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	125.19
Minimum settling velocity of 90% of particles (mm s^1)	12.92
Time for 90% of particles to settle over 1 m (hours)	0.021

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S11
Sampling Date:	18/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.59**
Very Fine Silt % (4-8µm)	0.83
Fine Silt % (8-16µm)	1.20
Medium Silt % (16-31µm)	1.64
Course Silt % (31-63µm)	3.28
Total Silt (4-63µm)	**6.95**
Very Fine sand % (63-125µm)	7.88
Fine sand % (125-250µm)	20.97
Medium sand % (250-500µm)	29.69
Coarse sand % (500-1000µm)	16.80
Very Coarse sand % (1000-2000µm)	8.26
Total Sand (63-2000µm)	**83.60**
Total Gravels (>2000µm)	**8.86**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	16.80
1000	8.26
2000	5.04
4000	2.34
8000	1.48
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	338.49
Minimum settling velocity of 50% of particles (mm s^1)	94.48
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	84.21
Minimum settling velocity of 90% of particles (mm s^1)	5.85
Time for 90% of particles to settle over 1 m (hours)	0.048

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 20/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S13
Sampling Date:	17/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.00**
Very Fine Silt % (4-8µm)	0.02
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.28
Course Silt % (31-63µm)	1.24
Total Silt (4-63µm)	**1.78**
Very Fine sand % (63-125µm)	0.70
Fine sand % (125-250µm)	24.61
Medium sand % (250-500µm)	57.25
Coarse sand % (500-1000µm)	10.91
Very Coarse sand % (1000-2000µm)	3.07
Total Sand (63-2000µm)	**96.53**
Total Gravels (>2000µm)	**1.69**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.91
1000	3.07
2000	0.84
4000	0.85
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	330.13
Minimum settling velocity of 50% of particles (mm s^1)	89.87
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	183.10
Minimum settling velocity of 90% of particles (mm s^1)	27.64
Time for 90% of particles to settle over 1 m (hours)	0.010

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
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The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S14
Sampling Date:	17/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.16**
Very Fine Silt % (4-8µm)	1.31
Fine Silt % (8-16µm)	2.55
Medium Silt % (16-31µm)	4.97
Course Silt % (31-63µm)	7.48
Total Silt (4-63µm)	**16.32**
Very Fine sand % (63-125µm)	10.84
Fine sand % (125-250µm)	21.80
Medium sand % (250-500µm)	21.94
Coarse sand % (500-1000µm)	13.01
Very Coarse sand % (1000-2000µm)	5.55
Total Sand (63-2000µm)	**73.14**
Total Gravels (>2000µm)	**9.38**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.01
1000	5.55
2000	5.10
4000	3.63
8000	0.66
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	249.20
Minimum settling velocity of 50% of particles (mm s^1)	51.21
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	31.01
Minimum settling velocity of 90% of particles (mm s^1)	0.79
Time for 90% of particles to settle over 1 m (hours)	0.350

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Garnet Hooper
Customer: RPS Group
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 20/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2

Sample Name:	S15
Sampling Date:	17/12/2019
Sample Type:	Sediment
MAFRL Job Code:	RPS19-2
Client Reference:	EEN19234.001
Analysis Date:	14/01/2020
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.77**
Very Fine Silt % (4-8µm)	1.05
Fine Silt % (8-16µm)	2.07
Medium Silt % (16-31µm)	4.30
Course Silt % (31-63µm)	6.81
Total Silt (4-63µm)	**14.24**
Very Fine sand % (63-125µm)	10.94
Fine sand % (125-250µm)	22.99
Medium sand % (250-500µm)	20.80
Coarse sand % (500-1000µm)	16.77
Very Coarse sand % (1000-2000µm)	9.60
Total Sand (63-2000µm)	**81.11**
Total Gravels (>2000µm)	**3.88**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	16.77
1000	9.60
2000	3.24
4000	0.64
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	257.65
Minimum settling velocity of 50% of particles (mm s^1)	54.74
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	37.99
Minimum settling velocity of 90% of particles (mm s^1)	1.19
Time for 90% of particles to settle over 1 m (hours)	0.233

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock and shell present.

Signatory: Jamie Woodward
Date: 20/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Joanne Oliveri
Client	SGS AUSTRALIA - AU INTERLABS
Address	5266 683 ENVI WRS PERTH 28 Millrose Drive Malaga WA 6090
Telephone	(08) 9475 0099
Facsimile	(Not specified)
Email	Joanne.Oliveri@sgs.com
Project	**10320a**
Order Number	**10320a**
Samples	16

LABORATORY DETAILS

Manager	Adam Atkinson
Laboratory	SGS Melbourne EH&S
Address	10/585 Blackburn Road Notting Hill Victoria 3168
Telephone	+61395743200
Facsimile	+61395743399
Email	Au.SampleReceipt.Melbourne@sgs.com
SGS Reference	**ME313301 R0**
Date Received	8/1/2020
Date Reported	25/3/2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(22793).

SIGNATORIES

S. Rutkowski

Stephen RUTKOWSKI
Senior Health Physicist

Radionuclides by Gamma Ray Spectrometry in solids [AS303/AS406] Tested: 24/3/2020

PARAMETER	UOM	LOR	S1 SOIL - 16/12/2019 ME313301.001	S2 SOIL - 16/12/2019 ME313301.002	S3 SOIL - 16/12/2019 ME313301.003	S4 SOIL - 16/12/2019 ME313301.004	S5 SOIL - 19/12/2019 ME313301.005
Radium-226	Bq/kg	-	8.08 ±0.99	9.43 ±1.22	7.16 ±0.88	8.98 ±1.05	9.54 ±0.94
Radium-228	Bq/kg	-	3.56 ±1.18	1.87 ±0.94	3.22 ±0.93	1.89 ±1.03	1.48 ±0.64
Thorium-228	Bq/kg	-	3.16 ±0.57	8.91 ±1.27	6.51 ±0.92	8.27 ±1.02	5.58 ±0.71

PARAMETER	UOM	LOR	S6 SOIL - 19/12/2019 ME313301.006	S7 SOIL - 18/12/2019 ME313301.007	S8 SOIL - 18/12/2019 ME313301.008	S9 SOIL - 18/12/2019 ME313301.009	S10 SOIL - 18/12/2019 ME313301.010
Radium-226	Bq/kg	-	7.13 ±0.90	9.03 ±0.91	9.81 ±1.15	8.61 ±1.23	7.71 ±0.98
Radium-228	Bq/kg	-	<3.30	1.94 ±0.81	2.48 ±1.00	3.61 ±1.50	2.82 ±1.07
Thorium-228	Bq/kg	-	5.12 ±0.84	5.02 ±0.68	2.78 ±0.54	4.88 ±0.89	3.28 ±0.67

PARAMETER	UOM	LOR	S11 SOIL - 18/12/2019 ME313301.011	S13 SOIL - 17/12/2019 ME313301.012	S14 SOIL - 17/12/2019 ME313301.013	S15 SOIL - 17/12/2019 ME313301.014	Dup 1 SOIL - 18/12/2019 ME313301.015
Radium-226	Bq/kg	-	6.81 ±0.99	7.80 ±0.80	8.04 ±0.84	7.68 ±0.82	7.98 ±0.86
Radium-228	Bq/kg	-	2.12 ±0.97	1.85 ±0.63	1.69 ±0.84	2.10 ±0.91	1.45 ±0.64
Thorium-228	Bq/kg	-	3.51 ±0.61	2.82 ±0.46	2.61 ±0.50	1.99 ±0.42	3.51 ±0.56

PARAMETER	UOM	LOR	Dup 2 SOIL - 18/12/2019 ME313301.016
Radium-226	Bq/kg	-	6.35 ±1.18
Radium-228	Bq/kg	-	<6.70
Thorium-228	Bq/kg	-	6.33 ±1.15

METHOD	METHODOLOGY SUMMARY
AS303/406	Analysis of radionuclides in solid samples by high resolution gamma ray spectrometry after preparation to meet standard calibrated geometries. Preparation involves drying, crushing and sieving, and setting in an epoxy resin where necessary.

FOOTNOTES

*	NATA accreditation does not cover the performance of this service.	-	Not analysed.	UOM	Unit of Measure.
**	Indicative data, theoretical holding time exceeded.	NVL	Not validated.	LOR	Limit of Reporting.
		IS	Insufficient sample for analysis.	↑↓	Raised/lowered Limit of Reporting.
		LNR	Sample listed, but not received.		

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

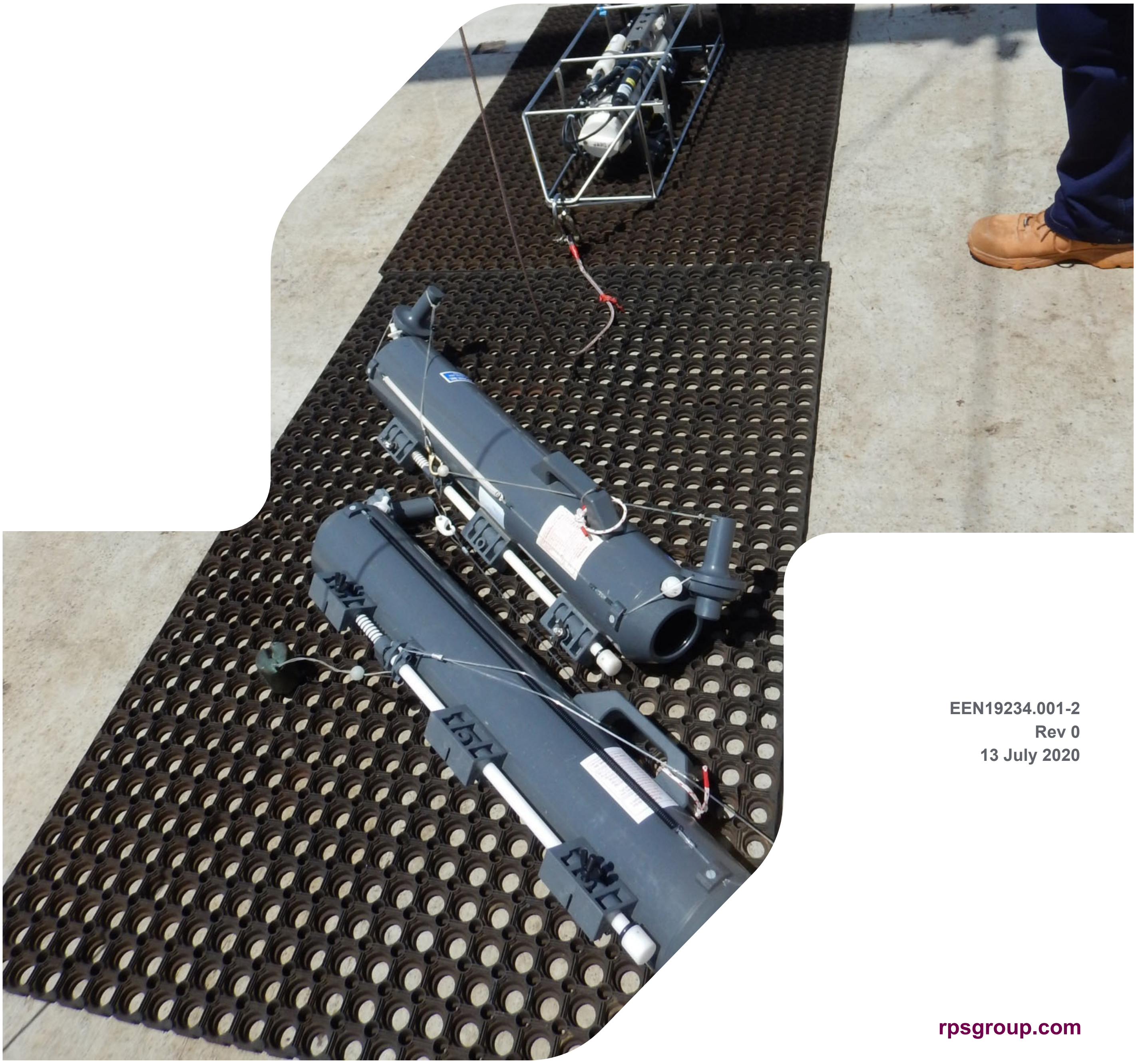
For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

Attachment 5 Water Quality

MARINE WATER QUALITY SURVEY REPORT

Dorado development, December 2019



EEN19234.001-2
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13 July 2020

rpsgroup.com

Approval for issue

J. Fitzpatrick		13 July 2020

Prepared by:

RPS

Garnet Hooper PhD
Principal Marine Scientist

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
E garnet.hooper@rpsgroup.com.au

Prepared for:

Santos WA Energy Ltd

Sonja Mavrick
HSE Team Lead Dorado Development

Level 7, 100 St Georges Terrace
Perth WA 6000

T +61 8 6218 7100
E sonja.mavrick@santos.com

Contents

Tables

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ABBREVIATIONS AND ACRONYMS

Abbreviation/acronym	Full description or name
ALS	Australian Laboratory Services Pty Ltd
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
AS/NZS	Australian Standard/New Zealand Standard
BSL	Below sea level
BTEXN	Benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FPSO	Floating Production, Storage and Offloading facility/vessel
GPS	Global positioning system
KEF	Key Ecological Feature
LOR	Limit of reporting
MAFRL	Marine and Freshwater Research Laboratory (Murdoch University)
MRL	Minimum reporting limit
NATA	National Association of Testing Authorities
NORM	Naturally-occurring radiative material
NTU	Nephelometric turbidity unit
OPP	Offshore Project Proposal
PAH	Polycyclic aromatic hydrocarbon
ppb	Parts per billion
PSU	Practical salinity unit
S1-S	Site 1 – surface sample
S1-M	Site 1 – midwater sample
S1-B	Site 1 – near seabed sample
TRH	Total recoverable hydrocarbon
TSS	Total suspended solids
WHP	Wellhead platform

EXECUTIVE SUMMARY

Santos is planning the Dorado Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 130 km north of Port Hedland. The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority.

The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project and this assessment requires an understanding of the status of the receiving environment. Santos identified uncertainty in the status of the marine environment in the vicinity of the development and commissioned ecological studies to provide environmental data to support appropriate assessment. A key component of the marine environmental characterisation studies was a water quality survey.

RPS was commissioned to conduct a water quality survey at the Dorado Project location between 16 and 19 December 2019. The objective of the study was to characterise the physico-chemical characteristics of the marine waters in the area.

The survey team measured a range of physical and chemical analytes throughout the water column at 15 locations spread across the Survey Area. Sampling involved water column profiling and collection of water samples for laboratory analyses of a suite of potential contaminants, nutrients, microalgal pigments and suspended solids. There was a clear relationship between some analytes and water depth (and therefore distance from shore) and the inshore sites.

Stratification of the water column was indicated by temperature, pH and dissolved oxygen measurements, with levels generally decreasing with depth. At shallower sampling sites a thermocline was observed at depths between 25-50m with warmer water near the surface possibly due to solar heating and a lack of vertical mixing. These data are comparable to data collected off the North West Cape (Exmouth) where thermoclines were observed in both surface waters (0-100m) and mid-profile waters (75-150m) (Lowe et al. 2012). They found thermoclines are seasonal, therefore this trend may change in future sampling events for the Dorado Project. pH levels were generally consistent and higher towards the surface, possibly due to the uptake of dissolved carbon dioxide in surface waters by planktonic photosynthesis. pH then decreased rapidly with increased depth possibly due to oxidation possibly decaying organic matter sinking from shallower depths. It has been demonstrated that decomposition produces carbonic acid (from the dissolution of liberated carbon dioxide) and the release of hydrogen ions cause a decrease in pH (Hinga 2002). Finally, increased oxygen levels are commonly recorded in surface waters due to exchange of oxygen across the air-water interface, therefore a decline in dissolved oxygen with depth is not unexpected.

Profiles at sampling locations in deeper waters were generally different to those in shallower waters. Sites S4, S5, S6 and S15 tended to have different profiles in temperature, pH, dissolved oxygen, NTU and chlorophyll a. The differences in temperature and pH profiles suggest there may be some vertical mixing associated with the sloping seabed at these locations because temperature and pH continued to decline with depth beyond 50m, whereas temperature and pH at the shallower sites tended to remain constant below 50m.

1 INTRODUCTION

1.1 Background

Santos is planning the Dorado Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 130 km north of Port Hedland (Figure 3 1). The Dorado Project will target the Dorado oil field with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading (FPSO) facility. There is also potential for future development of surrounding reservoirs within the Dorado Project Survey Area (Dorado Survey Area). These may be developed and tied back to a WHP via flowlines.

The Dorado Project will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, administered by the National Offshore Petroleum Safety and Environmental Management Authority. The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project, appropriate to the nature and scale of each impact or risk. A marine environmental characterisation survey program was required to characterise the benthic habitats, macrofaunal and infaunal communities, and water and sediment quality within the Dorado Survey Area. This report provides the outcomes of the water quality survey conducted between 16 and 19 December 2019.

The water quality data herein will inform the evaluation of potential impacts to water quality associated with the Dorado Project.

1.2 Objectives

The specific objective of the study was to characterise the marine water quality within the Dorado Survey Area. This report provides a technical summary of the data from water samples collected in the survey area in December 2019.

2 METHODS

Field sampling was conducted in accordance with the Sampling Analysis and Quality Plan (SAQP).

2.1 Water quality sampling sites

An array of fifteen pre-determined sampling sites provided coverage across the Survey Area (Table 2-1, Figure 2-1). The sampling sites extended from the Dorado Project Area into and beyond the ‘ancient coastline at 125 m water depth’ key ecological feature (DSEWPaC 2008). Sites were also distributed to provide representative samples across a range of CSIRO preliminary ecotypes (Keesing et al. 2020).

Table 2-1: Water quality sampling site depths (m below sea level (BSL)) and locations

Site	Depth (m BSL)	Latitude (DMS)*	Longitude (DMS)*	Easting (m)*	Northing (m)*
S1	91.9	19° 6' 33.228" S	118° 30' 46.440" E	659143	7886398
S2	87.4	19° 4' 50.736" S	118° 23' 26.340" E	646306	7889656
S3	100.9	18° 55' 35.472" S	118° 23' 13.632" E	646070	7906729
S4	121.3	18° 50' 41.388" S	118° 31' 0.552" E	659807	7915658
S5	138.7	18° 40' 16.464" S	118° 51' 55.836" E	696755	7934523
S6	106.3	18° 47' 54.528" S	118° 49' 26.292" E	692228	7920484
S7	99.9	18° 52' 49.836" S	118° 49' 24.096" E	692071	7911405
S8	91.4	19° 1' 38.316" S	118° 44' 36.528" E	683494	7895240
S9	84.9	19° 5' 51.144" S	118° 50' 59.316" E	694605	7887352
S10	78.8	19° 11' 24.468" S	118° 47' 4.092" E	687625	7877174
S11	61.6	19° 17' 41.424" S	119° 2' 9.420" E	713939	7865292
S12	81.2	19° 7' 55.020" S	119° 3' 1.332" E	715667	7883307
S13	85.4	19° 3' 26.064" S	119° 6' 11.520" E	721325	7891512
S14	95.9	18° 51' 25.488" S	119° 8' 38.184" E	725883	7913620
S15	111.1	18° 46' 38.964" S	119° 3' 15.624" E	716542	7922543

*GPS Datum = WGS84; UTM Zone 50K.

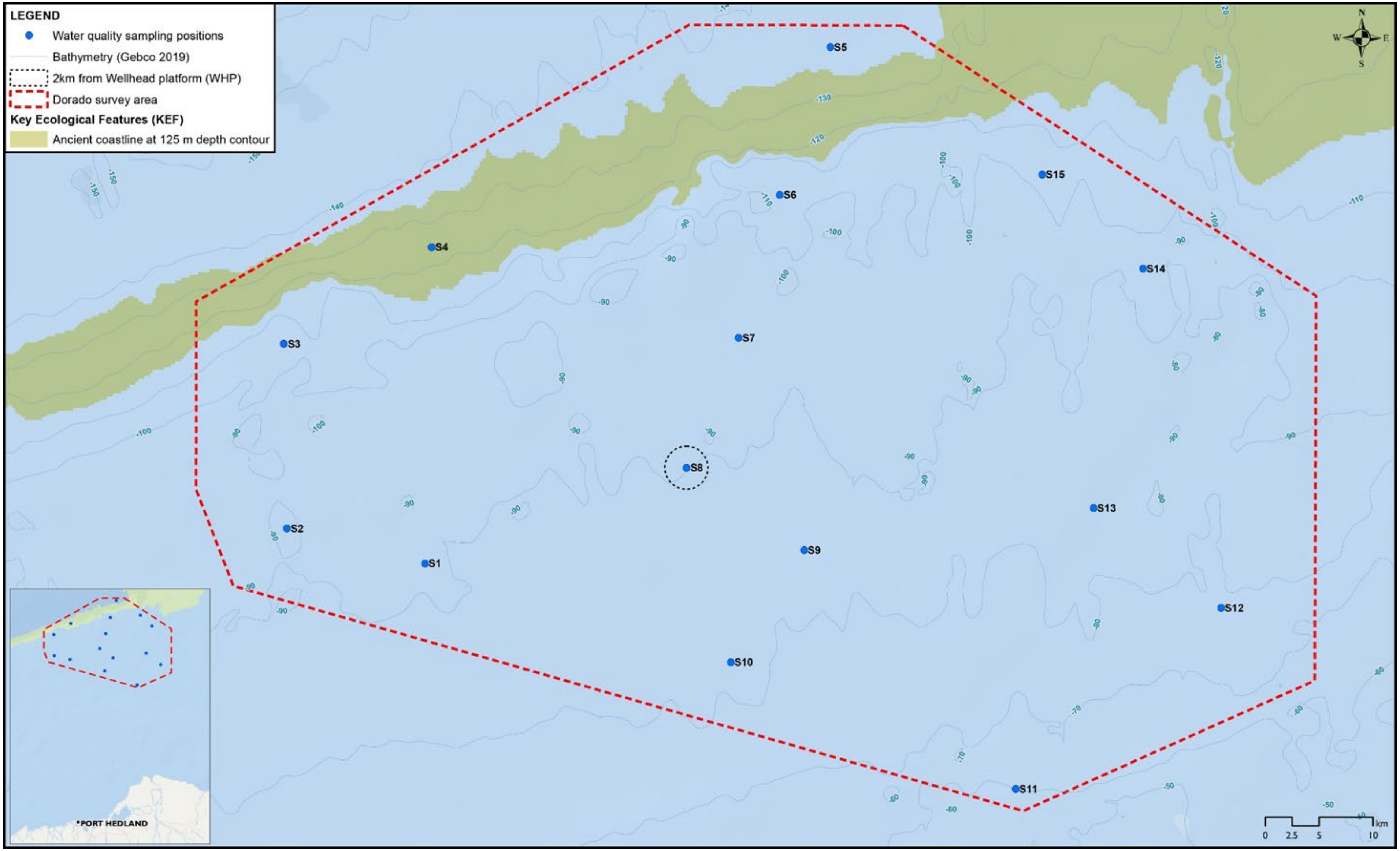


Figure 2-1: Water quality sampling sites

2.2 Timing

Water sampling was undertaken in summer, during daylight hours from 16 to 19 December 2019.

2.3 Water column profiling

The water column at each site was profiled using a Seabird Electronics SBE 19+ v2 profiler with auxiliary sensors and a 600 m depth rating. All sensors had been calibrated by the Marine and Freshwater Research laboratory (MAFRL) prior to mobilisation (see Appendix A for calibration certificate). During deployment, the profiler was lowered through the water column at a consistent rate of ~0.5 ms-1.

The measured physico-chemical parameters of the water column comprised the following:

- Depth (pressure)
- Salinity (conductivity)
- Water temperature
- pH
- Dissolved oxygen
- Turbidity
- Photosynthetically-active radiation (PAR)
- Chlorophyll-a
- Hydrocarbon concentration (using an ultraviolet fluorimeter calibrated for crude oil products, which measures the fluorescence of six-sided aromatic carbon rings. The term ‘crude oil’ simply identifies that the fluorimeter is measuring the fluorescence of heavier oil types with lower API gravity).

2.4 Water quality sampling

Sampling was conducted using 10 L Niskin bottles, arranged in a “daisy chain” to facilitate collection of samples from the mid-water and near seabed. A separate Niskin was used to collect the near surface samples. Water samples were collected from three depths:

- Near surface - between 2 and 5 m below sea level (BSL)
- Mid-water - half the full depth of the water column
- Near seabed - within 5 m of the seabed.

2.4.1 Sample collection

Pre-cleaned sample containers were obtained from the relevant analytical lab prior to mobilisation. All water samples were filtered on site, preserved and handled in accordance with Australian and New Zealand Standards (AS/NZS 5667.1:1998 water quality sampling – guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples). The following information was recorded when samples were collected:

- Site name
- Time and date each sample was collected
- Waypoint number (global positioning system (GPS) coordinates)
- Water depth from which the sample was collected.

2.4.2 Sample processing, preservation and storage

All samples were processed and preserved in accordance with Australian and New Zealand Standard (AS/NZS 5667.1:1998) and the requirements of the analytical laboratories. Due to the remote nature of the survey area, preservation methods were selected to maximise sample holding times. Water sampling was planned to ensure samples could be delivered to the analytical laboratories within holding time requirements for each parameter.

Sample containers were supplied by the analytical laboratories and were pre-labelled prior to the survey. Samples collected were recorded on sample log sheets, then stored under required conditions (Appendix B). A chain of custody form detailing the samples and analyses required was supplied to the National Association of Testing Authorities (NATA)-accredited laboratories with the samples.

Samples were filtered on board the vessel for nutrients, pigments (chlorophyll-a and phaeophytin a) and metals/metalloids. Both filtered and unfiltered samples were collected for the analysis of metals/metalloids. Unfiltered samples provide data on total metals in solution, whereas filtered samples provide data on the bioavailable component. A known volume of water was filtered through 0.2 µm GF/F filter paper for pigment sampling. These were then carefully sealed in pre-labelled envelopes and frozen. Nutrients and metals/metalloids were filtered into a pre-rinsed sample container. Nutrient samples were frozen, whereas metal/metalloid samples with pre-added acid were kept chilled at ~4 °C.

The following procedures were implemented for sampling of dissolved ultra-trace metals and organics (hydrocarbons):

- Sample containers were not pre-rinsed
- Metals samples were passed through a 0.45 µm filter
- Samples containers were not filled completely
- Samples were stored at ~4 °C (not frozen), and organics samples were also kept in the dark.

The following procedures were implemented for sampling of total nutrients:

- Sample containers were pre-rinsed three times
- Samples containers were not filled completely
- Samples were stored frozen.

Hydrocarbon samples were poured into sample bottles (leaving minimal air space), then chilled. Sample containers for volatile hydrocarbons (total recoverable hydrocarbons (TRH) C6-C9 and benzene, toluene, ethylbenzene and naphthalene (BTEXN)) contained sulphuric acid preservative.

Unfiltered naturally-occurring radioactive materials (NORMs) samples were transferred into sample containers with nitric acid as a preservative, then chilled.

During water sampling, the holding container, syringe and filter were flushed three times using sample water to mitigate contamination risk.

2.4.3 Sample analysis

Analytes, analytical laboratories, relevant storage and preservation methods and holding times are presented in Appendix B. All laboratory analyses were undertaken using standard NATA-accredited methods.

2.4.4 Data analysis

The water quality data were compared against relevant guideline levels (where available) from the ANZG 2018 guidelines.

Multivariate analysis of water quality sample data at surface, middle and bottom water depths was undertaken using the Plymouth Routines In Multivariate Ecological Research (PRIMER) v7 software (Clarke & Gorley 2015).

After transformation and normalisation of data, resemblance matrices were derived based on Euclidean distance. The ‘Cluster’ routine with similarity profile (SIMPROF) were used to identify groupings of samples based on survey data. Non-metric multi-dimensional scaling (n-MDS) was used to represent the relative distribution of sample data in 2-dimensional space to identify relationships between sample sites. The principal components analysis (PCA) routine was used to determine the relationship between principal analytes and the distribution of sample sites.

2.4.5 Quality control procedures

Each Niskin was cleaned at the beginning of the trip and stored with the ends closed between deployments. Decon 90 was used to rinse the Niskin bottles in any cases where contamination may have occurred during the survey. The bottles were further washed with site water as they were lowered to sampling depth.

The following quality control process was undertaken to quantify potential sample contamination that could have occurred during collection, handling, storage or transport. Low analyte concentration water provided by the laboratories were used in two tests:

- Field blank: low analyte water was poured into a sample container in the field during sampling, but with no filtering or additional handling. Field blanks test for any contamination of samples during sample collection.
- Transport blank: low analyte water was poured into a sample container at the end of field sampling, with no filtering or additional handling. Transport blanks test for any contamination of samples during transport and storage.

Duplicate samples collected to determine potential variability in analysis. A duplicate sample is collected by deploying the Niskin at the same location a second time. Duplicates were collected at the following sites:

- Duplicate 1 (collected at Site S9)
- Duplicate 2 (collected at Site S5)
- Duplicate 3 (collected at Site S12)
- Duplicate 4 (collected at Site S4).

3 RESULTS

The following sections summarise the data collected from the water column profiles and laboratory analysis of water samples. Full laboratory reports can be found in Appendix C.

3.1 Water column profiles

3.1.1 Salinity (conductivity)

There was very little difference in salinity profiles across sites and water depths, with salinity ranging from ~34.5 to ~35.4 practical salinity units (PSU). At most sites, salinity remained relatively high in the upper 20–25 m of the water column, but then decreased by an average of around 0.1–0.3 PSU between around 25–30 m BSL. Data indicated that this was potentially due to formation of a halocline at this depth as values varied greatly (within a range of up to ~0.7 PSU) over a short depth range. Salinity generally remained relatively consistent throughout the rest of the water column (i.e. deeper than ~30 m BSL). However, considerable variability in PSU over small depth ranges was evident to at least 100 m BSL at Sites S4, S5, S6 and S15 (the deepest and northernmost sites). The maximum range in salinity recorded throughout the profile at any one site was at Site S10 (0.66 PSU), with the minimum range recorded at Site S11 (0.32 PSU). There were no apparent cross-shelf variations in salinity profiles (Figure 3-1).

3.1.2 Water temperature

Sea surface water temperatures ranged from 28.8°C to 30.7°C across the study area, with both minimum and maximum temperatures recorded at shallow sites (sites S11 and S1, respectively). Near seabed temperatures varied with depth at each site, ranging from 21.7°C at the deepest site (Site S5) to 27.3°C at the shallowest site (Site S11). Seabed temperatures were consistent with those recorded in the region during December 2017 (RPS 2019). Temperatures remained relatively consistent in the upper 15–30 m of the water column, but generally decreased by up to 4.5°C at around 70 m BSL. Data indicated a potential thermocline in this depth range. A continuous decline in seawater temperature was recorded at Site S5 (the deepest site sampled) to a depth of ~100 m BSL, with temperature then remaining consistent to the seabed. Temperature profiles at the northern-most sites (sites S4, S5, S6 and S15) tended to decline at a constant rate and did not o show a clear thermocline (Figure 3-2).

3.1.3 pH

The pH in surface waters in the survey area ranged from 8.18 to 8.32 across the study area. Profiles in shallower water sites tended to have small differences in pH through the water column, with bottom waters generally lower in pH than surface waters. The pH profiles at the offshore sites tended to have a larger difference in pH through the water column (due to the greater water depth) and also tended to have greater changes in pH in the mid-water column compared to shallow water sites (Figure 3-3).

3.1.4 Dissolved oxygen

Dissolved oxygen in surface waters ranged from ~95 % to >100% saturation. Levels then remained consistent or increased to a depth of 30–60 m BSL, then either decreased rapidly over a ~15 m depth range and remained relatively consistent to the seabed, or declined more gradually to the seabed. The general trends in the dissolved oxygen profiles were similar to those of the pH profiles. Dissolved oxygen at the offshore, deeper sites (sites S4, S5, S6, S14, and S15) showed a less steep decline in dissolved oxygen in the mid-water column and dropped to a much lower level of dissolved oxygen (60 – 70%) near the seabed (Figure 3-4).

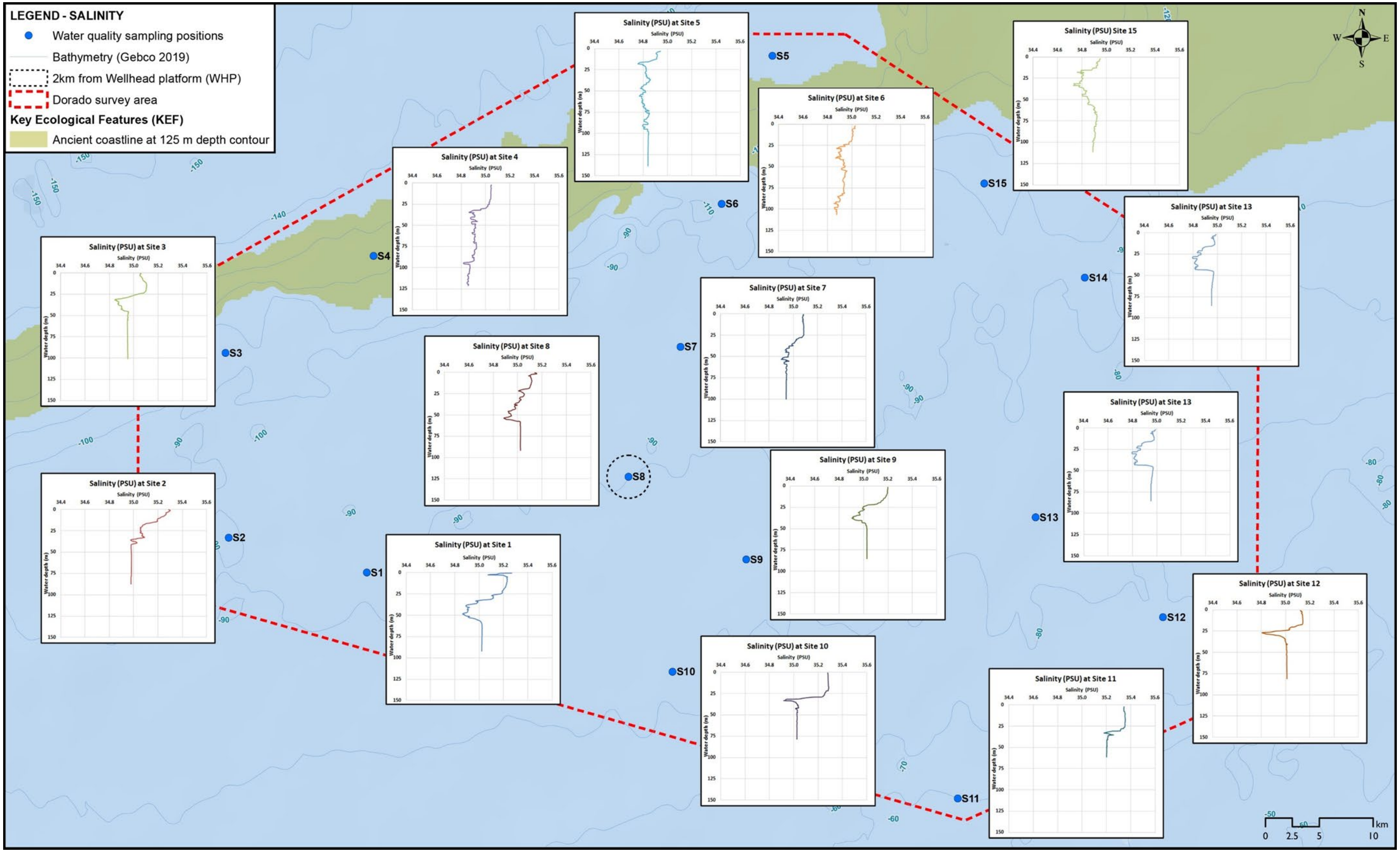


Figure 3-1: Across shelf salinity profiles

3.1.5 Turbidity

Turbidity was low (<0.5 NTU) in the upper 30 – 80 m of the water column. Turbidity increased with depth, increasing to around 1 – 2.5 NTU (Sites S2, S3, S4, S14 and S15) and 3.5 – 4.2 NTU at Sites S2, S5 and S6. The large increase in turbidity at the bottom of the profile at Site S7 (peak of 30.4 NTU) was probably due to the water column profiler contacting the seabed and generating a turbid plume.

Turbid water was recorded up to 50 m above the seabed at Sites S2, S3, S5, S6, S7, S14 and S15 which are located in deeper waters (Figure 3-5).

3.1.6 Photosynthetically active radiation (PAR)

PAR generally declined with depth in a logarithmic relationship and there was very little light below 50m. Due to differences in sampling times and weather conditions, clear trends in PAR levels were not comparable among sites. The data for PAR profiles at each site are in Appendix D.

3.1.7 Chlorophyll-a

Chlorophyll-a concentrations in surface waters ranged from around 0 to 0.3 µg L-1, then generally increased gradually over the upper ~30 m of the water column. Concentrations then increased to a peak of between 2.2 to 4.2 µg L-1 between 33 and 63 m BSL (depending on site). Chlorophyll-a then declined to around one-third to one-half of peak concentrations before remaining consistent to the seabed at most sites, or declined more gradually towards the seabed (at Sites S4, S6 and S15).

While all sites showed an increase in chlorophyll-a concentrations at approximately 50 m BSL which declined slightly for the remainder of the profile, sites S4, S5, S6, and S15 showed a greater rate of decline in chlorophyll-a concentration as depth increased and decreased to a lower concentration (Figure 3-6).

3.1.8 Hydrocarbons (crude oil)

Hydrocarbon concentrations ranged from 0 to 0.77 µg L-1 in surface waters, with variability decreasing with depth to concentrations of between 0.06 and 0.25 µg L-1 by 20 m BSL (Figure 3 8). Concentrations then either increased gradually to between 60 and 100 m at some sites (e.g. Sites S4, S5, S6, S7, S8, and S15) or increased more rapidly to a peak at between 40 and 50 m BSL, before remaining relatively consistent to the seabed at the shallower sampling sites.

There were no cross shelf trends in profiles of hydrocarbons (Figure 3-7).

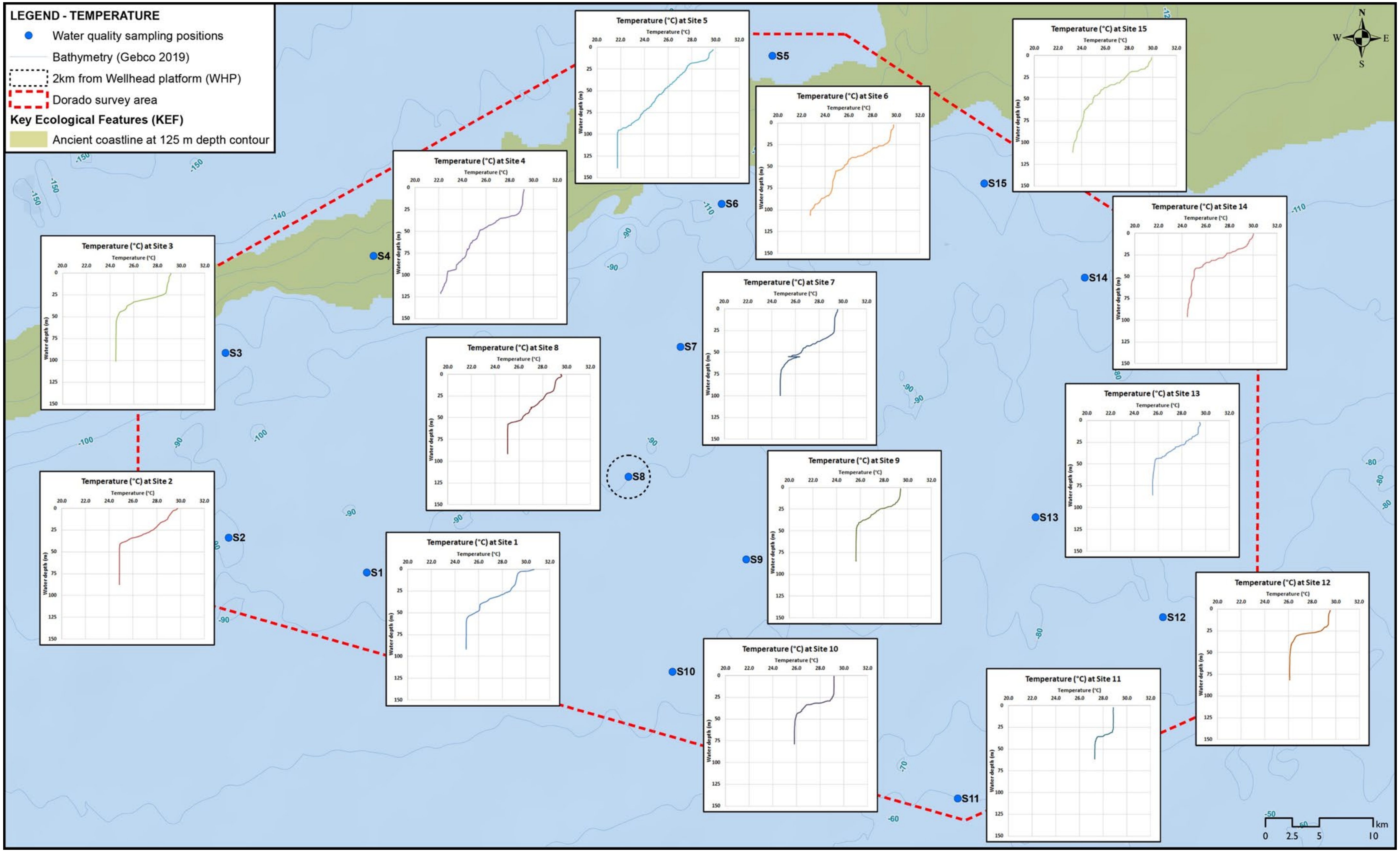


Figure 3-2: Across-shelf water temperature profiles

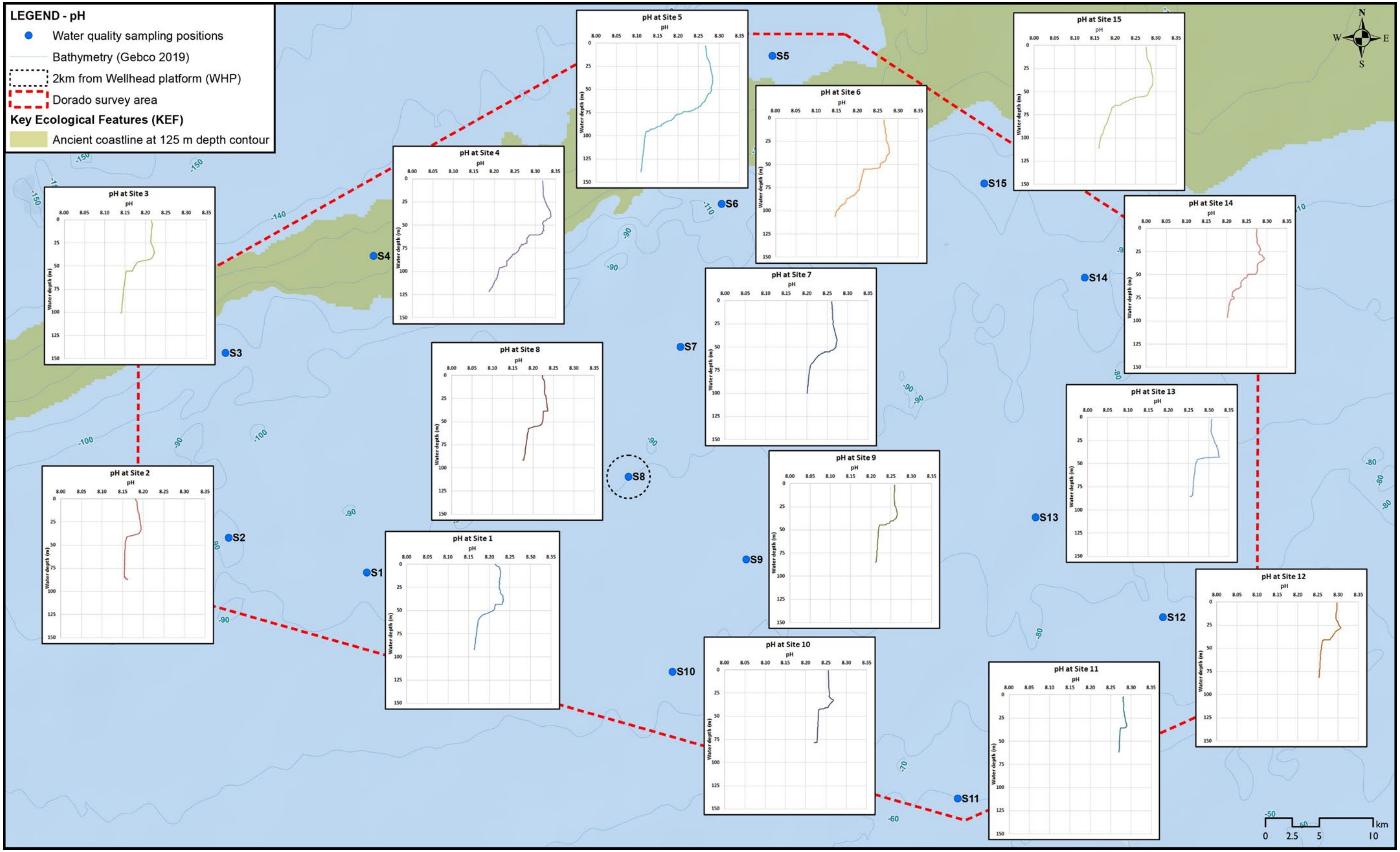


Figure 3-3: Across-shelf pH profiles

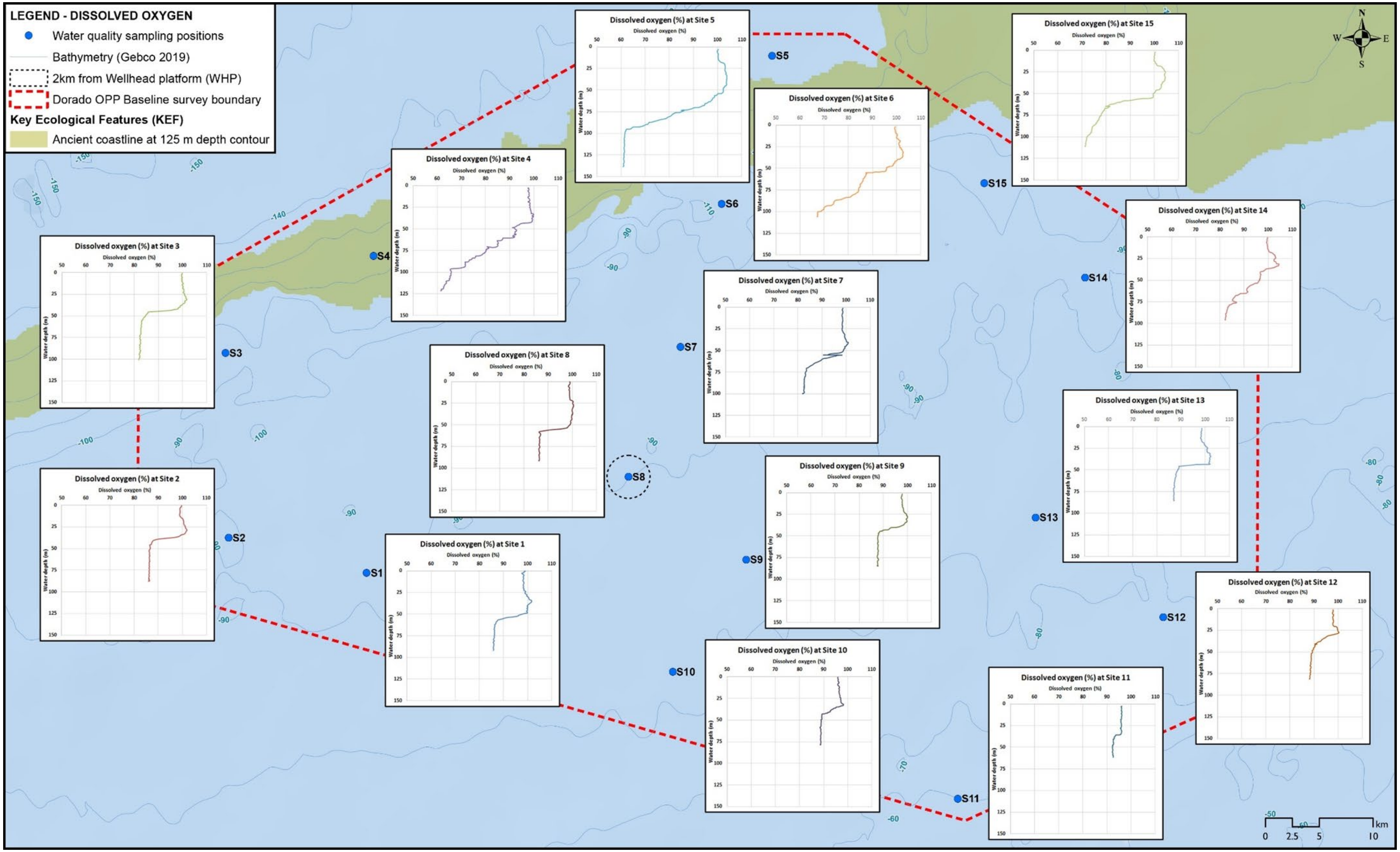


Figure 3-4: Across-shelf dissolved oxygen profiles

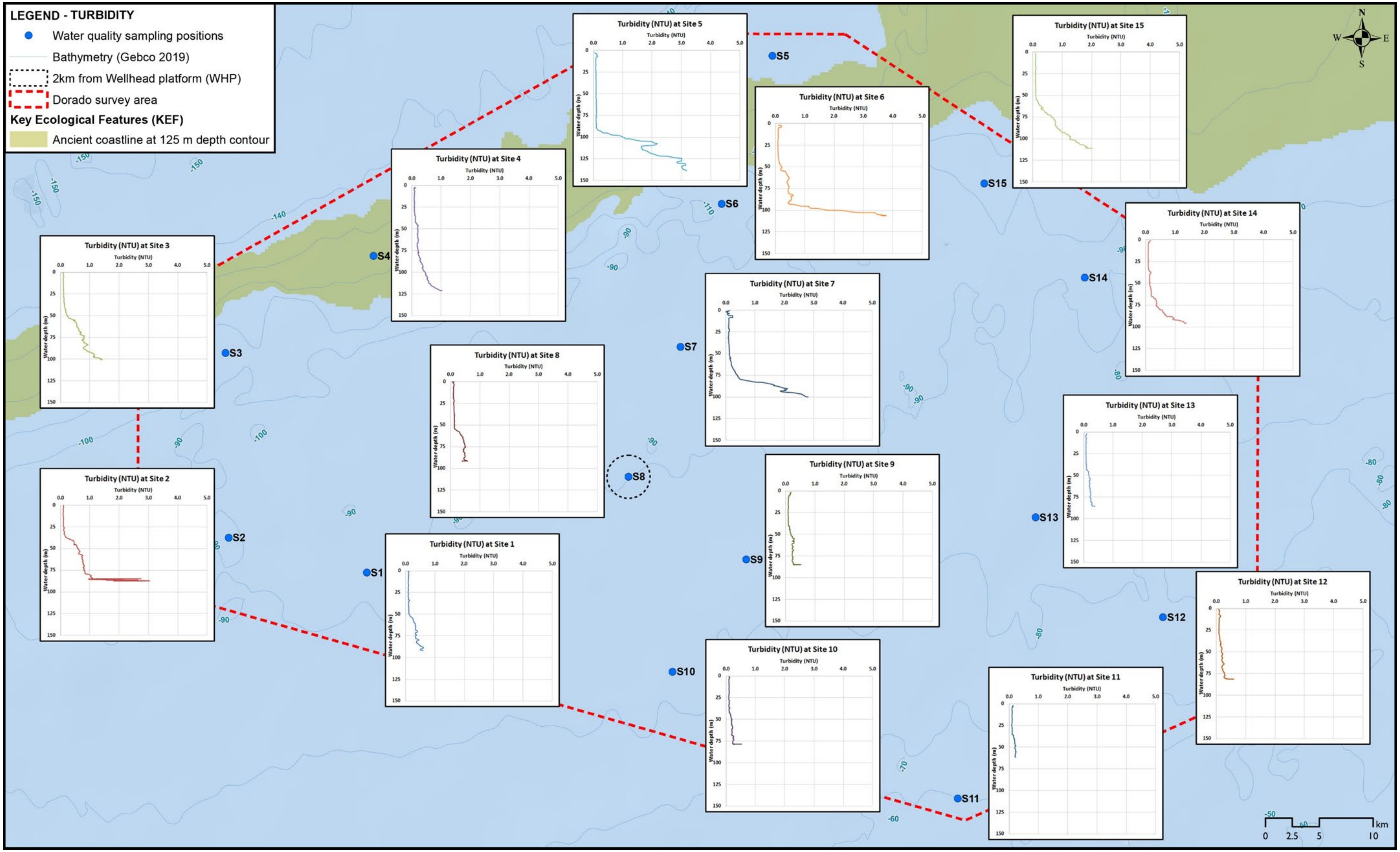


Figure 3-5: Across-shelf turbidity profiles

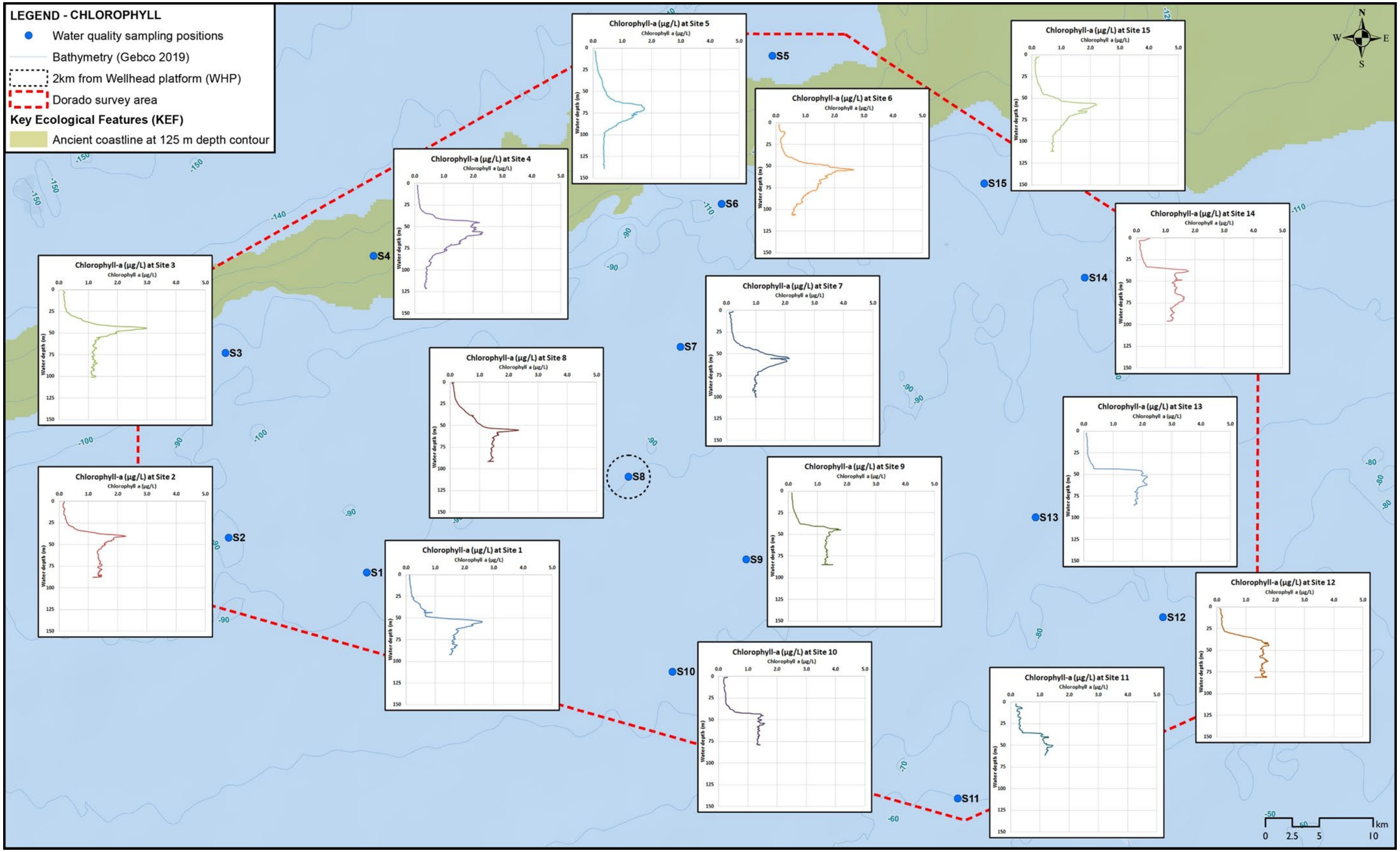


Figure 3-6: Across-shelf chlorophyll-a profiles

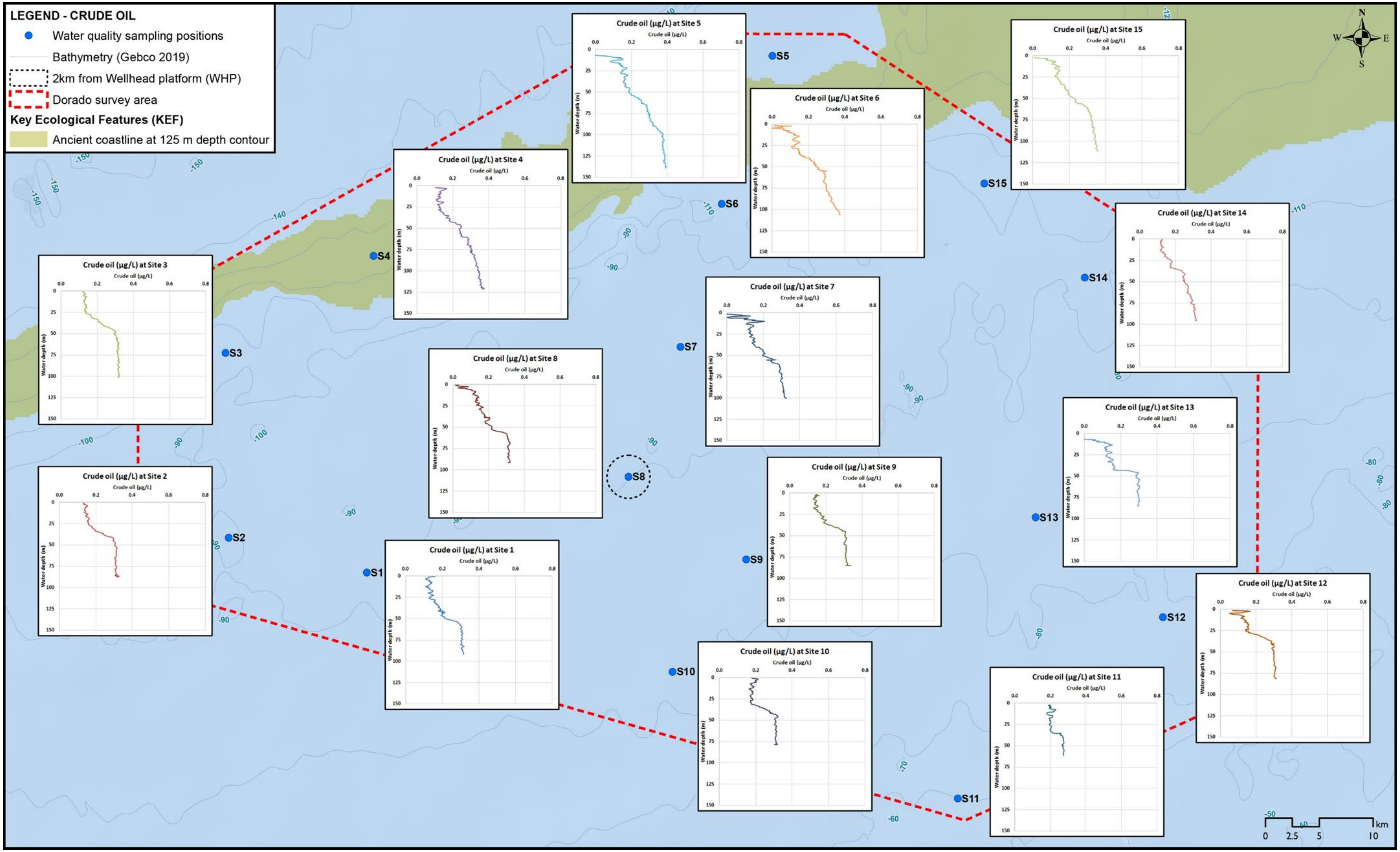


Figure 3-7: Across-shelf hydrocarbon (crude oil) profiles

3.2 Water quality samples

3.2.1 Nutrients and pigments

3.2.1.1 Nitrogen

The test for total nitrogen provides data for all nitrogen compounds in the water samples, which is present as nitrite (NO_2), nitrate (NO_3), ammonium (NH_4^+) and organic nitrogen compounds.

Nitrite and nitrate were recorded at detectable levels at all sites except Site S11 (Figure 3-8, Table 3-1). Nitrite and nitrate were recorded in bottom water samples only at Sites S1, S2, S5, S7, S10 and S15. The compounds were recorded in both bottom (near seabed) and midwater samples at Sites S3, S4, S6, S8, S9, S12 and S14, and in bottom and surface water samples (but not in midwater) at Site S13. Nitrite and nitrate were recorded at concentrations of 2 to 15 µg N L-1 in midwater samples, but at much higher concentrations (8–150 µg N L-1) in near-seabed samples. Concentrations ranged from 2 µg N L-1 at Sites S8 and S12 to ≥100 µg N L-1 at Sites S4, S5, S6 and S15 (i.e. all of the deepest sites), with a maximum concentration of 150 µg N L-1 in the bottom waters of Site S5 (the deepest site). Near seabed concentrations were related to the water depth at the site, with lowest concentrations recorded at the shallowest sites (<80 m BSL; Sites 10, 11 and 12) and greatest at the deepest sites (>100 m BSL; Sites S4, S5, S6 and S15). The ANZG (2018) default guideline value for nitrate and nitrite in slightly disturbed tropical Australian marine offshore ecosystems is 4 µg N L-1.

Ammonium was only detected at one site, Site S15, in the mid-water sample (5 µg N L-1). This was below the ANZG (2018) default species protection guideline value of 6 µg N L-1 for ammonium in slightly disturbed tropical Australian marine offshore ecosystems which 95% species protection. The slightly disturbed level of protection has been applied here because the environment being assessed has had some small but measurable level of human activity.

Total nitrogen concentrations indicated the presence of other organic nitrogen compounds, with only the Site S5 midwater sample (excluding the field and transport blanks) being below the LOR of 50 µg N L-1. Total nitrogen concentrations ranged from 50 µg N L-1 in the Site 12 bottom sample to 170 µg N L-1 in the Site S4 and S5 bottom samples. Near seabed (Sites S1, S2, S3, S4, S5, S6, S8, S9, S14 and S15), midwater (Site S6) and surface (Sites S8, S12 and S14) samples were found to meet or exceed the ANZG (2018) default guideline value of 100 µg N L-1 for total nitrogen in slightly disturbed tropical Australian marine offshore ecosystems.

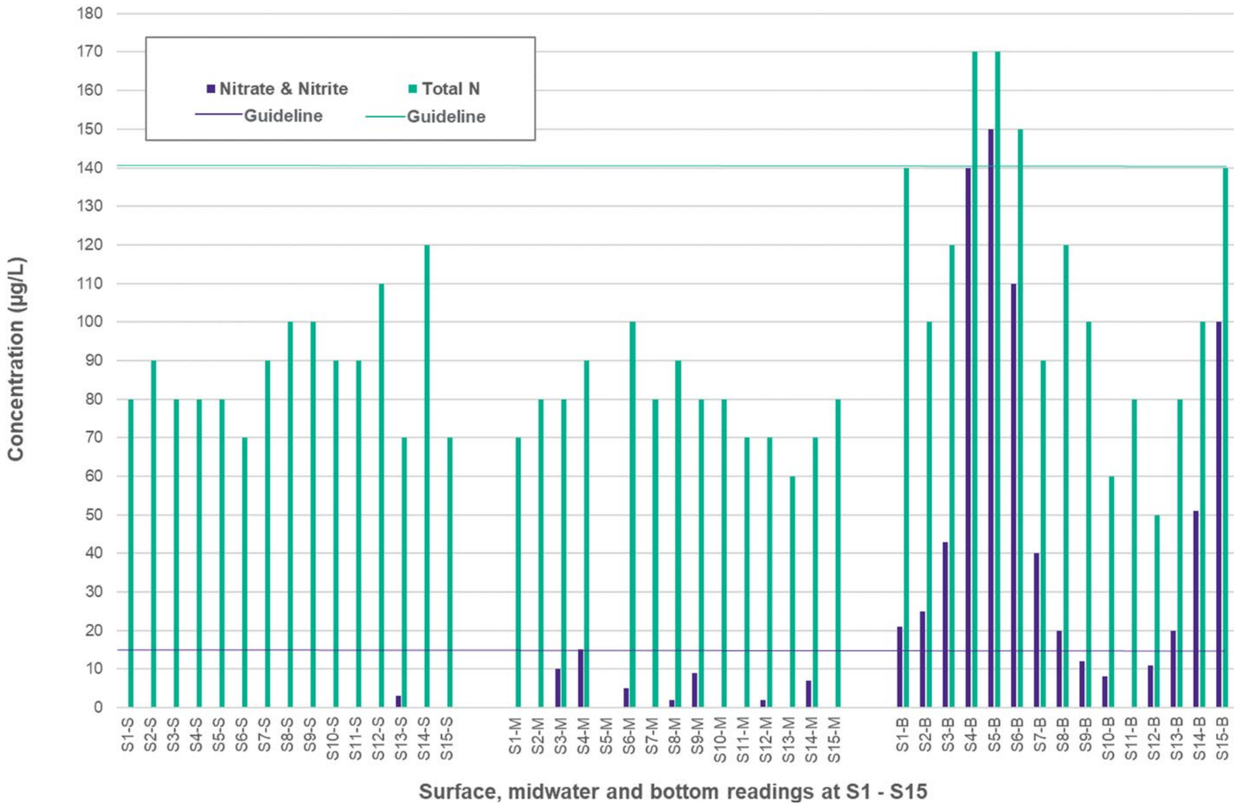
In summary, the data from samples collected in the Dorado baseline survey area indicated that total nitrogen concentrations varied greatly and generally increased with depth. Total nitrogen in surface samples mainly comprised organic nitrogen, while the contribution of nitrate and nitrite to total nitrogen increased with depth (Figure 3-8).

3.2.1.2 Phosphorus

The results for total phosphorus comprise the concentration of phosphorus that occurs in orthophosphate and organic phosphate compounds.

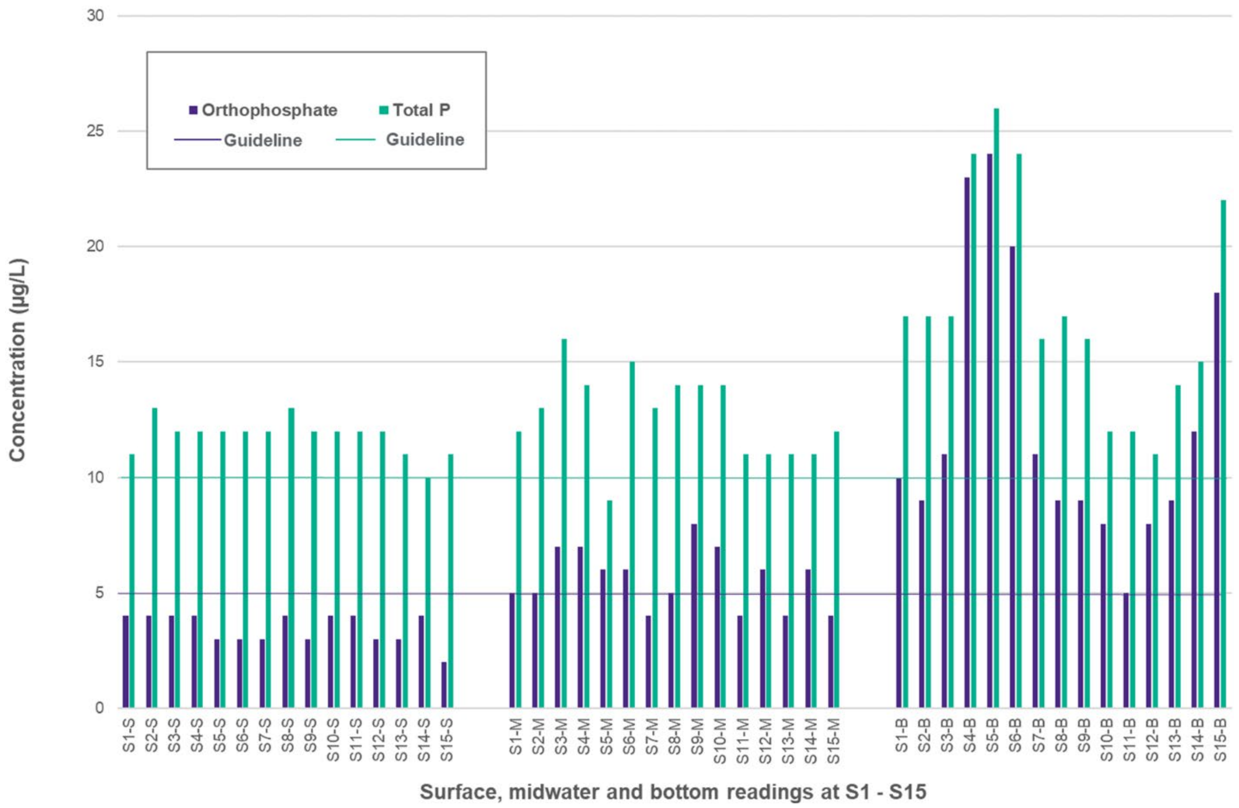
Orthophosphate (filterable reactive phosphorus) concentrations ranged from 2 to 24 µg P L-1 (Figure 3-9, Table 3-1). All results were above LOR. Twenty-two of the 45 samples collected exceeded the ANZG (2018) default guideline value of 5 µg P L-1 for orthophosphate in slightly disturbed tropical Australian marine offshore ecosystems. Surface waters at all sites were below the guideline value; exceedances either occurred in near seabed samples (Sites S1, S2, S7, S8, S13 and S15) or both near seabed and midwater samples (Sites S3, S4, S5, S6, S9, S10, S12 and S14). Surface concentrations ranged from 2 to 4 µg P L-1, midwater concentrations ranged from 4 to 8 µg P L-1, and near-seabed concentrations ranged from 5 to 24 µg P L-1. Highest near seabed concentrations were found at the deepest sites (Sites S4, S5, S6 and S15).

Total phosphorous showed the same general trend of increasing concentrations of phosphorus with depth (Figure 3-9), with peak concentrations at the same four deepest sites (Sites S4, S5, S6 and S15). Almost all samples, with the exception of Site S5 midwater and Site S14 surface, exceeded the ANZG (2018) default guideline value of 10 µg P L-1 for total phosphorus in slightly disturbed tropical Australian marine offshore ecosystems.



*Note: Concentrations below limits of reporting have not been presented. Guideline value for Nitrate & Nitrite is 15 µg/L; Guideline value for Total Nitrogen is 140 µg/L.

Figure 3-8: Nitrate and nitrite and total nitrogen (N) concentrations in surface, midwater and near-bottom samples at sites S1 to S15



*Note: Guideline value for orthophosphate is 5 µg/L; Guideline value for Total P is 10 µg/L.

Figure 3-9: Orthophosphate and total phosphorous (P) concentrations in surface, midwater and near-bottom samples at sites S1 to S15

3.2.1.3 Pigments

Chlorophyll-a concentrations were used as an indicator of the likely level of phytoplankton biomass across the Dorado Survey Area. Chlorophyll-a concentrations ranged from <0.1 µg L-1 to 0.8 µg L-1 (Table 3-1). All concentrations were below the ANZG (2018) default guideline value of 9 µg L-1 for chlorophyll-a in slightly disturbed tropical Australian marine offshore ecosystems. Concentrations were lowest at the surface, and highest in either midwater (Sites S3, S4, S5, S6, S8, S9, S12) or near seabed samples (Sites S1, S2, S7, S10, S11, S13, S14, S15).

Phaeophytin a was also sampled as this pigment is a breakdown product of chlorophyll-a and can be used to indicate if phytoplankton are blooming or declining. Phaeophytin a was detected in 18 samples and 13 of those were taken near the seabed. Concentrations ranged from <0.2 µg L-1 (i.e. below LOR) to 0.6 µg L-1 (Table 3-1). There is no ANZG (2018) default guideline value for phaeophytin a.

3.2.2 Total suspended solids

Total suspended solids (TSS) concentrations were low and ranged from <0.5 mg L-1 (below LOR) to 5.4 mg L-1 (Figure 3-10, Table 3-1). Highest TSS concentrations were recorded in near seabed samples (5.4 mg L-1 was recorded at Site 5 – the deepest site) and lowest values in surface waters (concentrations were only slightly above LOR at Site S1, at 0.7 mg L-1). Midwater concentrations peaked at 1.0 mg L-1 at Sites S11 and S14.

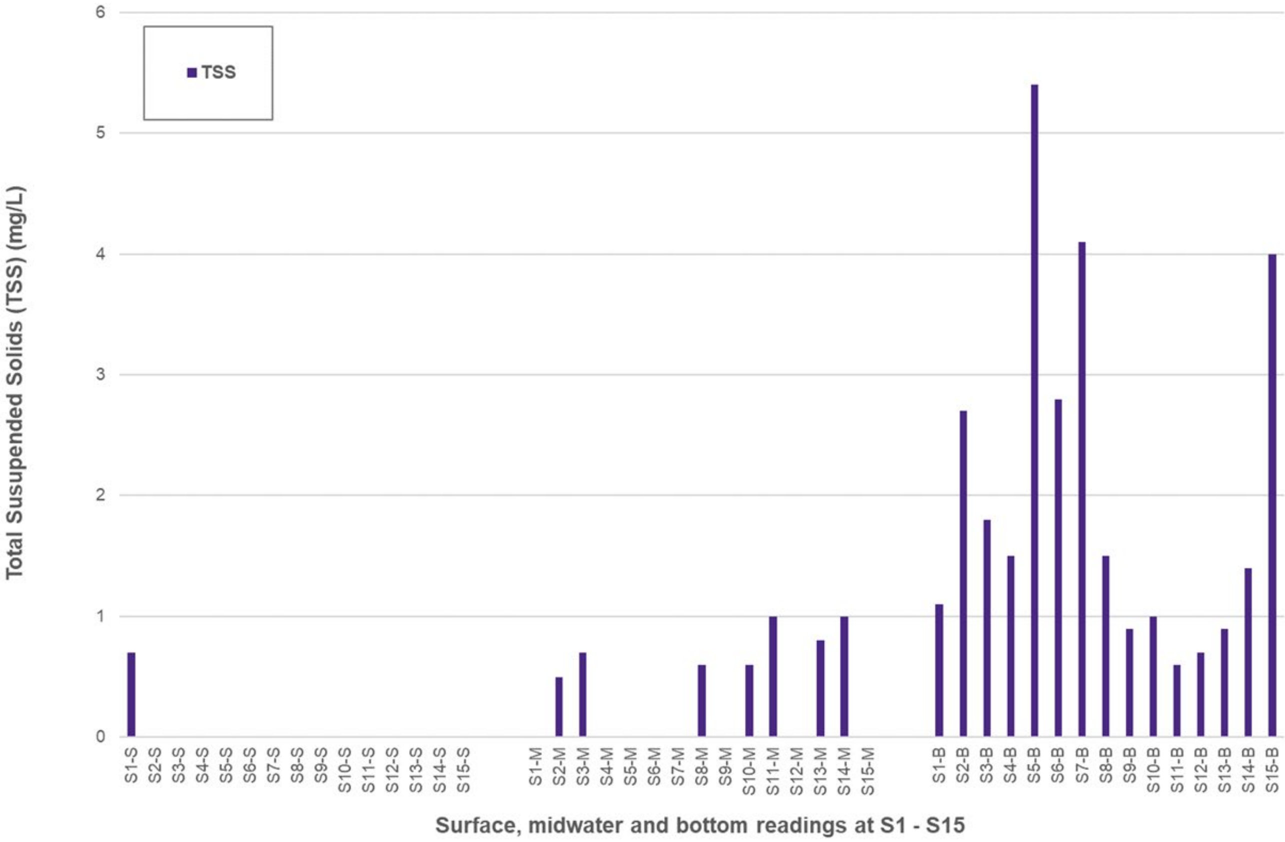


Figure 3-10: Total suspended solids (TSS) concentrations in surface, midwater and near-bottom samples at sites S1 to S15

Table 3-1: Nutrients, pigments and suspended solids

Sample	Ammonia	Nitrate and nitrite	Total nitrogen	Orthophosphate	Total phosphorus	Chlorophyll-a	Phaeophytin a	Total suspended solids
Unit	**µg N L-1**	**µg N L-1**	**µg N L-1**	**µg P L-1**	**µg P L-1**	**µg L-1**	**µg L-1**	**mg L-1**
LOR	**<3**	**<2**	**<50**	**<2**	**<5**	**<0.1**	**<0.2**	**<0.5**
Guideline value[a]	**6**	**15**	**140**	**5**	**10**	**0.9**	**N/A**	**N/A**
S1-S	<3	<2	80	4	11	<0.1	<0.2	0.7
S1-M	<3	<2	70	5	12	0.3	<0.2	<0.5
S1-B	<3	21	140	10	17	0.6	0.4	1.1
S2-S	<3	<2	90	4	13	<0.1	<0.2	<0.5
S2-M	<3	<2	80	5	13	0.1	<0.2	0.5
S2-B	<3	25	100	9	17	0.4	0.5	2.7
S3-S	<3	<2	80	4	12	<0.1	<0.2	<0.5
S3-M	<3	10	80	7	16	0.8	0.6	0.7
S3-B	<3	43	120	11	17	0.1	0.6	1.8
S4-S	<3	<2	80	4	12	<0.1	<0.2	<0.5
S4-M	<3	15	90	7	14	0.7	0.3	<0.5
S4-B	<3	140	170	23	24	<0.1	<0.2	1.5
S5-S	<3	<2	80	3	12	<0.1	<0.2	<0.5
S5-M	<3	<2	<50	6	9	0.2	<0.2	<0.5
S5-B	<3	150	170	24	26	<0.1	0.4	5.4
S6-S	<3	<2	70	3	12	<0.1	<0.2	<0.5
S6-M	<3	5	100	6	15	0.5	0.3	<0.5
S6-B	<3	110	150	20	24	<0.1	0.4	2.8
S7-S	<3	<2	90	3	12	<0.1	<0.2	<0.5
S7-M	<3	<2	80	4	13	0.2	<0.2	<0.5
S7-B	<3	40	90	11	16	0.2	0.6	4.1
S8-S	<3	<2	100	4	13	<0.1	<0.2	<0.5
S8-M	<3	2	90	5	14	0.4	<0.2	0.6
S8-B	<3	20	120	9	17	0.3	0.5	1.5
S9-S	<3	<2	100	3	12	0.1	<0.2	<0.5
S9-M	<3	9	80	8	14	0.6	<0.2	<0.5
S9-B	<3	12	100	9	16	0.5	0.3	0.9
S10-S	<3	<2	90	4	12	<0.1	<0.2	<0.5
S10-M	<3	<2	80	7	14	0.3	0.2	0.6
S10-B	<3	8	60	8	12	0.6	0.3	1
S11-S	<3	<2	90	4	12	0.1	<0.2	<0.5
S11-M	<3	<2	70	4	11	0.1	<0.2	1
S11-B	<3	<2	80	5	12	0.2	<0.2	0.6
S12-S	<3	<2	110	3	12	0.3	<0.2	<0.5
S12-M	<3	2	70	6	11	0.4	<0.2	<0.5
S12-B	<3	11	50	8	11	0.3	0.3	0.7
S13-S	<3	3	70	3	11	<0.1	<0.2	<0.5
S13-M	<3	<2	60	4	11	0.2	<0.2	0.8
S13-B	<3	20	80	9	14	0.7	0.4	0.9
S14-S	<3	<2	120	4	10	0.1	<0.2	<0.5
S14-M	<3	7	70	6	11	0.3	0.3	1
S14-B	<3	51	100	12	15	0.5	0.3	1.4
S15-S	<3	<2	70	2	11	<0.1	<0.2	<0.5
S15-M	5	<2	80	4	12	0.1	<0.2	<0.5
S15-B	<3	100	140	18	22	0.2	0.4	4

A Default trigger value for slightly disturbed tropical marine offshore ecosystems (ANZG 2018). Exceedances of default trigger values are indicated by values in bold and underlined.

3.2.3 Metals/metalloids

No metals/metalloids in the water samples collected across the Dorado baseline survey area were above ANZG (2018) recommended trigger values for slightly to moderately disturbed marine systems (where available) or, in the case of arsenic (As), above the ANZG (2018) low reliability trigger values (Table 3-2).

Filtered and unfiltered cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni) and mercury (Hg) concentrations were all at or below LOR and hence guidelines levels. Filtered and unfiltered cobalt (Co) concentrations were all at or below LOR except S6-M at 0.06 µg L-1, with all samples below ANZG (2018) guideline levels (Table 3-2).

Filtered arsenic (As) concentrations ranged from 1.6 to 1.9 µg L-1, with lowest concentrations recorded from Site S1 surface and midwater samples, and peak concentrations recorded in nine samples. Unfiltered arsenic was recorded over a similar range, with 1.7 µg L-1 recorded from nine samples and 2.0 µg L-1 recorded in Site S11 and Site S13 midwater samples. All recorded concentrations were below the ANZG (2018) guideline level of 4.5 µg L-1 (Table 3-2).

Filtered barium (Ba) concentrations were recorded between 5.2 and 6.3 µg L-1. Unfiltered barium concentrations were also recorded over a similar range (5.1–6.4 µg L-1). In both cases, lowest levels were recorded from Site S14 surface waters and peak levels from the Site S6 midwater sample (Table 3-2). There is no guideline level for barium.

Filtered copper (Cu) concentrations ranged from below LOR (<0.2 µg L-1) in 28 samples to 0.7 µg L-1 in the Site S7 surface sample. Unfiltered copper was also recorded below LOR (<0.2 L-1) in 20 samples, with peak concentrations of 0.4 µg L-1 recorded in Site S2 midwater and Site S7 surface samples. All concentrations were below the ANZG (2018) guideline level of 1.3 µg L-1 (Table 3-2).

Filtered zinc (Zn) concentrations ranged from below LOR (<1.0 µg L-1) in 28 samples to 3 µg L-1 in the Site S8 midwater sample. Unfiltered zinc was also recorded below LOR (<1.0 µg L-1) in 32 samples, with the peak concentration of 5 µg L-1 recorded from the Site S13 surface sample. All samples were below the ANZG (2018) guideline level of 7.0 µg L-1 (Table 3-2).

3.2.4 Hydrocarbons

Total recoverable hydrocarbon (TRH) concentrations were not measured above limits of reporting in any samples except in the Site 8 surface sample, where very low concentrations of the C29-C36 fraction were recorded (70 µg L-1) (Table 3-3). BTEXN were also recorded at low concentrations in the same sample (Table 3-3). Relative to guideline values toluene was at the 99% species protection of 110 µg L-1 , at the 90% level of species protection limit for ethylbenzene, and below the 80% species protection factor for naphthalene and m-xylene (ANZG 2018).

Table 3-2: Filtered and unfiltered metals/metalloids

Sample	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
	Filtered (bioavailable fraction)										Unfiltered (total)									
Unit	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	mg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	µg L-1	mg L-1	µg L-1	µg L-1	µg L-1
Limit of reporting (LOR)	<0.5	<0.5	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	<0.5	<0.5	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1
Guideline value	4.5a	N/A	0.7b	1.0c	27.0c	1.3c	0.0001a	7.0b	4.4c	15.0c	4.5a	N/A	0.7b	1.0c	27.0c	1.3c	0.0001b	7.0b	4.4c	15.0c
S1-S	1.6	5.4	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	1	1.7	5.4	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	<1
S1-M	1.6	5.4	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	1	1.7	5.7	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S1-B	1.8	5.7	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.8	5.8	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	1
S2-S	1.7	5.4	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	<1	1.7	5.4	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	<1
S2-M	1.7	5.5	<0.1	<0.05	<0.2	0.4	<0.0001	<0.3	<0.1	2	1.7	5.6	<0.1	<0.05	<0.2	0.4	<0.0001	<0.3	<0.1	<1
S2-B	1.8	5.7	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1	1.8	5.8	<0.1	<0.05	0.4	0.3	<0.0001	<0.3	0.1	2
S3-S	1.8	5.4	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	1	1.8	5.6	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S3-M	1.8	5.8	<0.1	<0.05	<0.2	0.5	<0.0001	<0.3	<0.1	1	1.8	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1
S3-B	1.7	5.9	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	6	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S4-S	1.7	5.4	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.8	5.5	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S4-M	1.7	5.7	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1	1.8	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1
S4-B	1.8	6.1	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.9	6.3	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1
S5-S	1.8	5.5	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.5	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S5-M	1.7	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.9	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1
S5-B	1.9	6.1	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.8	6.1	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1
S6-S	1.7	5.6	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	1	1.8	5.7	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	1
S6-M	1.9	6.3	<0.1	0.06	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.9	6.4	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S6-B	1.9	5.8	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1	1.9	5.9	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	1
S7-S	1.8	5.5	<0.1	<0.05	0.2	0.7	<0.0001	<0.3	<0.1	<1	1.8	5.9	<0.1	<0.05	0.2	0.4	<0.0001	<0.3	<0.1	<1
S7-M	1.8	5.7	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.8	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S7-B	1.8	5.9	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	<1	1.7	5.9	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	1
S8-S	1.7	5.6	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	<1	1.7	5.6	<0.1	<0.05	0.2	0.3	<0.0001	0.3	<0.1	<1
S8-M	1.7	5.8	<0.1	<0.05	0.2	0.6	<0.0001	<0.3	<0.1	3	1.8	5.8	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	2
S8-B	1.8	5.8	<0.1	<0.05	0.2	0.4	<0.0001	<0.3	<0.1	<1	1.7	6	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	<1
S9-S	1.8	5.5	<0.1	<0.05	0.2	0.4	<0.0001	<0.3	<0.1	1	1.7	5.7	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	<1
S9-M	1.9	6.1	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.7	6	<0.1	<0.05	0.2	0.3	<0.0001	0.3	<0.1	1
S9-B	1.8	6	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	6.2	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1
S10-S	1.9	5.9	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	2	1.9	5.8	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	1
S10-M	1.8	6	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	2	1.9	6.2	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S10-B	1.8	6.1	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	6	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S11-S	1.8	5.9	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	1	1.8	5.9	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	<1
S11-M	1.8	5.7	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1	2	5.7	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1
S11-B	1.9	5.9	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.9	5.9	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S12-S	1.9	5.6	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.5	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	3
S12-M	1.8	5.9	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1	1.8	6	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	1
S12-B	1.8	6.1	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.9	6.4	<0.1	<0.05	0.2	<0.2	<0.0001	0.3	<0.1	<1
S13-S	1.8	5.6	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.9	5.6	<0.1	<0.05	0.2	0.3	<0.0001	<0.3	<0.1	5
S13-M	1.8	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	2	5.9	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1
S13-B	1.9	5.8	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1	1.8	6.1	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	1
S14-S	1.8	5.2	<0.1	<0.05	<0.2	0.2	<0.0001	<0.3	<0.1	1	1.8	5.1	<0.1	<0.05	0.2	0.2	<0.0001	<0.3	<0.1	<1
S14-M	1.7	5.5	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.4	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S14-B	1.8	5.6	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.7	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S15-S	1.8	5.3	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	<1	1.8	5.3	<0.1	<0.05	<0.2	0.3	<0.0001	<0.3	<0.1	<1
S15-M	1.8	5.4	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.8	5.4	<0.1	<0.05	0.2	<0.2	<0.0001	<0.3	<0.1	<1
S15-B	1.9	5.7	<0.1	<0.05	<0.2	<0.2	<0.0001	<0.3	<0.1	<1	1.9	5.7	<0.1	<0.05	0.2	<0.2	<0.0001	0.3	<0.1	1

a ANZG (2018) Low reliability trigger value

b ANZG (2018) 99% species protection level default guideline value (DGV), recommended for slightly to moderately disturbed marine systems

c ANZG (2018) 95% species protection level DGV, recommended for slightly to moderately disturbed marine systems (for chromium, value represents CrIII DGV).

Table 3-3: Total recoverable hydrocarbons, BTEXN (in µg L-1), and total petroleum hydrocarbons

Analyte (units)	LoR	S1-S	S1-M	S1-B	S2-S	S2-M	S2-B	S3-S	S3-M	S3-B	S4-S	S4-M	S4-B	S5-S	S5-M	S5-B
Total recoverable hydrocarbons (µg L-1)																
C6-C10 fraction	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction minus BTEX	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum C10-C40 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C16 fraction minus naphthalene	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN (µg L-1)																
Benzene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total xylenes	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
TPH(V)/BTEX surrogates (%)																
1.2-Dichloroethane-D4	0.1	98	103	102	101	104	104	104	94.5	97.7	95.3	107	102	99.6	109	107
Toluene-D8	0.1	100	98.8	99.6	98	99.5	98.6	100	101	101	102	97	100	103	98.9	100
4-Bromofluorobenzene	0.1	95.9	99.5	98.4	96	97.5	99.2	97.8	96.1	97.9	96.4	103	94.6	100	103	101
Analyte (units)	LoR	S6-S	S6-M	S6-B	S7-S	S7-M	S7-B	S8-S	S8-M	S8-B	S9-S	S9-M	S9-B	S10-S	S10-M	S10-B
Total recoverable hydrocarbons (µg L-1)																
C6-C10 fraction	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction minus BTEX	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	100	<100	<100	<100	<100	<100	<100	110	<100	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum C10-C40 fraction	100	<100	<100	<100	<100	<100	<100	110	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C16 fraction minus naphthalene	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN (µg L-1)																
Benzene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total xylenes	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
TPH(V)/BTEX surrogates (%)																
1.2-Dichloroethane-D4	0.1	109	106	107	109	108	105	101	99.5	91.9	102	100	108	127	109	126
Toluene-D8	0.1	98	98.2	97.1	100	97.5	99.4	100	100	101	99.9	101	99.3	95.8	93.4	97.1
4-Bromofluorobenzene	0.1	103	101	103	103	102	99.5	96.7	97.5	94	97.2	96.1	97	103	106	103

Analyte (units)	LoR	S11-S	S11-M	S11-B	S12-S	S12-M	S12-B	S13-S	S13-M	S13-B	S14-S	S14-M	S14-B	S15-S	S15-M	S15-B
Total recoverable hydrocarbons (µg L-1)																
C6-C10 fraction	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction minus BTEX	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum C10-C40 fraction	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C16 fraction minus naphthalene	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN (µg L-1)																
Benzene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
TPH(V)/BTEX surrogates (%)																
1.2-Dichloroethane-D4	0.1	116	130	110	121	110	116	115	112	85.8	92.6	87.4	89.6	88	91	90
Toluene-D8	0.1	99.3	94.7	98.9	95.8	100	98.6	99.5	99.4	98.6	101	101	103	101	102	103
4-Bromofluorobenzene	0.1	101	104	100	102	98.9	100	100	99.5	91.9	96.7	96.6	95	96.3	96.6	92.9

3.2.5 Naturally occurring radioactive materials (NORMS)

Nearly all the samples taken for naturally occurring radioactive materials (NORMS) were below the LOR (Table 3-4). In accordance with ISO 11929 testing standards, each separate test for an analyte has an individual LOR based on the statistical probability of detection due to the nature of testing radio nucleotides. Therefore, the LORs for an analyte (e.g. Radium266) are different among samples. Data points that are prefixed by the symbol '<' demonstrate that result is below the LOR for that sample. Three samples that exceeded the LOR for that sample include S1 Bottom Thorium228, S6 Middle Radium266, and S9 Bottom Radium266.

There are no ANZG (2018) trigger values for NORMs, however, there are guidelines for drinking water National Health and Medical Research Council (NHMRC) & ARMCANZ (2011) which are generally more stringent guidelines because they are related to human health. According to these guidelines, concentrations of Radium226 and Radium228 should not be above 4.89 (Bq/L) and 1.98 (Bq/L). All the data for the samples, including the three that exceeded LORs, are one to two orders of magnitude below these trigger values.

Table 3-4: Naturally occurring radioactive materials (NORMS)

Sample	Location	Radium266 (Bq/L)	Radium228 (Bq/L)	Thorium228 (Bq/L)
S1	Surface	<0.033	<0.078	<0.024
	Middle	<0.037	<0.13	<0.029
	Bottom	<0.048	<0.098	0.029 ±0.014
S2	Surface	<0.048	<0.096	<0.034
	Middle	<0.024	<0.088	<0.028
	Bottom	<0.039	<0.099	<0.027
S3	Surface	<0.044	<0.089	<0.030
	Middle	<0.049	<0.092	<0.036
	Bottom	<0.028	<0.12	<0.027
S4	Surface	<0.044	<0.15	<0.034
	Middle	<0.035	<0.11	<0.032
	Bottom	<0.042	<0.086	<0.035
S5	Surface	<0.046	<0.11	<0.030
	Middle	<0.034	<0.091	<0.030
	Bottom	<0.046	<0.091	<0.033
S6	Surface	<0.032	<0.13	<0.029
	Middle	0.029 ±0.018	<0.16	<0.034
	Bottom	<0.040	<0.080	<0.022
S7	Surface	<0.046	<0.090	<0.027
	Middle	<0.039	<0.091	<0.036
	Bottom	<0.041	<0.13	<0.023
S8	Surface	<0.055	<0.17	<0.036
	Middle	<0.062	<0.11	<0.040
	Bottom	<0.066	<0.15	<0.050
S9	Surface	<0.027	<0.093	<0.024
	Middle	<0.026	<0.092	<0.030
	Bottom	0.027 ±0.012	<0.11	<0.030
S10	Surface	<0.042	<0.13	<0.021
	Middle	<0.041	<0.17	<0.043
	Bottom	<0.051	<0.12	<0.040

Sample	Location	Radium266 (Bq/L)	Radium228 (Bq/L)	Thorium228 (Bq/L)
S11	Surface	<0.063	<0.15	<0.057
	Middle	<0.035	<0.092	<0.030
	Bottom	<0.026	<0.11	<0.035
S12	Surface	<0.039	<0.084	<0.035
	Middle	<0.044	<0.097	<0.027
	Bottom	<0.039	<0.13	<0.025
S13	Surface	<0.040	<0.16	<0.028
	Middle	<0.059	<0.13	<0.029
	Bottom	<0.049	<0.14	<0.024
S14	Surface	<0.038	<0.093	<0.040
	Middle	<0.036	<0.13	<0.035
	Bottom	<0.043	<0.089	<0.029
S15	Surface	<0.035	<0.088	<0.025
	Middle	<0.056	<0.17	<0.035
	Bottom	<0.050	<0.13	<0.035

3.2.6 Quality control samples

All samples were returned to the analytical laboratories within holding time requirements. one sample (S15-S) exceeded the holding time for hydrocarbons because the first laboratory extraction taken within the holding time was broken during analysis. The second extraction exceeded the holding time by six days (see Appendix C). The results from the second extraction were all below limits of reporting for hydrocarbons. This result was consistent with the other results for the site.

Results from laboratory analysis of the transport blank and field blank showed that samples were below limits of detection for all analytes, demonstrating that QA/QC procedures to mitigate risk of sample contamination were effective.

Multivariate analysis of sample data, including QA/QC samples, identified that duplicates 1, 2 and 4 were not significantly different to the representative sample for each site (surface samples from sites 9, 5 and 4, respectively). Duplicate sample 3 was found to be significantly different to the representative site sample (surface site 12), due to lower levels of chlorophyll-a, unfiltered copper and unfiltered zinc. Filtered copper was at the limit of detection in the duplicate sample, but below the limit of detection in the representative sample. Field notes taken at the time of sample collection indicated that there was a ‘slick’ of plankton at the surface, and the differences in the chlorophyll-a recorded indicate that patchiness in this slick (due to windrows) may explain the differences observed between the duplicate and the representative sample in surface waters of site 12.

3.3 Multivariate analysis of water quality samples

Multivariate analysis was undertaken to identify if any trends existed between analytes and sampling locations. The data analysed in these analyses are all the analytes collected from the surface (S), middle (M), and bottom (B) water samples as indicated by their colour, including quality control (QC) samples and the number against each sample indicates the sampling location.

A cluster analysis generally identified three separate clusters of data as identified by the grouping of red lines (Figure 3-11). The field blank (FB) and transport blank (TB) are nested separately given they did not contain the analytes tested and show they were not contaminated with the tested analytes. Samples taken from the bottom at locations 4, 5, 6, and 15 are also grouped separately from all the other samples.

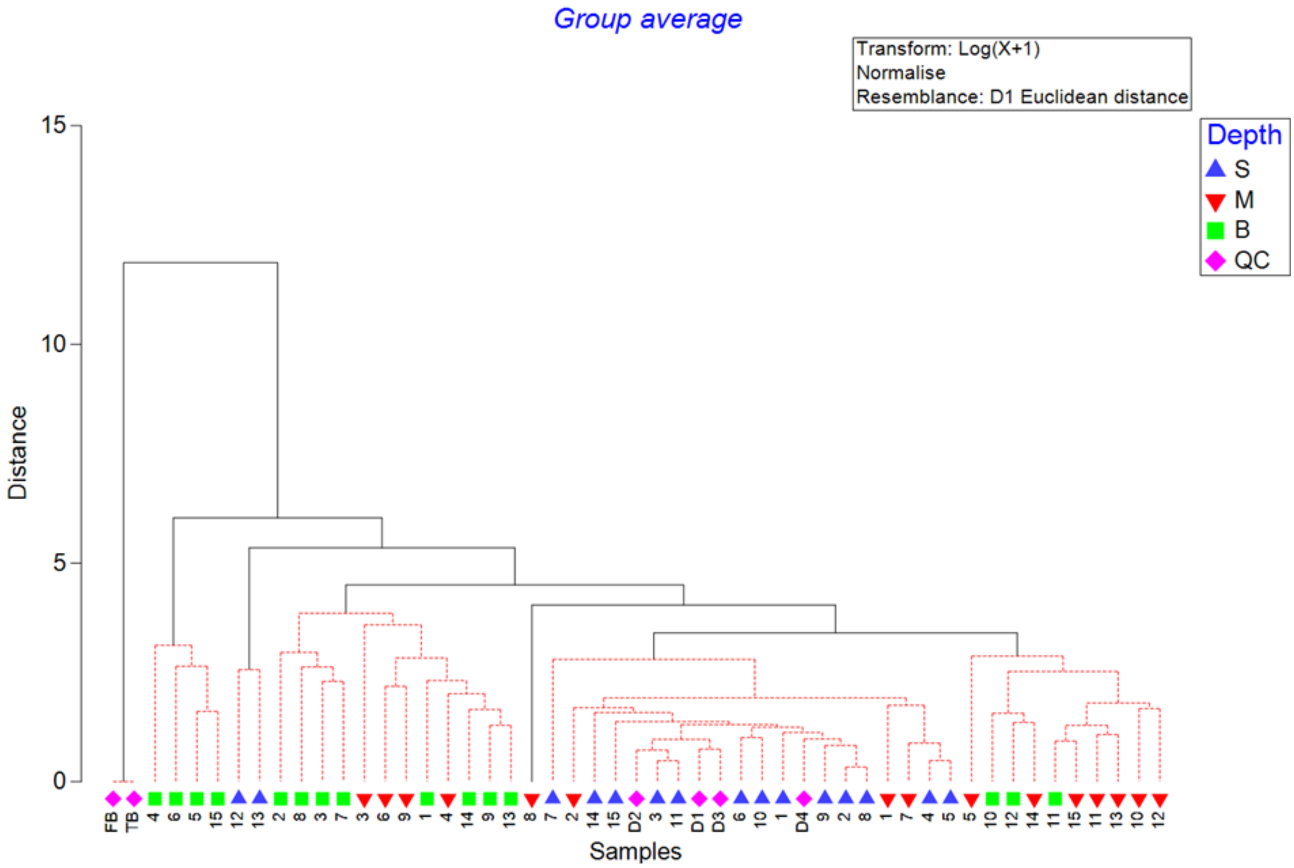


Figure 3-11: Cluster analysis of water quality sample analytes at surface, middle and bottom depths across all sampling sites

Similarly, an n-MDS analysis shows there are differences in the samples taken between the surface (S), middle (M) and bottom (B) locations as indicated by the spatial separation of these samples (Figure 3-12). The duplicate quality control samples (QC) are grouped amongst the samples in which they were taken and demonstrate that contamination has not occurred. The n-MDS plot does not directly identify what is driving differences between surface, middle and bottom samples, so PCA analysis was undertaken.

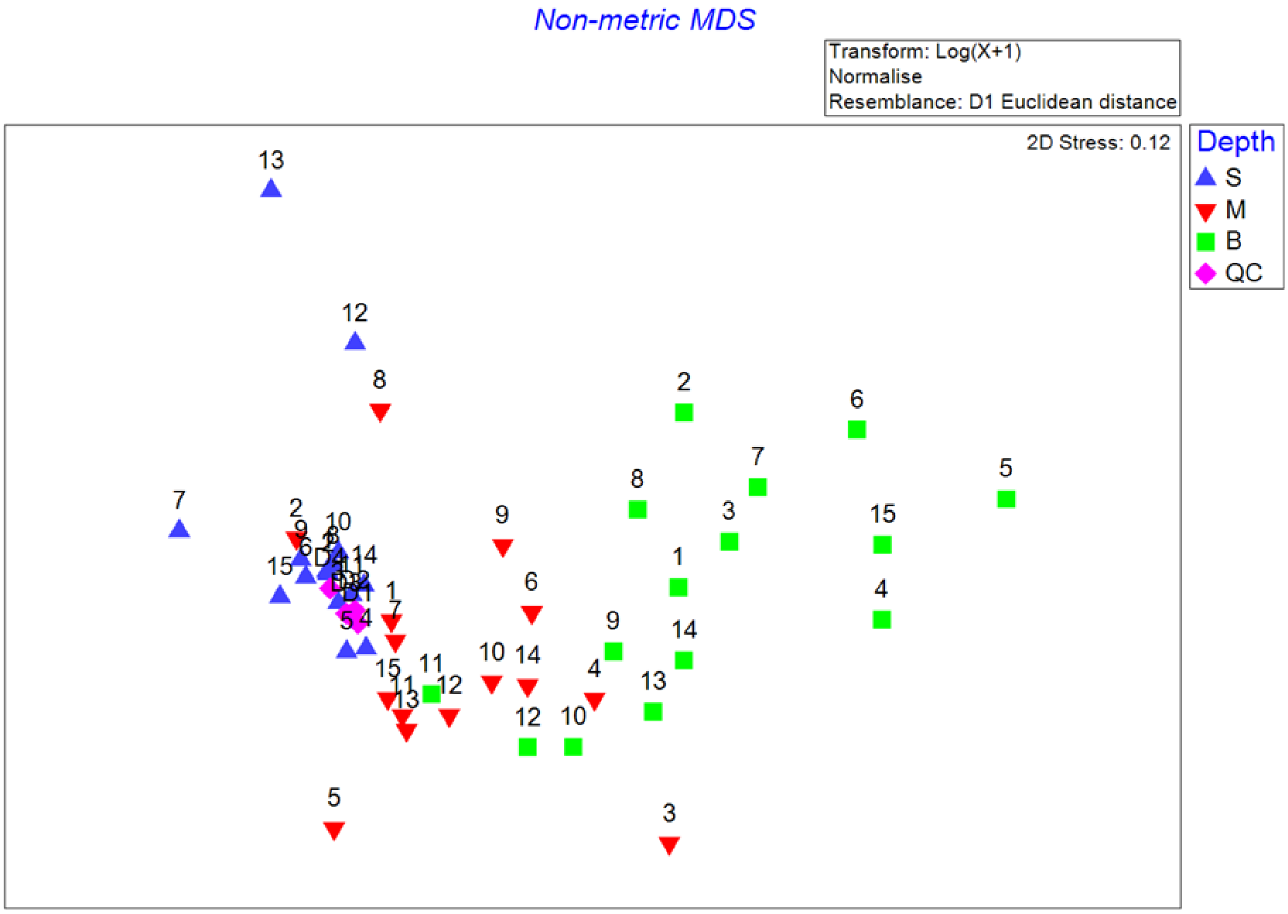


Figure 3-12: MDS analysis of water quality sample analytes at surface, middle and bottom depths across all sampling sites

The PCA analysis below shows the factors that are driving the separation and groupings identified in the cluster analysis and MDS plot (Figure 3-13). The vectors in the circle are the analytes that were tested, the direction relates to the direction in which the vector is explaining differences between samples, and length of each vector relates to the relative strength of the relationship between the factor and sample. This analysis shows the bottom samples generally had different levels of TSS, Chlorophyll a, Ortho-P, Phaeophytin a and NO3 + NO2 as indicated by the grouping of the locations in the direction of these vectors, relative to the other sampling locations. The grouping of locations 4, 5, 6, and 15 identified in the cluster analysis are slightly separated along the same vector trajectory suggesting these factors were likely explaining the differences at these locations. The pink duplicate samples are grouped with the surface samples suggesting they are similar, while the field and travel blanks (FTB) are completely separate and show they were not contaminated.

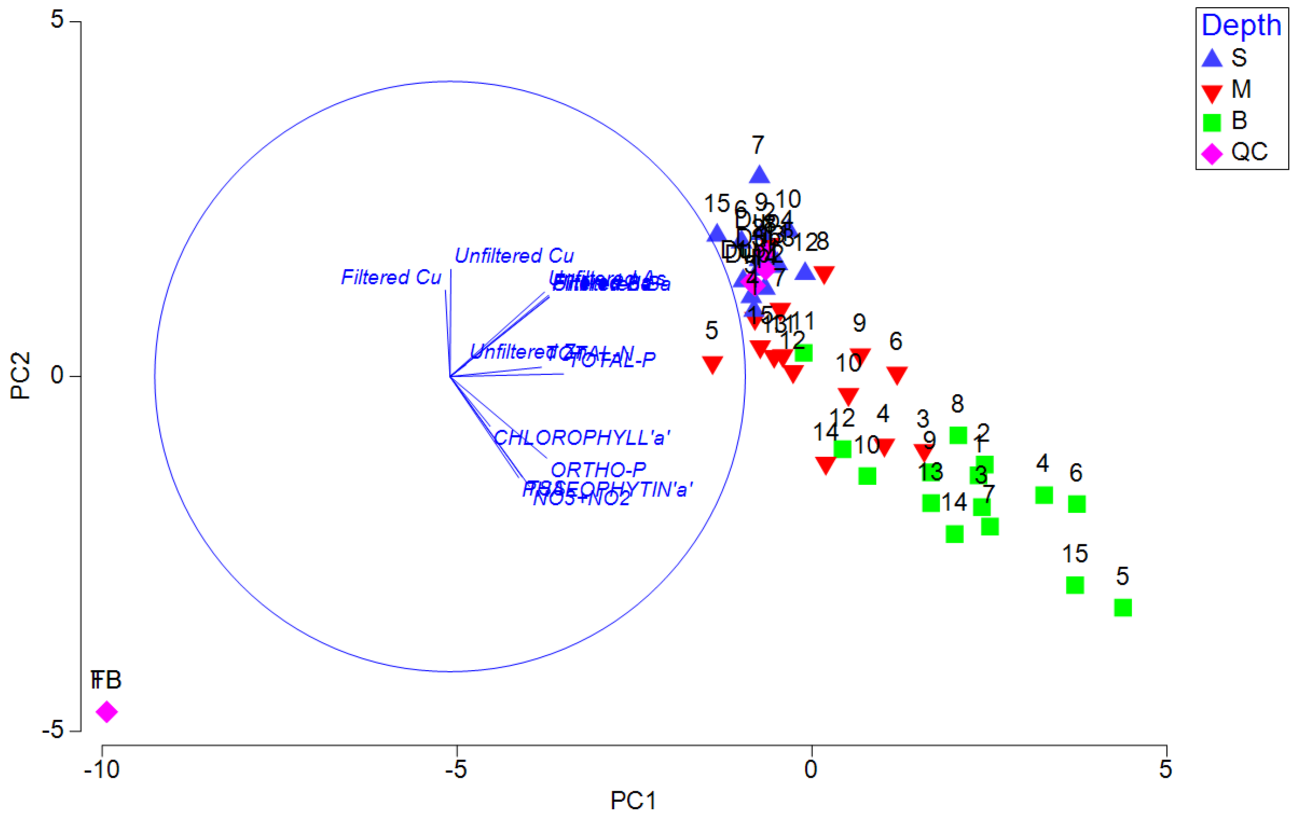


Figure 3-13: PCA analysis of water quality sample analytes at surface, middle and bottom depths across all sampling sites discussion

This study characterises the water quality conditions through the water column at 15 sites across the Dorado Survey Area during the Austral summer. The data showed that water quality conditions were typical of offshore waters of the Pilbara and North West Shelf. For example, water temperatures were within the range recorded between October 2017 and April 2019 during the Bedout Basin metocean deployments (RPS 2019). The water column profiles during the present study showed a maximum of 30.65 °C at the surface and a minimum of 21.73 °C near the seabed; water temperatures measured during the metocean deployment ranged from a maximum of 31.18°C at ~13 m below the sea surface in 100 m water depth to a minimum of 19.68°C at ~1.5 m above seabed in 140 m water depth (RPS 2019).

There was a general trend of higher salinity near the sea surface which may be explained by increased evaporation. Since the survey area is remote from any potential terrestrial sources of freshwater input, factors affecting salinity are likely to be either climatic or hydrographic. Mahjabin et al. (2016) found salinity was higher in the Pilbara waters during the summer months and attributed this to higher rates of evaporation in this season. The elevated salinity in surface waters has also been linked to stratification off the Pilbara coast with heavier, more saline waters sinking and forming a dense layer closer to the seabed (Mahjabin et al. 2016). However, this is generally a winter phenomenon and was not observed in the present study conducted in summer, suggesting that the structure of the water column may change seasonally.

Stratification of the water column was also indicated by temperature, pH and dissolved oxygen changes with depth. At shallower sampling sites a thermocline was observed at depths between 25 - 50 m BSL, with warmer water near the surface, possibly due to solar heating and a lack of vertical mixing. Temperature levels below the thermocline generally decreased with depth. These data are comparable to data collected by RPS (2019), where a thermocline was recorded in the upper water column, which moved downwards in the water column in January due to the cooling of near seabed waters caused by very strong advective cooling events. Similarly, Lowe et al. (2012) observed thermoclines in surface waters (0-100 m BSL) and mid-column waters (75-150 m BSL) off the North West Cape (Exmouth). These thermoclines were found to be seasonal, and the occurrence and depth of thermoclines are likely to be variable across the year at the Dorado Project location also.

The pH levels were generally consistent and higher towards the surface, possibly due to the removal of acidic dissolved carbon dioxide from surface waters by planktonic photosynthesis. The pH then decreased rapidly with increased depth, potentially due to oxidation of decaying organic matter sinking from shallower depths. It has been demonstrated that decomposition produces carbonic acid (from the dissolution of liberated carbon dioxide) and the release of hydrogen ions cause a decrease in pH (Hinga 2002). Higher oxygen concentrations are common in surface waters due to the exchange of oxygen across the air-water interface.

Profiles at sampling locations in deeper waters further offshore (sites S4, S5, S6 and S15) tended to have a greater difference in temperature, pH, dissolved oxygen, NTU and chlorophyll-a values between the surface and seabed. The upper 20 m of the water column were mostly similar between all profiles, however values for these parameters at these locations continued to decline with increasing depth generally at a consistent rate. The differences in temperature and pH profiles among deeper and shallower sites suggest there may be some vertical mixing associated with the sloping seabed at these locations because temperature and pH continued to decline with depth beyond 50 m BSL, whereas temperature and pH at the shallower sites tended to remain constant below 50 m BSL.

Turbidity was generally higher near the seabed and at deeper sites further offshore. The deeper, offshore locations also had higher levels of silt in sediment samples (RPS 2020) which suggests this turbidity resulted from the resuspension of fine surficial sediments by current or tidal movements near the seabed. RPS (2019) also found higher turbidity during spring tide periods – when the water column profiling and water sampling was undertaken when water column currents tend to be much faster.

The chlorophyll-a data obtained from the profiles using the Seabird logger generally reflected what was recorded in the water quality samples taken from the surface, middle and bottom waters at each site. The highest concentrations of chlorophyll-a were observed in the mid-water column at approximately 50 m BSL. The North West Shelf Joint Environmental Management Study (2007) found a similar pattern of primary production, with a peak at around 70 m BSL. The peak was attributed to balance between sufficient light levels to support photosynthesis combined with elevated nitrate levels to maximise phytoplankton growth. Despite nutrient levels generally increasing with depth, light availability appears to be the factor that limits phytoplankton growth at depth in the Dorado Survey Area.

Most potential contaminants tested were below the limits of reporting or ANZG (2018) recommended trigger values. Nutrients were the only analytes which exceeded trigger values; however, these values are generally only a guide since they can fluctuate greatly under natural conditions and have previously been recorded at higher concentrations off the North West Shelf (e.g. Woodside 2007, Woodside 2020). Nutrient concentrations (ammonia, nitrate, nitrite and orthophosphate) generally increased with depth, likely due to nutrient compounds being released during the decay of organic material, which sinks through the water column and accumulates on the sea floor. Other studies on the North West Shelf have found much higher nutrient concentrations, with nitrogen concentrations at depth reaching 711 µg/L (Woodside 2007). Nutrient concentrations measured in such low concentrations (µg/L) can vary greatly due to complex cycling that involves both biotic and abiotic factors. The natural exceedance of nutrient trigger levels highlights the need for this study which has characterised water quality conditions that are location specific and can inform future activities in the Dorado Survey Area.

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Appendix A
SBE 19plus v2 calibration certificates

Marine and Freshwater
Research Laboratory
Environmental Science

Murdoch UNIVERSITY

Telephone: +61 8 93602907 Facsimile: +61 8 93606613

SBE 19 Plus V2 - 600m (19P-7123) - Salinity, Temperature, DO, pH,Turbidity Chlorophyll 'a' and Cude Oil sensor check

Client: RPS Australia Asia Pacific — Analyst: K.Wienczugov

Address: Level 2, 27-31 Troode St, West Perth WA 6005 — Date: 6/12/2019

Contact: Garnet Hooper Email: Garnet.Hooper@jrpsgroup.com.au — Phone: 9211 1131 — Job: Santos Dorado Survey December 2019

Table 1 Salinity Calibration Check

SBE 19 Plus V2 - 600m	[1]Laboratory Salinity Check Water	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 0.1psu	Date Checked / Name
Serial No: 19P-7123	Salinity (psu ± 0.1)	Salinity (psu)	Salinity Reading (psu)	Pass/Fail	
	36.7 ± 0.1	36.781	36.738	Pass	6/12/2019 K.Wienczugow

[1]Laboratory salinity check water was prepared by calibrating against IAPSO standard seawater 35.00 psu. [2]MAFRL's SBE 19 *Plus V2 - 100m* CTD was tested as an additional comparitive measure.

Table 2 Temperature Calibration Check

SBE 19 Plus V2 - 600m	[3]Laboratory Temperature Check	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 0.1°C	Date Checked / Name
Serial No: 19P-7123	Temperature (± 0.1 °C)	Temperature (°C)	Temperature Reading (°C)	Pass/Fail	
	24.3 ± 0.1	24.261	24.245	Pass	6/12/2019 K.Wienczugow

[3]Laboratory temperature check made with a NATA accredited -5.0 to 50.0°C immersion thermometer (Serial number: 0681667). [2]MAFRL's SBE 19 *Plus V2* - 100m CTD was tested as an additional comparitive measure.

Table 3 pH Calibration Check

Model: SBE 18-I	[4]Laboratory pH Check		SBE 19 Plus V2 - 600m	Tolerance ± 0.1 pH Unit	Date Calibrated / Name
Serial Number:18-0946	pH Standard (± 0.01)		pH Reading post Cal	Pass/Fail	
	4.00 @ 20°C		4.00	Pass	6/12/2019 K.Wienczugow
	7.02 @ 20°C		7.00	Pass	6/12/2019 K.Wienczugow
	10.06 @ 20°C		9.93	Pass	6/12/2019 K.Wienczugow

[4]pH calibration performed with traceable pH standards according to Sea-Bird Application note 18-1 for pH sensor calibration (Slope = 4.7257, Offset = 2.5828)

Table 4 DO Calibration Check

Model: SBE 43		[5]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 5%	Date Checked / Name
Serial Number:432365		Dissolved Oxygen (%)	Dissolved Oxygen Reading (%)	Pass/Fail	
		86.96	83.93	Pass	6/12/2019 K.Wienczugow

[5]Dissolved Oxygen calibration checked and compared against a cleaned and calibrated SBE 43 DO sensor from MAFRL's SBE 19 *Plus V2* - 100m CTD.

Table 5 Turbidity Calibration Check

Model: Wet Labs - NTU	[6]Laboratory Turbidity Standard		[7]SBE 19 Plus V2 - 600m	Tolerance ± 5%	Date Calibrated / Name
Serial Number: 201	Turbidity (NTU ± 0.1)		Turbidity Reading (NTU)	Pass/Fail	
	0.0		0.00	Pass	6/12/2019 K.Wienczugow
	5.0		5.01	Pass	6/12/2019 K.Wienczugow
	10.0		10.04	Pass	6/12/2019 K.Wienczugow

[6]Zero NTU standard prepared from 0.2µm filtered deionised distilled water. Freshly prepared primary formazin standard 4000 NTU was diluted for a three point check carried out in a non reflective black plastic bucket.

[7]Average turbidity readings were calculated using Sea Save software taken from WET Labs ECO-NTU turbidity probe and calibration coefficients were optimised for maximum accuracy within operational range (Range 0-34 NTU) (Scale factor = 6.30000, Dark Output = 0.09600).

Signatory:

Please note this report is not covered by NATA accreditation

Date: 29/01/20

Marine and Freshwater
Research Laboratory
Environmental Science

Murdoch UNIVERSITY

Telephone: +61 8 93602907 Facsimile: +61 8 93606613

SBE 19 Plus V2 - 600m (19P-7123) - Salinity, Temperature, DO, pH,Turbidity Chlorophyll 'a' and Cude Oil sensor check

Client: RPS Australia Asia Pacific — Analyst: K.Wienczugov

Address: Level 2, 27-31 Troode St, West Perth WA 6005 — Date: 6/12/2019

Contact: Garnet Hooper   Email: Garnet.Hooper@jrpsgroup.com.au   Phone: 9211 1131   Job: Santos Dorado Survey December 2019

Table 6 Chlorophyll 'a' - Fluorescence Calibration Check

Model: Cyclops-7 2108-000	[8]Laboratory Zero Standard		[9]SBE 19 Plus V2 - 600m	Tolerance ± %	Date Checked / Name
Serial Number: 2180475			**Fluorescence Response (Volts)**	**Pass/Fail**	
	DDI Blank water / Full Response		0.00 / 4.91	Pass	6/12/2019 K.Wienczugow

[8]Zero Fluorescence standard prepared from 0.2µm filtered deionised distilled water in black plastic bucket.

[9]Measurements taken with Cyclops-7 Chorophyll 'a' Fluorescence probe are logged as raw voltage (Range 0-5 Volts) for post processing against field extracted Chlorophyll 'a' samples (Scale factor = 1.0, Offset= 0.0).

Table 7 Crude Oil - Fluorescence Calibration Check

Model: Cyclops-7 2108-000	[10]Laboratory Quinine Sulphate Standards			[10]SBE 19 Plus V2 - 600m	Date Calibrated / Name
Serial Number: 2180528	**Concentration (µg/L)**			**Crude oil Response (V)**	
	0			0.310	6/12/2019 K.Wienczugow
	10			0.490	6/12/2019 K.Wienczugow
	20			0.692	6/12/2019 K.Wienczugow
	40			0.940	6/12/2019 K.Wienczugow
	100			3.400	6/12/2019 K.Wienczugow

[10]Average readings were calculated using Sea Save software and a Cyclops-7 Crude Oil sensor and calibration coefficients were calculated against Quinine Sulphate standard (Range: 0-100µg/L QS) (Scale = 21.00, Offset= -4.00).

Crude Oil Fluorescence measurements require post processing against laboratory tested water samples to enable concentrations of PAH's to be extrapolated to the water column profile data.

Signatory:

Date: 29/01/20

Marine and Freshwater
Research Laboratory
Environmental Science

Murdoch UNIVERSITY

Telephone: +61 8 93602907 Facsimile: +61 8 93606613

SBE 19 Plus V2 - 1000m (19P-7399) - Salinity, Temperature, DO, pH, Turbidity, Chlorophyll 'a' and Crude Oil sensor check

Client: RPS Australia Asia Pacific — Analyst: K.Wienczugov

Address: Level 2, 27-31 Troode St, West Perth WA 6005 — Date: 6/12/2019

Contact: Garnet Hooper Email: Garnet.Hooper@jrpsgroup.com.au — Phone: 9211 1131 — Job: Santos Dorado Survey December 2019

Table 1 Salinity Calibration Check

SBE 19 Plus V2 - 1000m	[1]Laboratory Salinity Check Water	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 1000m	Tolerance ± 0.1psu	Date Checked / Name
Serial No: 19P-7399	Salinity (psu ± 0.1)	Salinity (psu)	Salinity Reading (psu)	Pass/Fail	
	36.7 ± 0.1	36.783	36.747	Pass	6/12/2019 K.Wienczugow

[1]Laboratory salinity check water was prepared by calibrating against IAPSO standard seawater 35.00 psu. [2]MAFRL's SBE 19 *Plus V2 - 100m* CTD was tested as an additional comparitive measure.

Table 2 Temperature Calibration Check

SBE 19 Plus V2 - 1000m	[3]Laboratory Temperature Check	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 1000m	Tolerance ± 0.1°C	Date Checked / Name
Serial No: 19P-7399	Temperature (± 0.1 °C)	Temperature (°C)	Temperature Reading (°C)	Pass/Fail	
	24.3 ± 0.1	24.261	24.282	Pass	6/12/2019 K.Wienczugow

[3]Laboratory temperature check made with a NATA accredited -5.0 to 50.0°C immersion thermometer (Serial number: 0681667). [2]MAFRL's SBE 19 *Plus V2* - 100m CTD was tested as an additional comparitive measure.

Table 3 pH Calibration Check

Model: SBE 18-I	[4]Laboratory pH Check		SBE 19 Plus V2 - 1000m	Tolerance ± 0.1 pH Unit	Date Calibrated / Name
Serial Number:18-0946	pH Standard (± 0.01)		pH Reading	Pass/Fail	
	4.00 @ 20°C		4.01	Pass	6/12/2019 K.Wienczugow
	7.02 @ 20°C		7.08	Pass	6/12/2019 K.Wienczugow
	10.06 @ 20°C		10.01	Pass	6/12/2019 K.Wienczugow

[4]pH calibration performed with traceable pH standards according to Sea-Bird Application note 18-1 for pH sensor calibration (Slope = 4.7564, Offset = 2.5795)

Table 4 DO Calibration Check

Model: SBE 43		[5]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 1000m	Tolerance ± 5%	Date Checked / Name
Serial Number:432365		Dissolved Oxygen (%)	Dissolved Oxygen Reading (%)	Pass/Fail	
		86.96	89.07	Pass	6/12/2019 K.Wienczugow

[5]Dissolve Oxygen calibration checked and compared against a cleaned and calibrated SBE 43 DO sensor from MAFRL's SBE 19 Plus V2 - 100m CTD.

Table 5 Turbidity Calibration Check

Model: Cyclops-7 2108-000	[6]Laboratory Turbidity Standard		[7]SBE 19 Plus V2 - 1000m	Tolerance ± 5%	Date Calibrated / Name
Serial Number: 2180476	Turbidity (NTU ± 0.1)		Turbidity Reading (NTU)	Pass/Fail	
	0.0		0.01	Pass	6/12/2019 K.Wienczugow
	5.0		5.08	Pass	6/12/2019 K.Wienczugow
	10.0		10.00	Pass	6/12/2019 K.Wienczugow

[6]Zero NTU standard prepared from 0.2µm filtered deionised distilled water. Freshly prepared primary formazin standard 4000 NTU was diluted for a three point check carried out in a non reflective black plastic bucket.

[7]Average turbidity readings were calculated using Sea Save software taken from Cyclops-7 turbidity probe and calibration coefficients were optimised for maximum accuracy within operational range (Range 0-34 NTU) (Scale factor = 7.50, Offset = -0.140).

Signatory:

Date: 29/01/20

*Please note this report is not covered by NATA accreditation

Marine and Freshwater
Research Laboratory
Environmental Science
Telephone: +61 8 93602907 Facsimile: +61 8 93606613

Murdoch UNIVERSITY

SBE 19 Plus V2 - 1000m (19P-7399) - Salinity, Temperature, DO, pH, Turbidity, Chlorophyll 'a' and Crude Oil sensor check

Client: RPS Australia Asia Pacific | Analyst: K.Wienczugov
Address: Level 2, 27-31 Troode St, West Perth WA 6005 | Date: 6/12/2019
Contact: Garnet Hooper Email: Garnet.Hooper@jrpsgroup.com.au | Phone: 9211 1131 | Job: Santos Dorado Survey December 2019

Table 6 Chlorophyll 'a' - Fluorescence Calibration Check

Model: Cyclops-7 2108-000	[8]Laboratory Zero Standard		[9]SBE 19 Plus V2 - 1000m	Tolerance ±%	Date Checked / Name
Serial Number: 2180572			Fluorescence Response (Volts)	Pass/Fail	
	DDI Blank water		0.00	Pass	6/12/2019 K.Wienczugow
	Full response		4.92		

[8]Zero Fluorescence standard prepared from 0.2µm filtered deionised distilled water in black plastic bucket.

[9]Measurements taken with Cyclops-7 Chorophyll 'a' Fluorescence probe are logged as a voltage (Range 0-5 Volts) for post processing against field extracted Chlorophyll 'a' samples (Scale factor = 1.0, Offset= 0.0).

Table 7 Crude Oil - Fluorescence Calibration Check

Model: Cyclops-7 2108-000	[10]Laboratory Quinine Sulphate Standards			[10]SBE 19 Plus V2 - 1000m	Date Calibrated / Name
Serial Number: 2180580	Concentration (µg/L)			Crude oil Response (V)	
	0			0.390	6/12/2019 K.Wienczugow
	10			0.453	6/12/2019 K.Wienczugow
	20			0.749	6/12/2019 K.Wienczugow
	30			1.110	6/12/2019 K.Wienczugow
	40			1.460	6/12/2019 K.Wienczugow
	100			4.750	6/12/2019 K.Wienczugow

[10]Average readings were calculated using Sea Save software and a Cyclops-7 Crude Oil sensor and calibration coefficients were calculated against Quinine Sulphate standard (Range: 0-100µg/L QS) (Scale = 21.00, Offset= -1.00).

Crude Oil Fluorescence measurements require post processing against laboratory tested water samples to enable concentrations of PAH's to be extrapolated to the water column profile data.

Signatory:

Date: 29/01/20

*Please note this report is not covered by NATA accreditation

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Appendix B
Details of laboratory analysis

APPENDIX B: DETAILS OF LABORATORY ANALYSIS

Table B-1: Analytes, laboratories, sample storage/preservation and holding times

Analyte	Laboratory	Storage container	Preservation	Holding time
Total nitrogen	MAFRL	Polypropylene	Freeze	1 month
Total phosphorus	MAFRL	Polypropylene	Freeze	1 month
Ammonium	MAFRL	Polypropylene	0.45 µm filter and freeze	1 month
Nitrate and nitrite	MAFRL	Polypropylene	0.45 µm filter and freeze	1 month
Orthophosphate	MAFRL	Polypropylene	0.45 µm filter and freeze	1 month
Chlorophyll-*a* and phaeophytin *a*	MAFRL	Seed envelope	GFF filter and freeze	1 month
Total suspended solids	MAFRL	Seed envelope	GFC filter and freeze	1 month
Arsenic	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Barium	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Cadmium	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Chromium	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Cobalt	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Copper	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Mercury	MAFRL	Amber glass with Teflon cap liner	Acidify with nitric acid to pH 1–2, add potassium dichromate	1 month
Nickel	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Lead	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
Zinc	MAFRL	Polypropylene	Acidify with nitric acid to pH 1–2	1 month
BTEXN	ALS	Amber glass with Teflon cap liner	Acidify with sulphuric acid, chill to 4 °C	1 week
TRH (C_{10}–C_{36})	ALS	Amber glass with Teflon cap liner	Chill to 4 °C	1 week
PAHs	ALS	Amber glass with Teflon cap liner	Chill to 4 °C	1 week
$Radium^{226}$	SGS	Polypropylene	Acidify with nitric acid to pH 1–2	2 months
$Radium^{228}$	SGS	Polypropylene	Acidify with nitric acid to pH 1–2	2 months
$Thorium^{228}$	SGS	Polypropylene	Acidify with nitric acid to pH 1–2	2 months

Appendix C
Analytical laboratory reports

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1913562**	Page	: 1 of 14
Client	: **RPS Australia West Pty Ltd**	Laboratory	: Environmental Division Perth
Contact	: GARNET HOOPER	Contact	: Rhiannon Steere
Address	: PO BOX 170 WEST PERTH WA 6872	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: 08 9211 1131	Telephone	: 08 9406 1306
Project	: RPS19-1	Date Samples Received	: 23-Dec-2019 07:00
Order number	: ----	Date Analysis Commenced	: 23-Dec-2019
C-O-C number	: ----	Issue Date	: 06-Jan-2020 17:33
Sampler	: ----		
Site	: ----		
Quote number	: EP/954/19		
No. of samples received	: 51		
No. of samples analysed	: 51		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
ShukHui Li	Client Services - Technical Manager	Perth Organics, Wangara, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: MARINE WATER (Matrix: WATER)			Client sample ID	S1-S	S1-M	S1-B	S2-S	S2-M
			Client sampling date / time	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913562-001	EP1913562-002	EP1913562-003	EP1913562-004	EP1913562-005
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**98.0**	**103**	**102**	**101**	**104**
Toluene-D8	2037-26-5	2	%	**100.0**	**98.8**	**99.6**	**98.0**	**99.5**
4-Bromofluorobenzene	460-00-4	2	%	**95.9**	**99.5**	**98.4**	**96.0**	**97.5**

Analytical Results

Sub-Matrix: **MARINE WATER** (Matrix: **WATER**)			*Client sample ID*	**S2-B**	**S3-S**	**S3-M**	**S3-B**	**S4-S**
			Client sampling date / time	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	19-Dec-2019 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1913562-006**	**EP1913562-007**	**EP1913562-008**	**EP1913562-009**	**EP1913562-010**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**104**	**104**	**94.5**	**97.7**	**95.3**
Toluene-D8	2037-26-5	2	%	**98.6**	**100**	**101**	**101**	**102**
4-Bromofluorobenzene	460-00-4	2	%	**99.2**	**97.8**	**96.1**	**97.9**	**96.4**

Analytical Results

Sub-Matrix: **MARINE WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	S4-M	S4-B	S5-S	S5-M	S5-B
Client sampling date / time				19-Dec-2019 00:00	19-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00
				EP1913562-011	EP1913562-012	EP1913562-013	EP1913562-014	EP1913562-015
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**107**	**102**	**99.6**	**109**	**107**
Toluene-D8	2037-26-5	2	%	**97.0**	**100**	**103**	**98.9**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**103**	**94.6**	**100.0**	**103**	**101**

Analytical Results

Sub-Matrix: MARINE WATER (Matrix: WATER)			Client sample ID	S6-S	S6-M	S6-B	S7-S	S7-M
			Client sampling date / time	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913562-016	EP1913562-017	EP1913562-018	EP1913562-019	EP1913562-020
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**109**	**106**	**107**	**109**	**108**
Toluene-D8	2037-26-5	2	%	**98.0**	**98.2**	**97.1**	**100**	**97.5**
4-Bromofluorobenzene	460-00-4	2	%	**103**	**101**	**103**	**103**	**102**

Analytical Results

Sub-Matrix: MARINE WATER (Matrix: WATER)			Client sample ID	S7-B	S8-S	S8-M	S8-B	S9-S
			Client sampling date / time	17-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00	16-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913562-021	EP1913562-022	EP1913562-023	EP1913562-024	EP1913562-025
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	**70**	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	**70**	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	**110**	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	**110**	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**105**	**101**	**99.5**	**91.9**	**102**
Toluene-D8	2037-26-5	2	%	**99.4**	**100**	**100**	**101**	**99.9**
4-Bromofluorobenzene	460-00-4	2	%	**99.5**	**96.7**	**97.5**	**94.0**	**97.2**

Analytical Results

Sub-Matrix: **MARINE WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	S9-M	S9-B	S10-S	S10-M	S10-B
			Client sampling date / time	16-Dec-2019 00:00	16-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00
				EP1913562-026	**EP1913562-027**	**EP1913562-028**	**EP1913562-029**	**EP1913562-030**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**100**	**108**	**127**	**109**	**126**
Toluene-D8	2037-26-5	2	%	**101**	**99.3**	**95.8**	**93.4**	**97.1**
4-Bromofluorobenzene	460-00-4	2	%	**96.1**	**97.0**	**103**	**106**	**103**

Analytical Results

Sub-Matrix: MARINE WATER (Matrix: WATER)			Client sample ID	S11-S	S11-M	S11-B	S12-S	S12-M
			Client sampling date / time	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913562-031	EP1913562-032	EP1913562-033	EP1913562-034	EP1913562-035
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**116**	**130**	**110**	**121**	**110**
Toluene-D8	2037-26-5	2	%	**99.3**	**94.7**	**98.9**	**95.8**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**101**	**104**	**100**	**102**	**98.9**

Analytical Results

Sub-Matrix: **MARINE WATER** (Matrix: **WATER**)			*Client sample ID*	S12-B	S13-S	S13-M	S13-B	S14-S
			Client sampling date / time	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	18-Dec-2019 00:00	17-Dec-2019 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1913562-036**	**EP1913562-037**	**EP1913562-038**	**EP1913562-039**	**EP1913562-040**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**116**	**115**	**112**	**85.8**	**92.6**
Toluene-D8	2037-26-5	2	%	**98.6**	**99.5**	**99.4**	**98.6**	**101**
4-Bromofluorobenzene	460-00-4	2	%	**100**	**100**	**99.5**	**91.9**	**96.7**

Analytical Results

Sub-Matrix: **MARINE WATER** (Matrix: **WATER**)			*Client sample ID*	**S14-M**	**S14-B**	**S15-S**	**S15-M**	**S15-B**
			Client sampling date / time	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00	17-Dec-2019 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EP1913562-041**	**EP1913562-042**	**EP1913562-043**	**EP1913562-044**	**EP1913562-045**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**87.4**	**89.6**	**88.0**	**91.0**	**90.0**
Toluene-D8	2037-26-5	2	%	**101**	**103**	**101**	**102**	**103**
4-Bromofluorobenzene	460-00-4	2	%	**96.6**	**95.0**	**96.3**	**96.6**	**92.9**

Analytical Results

Sub-Matrix: MARINE WATER (Matrix: WATER)			Client sample ID	Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 4	Transport Blank
			Client sampling date / time	17-Dec-2019 00:00	17-Dec-2019 00:00	18-Dec-2019 00:00	19-Dec-2019 00:00	18-Dec-2019 00:00
Compound	CAS Number	LOR	Unit	EP1913562-046	EP1913562-047	EP1913562-048	EP1913562-049	EP1913562-050
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	**4**
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	**4**
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**88.9**	**89.0**	**89.2**	**89.2**	**86.8**
Toluene-D8	2037-26-5	2	%	**101**	**100**	**99.8**	**100**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**96.4**	**91.0**	**93.7**	**93.1**	**96.8**

Analytical Results

Sub-Matrix: **MARINE WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Field Blank	----	----	----	----
			Client sampling date / time	16-Dec-2019 00:00	----	----	----	----
				EP1913562-051	--------	--------	--------	--------
				Result	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ **Total Xylenes**	----	2	µg/L	<2	----	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**104**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**98.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**97.1**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **MARINE WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	61	141
Toluene-D8	2037-26-5	73	126
4-Bromofluorobenzene	460-00-4	60	125

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<0.5
Analysis Date			23/12/2019		10/01/2020		15/01/2020		7/01/2020
File			19122301,02,20012101		20011001		20011503		200107
S1-S	16/12/2019	<3	4	<2	11	80	<0.1	<0.2	0.7
S1-M	16/12/2019	<3	5	<2	12	70	0.3	<0.2	<0.5
S1-B	16/12/2019	<3	10	21	17	140	0.6	0.4	1.1
S2-S	16/12/2019	<3	4	<2	13	90	<0.1	<0.2	<0.5
S2-M	16/12/2019	<3	5	<2	13	80	0.1	<0.2	0.5
S2-B	16/12/2019	<3	9	25	17	100	0.4	0.5	2.7
S3-S	16/12/2019	<3	4	<2	12	80	<0.1	<0.2	<0.5
S3-M	16/12/2019	<3	7	10	16	80	0.8	0.6	0.7
S3-B	16/12/2019	<3	11	43	17	120	0.1	0.6	1.8
S4-S	19/12/2019	<3	4	<2	12	80	<0.1	<0.2	<0.5
S4-M	19/12/2019	<3	7	15	14	90	0.7	0.3	<0.5
S4-B	19/12/2019	<3	23	140	24	170	<0.1	<0.2	1.5
S5-S	17/12/2019	<3	3	<2	12	80	<0.1	<0.2	<0.5
S5-M	17/12/2019	<3	6	<2	9	<50	0.2	<0.2	<0.5
S5-B	17/12/2019	<3	24	150	26	170	<0.1	0.4	5.4
S6-S	17/12/2019	<3	3	<2	12	70	<0.1	<0.2	<0.5
S6-M	17/12/2019	<3	6	5	15	100	0.5	0.3	<0.5
S6-B	17/12/2019	<3	20	110	24	150	<0.1	0.4	2.8
S7-S	17/12/2019	<3	3	<2	12	90	<0.1	<0.2	<0.5
S7-M	17/12/2019	<3	4	<2	13	80	0.2	<0.2	<0.5
S7-B	17/12/2019	<3	11	40	16	90	0.2	0.6	4.1
S8-S	16/12/2019	<3	4	<2	13	100	<0.1	<0.2	<0.5
S8-M	16/12/2019	<3	5	2	14	90	0.4	<0.2	0.6
S8-B	16/12/2019	<3	9	20	17	120	0.3	0.5	1.5

Signatory: Jamie Woodward
Date: 24/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD	Sampling	2000	4100	2100	4700	2700	3000	3000	2540D
SAMPLE CODE	Date	AMMONIA µg.N/L	ORTHO-P µg.P/L	NO3+NO2 µg.N/L	TOTAL-P µg.P/L	TOTAL-N µg.N/L	CHLOROPHYLL'a' µg/L	PHAEOPHYTIN'a' µg/L	TSS mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<0.5
Analysis Date			23/12/2019		10/01/2020		15/01/2020		7/01/2020
File			19122301,02,20012101		20011001		20011503		200107
S9-S	16/12/2019	<3	3	<2	12	100	0.1	<0.2	<0.5
S9-M	16/12/2019	<3	8	9	14	80	0.6	<0.2	<0.5
S9-B	16/12/2019	<3	9	12	16	100	0.5	0.3	0.9
S10-S	17/12/2019	<3	4	<2	12	90	<0.1	<0.2	<0.5
S10-M	17/12/2019	<3	7	<2	14	80	0.3	0.2	0.6
S10-B	17/12/2019	<3	8	8	12	60	0.6	0.3	1.0
S11-S	18/12/2019	<3	4	<2	12	90	0.1	<0.2	<0.5
S11-M	18/12/2019	<3	4	<2	11	70	0.1	<0.2	1.0
S11-B	18/12/2019	<3	5	<2	12	80	0.2	<0.2	0.6
S12-S	18/12/2019	<3	3	<2	12	110	0.3	<0.2	<0.5
S12-M	18/12/2019	<3	6	2	11	70	0.4	<0.2	<0.5
S12-B	18/12/2019	<3	8	11	11	50	0.3	0.3	0.7
S13-S	18/12/2019	<3	3	3	11	70	<0.1	<0.2	<0.5
S13-M	18/12/2019	<3	4	<2	11	60	0.2	<0.2	0.8
S13-B	18/12/2019	<3	9	20	14	80	0.7	0.4	0.9
S14-S	17/12/2019	<3	4	<2	10	120	0.1	<0.2	<0.5
S14-M	17/12/2019	<3	6	7	11	70	0.3	0.3	1.0
S14-B	17/12/2019	<3	12	51	15	100	0.5	0.3	1.4
S15-S	17/12/2019	<3	2	<2	11	70	<0.1	<0.2	<0.5
S15-M	17/12/2019	5	4	<2	12	80	0.1	<0.2	<0.5
S15-B	17/12/2019	<3	18	100	22	140	0.2	0.4	4.0
Duplicate 1	17/12/2019	<3	3	<2	11	80	0.2	<0.2	<0.5
Duplicate 2	17/12/2019	<3	4	<2	12	80	<0.1	<0.2	<0.5
Field Blank	16/12/2019	<3	<2	<2	<5	<50	<0.1	<0.2	<0.5

Signatory: Jamie Woodward
Date: 24/01/2020

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		**<3**	**<2**	**<2**	**<5**	**<50**	**<0.1**	**<0.2**	**<0.5**
Analysis Date			**23/12/2019**		**10/01/2020**		**15/01/2020**		**7/01/2020**
File			**19122301,02,20012101**		**20011001**		**20011503**		**200107**
Transport Blank	18/12/2019	<3	<2	<2	<5	<50	<0.1	<0.2	<0.5
Duplicate 3	18/12/2019	<3	3	<2	12	90	0.1	<0.2	<0.5
Duplicate 4	19/12/2019	<3	3	<2	13	90	<0.1	<0.2	<0.5

QA/QC Data	**Acceptance Criteria**								
Duplicate % Difference	<20% or <RL	<RL	4%	14%	2%	5%			
Spike Recovery	80-120%	106%	99%	109%	100%	111%			
Seawater control	80-120%	104%	95%	99%	98%	99%	99%		
Freshwater control	80-120%	103%	101%	103%	95%	104%			

Signatory: Jamie Woodward
Date: 24/01/2020

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WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
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Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr µg/L	Filtered Co µg/L	Filtered Ni µg/L	Filtered Cu µg/L	Filtered Zn µg/L	Filtered As µg/L	Filtered Cd µg/L	Filtered Ba µg/L	Filtered Pb µg/L	Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Analysis Date		16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	10/01/2020
File		20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011003-1402
S1-S	16/12/2019	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.4	<0.1	<0.0001
S1-M	16/12/2019	<0.2	<0.05	<0.3	0.2	1	1.6	<0.1	5.4	<0.1	<0.0001
S1-B	16/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.7	<0.1	<0.0001
S2-S	16/12/2019	<0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.4	<0.1	<0.0001
S2-M	16/12/2019	<0.2	<0.05	<0.3	0.4	2	1.7	<0.1	5.5	<0.1	<0.0001
S2-B	16/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
S3-S	16/12/2019	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.4	<0.1	<0.0001
S3-M	16/12/2019	<0.2	<0.05	<0.3	0.5	1	1.8	<0.1	5.8	<0.1	<0.0001
S3-B	16/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.9	<0.1	<0.0001
S4-S	19/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.4	<0.1	<0.0001
S4-M	19/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.7	<0.1	<0.0001
S4-B	19/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	6.1	<0.1	<0.0001
S5-S	17/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
S5-M	17/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.8	<0.1	<0.0001
S5-B	17/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	6.1	<0.1	<0.0001
S6-S	17/12/2019	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	5.6	<0.1	<0.0001
S6-M	17/12/2019	<0.2	0.06	<0.3	<0.2	<1	1.9	<0.1	6.3	<0.1	<0.0001
S6-B	17/12/2019	0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.8	<0.1	<0.0001
S7-S	17/12/2019	0.2	<0.05	<0.3	0.7	<1	1.8	<0.1	5.5	<0.1	<0.0001
S7-M	17/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
S7-B	17/12/2019	0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.9	<0.1	<0.0001
S8-S	16/12/2019	0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.6	<0.1	<0.0001
S8-M	16/12/2019	0.2	<0.05	<0.3	0.6	3	1.7	<0.1	5.8	<0.1	<0.0001
S8-B	16/12/2019	0.2	<0.05	<0.3	0.4	<1	1.8	<0.1	5.8	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 24/01/2020

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WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
Analysis Date		**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**10/01/2020**
File		**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011003-1402**
S9-S	16/12/2019	0.2	<0.05	<0.3	0.4	1	1.8	<0.1	5.5	<0.1	<0.0001
S9-M	16/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	6.1	<0.1	<0.0001
S9-B	16/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.0	<0.1	<0.0001
S10-S	17/12/2019	0.2	<0.05	<0.3	0.3	2	1.9	<0.1	5.9	<0.1	<0.0001
S10-M	17/12/2019	0.2	<0.05	<0.3	<0.2	2	1.8	<0.1	6.0	<0.1	<0.0001
S10-B	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.1	<0.1	<0.0001
S11-S	18/12/2019	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.9	<0.1	<0.0001
S11-M	18/12/2019	0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.7	<0.1	<0.0001
S11-B	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	5.9	<0.1	<0.0001
S12-S	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	5.6	<0.1	<0.0001
S12-M	18/12/2019	0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.9	<0.1	<0.0001
S12-B	18/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.1	<0.1	<0.0001
S13-S	18/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
S13-M	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.8	<0.1	<0.0001
S13-B	18/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.8	<0.1	<0.0001
S14-S	17/12/2019	<0.2	<0.05	<0.3	0.2	1	1.8	<0.1	5.2	<0.1	<0.0001
S14-M	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
S14-B	17/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
S15-S	17/12/2019	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.3	<0.1	<0.0001
S15-M	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.4	<0.1	<0.0001
S15-B	17/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	5.7	<0.1	<0.0001
Duplicate 1	17/12/2019	0.2	<0.05	<0.3	0.2	1	1.8	<0.1	5.3	<0.1	<0.0001
Duplicate 2	17/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.6	<0.1	<0.0001
Field Blank	16/12/2019	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 24/01/2020

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Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr µg/L	Filtered Co µg/L	Filtered Ni µg/L	Filtered Cu µg/L	Filtered Zn µg/L	Filtered As µg/L	Filtered Cd µg/L	Filtered Ba µg/L	Filtered Pb µg/L	Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Analysis Date		16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	10/01/2020
File		20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011003-1402
Transport Blank	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Duplicate 3	18/12/2019	<0.2	<0.05	<0.3	0.2	1	1.9	<0.1	5.3	<0.1	<0.0001
Duplicate 4	19/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.4	<0.1	<0.0001

QA/QC Data	Acceptance Criteria										
Duplicate % Difference	<20% or <RL	<RL	4%	<RL	8%	9%	3%	<RL	0%	<RL	8%
Spike Recovery	80-120%	94%	99%	92%	96%	93%	98%	94%	98%	92%	94%
Seawater control	80-120%	107%	109%	102%	111%	103%	99%	107%	100%	101%	102%
Freshwater control	80-120%	100%	103%	96%	105%	108%	97%	104%	104%	101%	101%

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Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Unfiltered Cr µg/L	Unfiltered Co µg/L	Unfiltered Ni µg/L	Unfiltered Cu µg/L	Unfiltered Zn µg/L	Unfiltered As µg/L	Unfiltered Cd µg/L	Unfiltered Ba µg/L	Unfiltered Pb µg/L	Total Ext Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Analysis Date		16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	16/01/2020	14/01/2020
File		20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011601-2303	20011401-03
S1-S	16/12/2019	0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.4	<0.1	<0.0001
S1-M	16/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.7	<0.1	<0.0001
S1-B	16/12/2019	0.2	<0.05	<0.3	0.2	1	1.8	<0.1	5.8	<0.1	<0.0001
S2-S	16/12/2019	<0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.4	<0.1	<0.0001
S2-M	16/12/2019	<0.2	<0.05	<0.3	0.4	<1	1.7	<0.1	5.6	<0.1	<0.0001
S2-B	16/12/2019	0.4	<0.05	<0.3	0.3	2	1.8	<0.1	5.8	0.1	<0.0001
S3-S	16/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
S3-M	16/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.8	<0.1	<0.0001
S3-B	16/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	6.0	<0.1	<0.0001
S4-S	19/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
S4-M	19/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.8	<0.1	<0.0001
S4-B	19/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	6.3	<0.1	<0.0001
S5-S	17/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
S5-M	17/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.8	<0.1	<0.0001
S5-B	17/12/2019	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.1	<0.1	<0.0001
S6-S	17/12/2019	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.7	<0.1	<0.0001
S6-M	17/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.9	<0.1	6.4	<0.1	<0.0001
S6-B	17/12/2019	0.2	<0.05	<0.3	0.3	1	1.9	<0.1	5.9	<0.1	<0.0001
S7-S	17/12/2019	0.2	<0.05	<0.3	0.4	<1	1.8	<0.1	5.9	<0.1	<0.0001
S7-M	17/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.8	<0.1	<0.0001
S7-B	17/12/2019	0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.9	<0.1	<0.0001
S8-S	16/12/2019	0.2	<0.05	0.3	0.3	<1	1.7	<0.1	5.6	<0.1	<0.0001
S8-M	16/12/2019	0.2	<0.05	<0.3	0.2	2	1.8	<0.1	5.8	<0.1	<0.0001
S8-B	16/12/2019	0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	6.0	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 24/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater
Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
Date Received: 21/12/2019
Our Reference: RPS19-2
Your Reference: EEN19234.001

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
Analysis Date		**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**14/01/2020**
File		**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011401-03**
S9-S	16/12/2019	0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.7	<0.1	<0.0001
S9-M	16/12/2019	0.2	<0.05	0.3	0.3	1	1.7	<0.1	6.0	<0.1	<0.0001
S9-B	16/12/2019	0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	6.2	<0.1	<0.0001
S10-S	17/12/2019	0.2	<0.05	<0.3	0.3	1	1.9	<0.1	5.8	<0.1	<0.0001
S10-M	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	6.2	<0.1	<0.0001
S10-B	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.0	<0.1	<0.0001
S11-S	18/12/2019	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.9	<0.1	<0.0001
S11-M	18/12/2019	0.2	<0.05	<0.3	<0.2	1	2.0	<0.1	5.7	<0.1	<0.0001
S11-B	18/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	5.9	<0.1	<0.0001
S12-S	18/12/2019	<0.2	<0.05	<0.3	0.3	3	1.8	<0.1	5.5	<0.1	<0.0001
S12-M	18/12/2019	0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	6.0	<0.1	<0.0001
S12-B	18/12/2019	0.2	<0.05	0.3	<0.2	<1	1.9	<0.1	6.4	<0.1	<0.0001
S13-S	18/12/2019	0.2	<0.05	<0.3	0.3	5	1.9	<0.1	5.6	<0.1	<0.0001
S13-M	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	2.0	<0.1	5.9	<0.1	<0.0001
S13-B	18/12/2019	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	6.1	<0.1	<0.0001
S14-S	17/12/2019	0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.1	<0.1	<0.0001
S14-M	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.4	<0.1	<0.0001
S14-B	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
S15-S	17/12/2019	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.3	<0.1	<0.0001
S15-M	17/12/2019	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.4	<0.1	<0.0001
S15-B	17/12/2019	0.2	<0.05	0.3	<0.2	1	1.9	<0.1	5.7	<0.1	<0.0001
Duplicate 1	17/12/2019	0.2	<0.05	<0.3	0.2	<1	1.9	<0.1	5.3	<0.1	<0.0001
Duplicate 2	17/12/2019	0.2	0.05	<0.3	0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
Field Blank	16/12/2019	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 24/01/2020

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WATER QUALITY DATA

Contact: Garnet Hooper
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, WEST PERTH WA 6005

Date of Issue: 24/01/2020
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Our Reference: RPS19-2
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METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
Analysis Date		**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**16/01/2020**	**14/01/2020**
File		**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011601-2303**	**20011401-03**
Transport Blank	18/12/2019	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Duplicate 3	18/12/2019	0.2	<0.05	<0.3	0.2	<1	1.9	<0.1	5.3	<0.1	<0.0001
Duplicate 4	19/12/2019	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.7	<0.1	<0.0001

Note: For results for compliance purposes uncertainity of measurement (MU) will sometimes affect the interpretation whether the result passes or fails the compliance limit.
Tables for measurement uncertainity are available online at www.mafrl.murdoch.edu.au

QA/QC Data	Acceptance Criteria	Cr	Co	Ni	Cu	Zn	As	Cd	Ba	Pb	Hg
Duplicate % Difference	<20% or <RL	<RL	21%	<RL	30%	12%	4%	<RL	0%	<RL	<RL
Spike Recovery	80-120%	97%	97%	94%	99%	89%	93%	95%	92%	92%	97%
Seawater control	80-120%	107%	109%	102%	111%	103%	99%	107%	100%	101%	100%
Freshwater control	80-120%	100%	103%	96%	105%	108%	97%	104%	104%	101%	102%

Signatory: Jamie Woodward
Date: 24/01/2020

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Joanne Oliveri
Client	SGS AUSTRALIA - AU INTERLABS
Address	5266 683 ENVI WRS PERTH 28 Millrose Drive Malaga WA 6090
Telephone	(08) 9475 0099
Facsimile	(Not specified)
Email	Joanne.Oliveri@sgs.com
Project	**10320**
Order Number	**10320**
Samples	45

LABORATORY DETAILS

Manager	Adam Atkinson
Laboratory	SGS Melbourne EH&S
Address	10/585 Blackburn Road Notting Hill Victoria 3168
Telephone	+61395743200
Facsimile	+61395743399
Email	Au.SampleReceipt.Melbourne@sgs.com
SGS Reference	**ME313343 R0**
Date Received	14/1/2020
Date Reported	13/5/2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(22793).

SIGNATORIES

S. Rutkowski

Stephen RUTKOWSKI
Senior Health Physicist

Radionuclides by Gamma Ray Spectrometry in liquids [ARS-SOP-AS301/AS406] Tested: 28/3/2020

			10320-1 S1-S	10320-2 S1-M	10320-3 S1-B	10320-4 S2-S	10320-5 S2-M
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			16/12/2019	16/12/2019	16/12/2019	16/12/2019	16/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.001**	**ME313343.002**	**ME313343.003**	**ME313343.004**	**ME313343.005**
Radium-226	Bq/L	-	<0.033	<0.037	<0.048	<0.048	<0.024
Radium-228	Bq/L	-	<0.078	<0.13	<0.098	<0.096	<0.088
Thorium-228	Bq/L	-	<0.024	<0.029	0.029 ±0.014	<0.034	<0.028

			10320-6 S2-B	10320-7 S3-S	10320-8 S3-M	10320-9 S3-B	10320-10 S4-S
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			16/12/2019	16/12/2019	16/12/2019	16/12/2019	19/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.006**	**ME313343.007**	**ME313343.008**	**ME313343.009**	**ME313343.010**
Radium-226	Bq/L	-	<0.039	<0.044	<0.049	<0.028	<0.044
Radium-228	Bq/L	-	<0.099	<0.089	<0.092	<0.12	<0.15
Thorium-228	Bq/L	-	<0.027	<0.030	<0.036	<0.027	<0.034

			10320-11 S4-M	10320-12 S4-B	10320-13 S5-S	10320-14 S5-M	10320-15 S5-B
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			19/12/2019	19/12/2019	17/12/2019	17/12/2019	17/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.011**	**ME313343.012**	**ME313343.013**	**ME313343.014**	**ME313343.015**
Radium-226	Bq/L	-	<0.035	<0.042	<0.046	<0.034	<0.046
Radium-228	Bq/L	-	<0.11	<0.086	<0.11	<0.091	<0.091
Thorium-228	Bq/L	-	<0.032	<0.035	<0.030	<0.030	<0.033

			10320-16 S6-S	10320-17 S6-M	10320-18 S6-B	10320-19 S7-S	10320-20 S7-M
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			17/12/2019	17/12/2019	17/12/2019	17/12/2019	17/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.016**	**ME313343.017**	**ME313343.018**	**ME313343.019**	**ME313343.020**
Radium-226	Bq/L	-	<0.032	0.029 ±0.018	<0.040	<0.046	<0.039
Radium-228	Bq/L	-	<0.13	<0.16	<0.080	<0.090	<0.091
Thorium-228	Bq/L	-	<0.029	<0.034	<0.022	<0.027	<0.036

			10320-21 S7-B	10320-22 S8-S	10320-23 S8-M	10320-24 S8-B	10320-25 S9-S
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			17/12/2019	16/12/2019	16/12/2019	16/12/2019	16/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.021**	**ME313343.022**	**ME313343.023**	**ME313343.024**	**ME313343.025**
Radium-226	Bq/L	-	<0.041	<0.055	<0.062	<0.066	<0.027
Radium-228	Bq/L	-	<0.13	<0.17	<0.11	<0.15	<0.093
Thorium-228	Bq/L	-	<0.023	<0.036	<0.040	<0.050	<0.024

			10320-26 S9-M	10320-27 S9-B	10320-28 S10-S	10320-29 S10-M	10320-30 S10-B
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			16/12/2019	16/12/2019	17/12/2019	17/12/2019	17/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.026**	**ME313343.027**	**ME313343.028**	**ME313343.029**	**ME313343.030**
Radium-226	Bq/L	-	<0.026	0.027 ±0.012	<0.042	<0.041	<0.051
Radium-228	Bq/L	-	<0.092	<0.11	<0.13	<0.17	<0.12
Thorium-228	Bq/L	-	<0.030	<0.030	<0.021	<0.043	<0.040

			10320-31 S11-S	10320-32 S11-M	10320-33 S11-B	10320-34 S12-S	10320-35 S12-M
			WATER	WATER	WATER	WATER	WATER
			-	-	-	-	-
			18/12/2019	18/12/2019	18/12/2019	18/12/2019	18/12/2019
PARAMETER	**UOM**	**LOR**	**ME313343.031**	**ME313343.032**	**ME313343.033**	**ME313343.034**	**ME313343.035**
Radium-226	Bq/L	-	<0.063	<0.035	<0.026	<0.039	<0.044
Radium-228	Bq/L	-	<0.15	<0.092	<0.11	<0.084	<0.097
Thorium-228	Bq/L	-	<0.057	<0.030	<0.035	<0.035	<0.027

Radionuclides by Gamma Ray Spectrometry in liquids [ARS-SOP-AS301/AS406] Tested: 28/3/2020 (continued)

PARAMETER	UOM	LOR	10320-36 S12-B WATER - 18/12/2019 ME313343.036	10320-37 S13-S WATER - 18/12/2019 ME313343.037	10320-38 S13-M WATER - 18/12/2019 ME313343.038	10320-39 S13-B WATER - 18/12/2019 ME313343.039	10320-40 S14-S WATER - 17/12/2019 ME313343.040
Radium-226	Bq/L	-	<0.039	<0.040	<0.059	<0.049	<0.038
Radium-228	Bq/L	-	<0.13	<0.16	<0.13	<0.14	<0.093
Thorium-228	Bq/L	-	<0.025	<0.028	<0.029	<0.024	<0.040

PARAMETER	UOM	LOR	10320-41 S14-M WATER - 17/12/2019 ME313343.041	10320-42 S14-B WATER - 17/12/2019 ME313343.042	10320-43 S15-S WATER - 17/12/2019 ME313343.043	10320-44 S15-M WATER - 17/12/2019 ME313343.044	10320-45 S15-B WATER - 17/12/2019 ME313343.045
Radium-226	Bq/L	-	<0.036	<0.043	<0.035	<0.056	<0.050
Radium-228	Bq/L	-	<0.13	<0.089	<0.088	<0.17	<0.13
Thorium-228	Bq/L	-	<0.035	<0.029	<0.025	<0.035	<0.035

METHOD	METHODOLOGY SUMMARY
ARS-SOP-AS301/AS406	Analysis of radionuclides in liquids by high resolution gamma ray spectrometry after radiochemical preparation. Radiochemical preparation involves total sample evaporation, sample co-precipitation using stable elemental carriers, or a combination thereof. In some cases, preparation may involve merely transferring liquid to a standard geometry container such as a Marinelli beaker.

FOOTNOTES

*	NATA accreditation does not cover the performance of this service.	-	Not analysed.	UOM	Unit of Measure.
**	Indicative data, theoretical holding time exceeded.	NVL	Not validated.	LOR	Limit of Reporting.
		IS	Insufficient sample for analysis.	↑↓	Raised/lowered Limit of Reporting.
		LNR	Sample listed, but not received.		

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

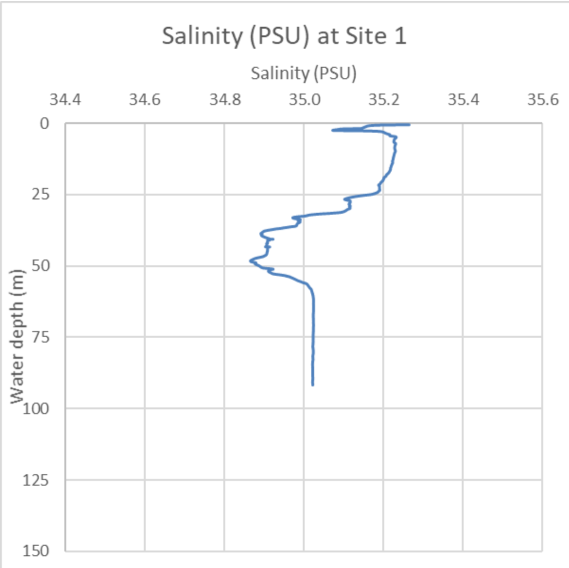
For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

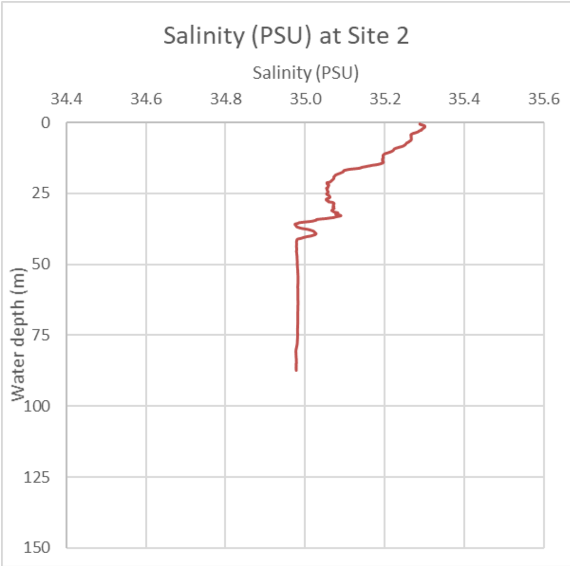
The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

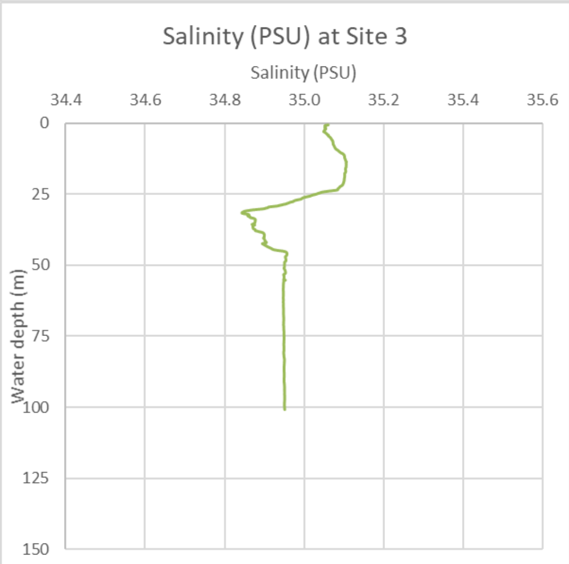
Appendix D
Individual water column profiles

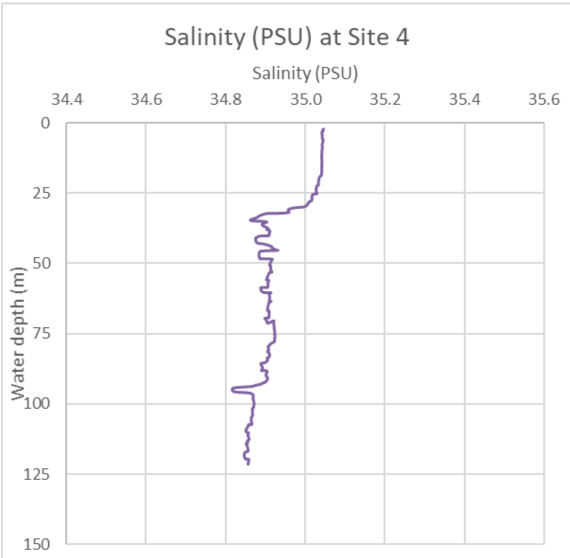
APPENDIX D: INDIVIDUAL WATER COLUMN PROFILES

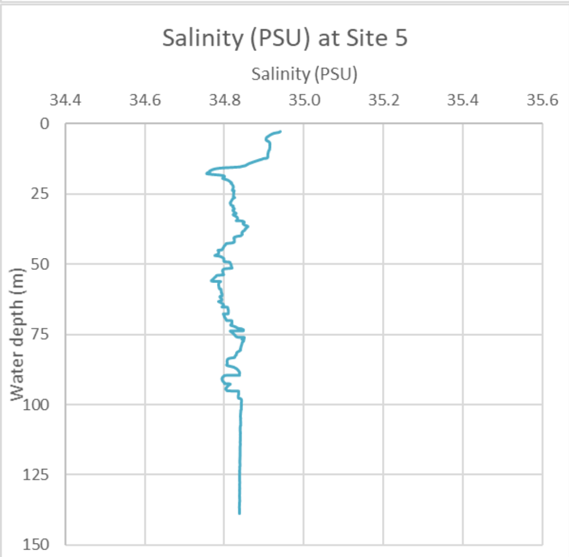
A.1.1 Salinity (conductivity)

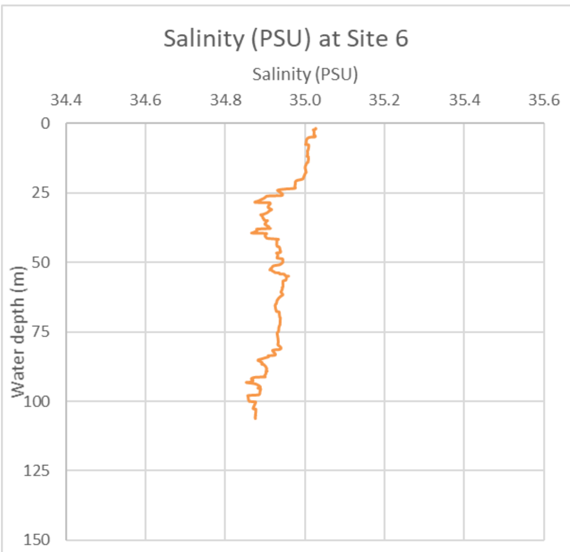


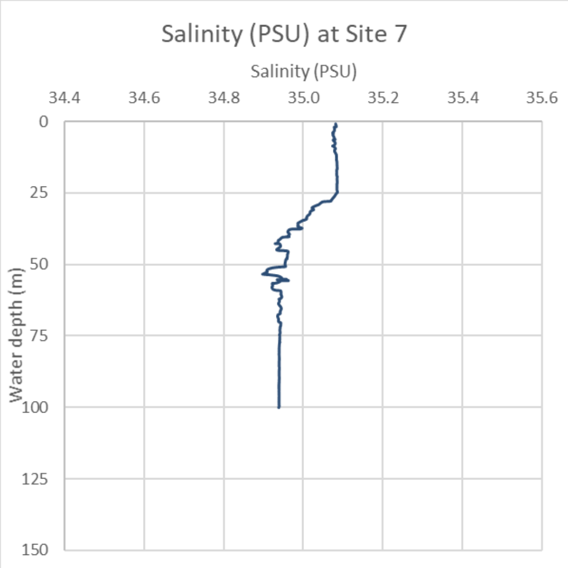


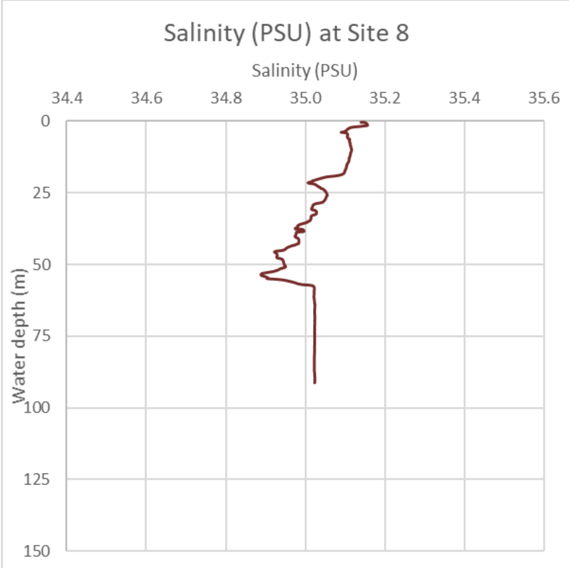


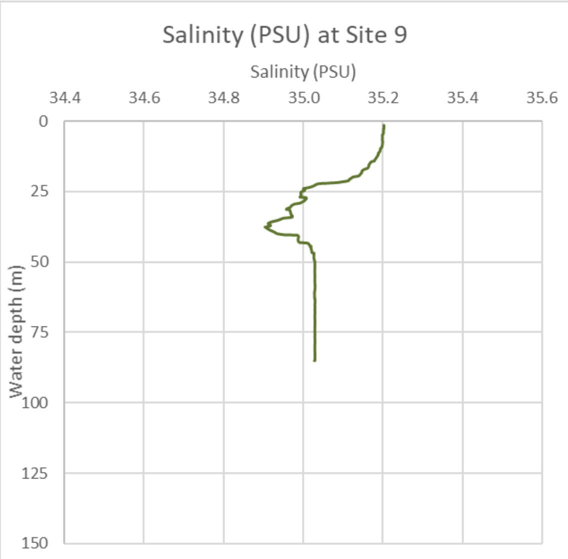


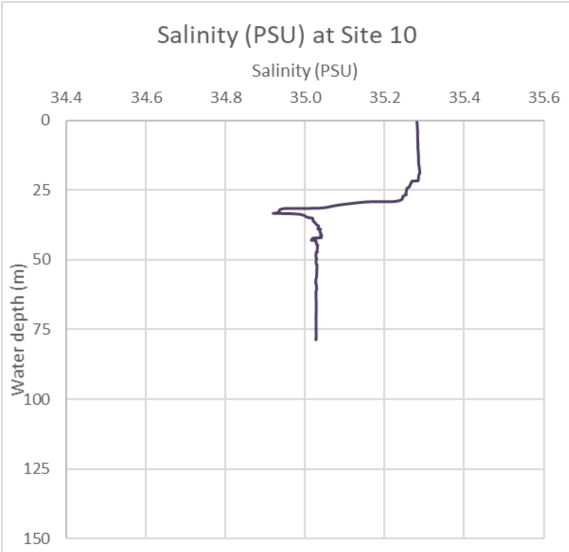


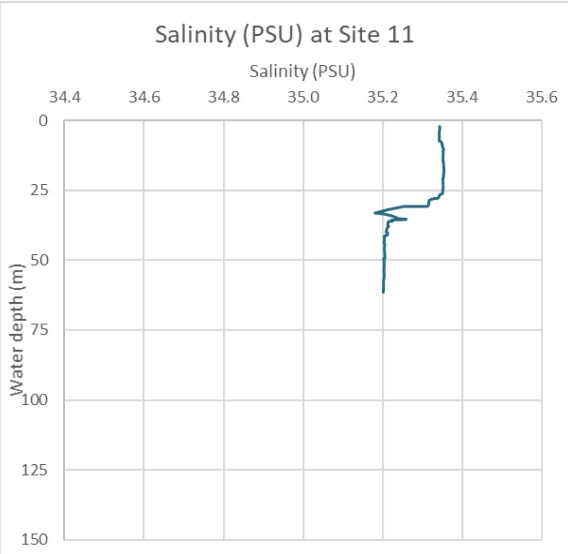


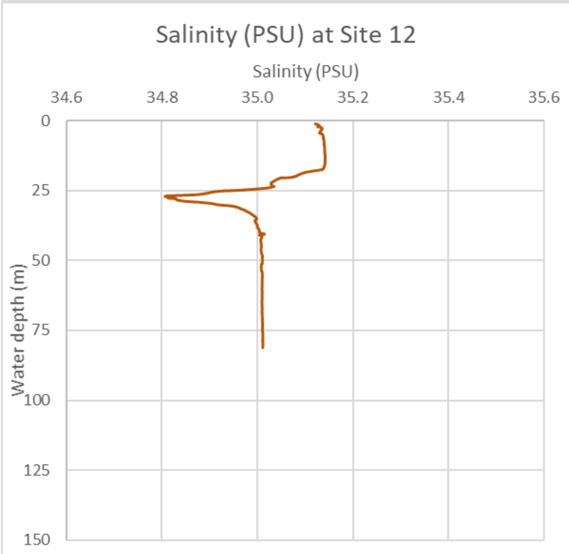

Salinity (PSU) at Site 7
Salinity (PSU)
34.4 34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150


Salinity (PSU) at Site 8
Salinity (PSU)
34.4 34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150


Salinity (PSU) at Site 9
Salinity (PSU)
34.4 34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150


Salinity (PSU) at Site 10
Salinity (PSU)
34.4 34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150


Salinity (PSU) at Site 11
Salinity (PSU)
34.4 34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150


Salinity (PSU) at Site 12
Salinity (PSU)
34.6 34.8 35.0 35.2 35.4 35.6
Water depth (m)
0 25 50 75 100 125 150

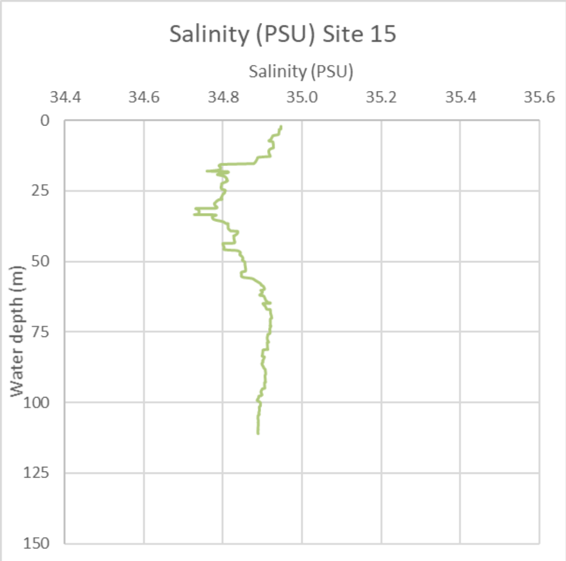
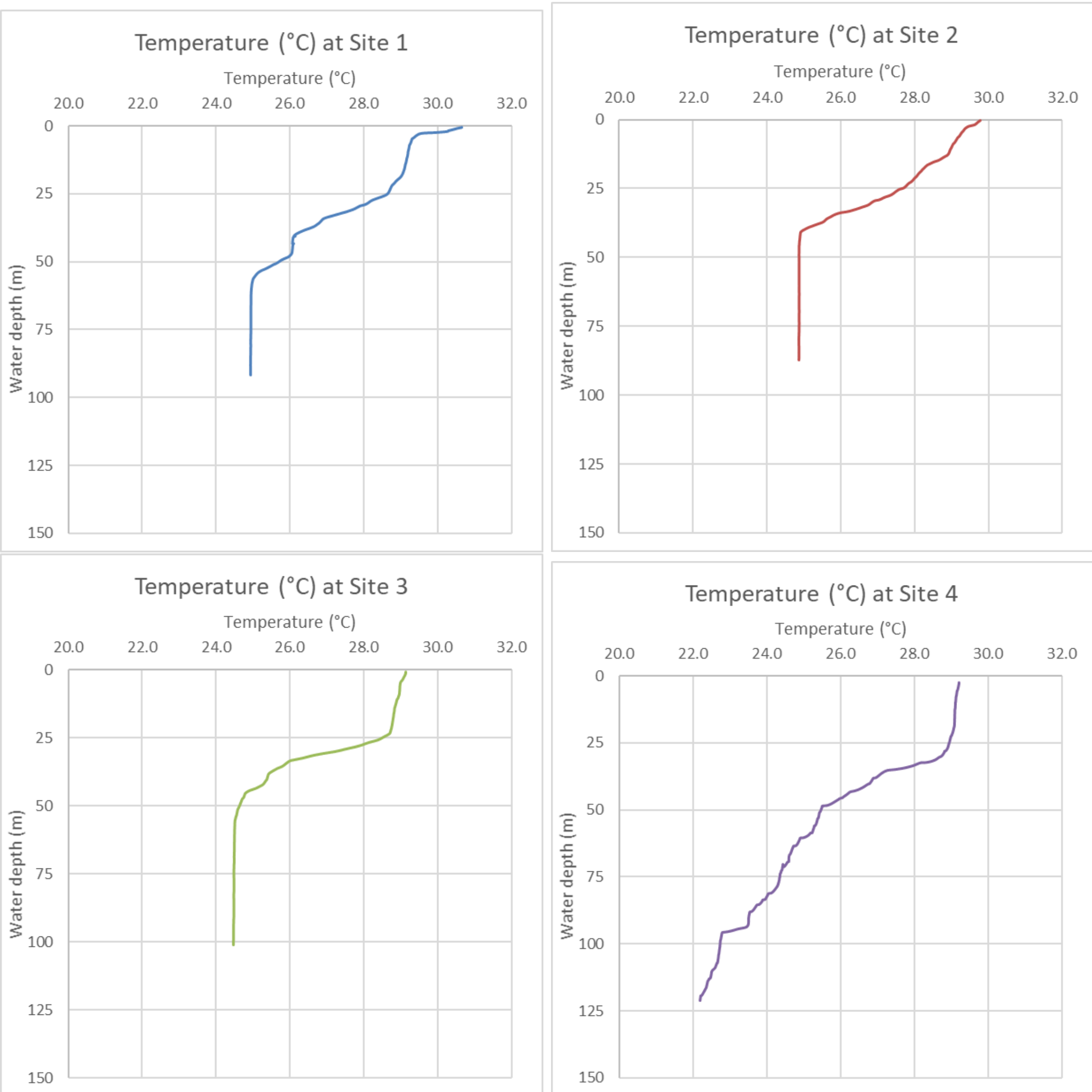
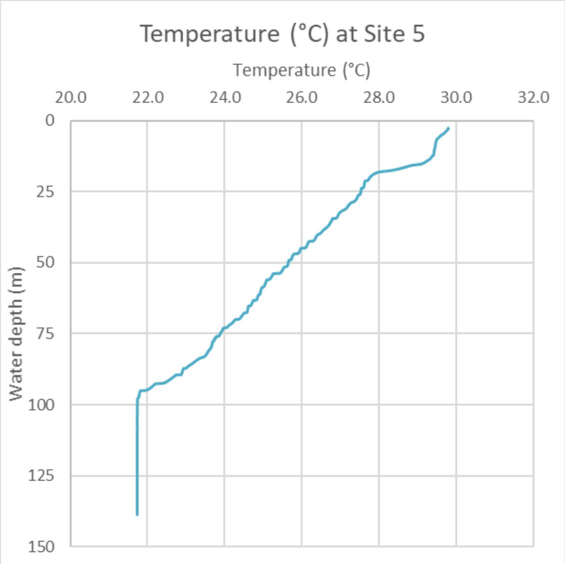
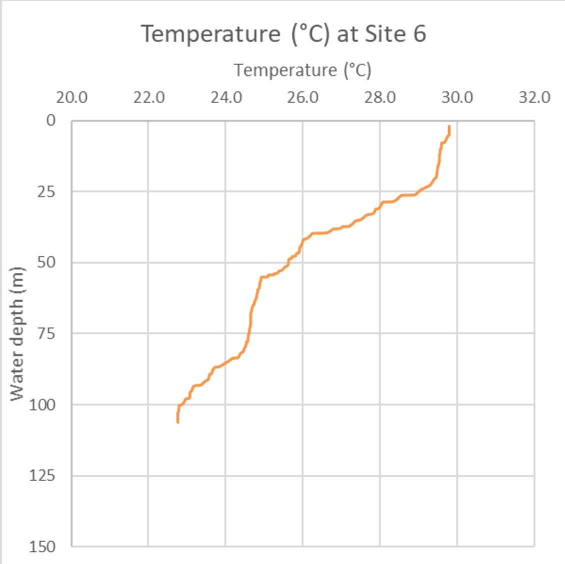


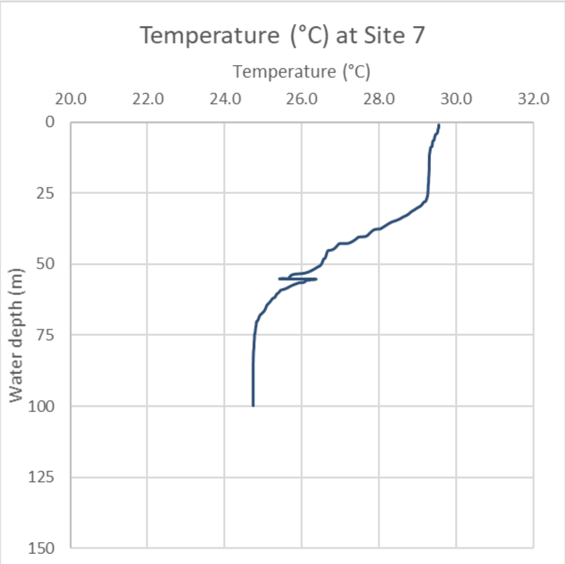
Figure D-1: Salinity profiles

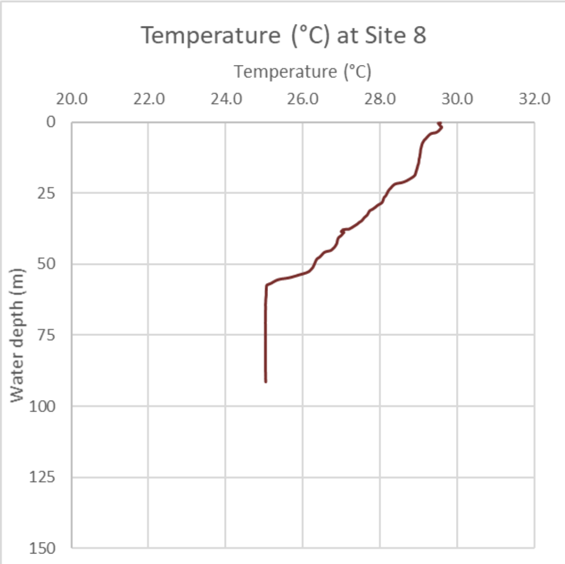
A.1.2 Water temperature

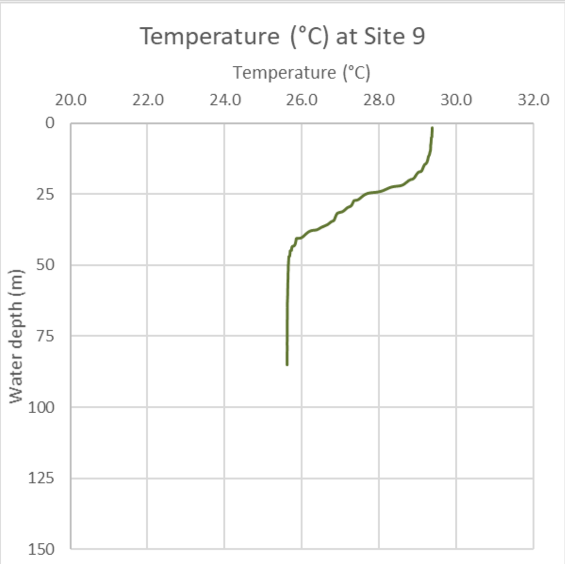


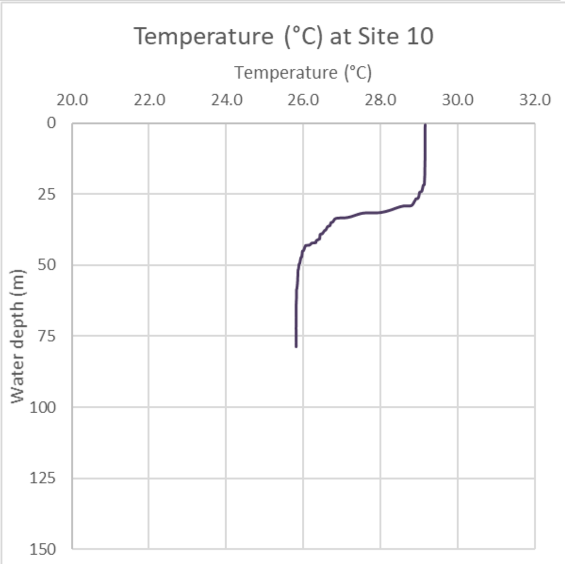

Temperature (°C) at Site 5
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150


Temperature (°C) at Site 6
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150


Temperature (°C) at Site 7
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150


Temperature (°C) at Site 8
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150


Temperature (°C) at Site 9
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150


Temperature (°C) at Site 10
Temperature (°C)
20.0 22.0 24.0 26.0 28.0 30.0 32.0
Water depth (m)
0 25 50 75 100 125 150

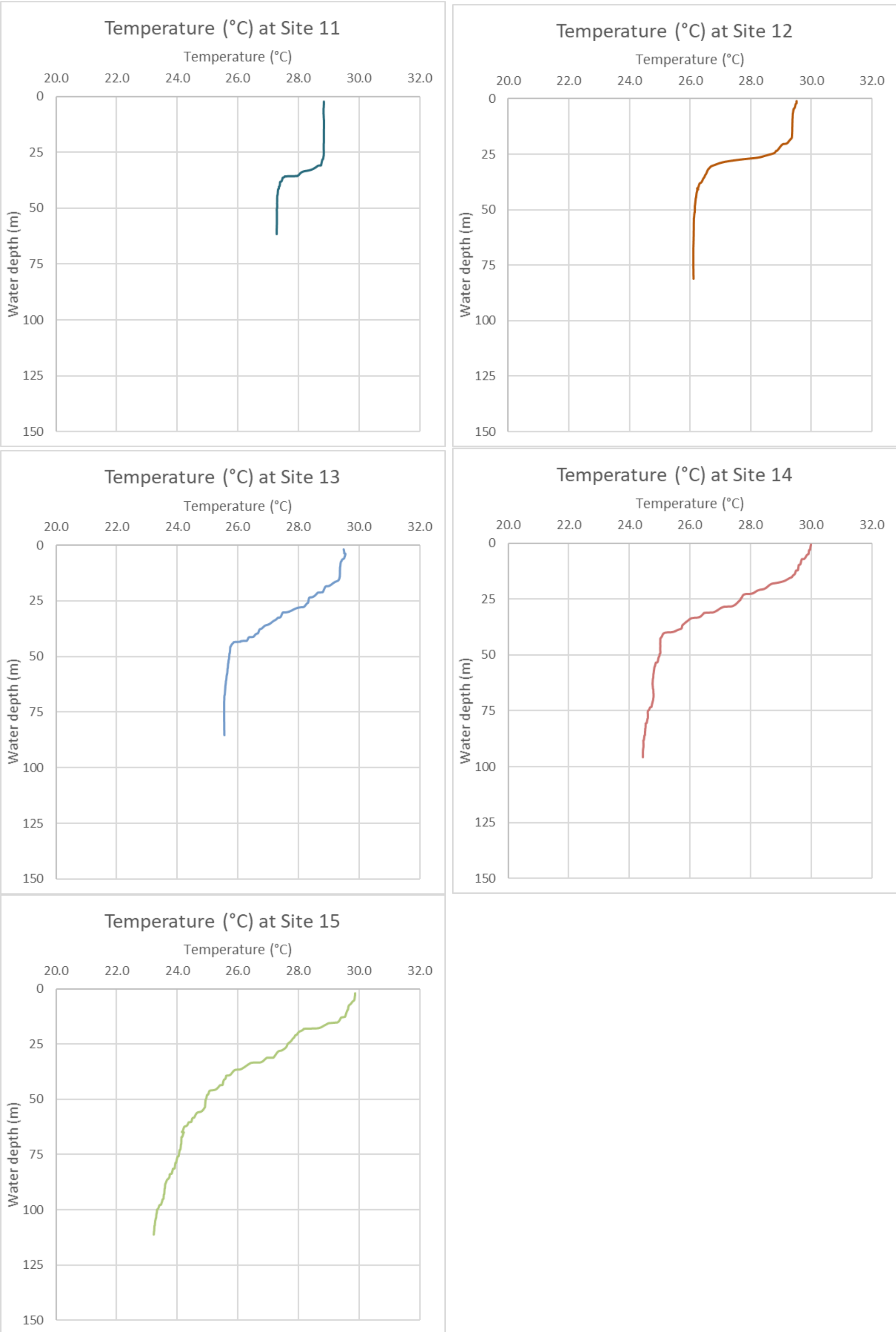
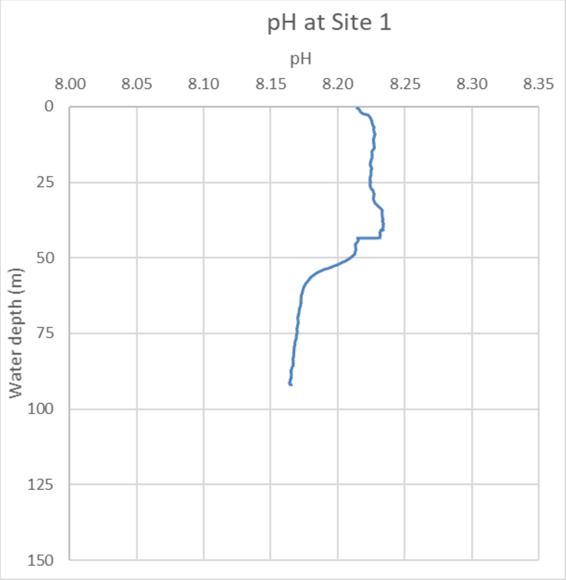
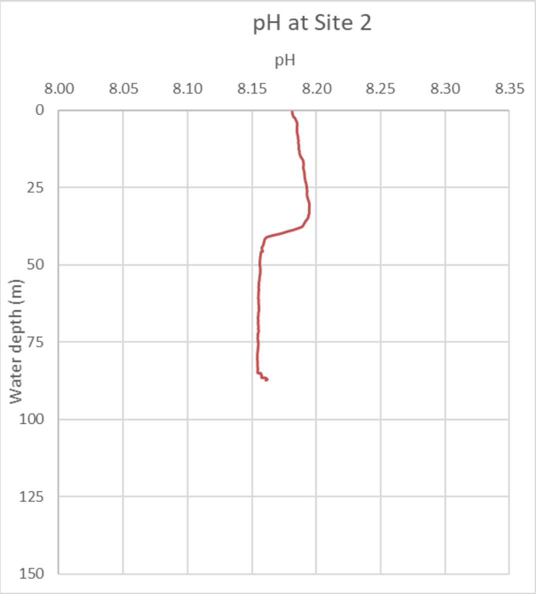


Figure D-2: Water temperature profiles

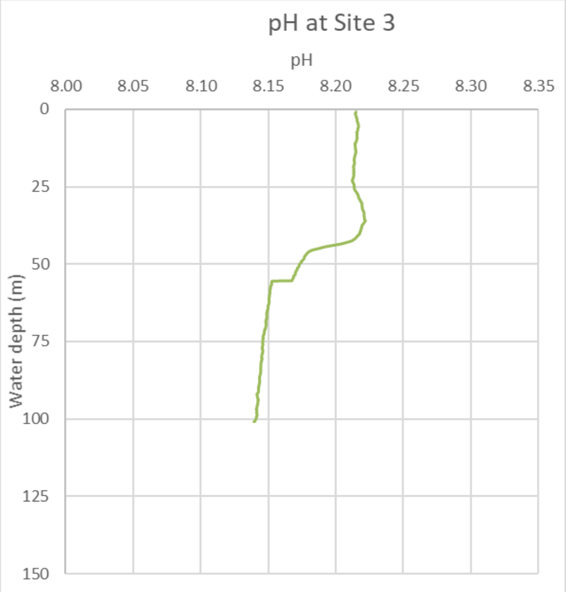
A.1.3 pH



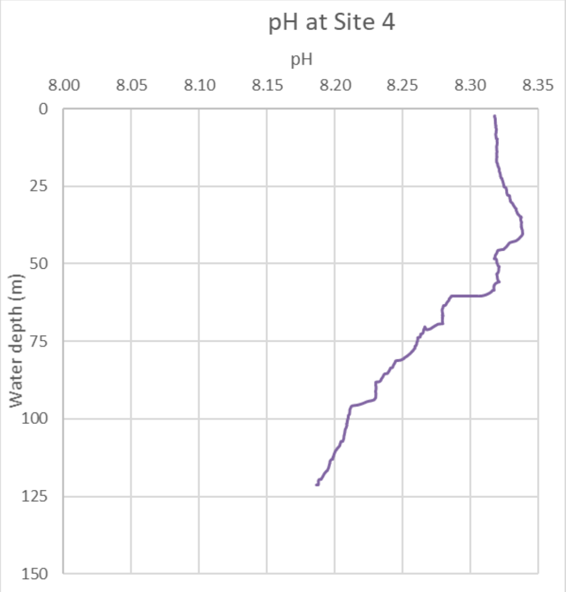
pH at Site 1
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30 8.35
0 25 50 75 100 125 150
Water depth (m)



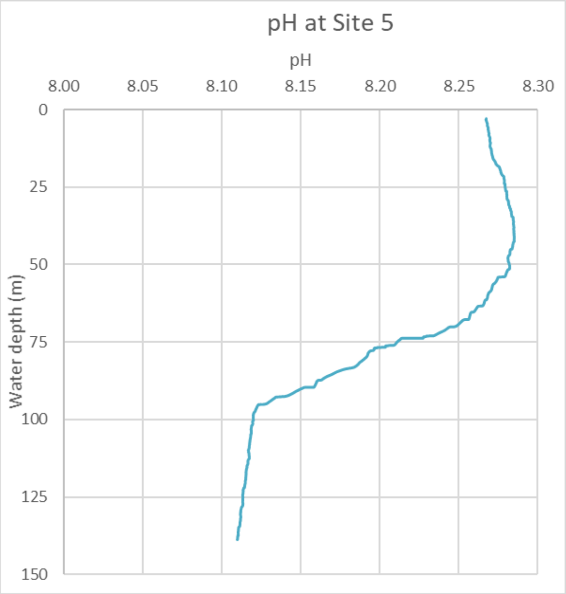
pH at Site 2
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30 8.35
0 25 50 75 100 125 150
Water depth (m)



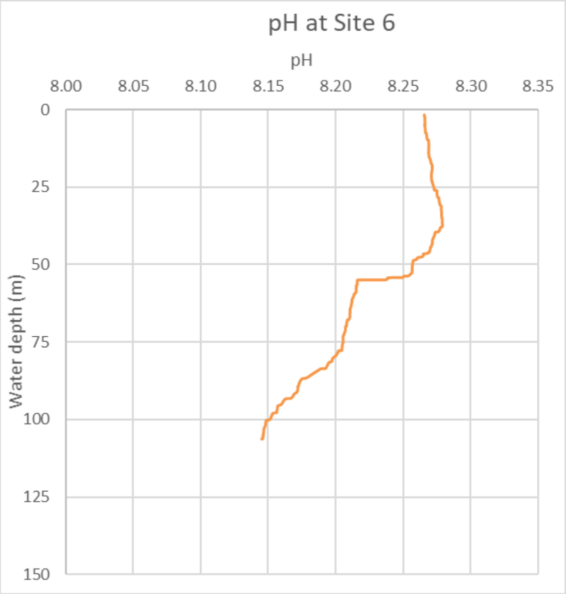
pH at Site 3
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30 8.35
0 25 50 75 100 125 150
Water depth (m)



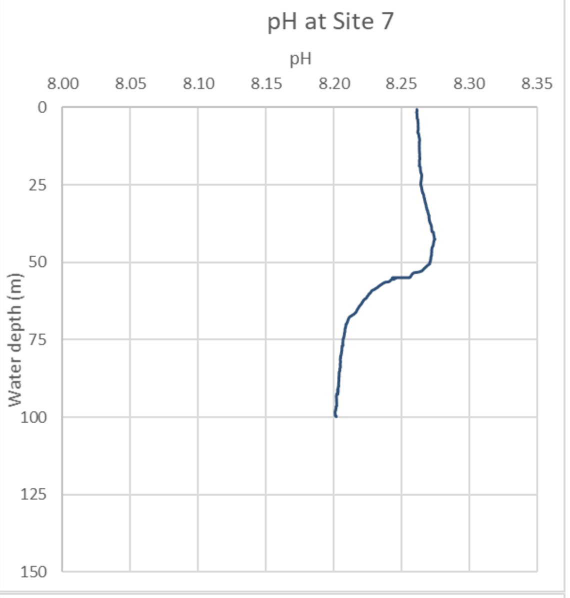
pH at Site 4
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30 8.35
0 25 50 75 100 125 150
Water depth (m)

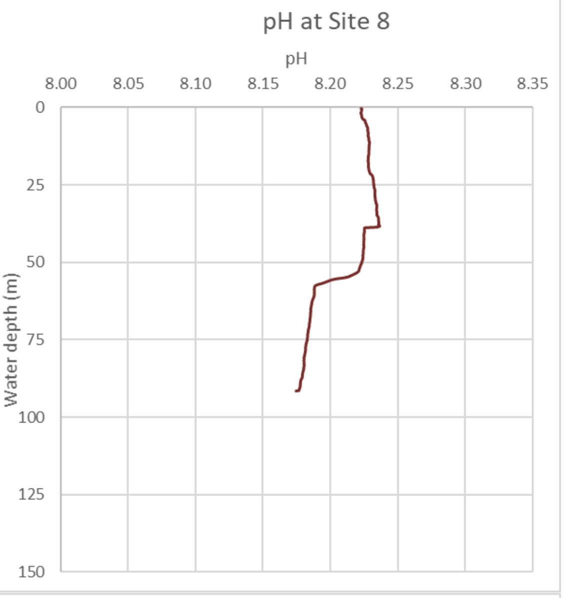


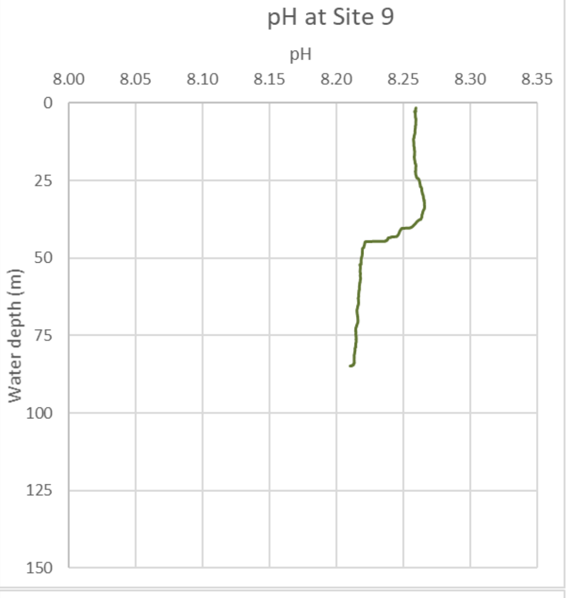
pH at Site 5
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30
0 25 50 75 100 125 150
Water depth (m)

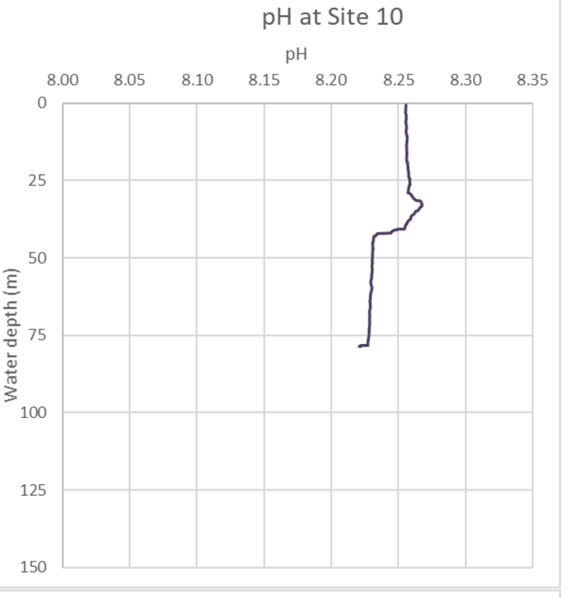


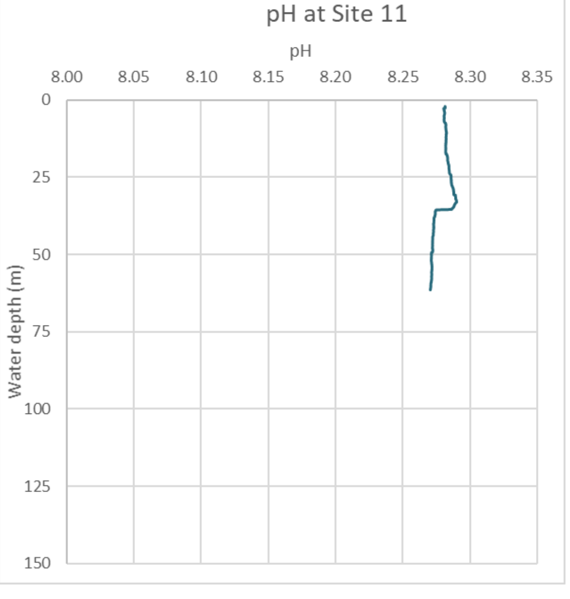
pH at Site 6
pH
8.00 8.05 8.10 8.15 8.20 8.25 8.30 8.35
0 25 50 75 100 125 150
Water depth (m)

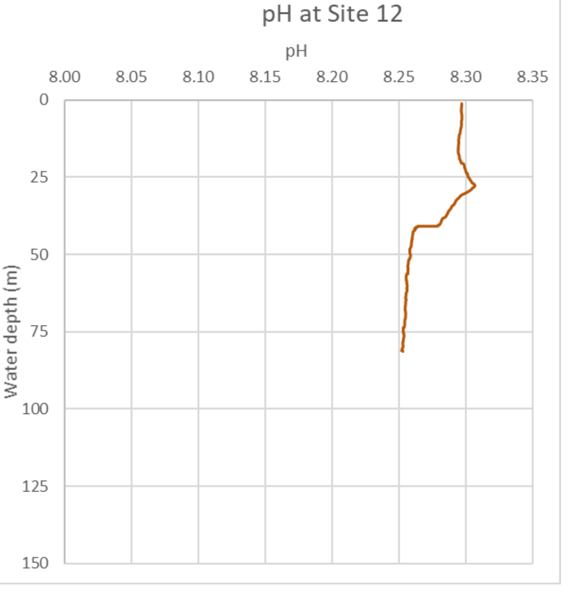

pH at Site 7
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150

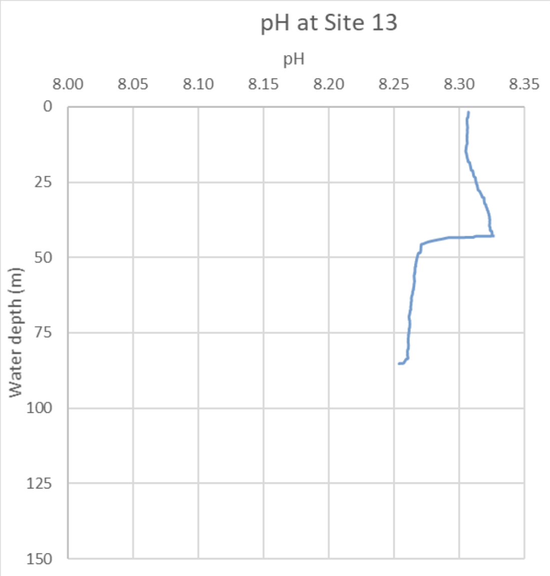

pH at Site 8
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150

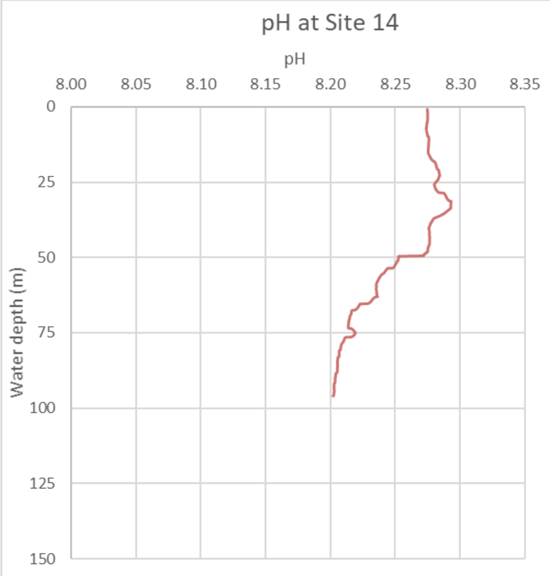

pH at Site 9
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150


pH at Site 10
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150


pH at Site 11
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150


pH at Site 12
pH
8.00
8.05
8.10
8.15
8.20
8.25
8.30
8.35
Water depth (m)
0
25
50
75
100
125
150





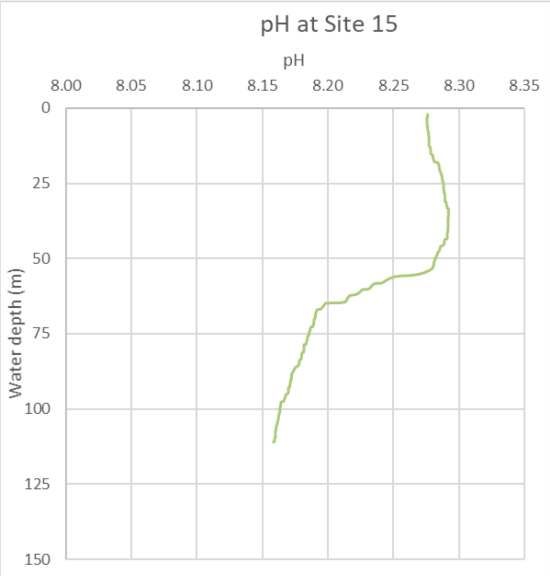
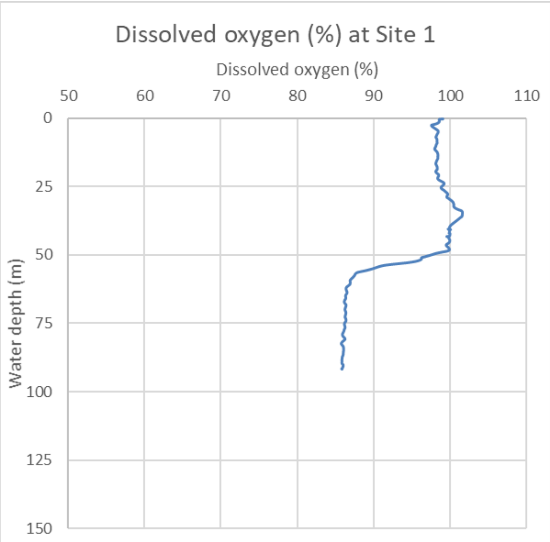
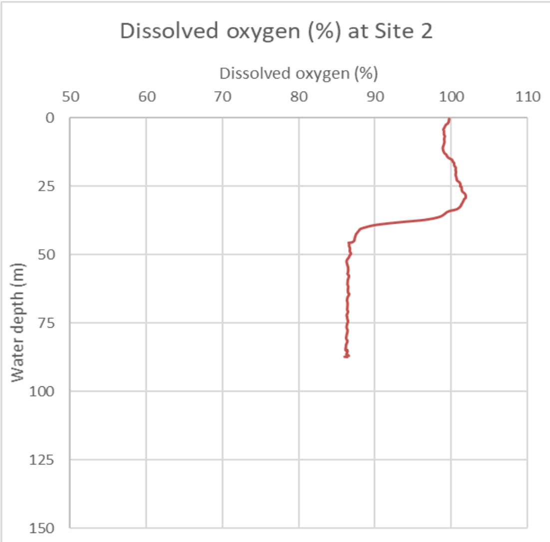
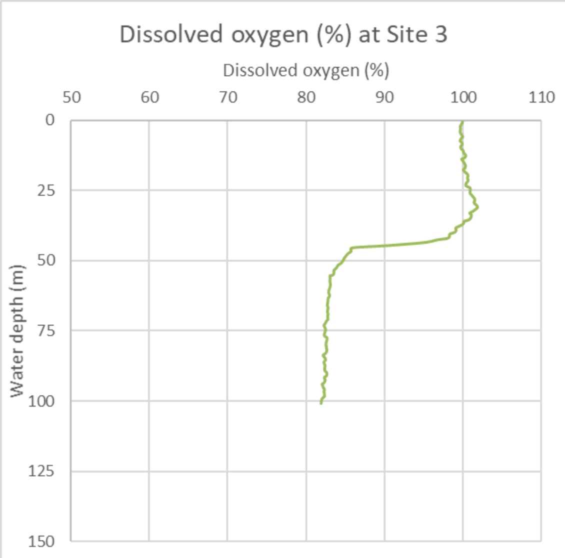


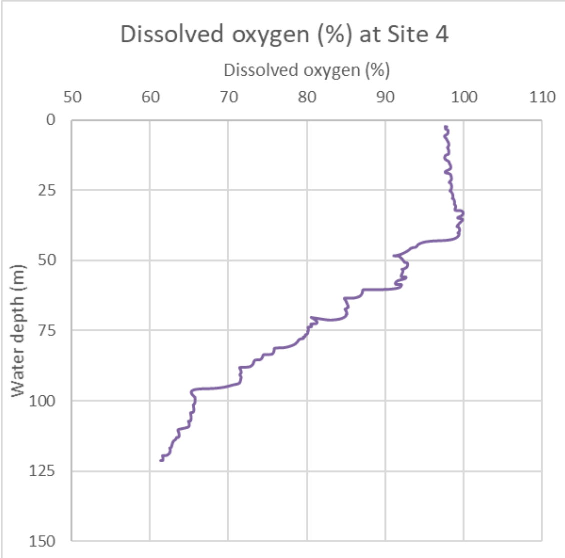
Figure D-3: pH profiles

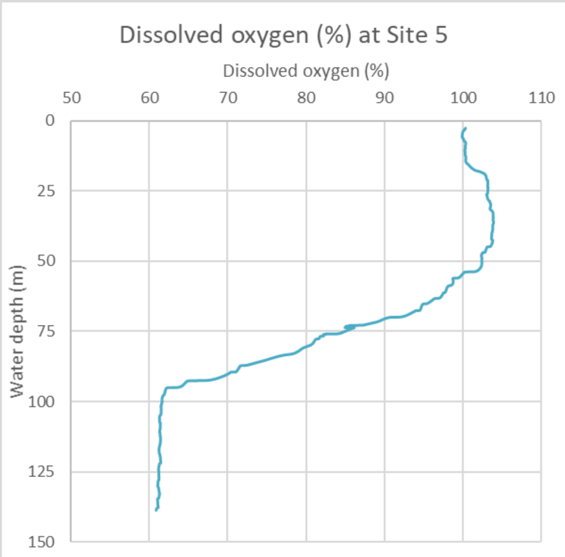
A.1.4 Dissolved oxygen

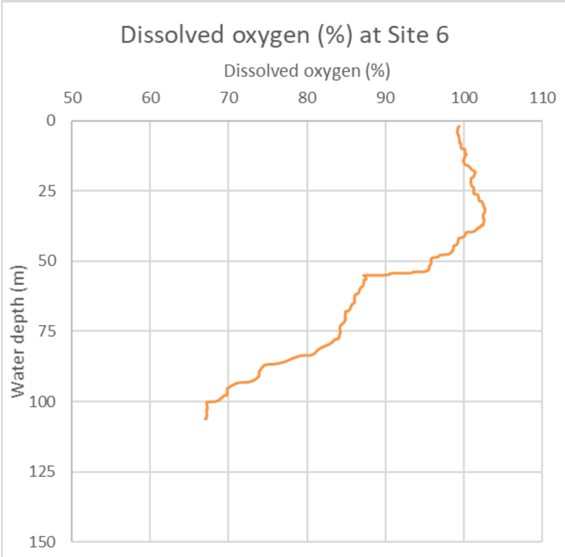


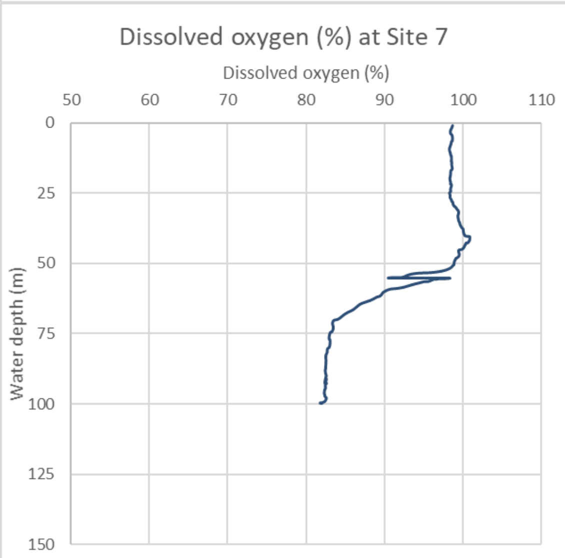


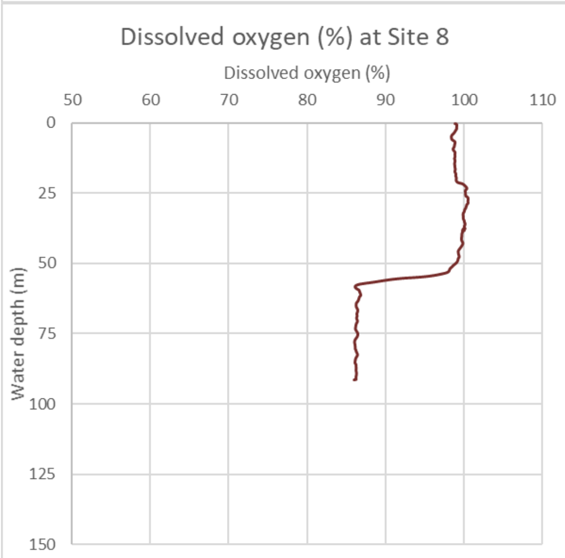

Dissolved oxygen (%) at Site 3
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

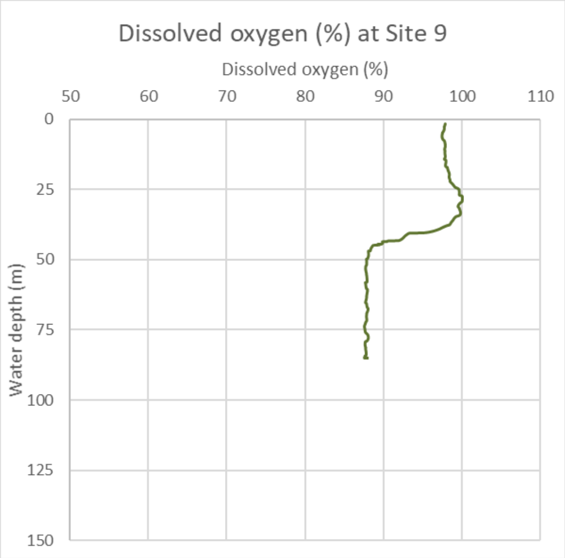

Dissolved oxygen (%) at Site 4
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

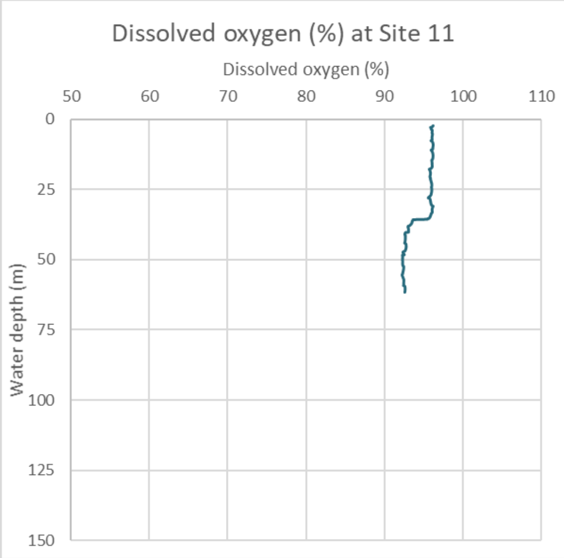

Dissolved oxygen (%) at Site 5
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

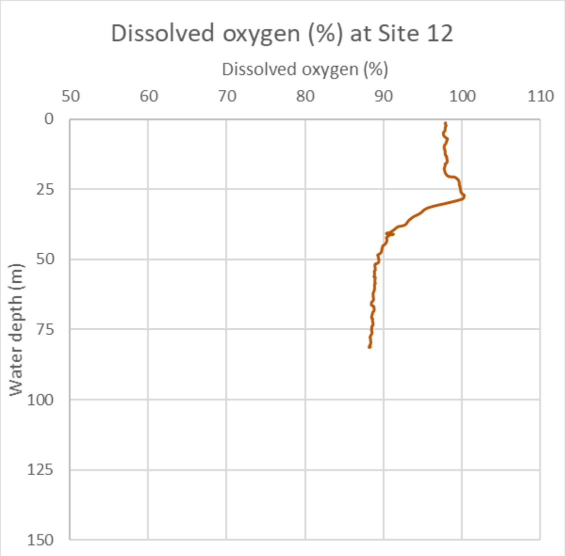

Dissolved oxygen (%) at Site 6
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

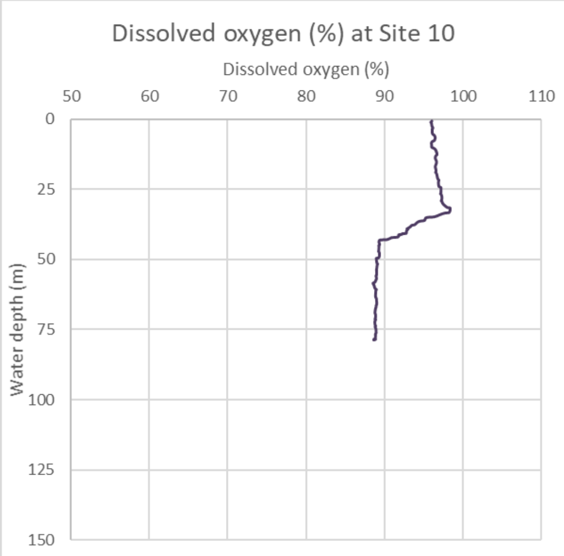

Dissolved oxygen (%) at Site 7
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

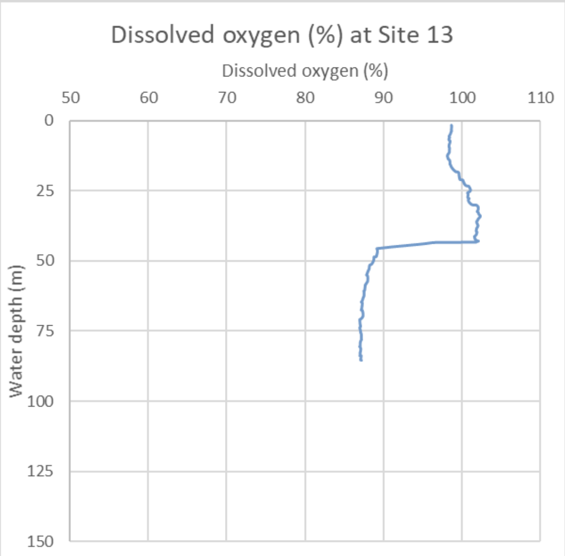

Dissolved oxygen (%) at Site 8
Dissolved oxygen (%)
50 60 70 80 90 100 110
Water depth (m)
0 25 50 75 100 125 150

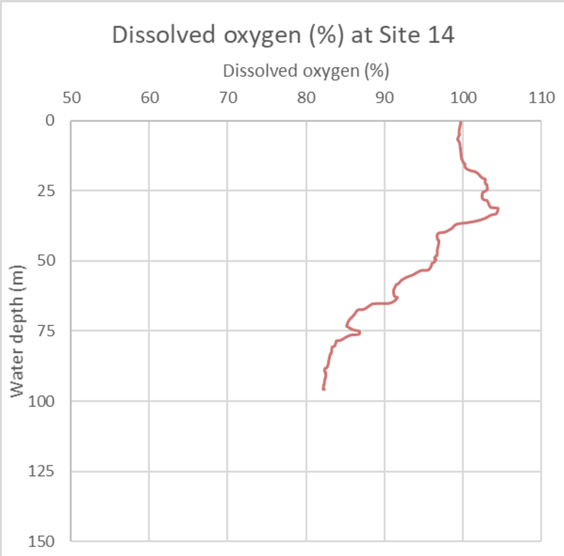

Dissolved oxygen (%) at Site 9
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)


Dissolved oxygen (%) at Site 11
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)


Dissolved oxygen (%) at Site 12
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)


Dissolved oxygen (%) at Site 10
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)


Dissolved oxygen (%) at Site 13
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)


Dissolved oxygen (%) at Site 14
Dissolved oxygen (%)
50
60
70
80
90
100
110
0
25
50
75
100
125
150
Water depth (m)

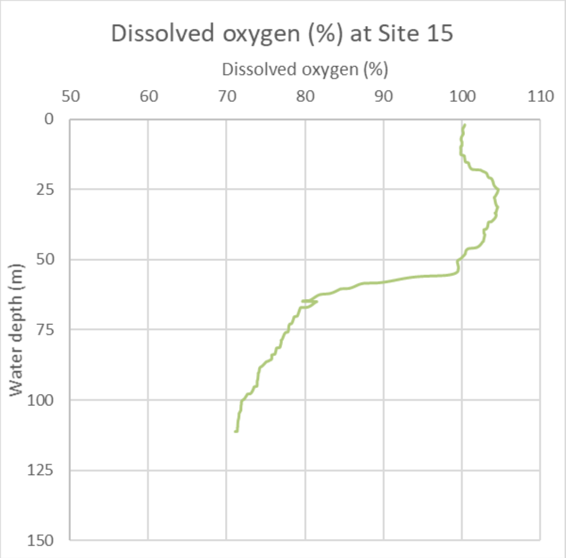
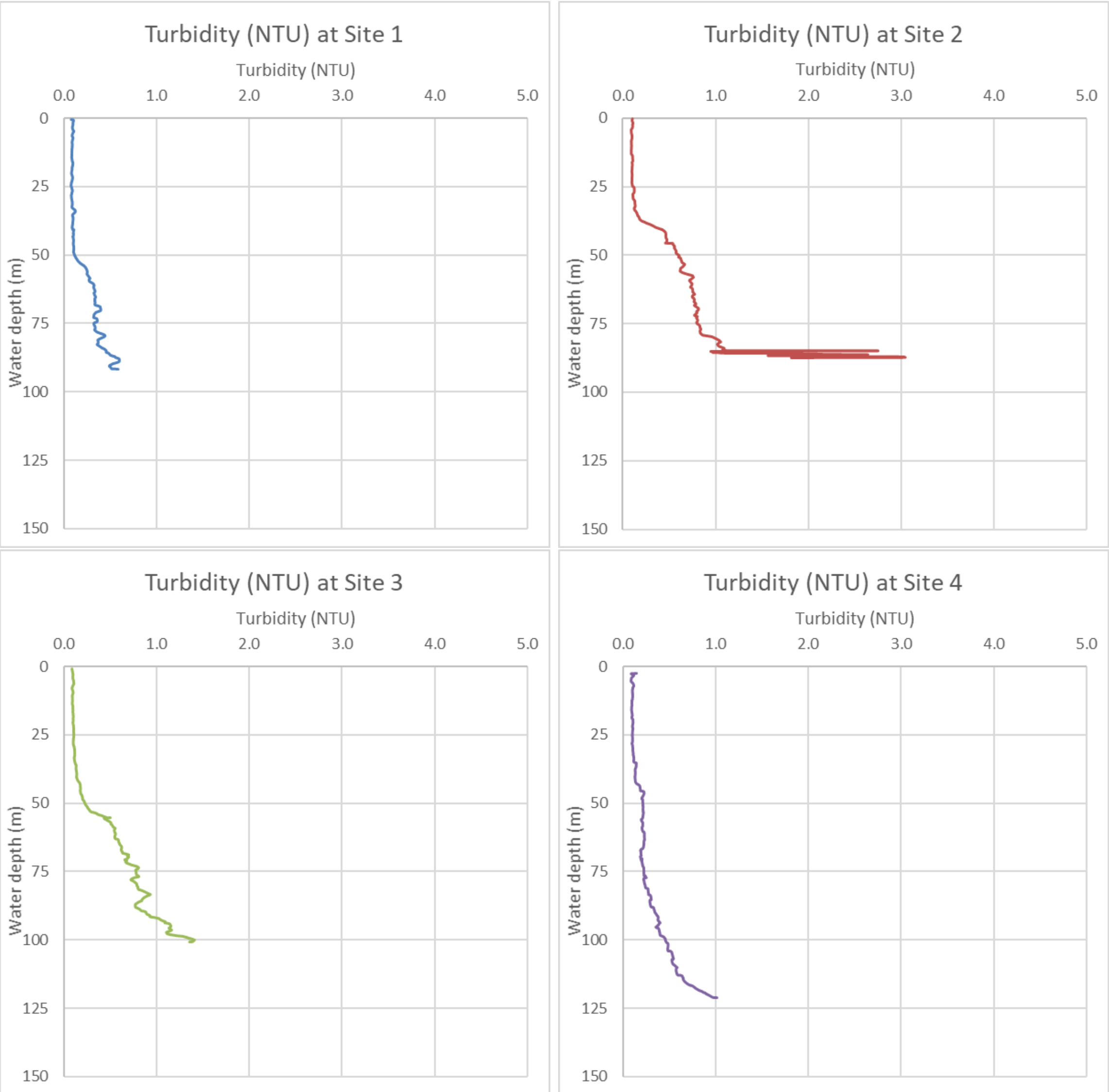
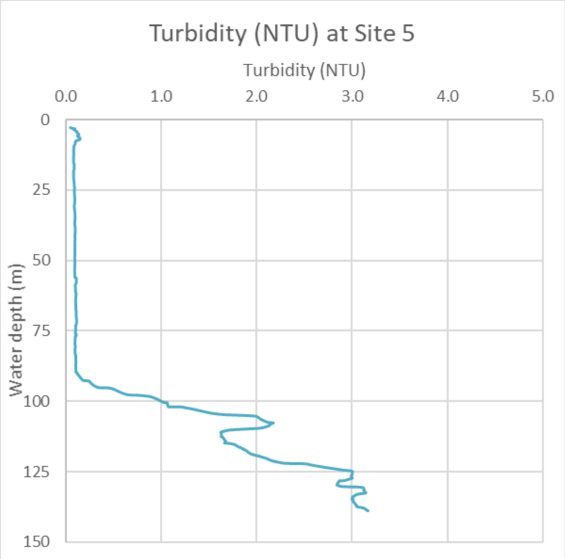
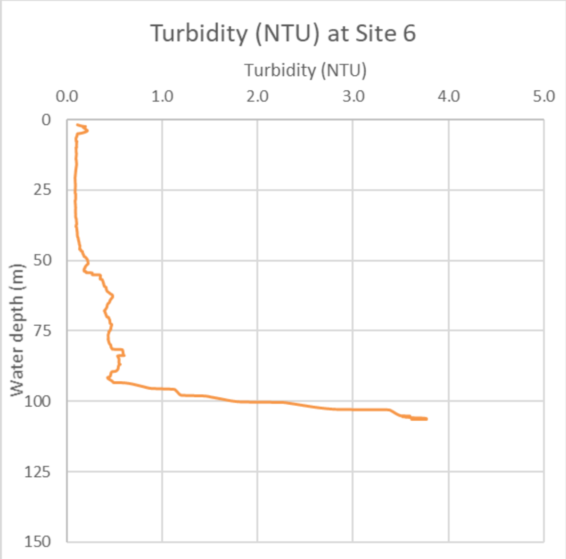


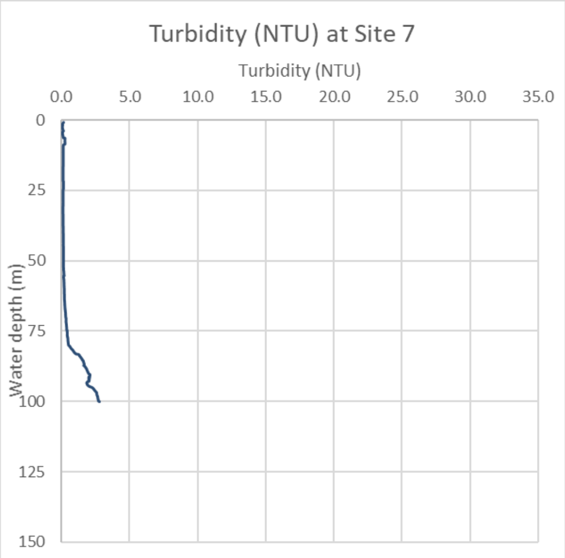
Figure D-4: Dissolved oxygen profiles

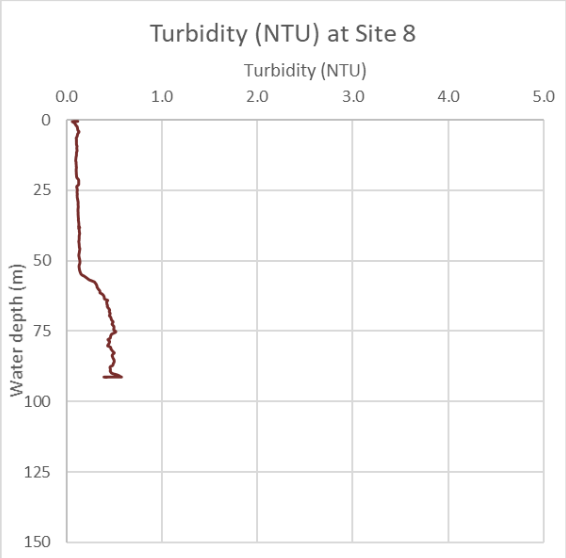
A.1.5 Turbidity

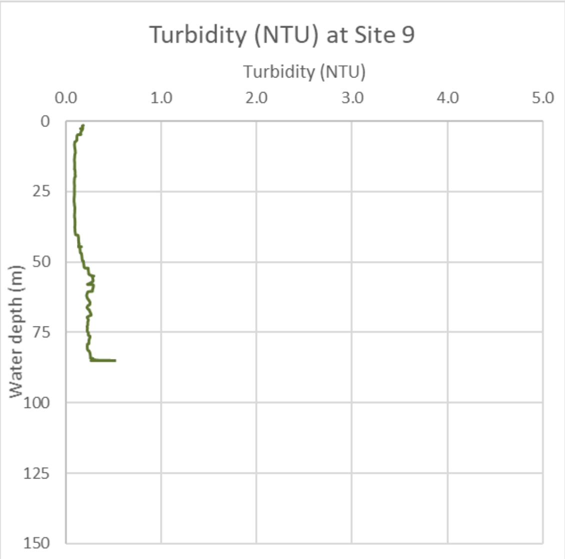


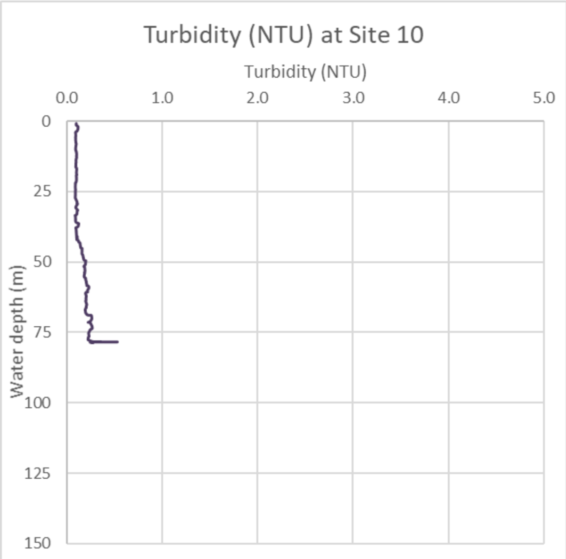

Turbidity (NTU) at Site 5
Turbidity (NTU)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Turbidity (NTU) at Site 6
Turbidity (NTU)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Turbidity (NTU) at Site 7
Turbidity (NTU)
0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0
Water depth (m)
0 25 50 75 100 125 150


Turbidity (NTU) at Site 8
Turbidity (NTU)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Turbidity (NTU) at Site 9
Turbidity (NTU)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Turbidity (NTU) at Site 10
Turbidity (NTU)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150

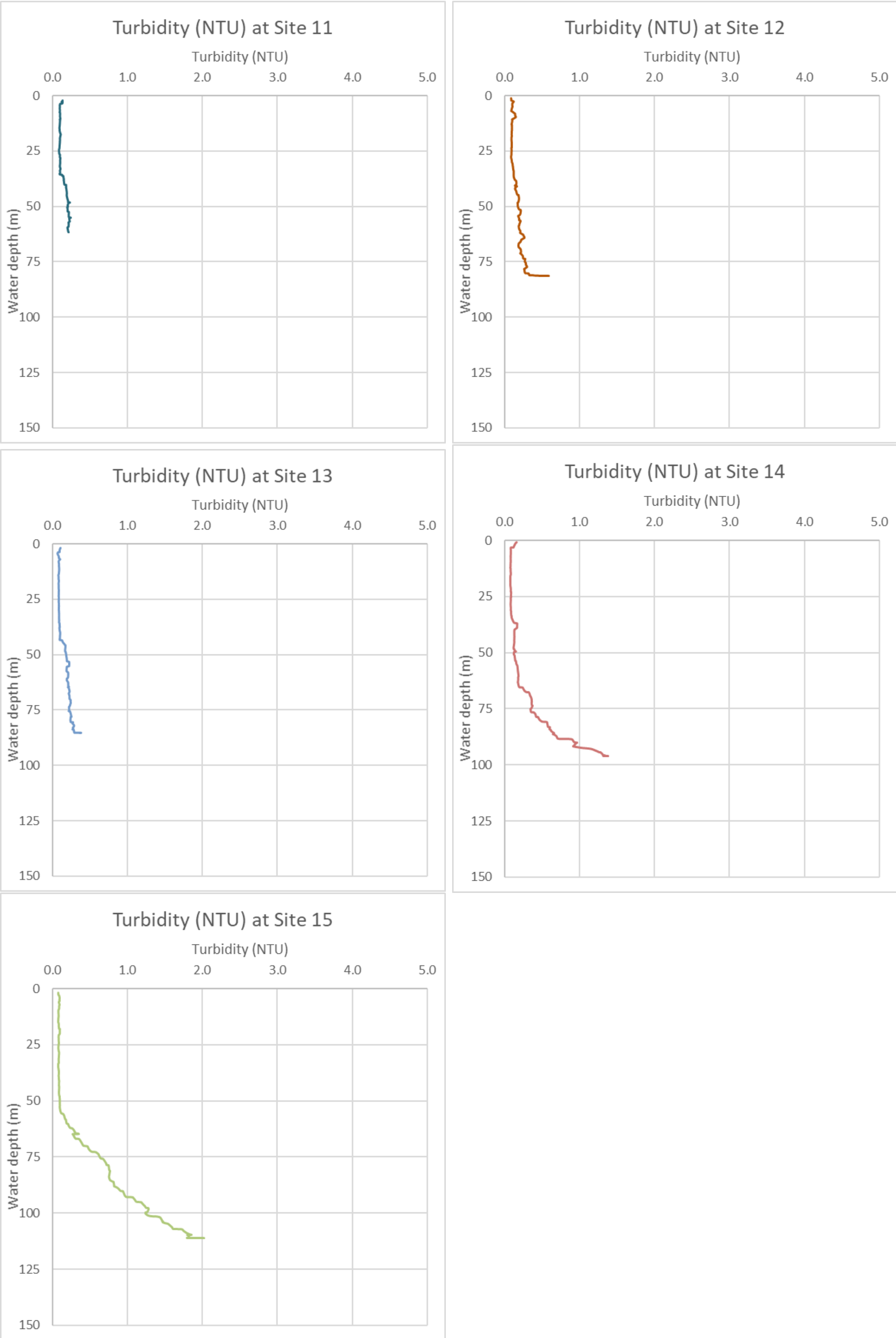
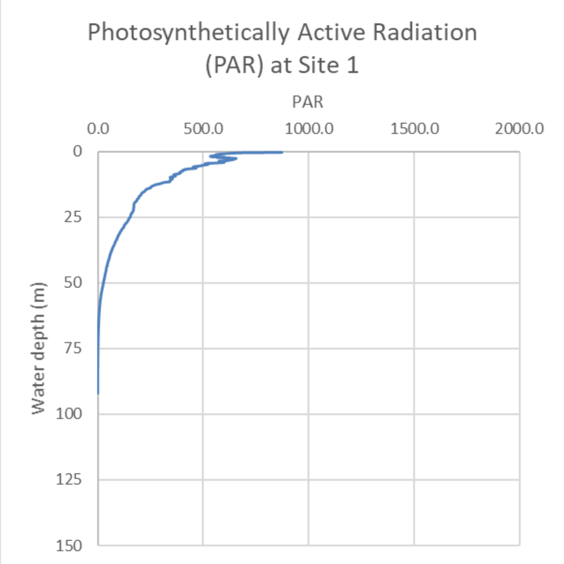
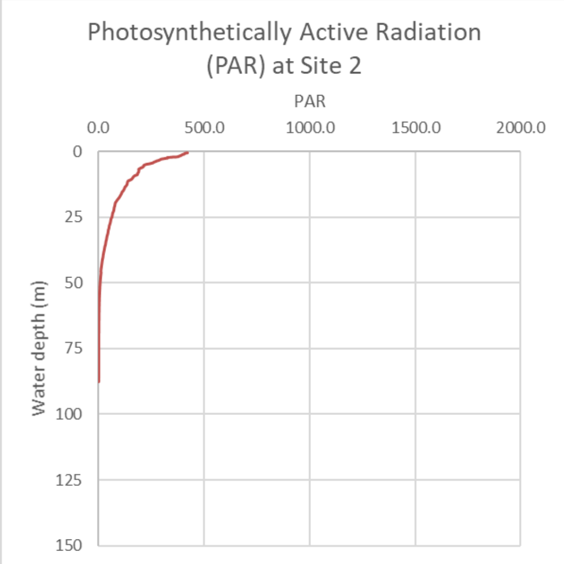
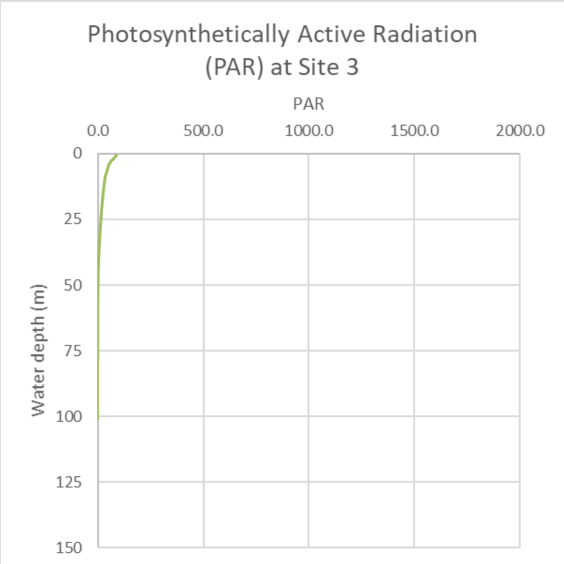


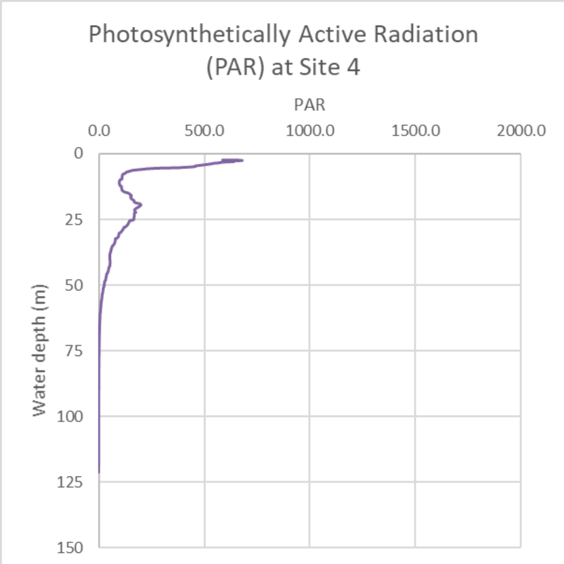
Figure D-5: Turbidity profiles

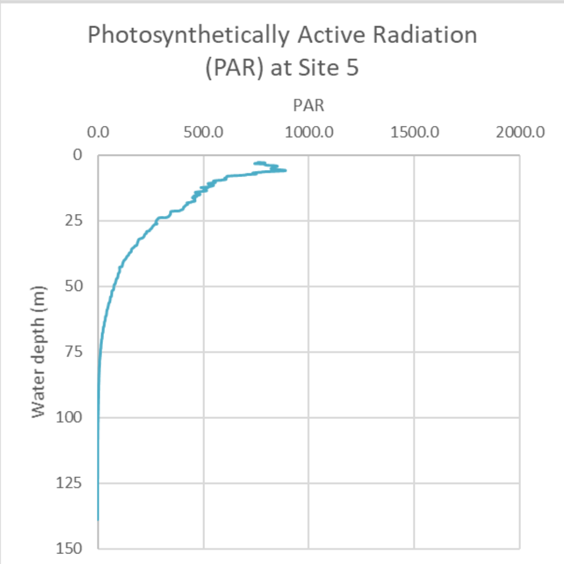
A.1.6 Photosynthetically active radiation (PAR)

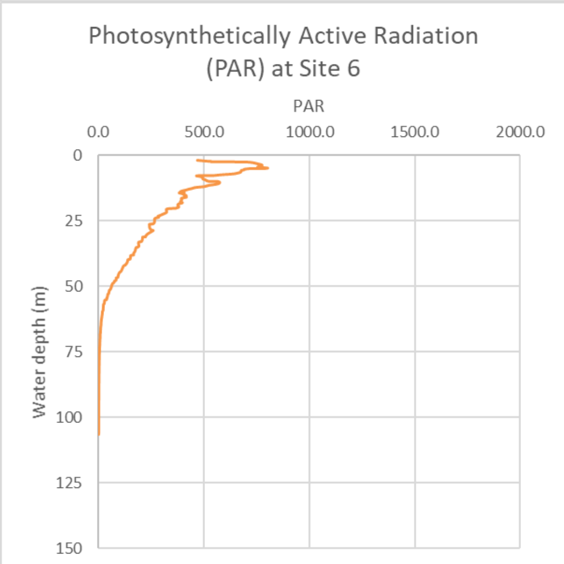


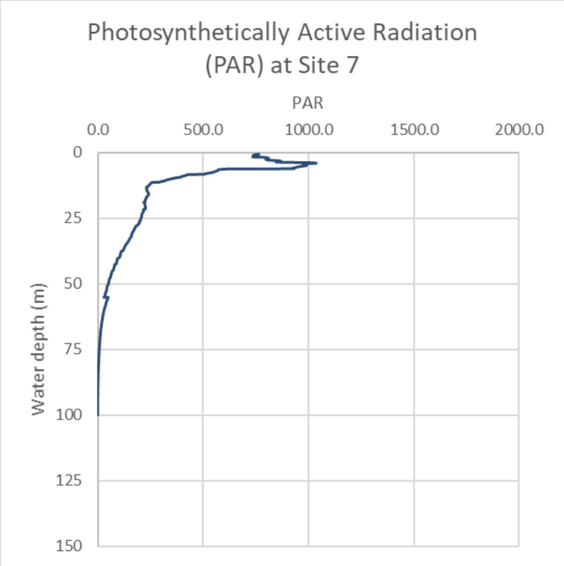


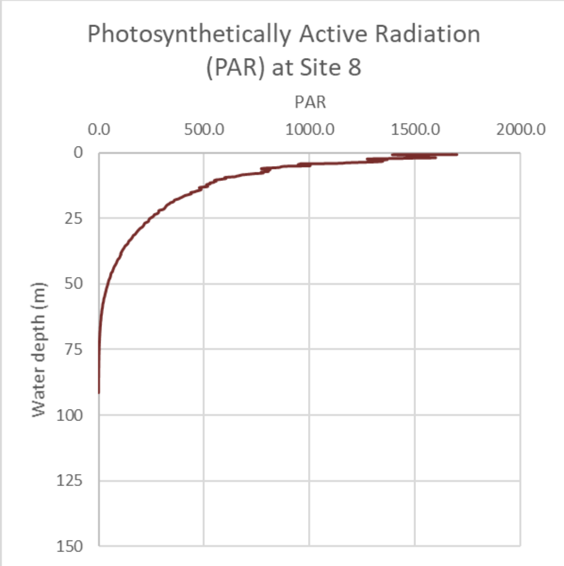









Photosynthetically Active Radiation
(PAR) at Site 7
PAR
0.0
500.0
1000.0
1500.0
2000.0
0
25
50
75
100
125
150
Water depth (m)


Photosynthetically Active Radiation
(PAR) at Site 8
PAR
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500.0
1000.0
1500.0
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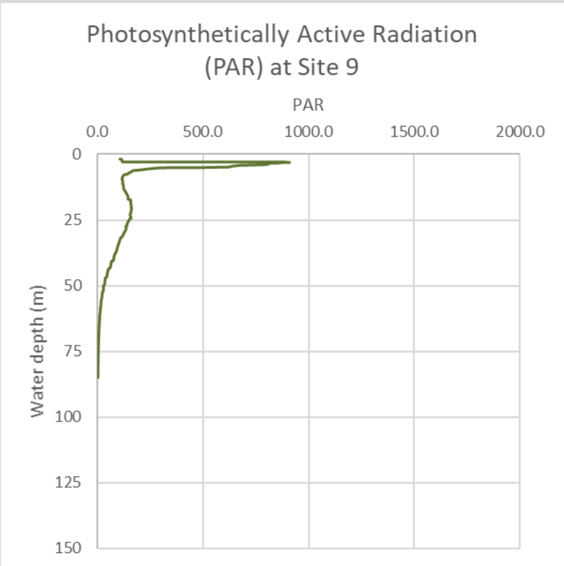
0
25
50
75
100
125
150
Water depth (m)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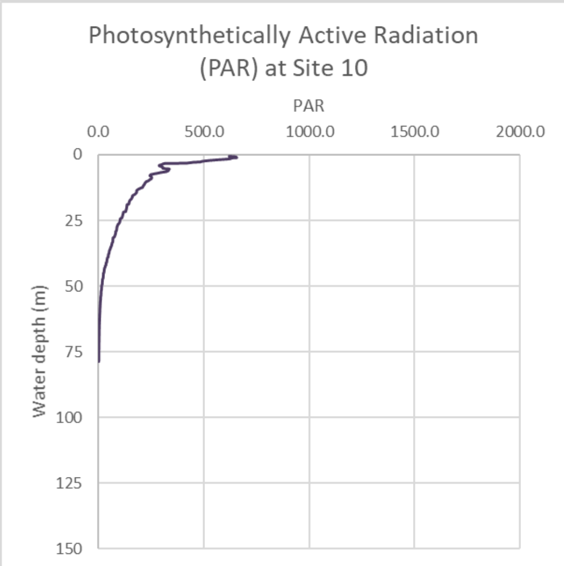
(PAR) at Site 9
PAR
0.0
500.0
1000.0
1500.0
2000.0
0
25
50
75
100
125
150
Water depth (m)


Photosynthetically Active Radiation
(PAR) at Site 10
PAR
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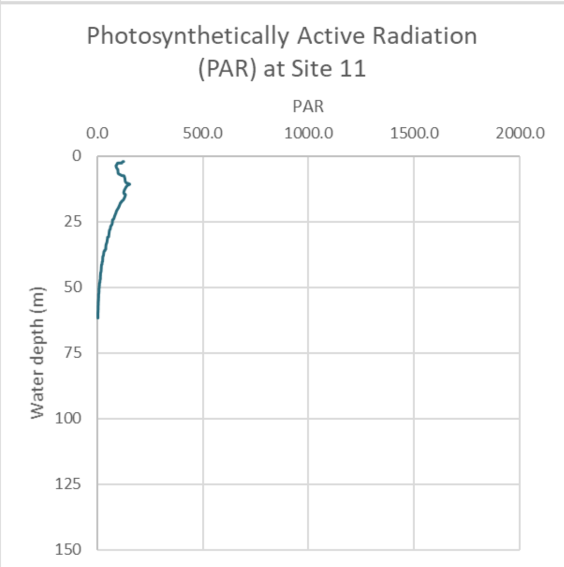
500.0
1000.0
1500.0
2000.0
0
25
50
75
100
125
150
Water depth (m)


Photosynthetically Active Radiation
(PAR) at Site 11
PAR
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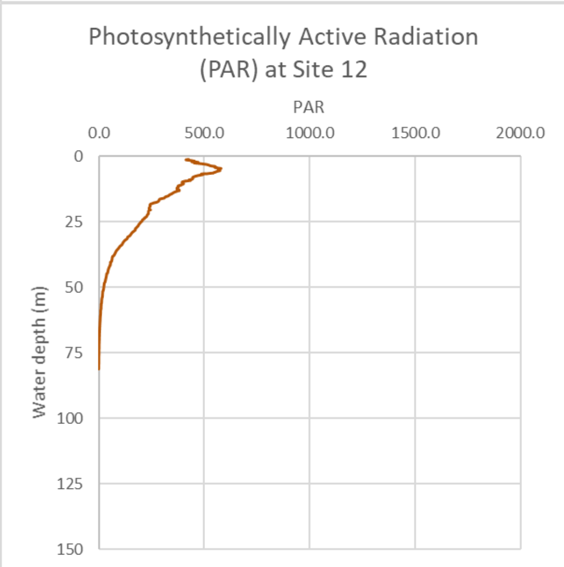
500.0
1000.0
1500.0
2000.0
0
25
50
75
100
125
150
Water depth (m)


Photosynthetically Active Radiation
(PAR) at Site 12
PAR
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500.0
1000.0
1500.0
2000.0
0
25
50
75
100
125
150
Water depth (m)

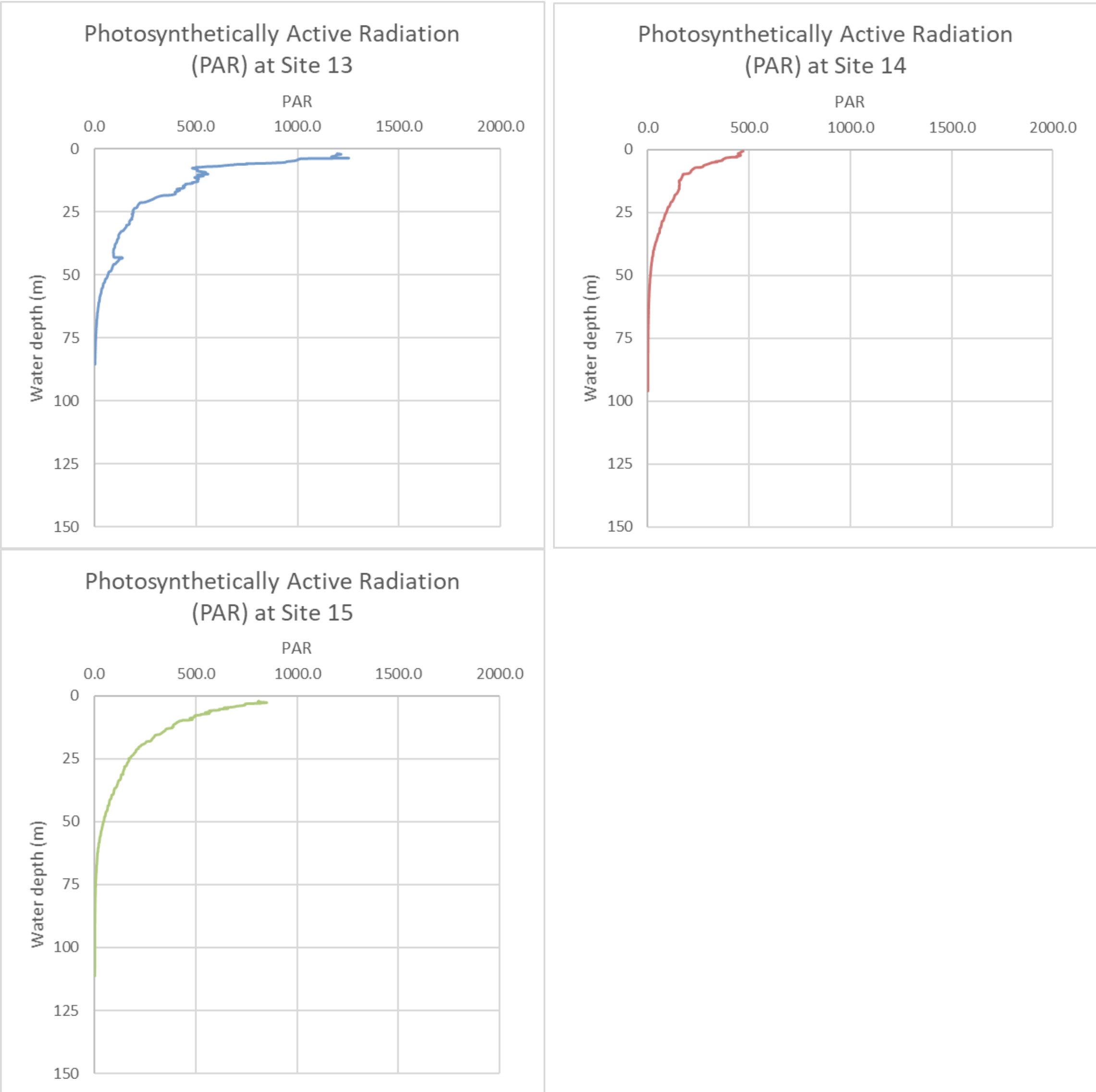
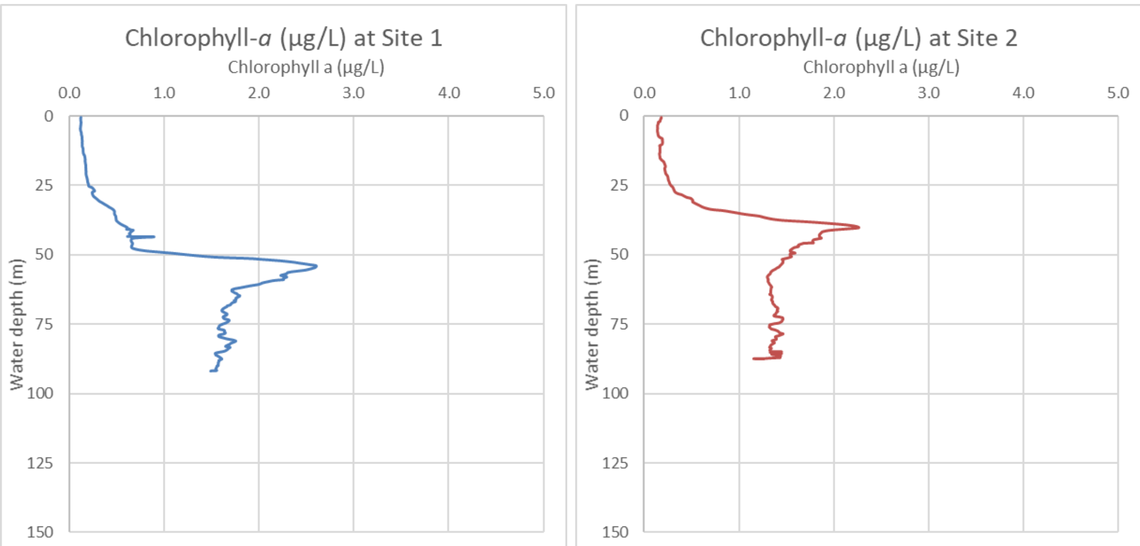
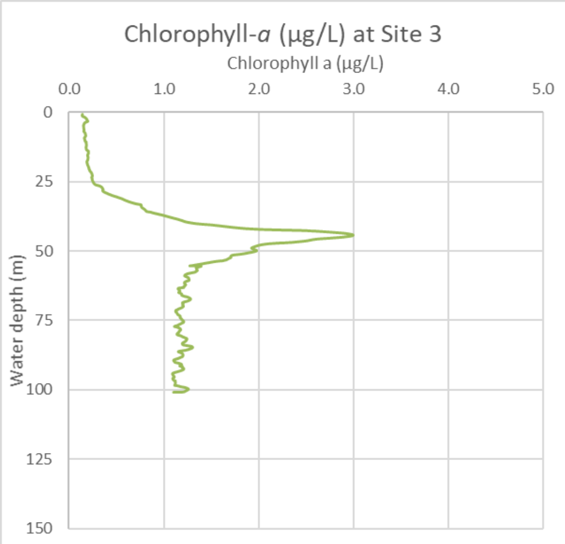
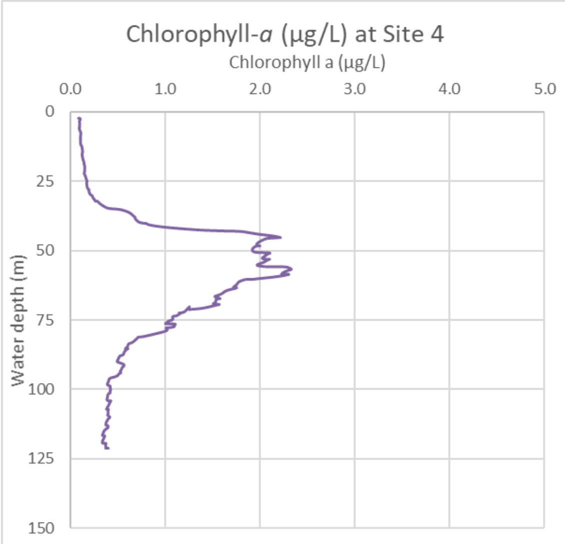


Figure 6: Photosynthetically active radiation (PAR) profiles

A.1.7 Chlorophyll-a




Chlorophyll-a (µg/L) at Site 3
Chlorophyll a (µg/L)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Chlorophyll-a (µg/L) at Site 4
Chlorophyll a (µg/L)
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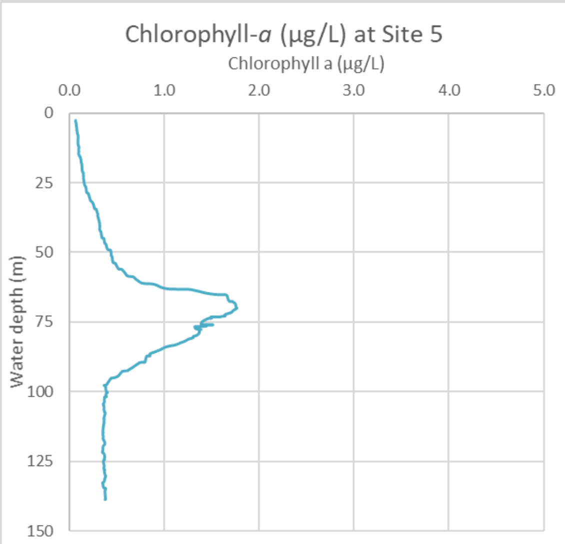
Water depth (m)
0 25 50 75 100 125 150


Chlorophyll-a (µg/L) at Site 5
Chlorophyll a (µg/L)
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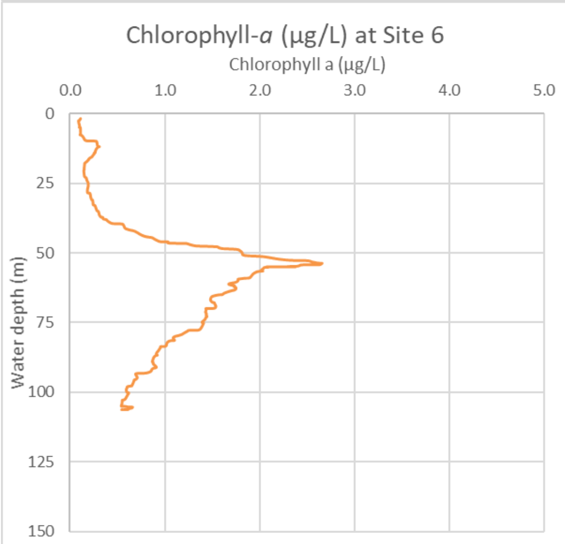
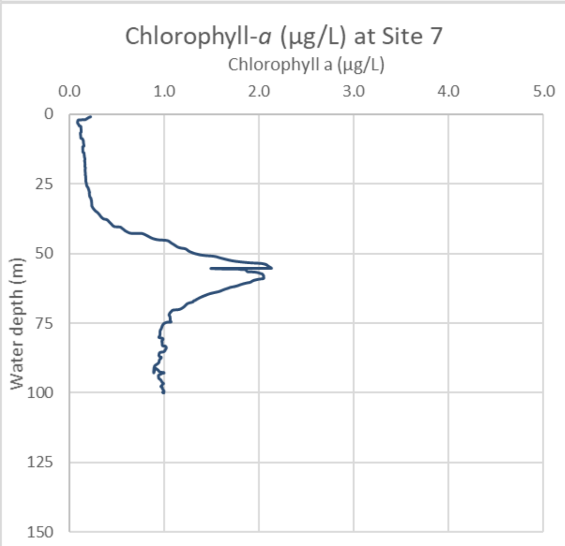
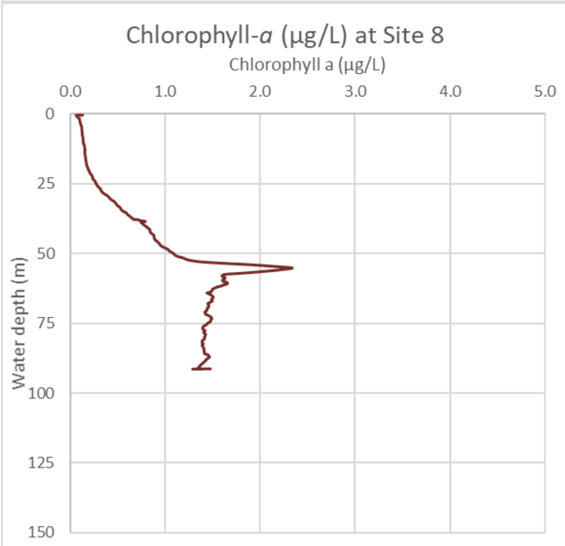
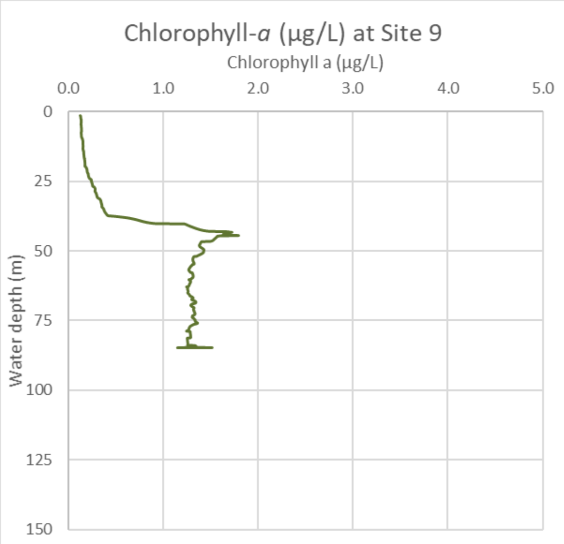
Water depth (m)
0 25 50 75 100 125 150

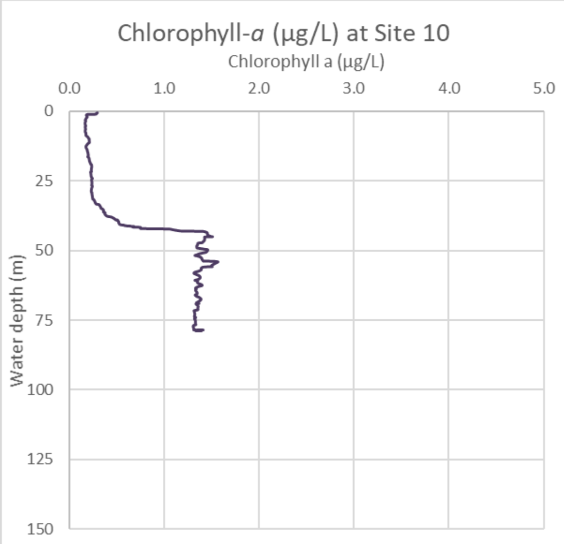

Chlorophyll-a (µg/L) at Site 6
Chlorophyll a (µg/L)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150


Chlorophyll-a (µg/L) at Site 7
Chlorophyll a (µg/L)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150

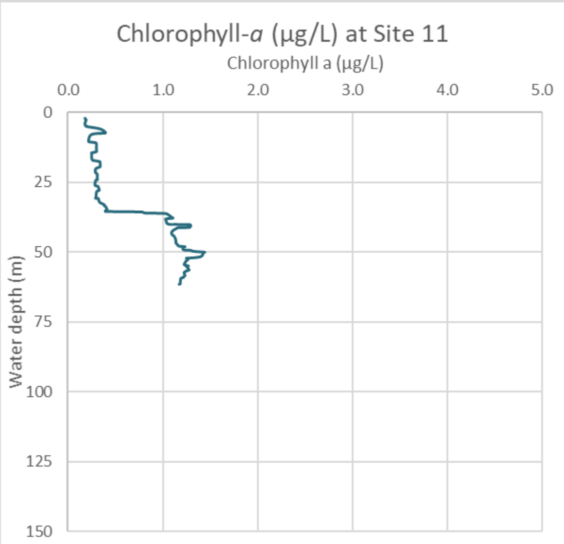

Chlorophyll-a (µg/L) at Site 8
Chlorophyll a (µg/L)
0.0 1.0 2.0 3.0 4.0 5.0
Water depth (m)
0 25 50 75 100 125 150



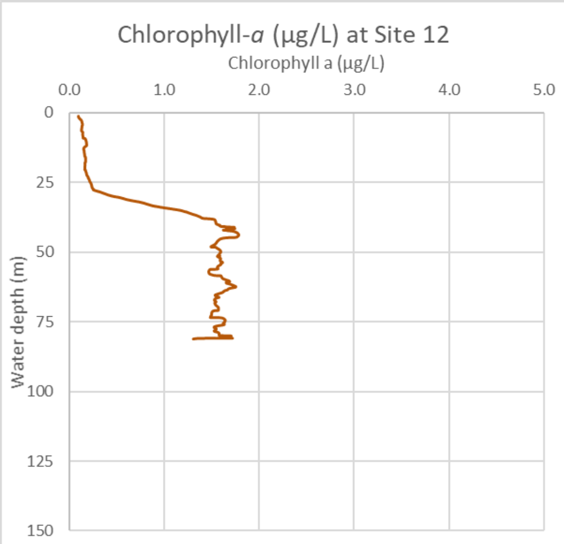
Chlorophyll-a (µg/L) at Site 9
Chlorophyll a (µg/L)
0.0
1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150



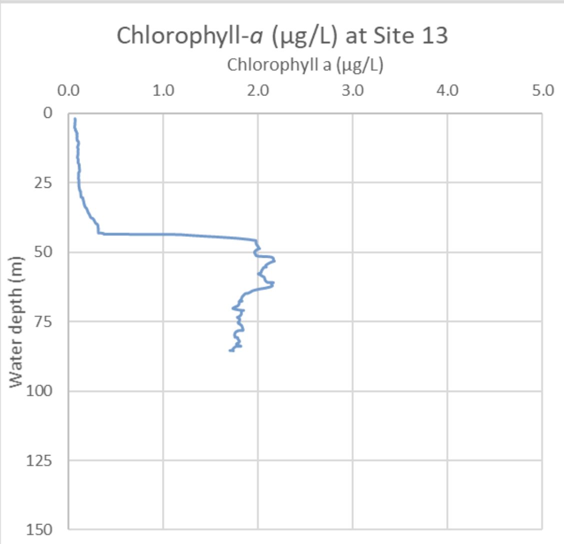
Chlorophyll-a (µg/L) at Site 10
Chlorophyll a (µg/L)
0.0
1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150



Chlorophyll-a (µg/L) at Site 11
Chlorophyll a (µg/L)
0.0
1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150



Chlorophyll-a (µg/L) at Site 12
Chlorophyll a (µg/L)
0.0
1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150



Chlorophyll-a (µg/L) at Site 13
Chlorophyll a (µg/L)
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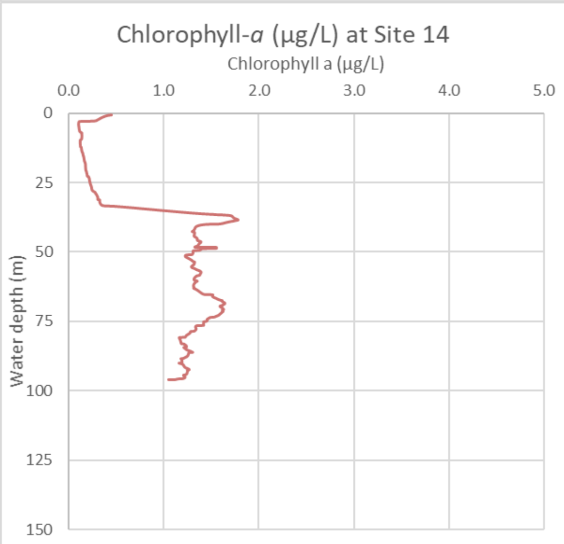
1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150



Chlorophyll-a (µg/L) at Site 14
Chlorophyll a (µg/L)
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1.0
2.0
3.0
4.0
5.0
Water depth (m)
0
25
50
75
100
125
150

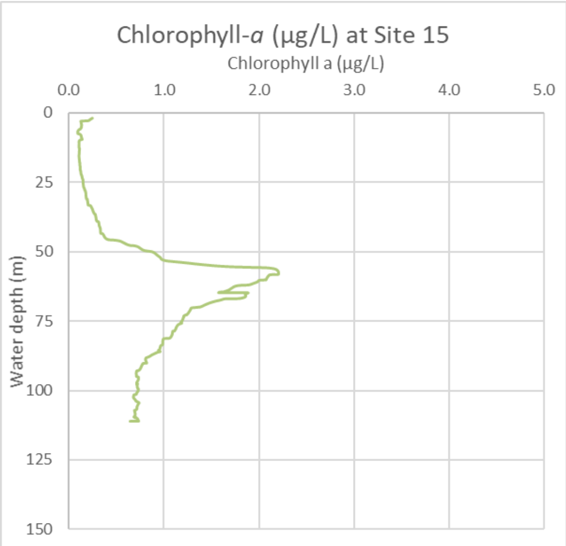
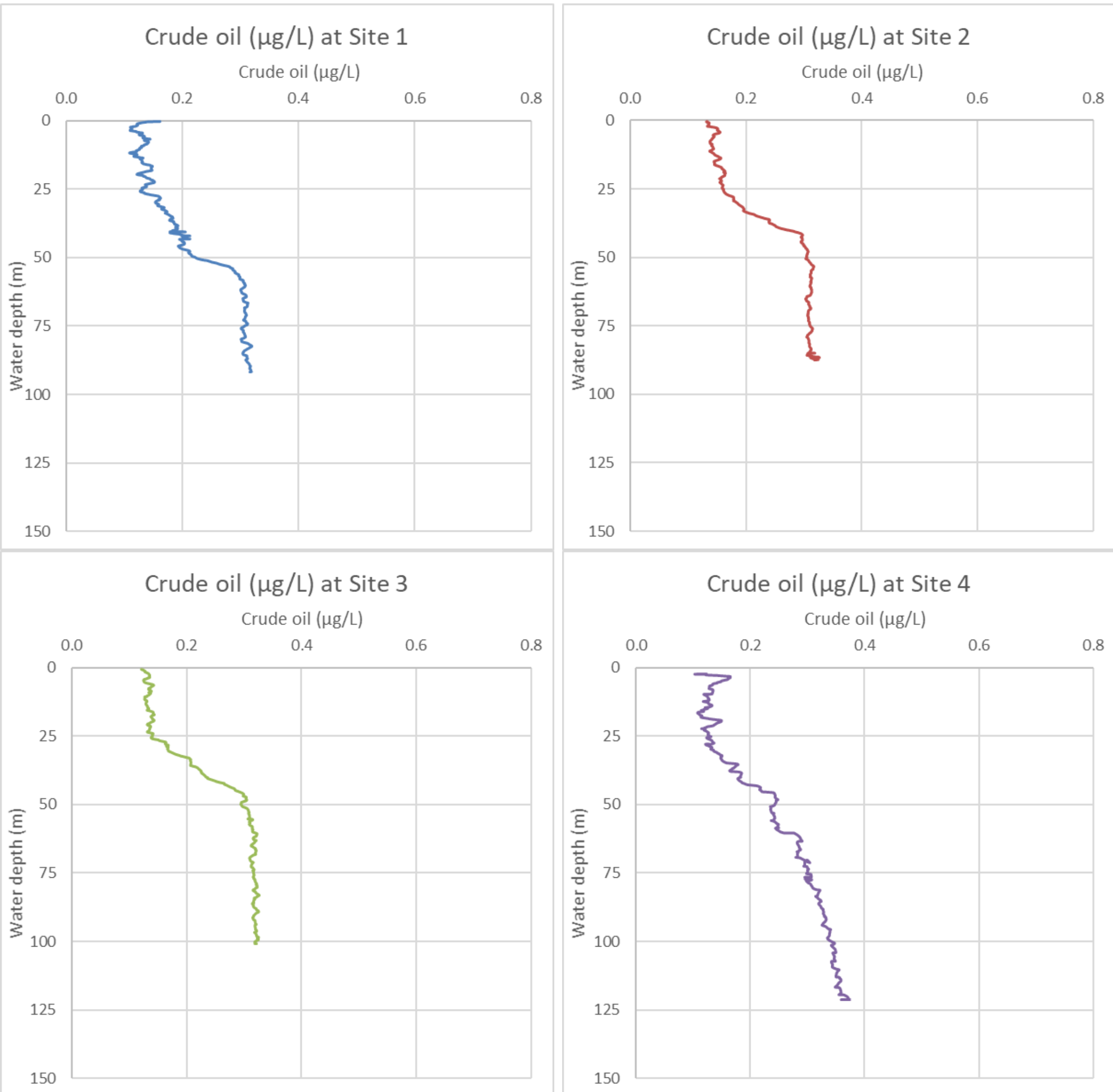
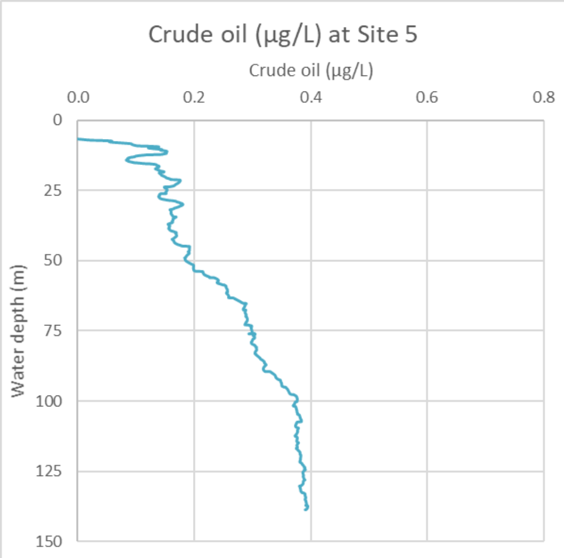
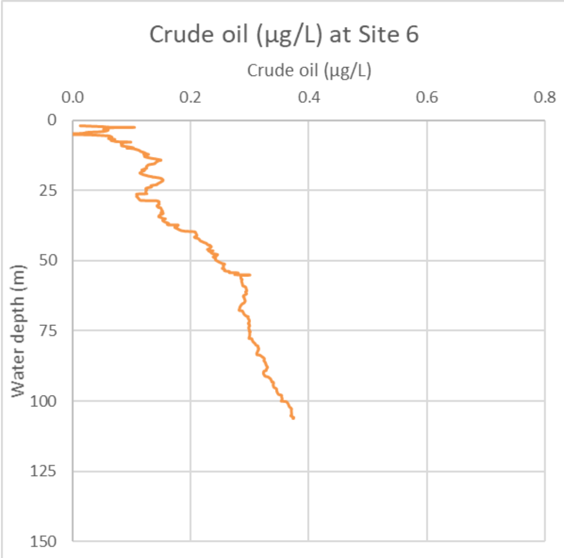


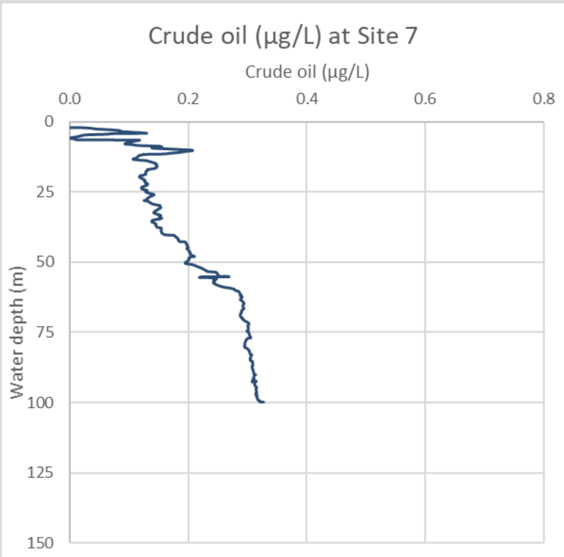
Figure 7: Chlorophyll-a profiles

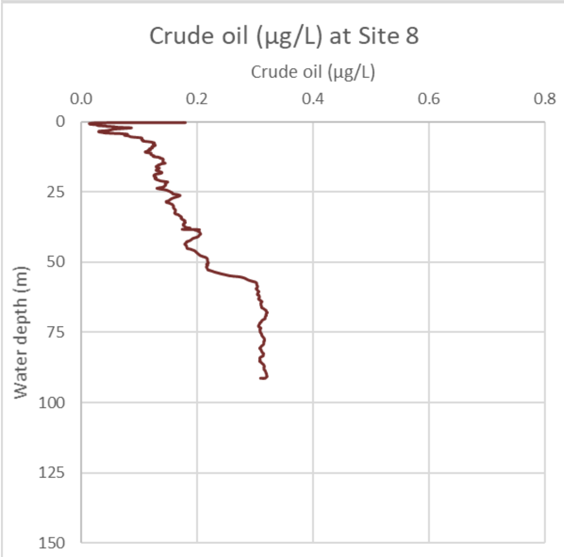
A.1.8 Hydrocarbons (crude oil)

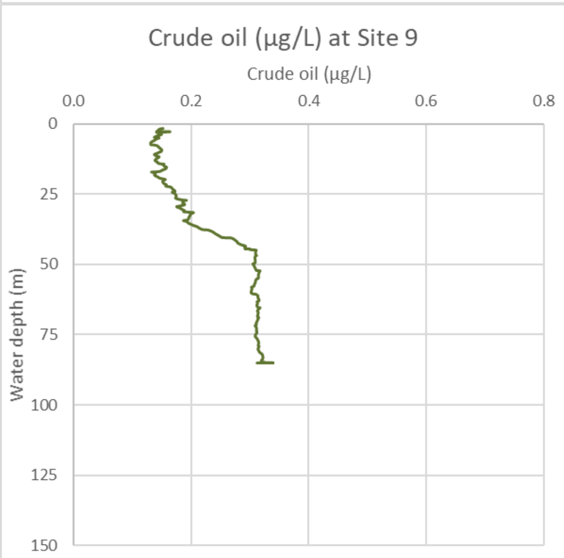


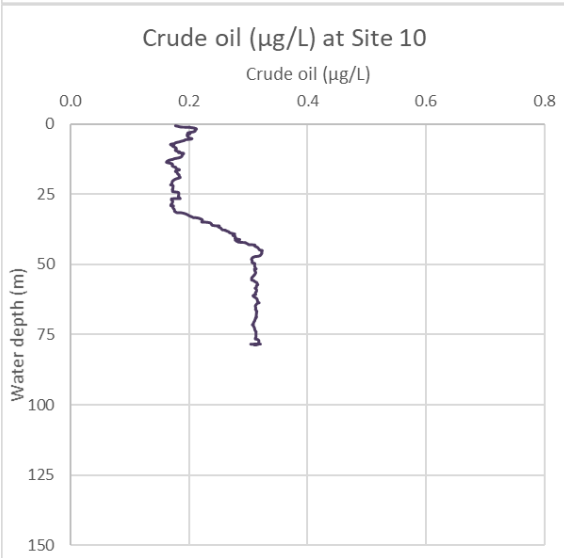

Crude oil (µg/L) at Site 5
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150


Crude oil (µg/L) at Site 6
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150


Crude oil (µg/L) at Site 7
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150


Crude oil (µg/L) at Site 8
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150


Crude oil (µg/L) at Site 9
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150


Crude oil (µg/L) at Site 10
Crude oil (µg/L)
0.0 0.2 0.4 0.6 0.8
Water depth (m)
0 25 50 75 100 125 150

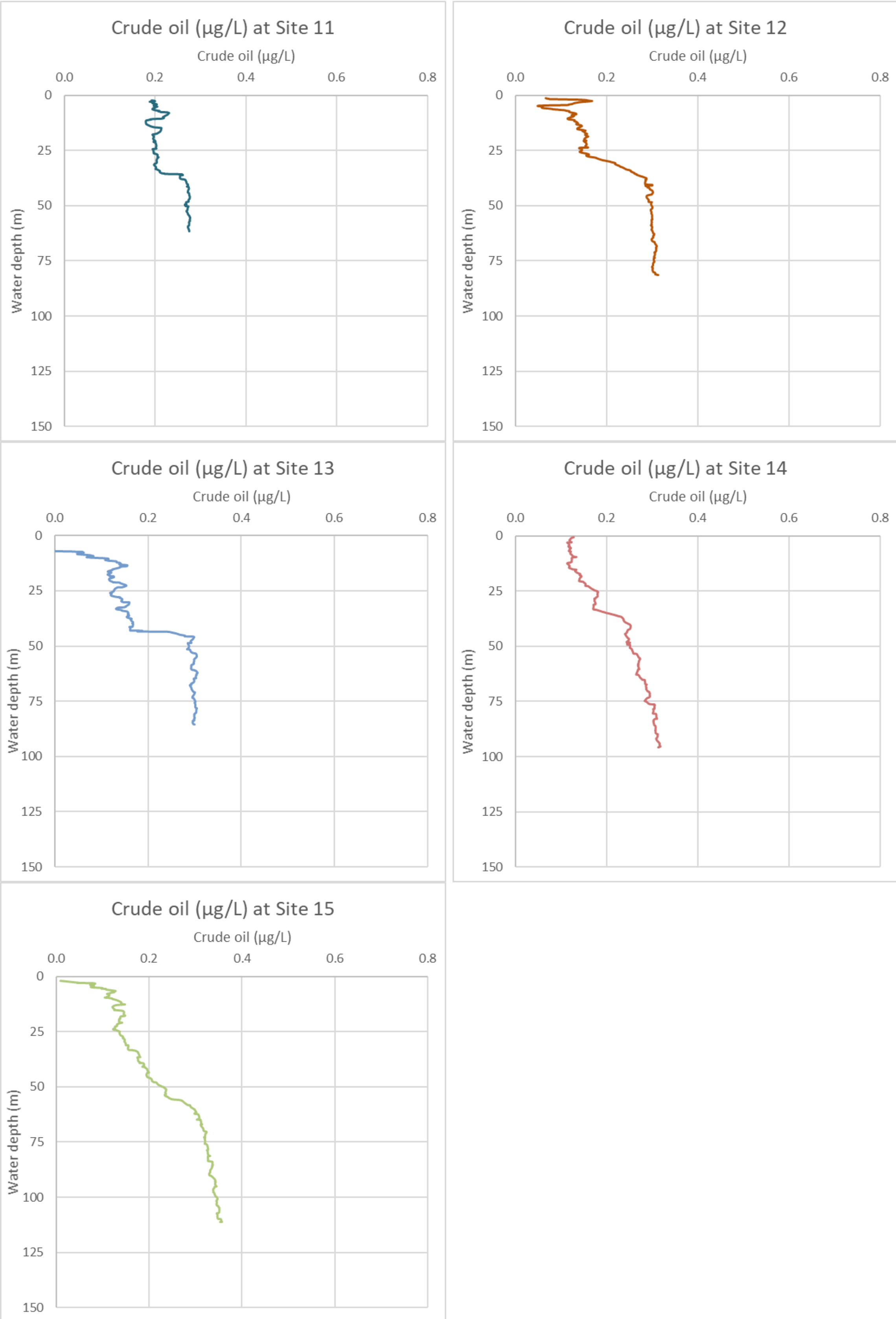


Figure D-8: Hydrocarbons (crude oil) profile

Attachment 6 Drill Cuttings and Fluids Modelling

DRILL CUTTINGS DISPERSION MODELLING - CUTTINGS REPORT

Report

MAQ0901J
CDM Smith Dorado
Discharge Modelling -
Cuttings Report
Final
26 August 2020

rpsgroup.com

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Tables

Figures

EXECUTIVE SUMMARY

Santos Limited (Santos) is planning for the development of the Dorado Oil Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia and approximately 140 km north of Port Hedland. The Dorado Project will target the Dorado oil field with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading (FPSO) facility.

To inform the impact assessment and support the preparation of the Offshore Project Proposal (OPP), a drill cuttings and drilling muds discharge modelling study was commissioned. The study considered the discharge of cuttings and muds from 12 successive wells from the WHP based on the proposed drilling schedule by Santos that comprised of 528 days for the total operation and 216 days of discharge.

The principal aim of the study was to calculate and quantify the distribution and sediment thicknesses from discharged drill cuttings and drilling muds on the sea floor.

Summary of Modelling Results

Results for a single well

- The modelling results demonstrated that larger particles (greater than 0.25 mm diameter) were predicted to settle typically within 1 km from the well, while the currents transported the smaller sediments (less than 0.25 mm) further away from the well.
- The maximum sediment thickness (or height of mound) was predicted to be 126 mm adjacent to the well location (<20 m).
- The maximum distance from the well to the natural threshold level (≥0.1 mm) was 1,115 m with a corresponding area of coverage of 0.65 km^2.
- The maximum distances to the low (1-10 mm) and high (≥10 mm) exposure thresholds was 837 m and 251 m, respectively.
- The greatest areas of coverage on the seafloor at the low and high exposure thresholds, was recorded as 0.29 km^2 and 0.02 km^2, respectively.

Results for the twelve wells

- The combined maximum thickness (or height of mound) predicted was 1,315 mm adjacent to the well location.
- Modelling predicted a zone of potential influence at the natural threshold level up to 2,871 m from the well while covering an area of 8.81 km^2.
- The low and high exposure thresholds were more localised and not expect beyond 954 m and 447 m, respectively.
- Greatest areas of coverage on the seafloor at the low and high exposure thresholds were 0.92 km^2 and 0.28 km^2, respectively.

1 INTRODUCTION

1.1 Background

Santos Limited (Santos) is planning for the development of the Dorado Development, located in the Bedout Basin offshore north-west Western Australia and approximately 140 km north of Port Hedland. The Dorado Development targets the Dorado reservoir with hydrocarbon being collected on a wellhead platform (WHP) and pumped by infield flowlines for processing on a floating production storage and offloading (FPSO) facility.

The Dorado Development will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations), administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk.

To inform the impact assessment and support the preparation of the OPP, CDM Smith (on behalf of Santos) has commissioned RPS to undertake a detailed sediment dispersion modelling study of discharged cuttings and drilling muds. This study considered the discharged cuttings and muds from 12 successive wells drilled at the WHP following installation of the WHP (see Table 1.1 and Figure 1.1). . The study considered the discharge of cuttings and muds from 12 successive wells from the WHP based on the proposed drilling schedule by Santos that comprised of 528 days for the total operation and 216 days of discharge. The principal aim of the study was to calculate and quantify the distribution and sediment thicknesses from discharged drill cuttings and drilling muds on the sea floor.

Table 1.1 Location of the proposed Dorado WHP used as the release site for the drill cuttings and drilling fluids dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water depth (m)
Dorado WHP	19° 01′ 38.001″	118° 44′ 36.744″	90

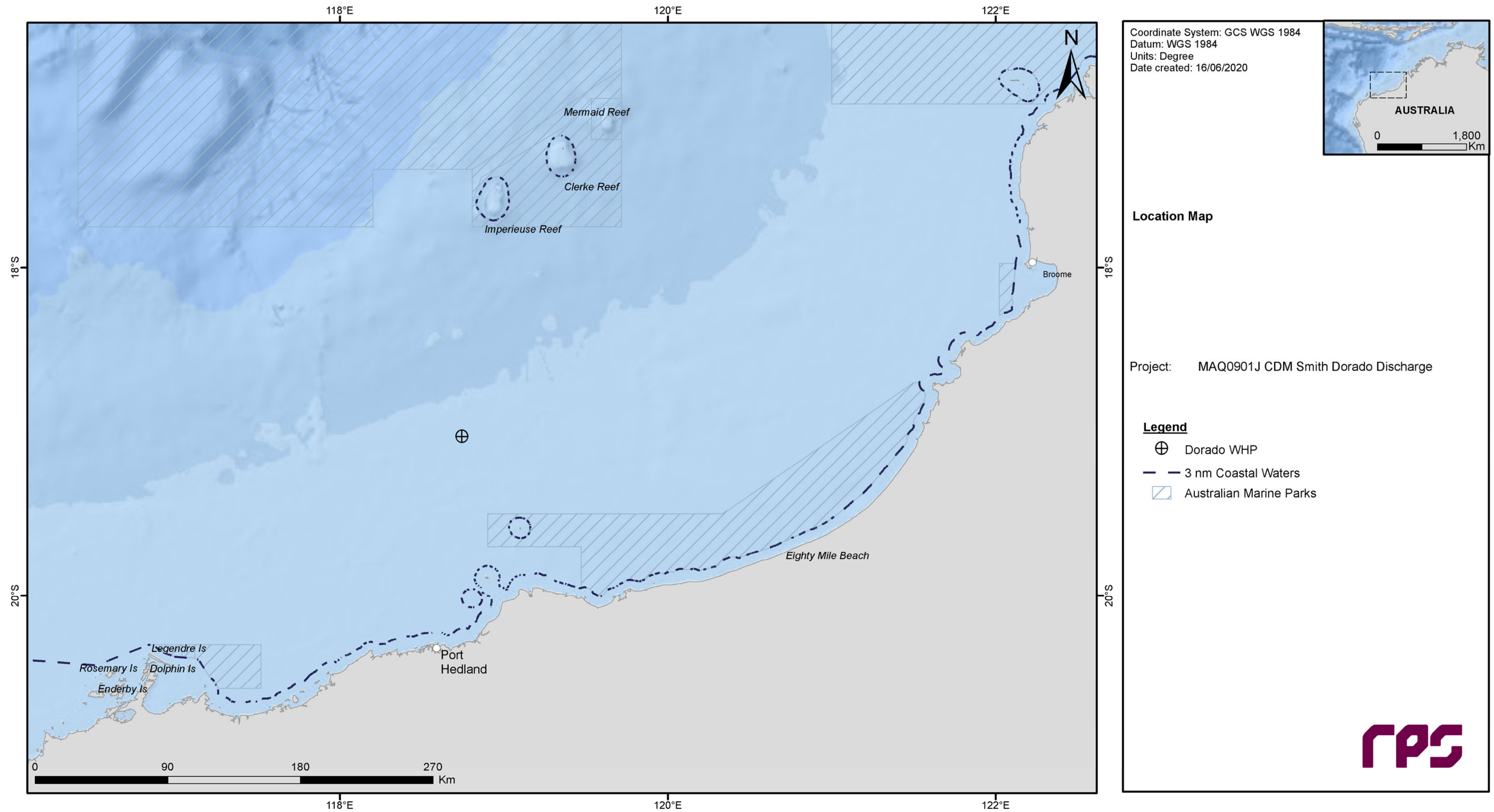

Figure 1.1 Location of the proposed Dorado WHP used as the release site for the cutting dispersion modelling assessment.

1.2 Modelling Scope

The scope of the modelling included the following components:

1. Assess Environmental Conditions.

- Assess the Southern Oscillation Index (SOI) for the period covering the ten-year (2009 to 2018), three-dimensional currents and determine a year representative of El Niño (2010), Neutral (2012) and La Niña (2015) conditions (or ENSO events), respectively.

2. Summarise the 528 day total drilling operation and consider the discharge of cuttings and muds from 12 successive wells drilled at the WHP for as input into the sediment dispersion model.
3. As part of a more robust approach, to consider the interannual variability (albeit minimal at the study site) the discharge of drill cuttings and muds were at the start of the El Niño (2010), Neutral (2012) and La Niña (2015) conditions.
4. Analysis of the results by commencing the discharge during El Niño (2010), Neutral (2012) and La Niña (2015) conditions and map the distribution and sediment thicknesses on the sea floor as well as suspended sediment concentrations in the water column.
5. Combine the results for the twelve wells and the ENSO events.

2 REGIONAL OCEAN CURRENTS

2.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region (< 100 m water depth). However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have an influence upon the net trajectory of discharges over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location. A comprehensive description of the circulation patterns of the Northwest Shelf is provided in a review by Condie and Andrewartha (2008).

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model (HYCOM), with estimates of the tidal currents generated by an RPS model set up for the study area (HYDROMAP).

2.2 Ocean Currents

The large scale drift currents were derived from the output of the global circulation model the Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet et al., 2007, 2009), created by the National Ocean Partnership Program (NOPP), as part of the US Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates ocean observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite observations, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density and sea height variations and the rotation of the earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (approximately 7 km at mid-latitudes) and a temporal resolution of one day.

A hindcast data set of HYCOM currents was obtained for a ten-year period spanning 2009 to 2018 (inclusive).

2.3 Tidal Currents

2.3.1 Description of Tidal Model: HYDROMAP

As the HYCOM model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984; Isaji et al., 2001;

Zigic et al., 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA) (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

2.3.2 Tidal Grid Setup

The same tidal model grid used in the oil spill study was used for this study. The grid extends approximately 3,870 km east-west by 3,220 km north-south over the eastern Indian Ocean. Figure 2.1 shows a subset of the grid between Exmouth and Derby.

The tidal domain is sub-gridded down to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over more complex bathymetry

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office (see Figure 2.2). Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

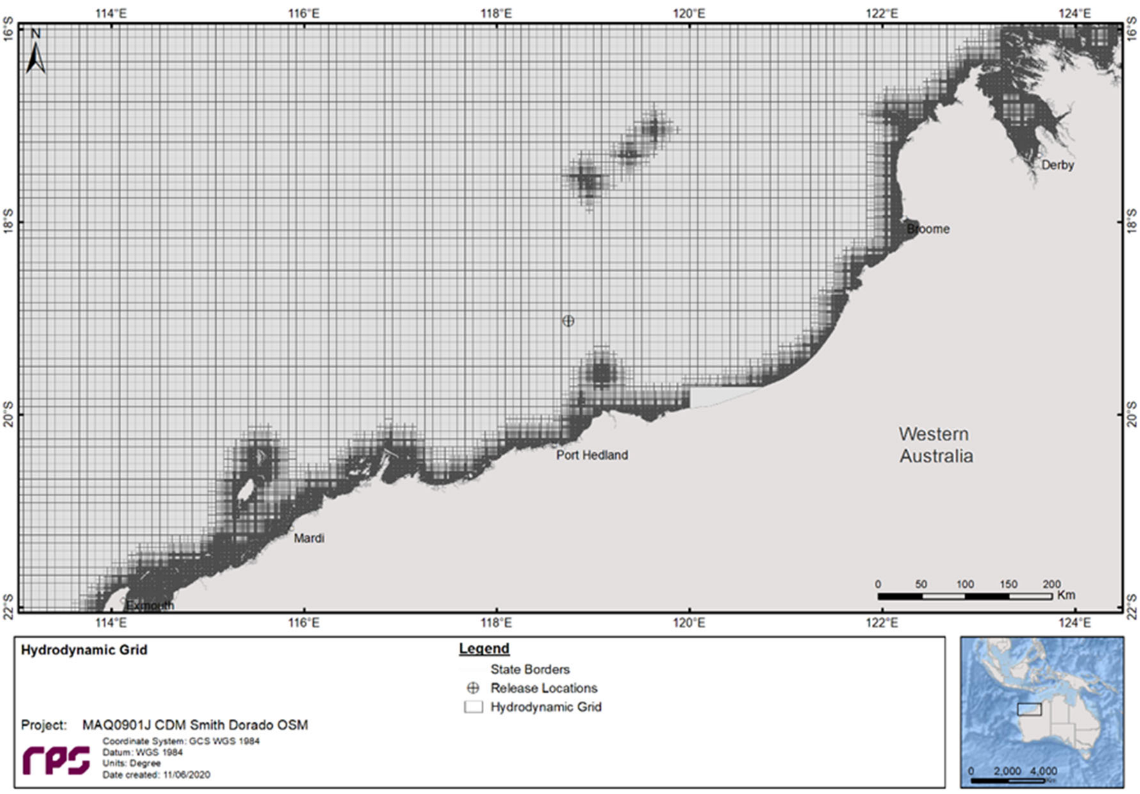

Figure 2.1 Subset of the model grid (grey wire mesh) used to generate the tidal currents. Higher-resolution areas are indicated by the denser mesh zones.

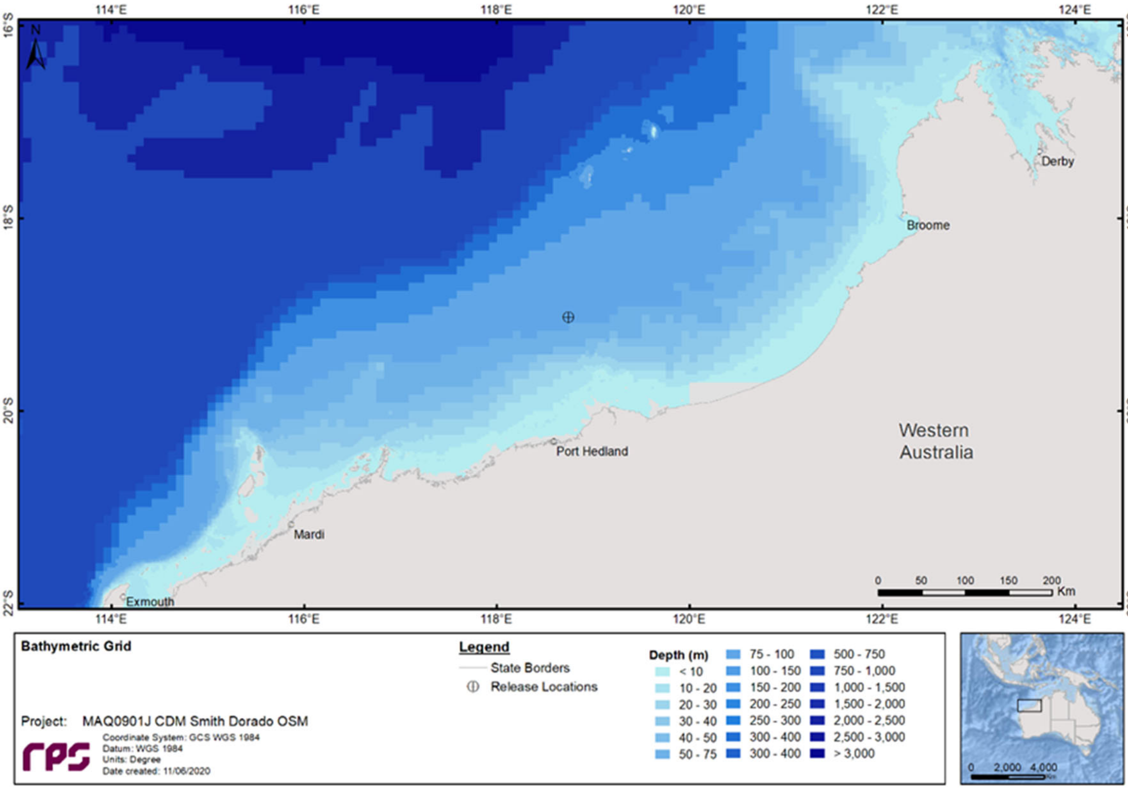

Figure 2.2 Subset of the bathymetry data used generate the tidal currents.

2.3.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

2.3.4 Tidal Model Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at five locations (see Figure 2.3).

Figure 2.4 and Figure 2.5 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graphs, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles.

To provide a statistical measure of the model performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is simply the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error (Willmott and Matsuura, 2005) and more readily understood.

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: X represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of 0 (Willmott, 1981). Willmott et al. (1985) also suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

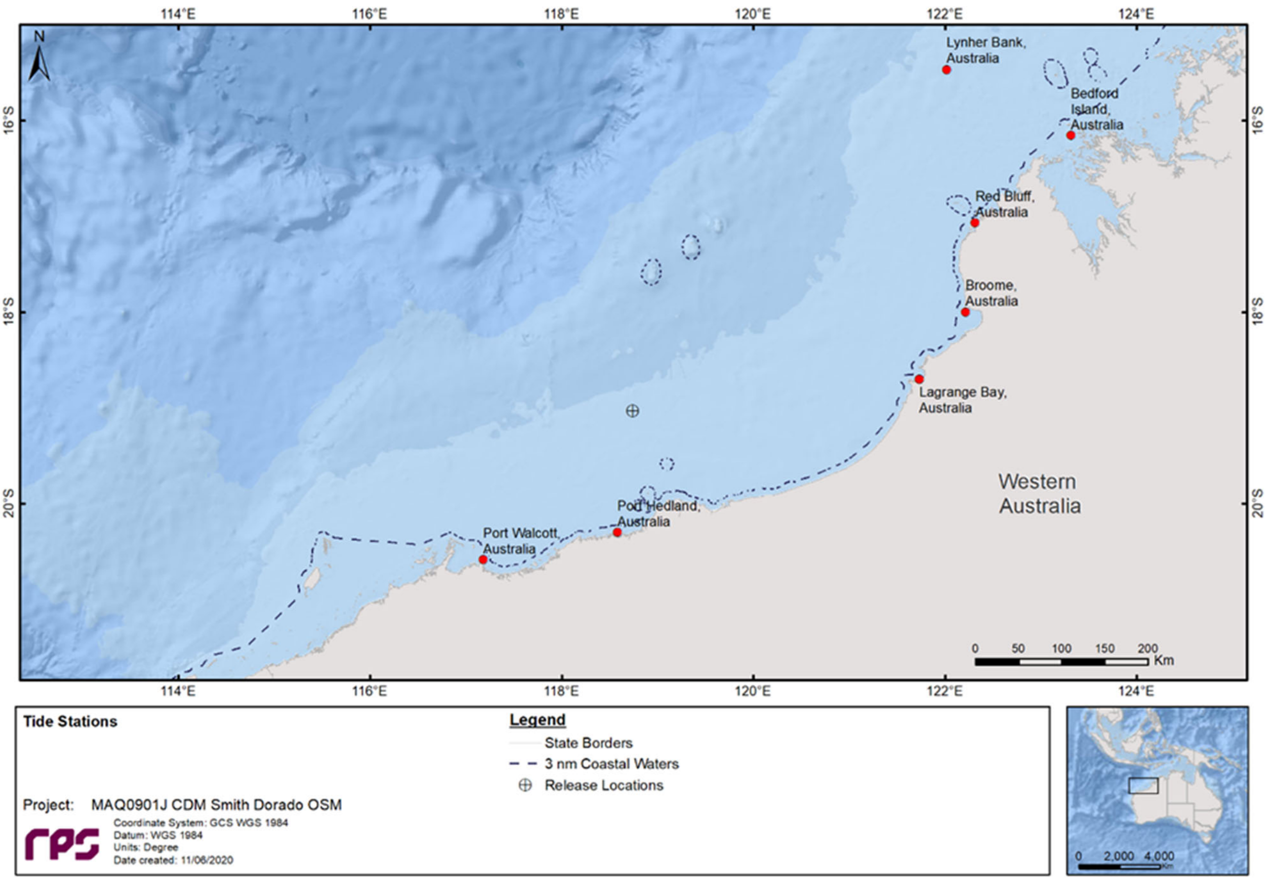

Figure 2.3 Tide stations used to validate surface elevation within the model.

Table 2.1 Statistical comparison between the observed and predicted surface elevations.

Tide Station	IOA	MAE (m)
Broome	0.90	1.11
Lagrange Bay	0.96	0.71
Lynher Bank	0.98	0.31
Port Hedland	0.98	0.33
Port Walcott	0.99	0.20
Red Bluff	0.98	0.46

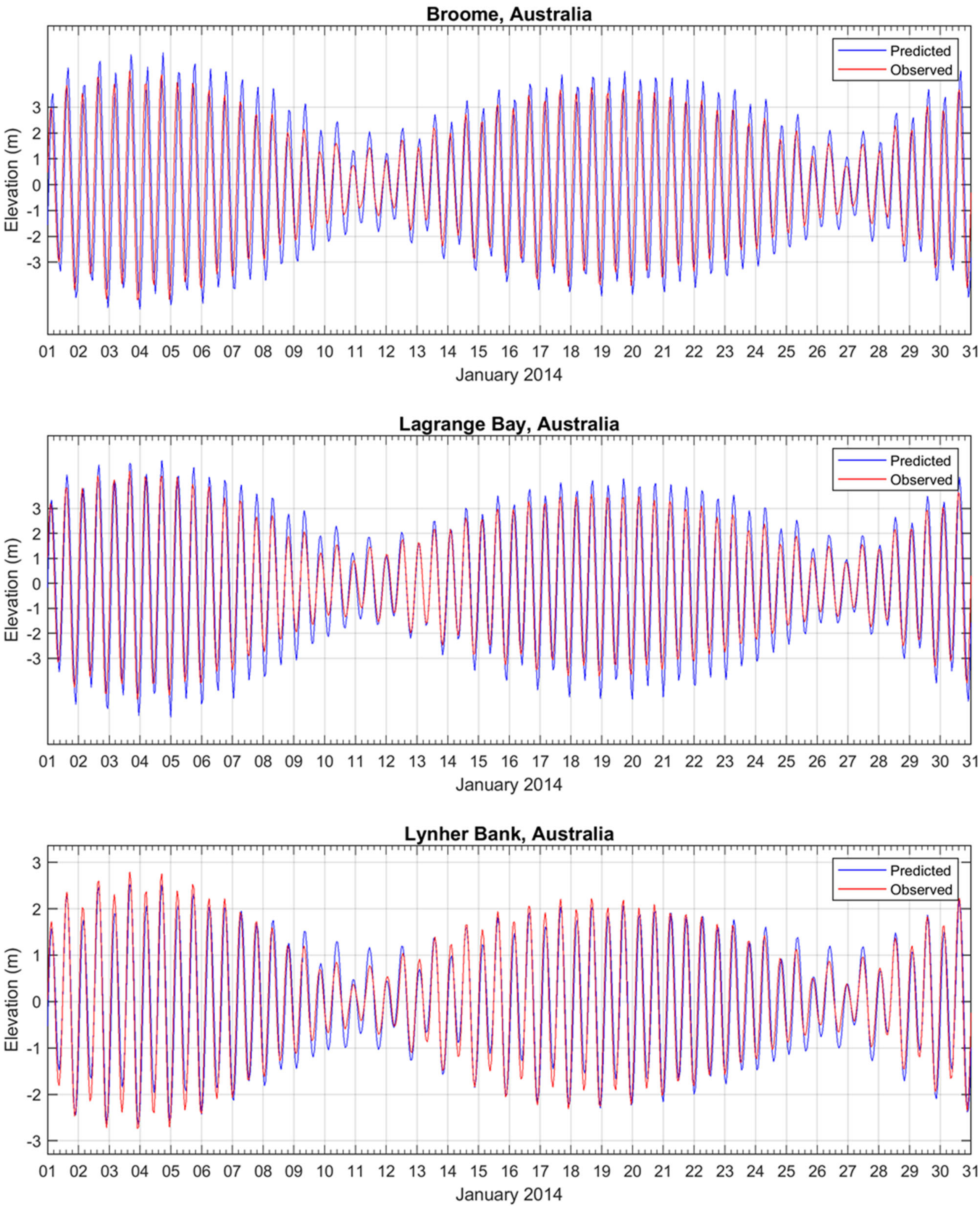

Figure 2.4 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

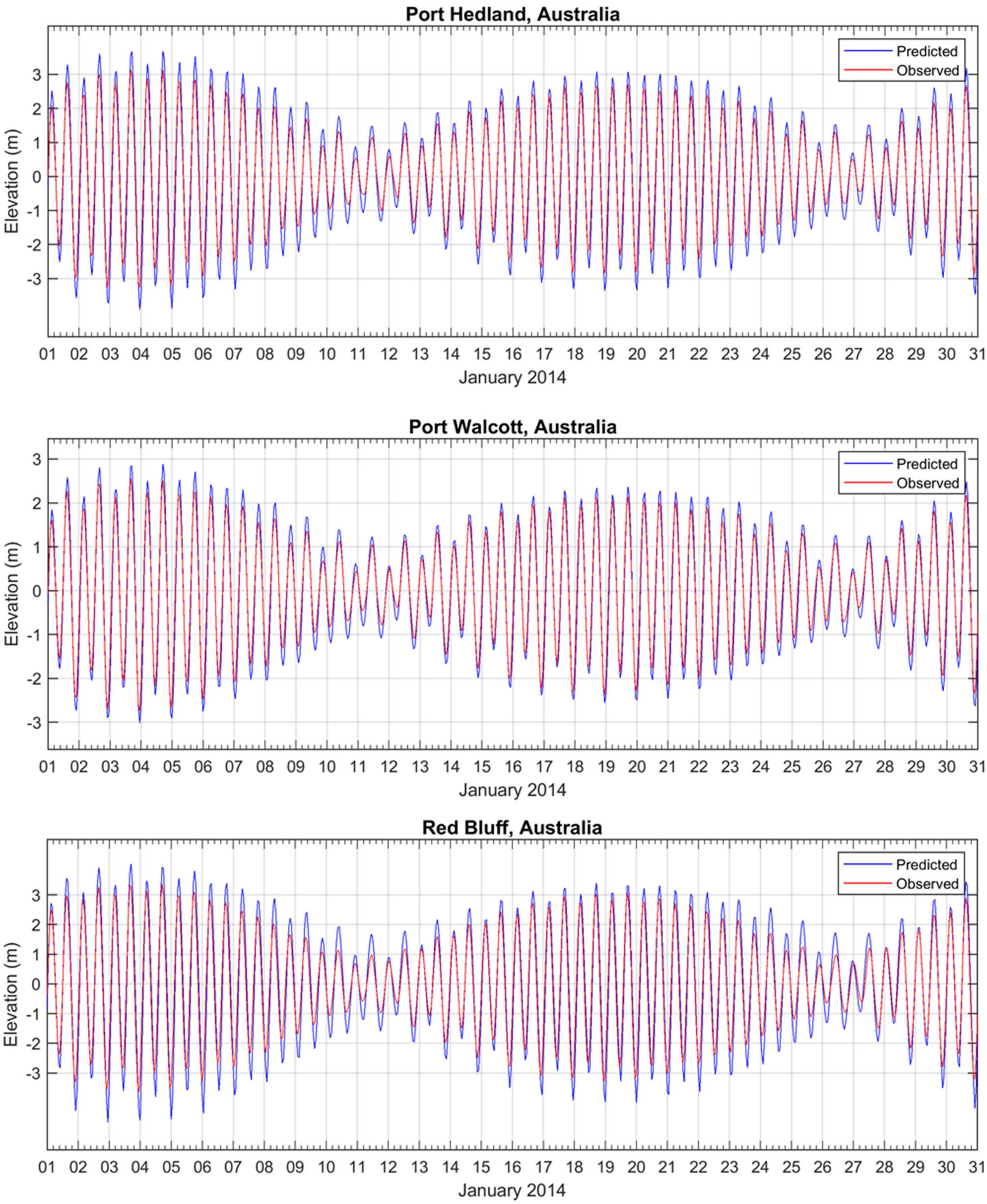

Figure 2.5 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

2.3.5 Current Model Validation

Generated current data were compared against current measurements within the Dorado Development area, using quantitative and visual comparisons at a range of depths.

Time series comparisons of the predicted and measured current speed and direction components at water depths of 40 m, 70 m and 110 m are presented in Figure 2.6, Figure 2.7 and Figure 2.8, respectively, for a two month period (January and February 2018). The time series comparisons reveal that the predicted currents offer a good match with the measured current speed and direction components at all water depths, with the magnitudes and timings of the peaks and troughs matching well.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001). The RMAE is relatively low in all depth layers indicating that the magnitude and range of current speeds match well, however, a slight overprediction of the predicted current magnitude is evident at times.

To compare directionality, roses for the predicted and measured currents at 40 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.9. The roses show that the predicted current direction is a good match with the measured direction. Both the predicted model direction and the measured data direction were in good alignment at each depth layer, portraying a dominant current direction along a northwest/southeast axis. The range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Dorado Development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Dorado Development.

Table 2.2 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds and directions at various depths at the Dorado Development area (January and February 2018).

Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
40 m	0.26	0.71	36.7	Good
70 m	0.26	0.80	29.9	Very good
110 m	0.26	0.85	27.9	Very good

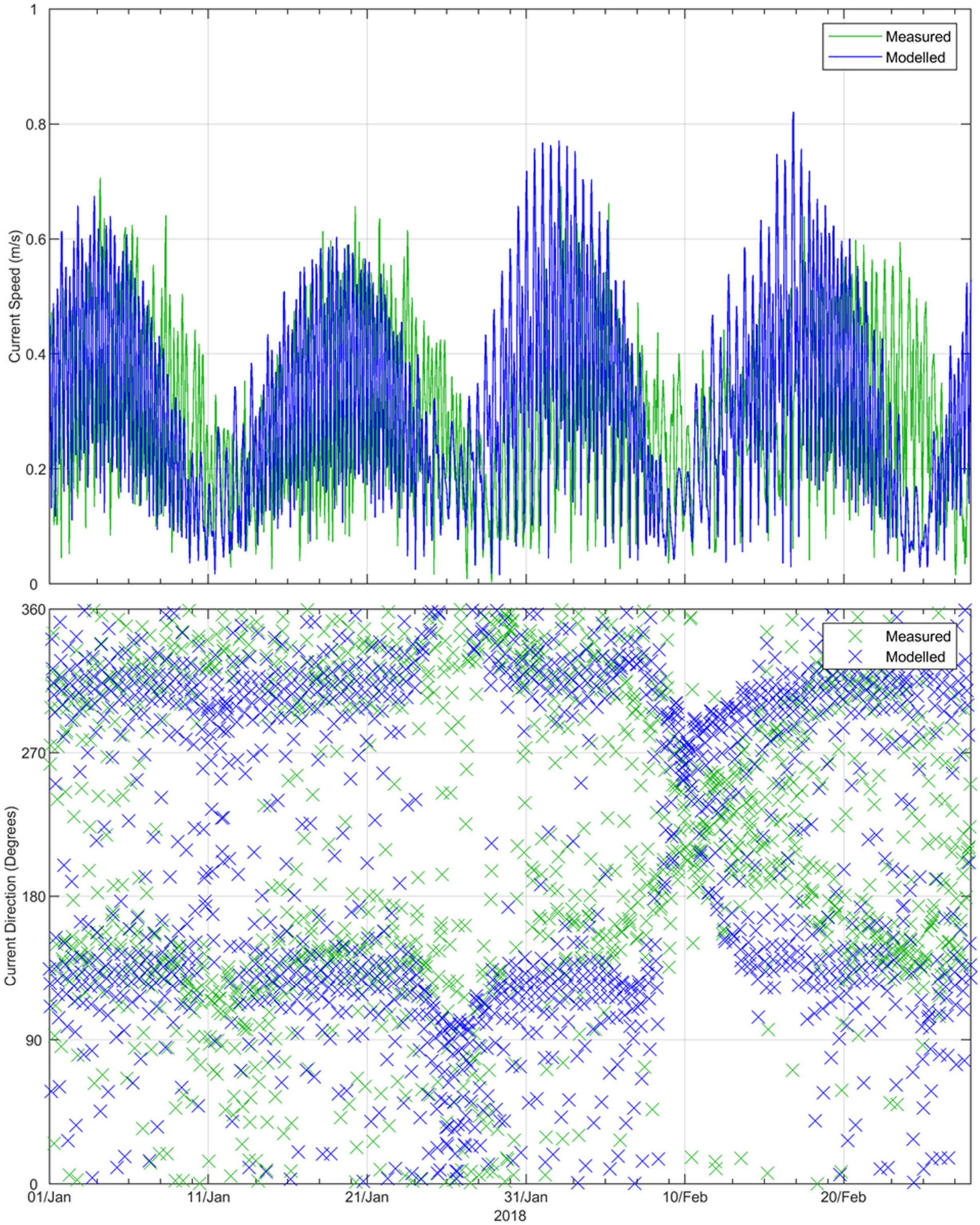

Figure 2.6 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 40 m for January and February 2018.

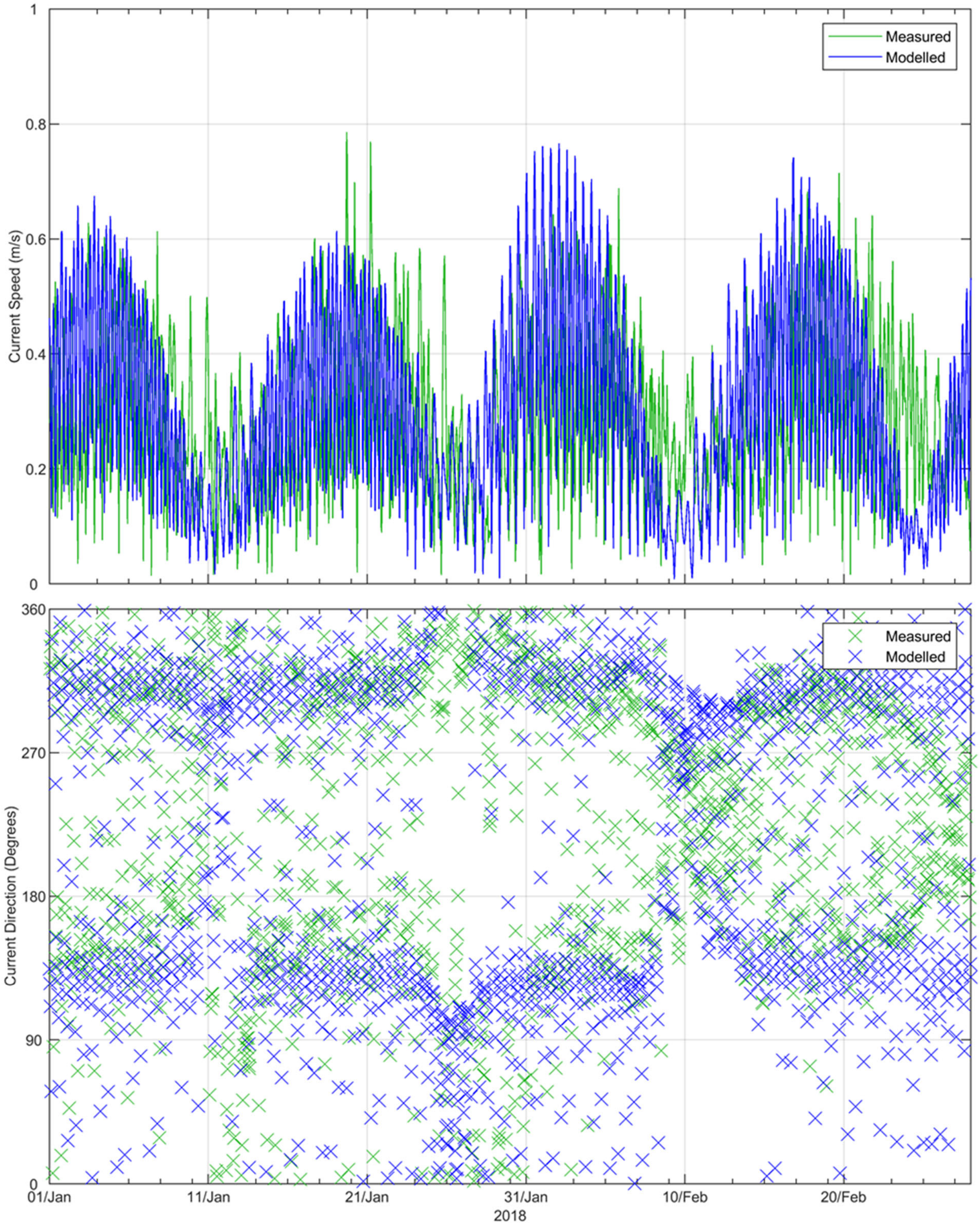

Figure 2.7 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 70 m for January and February 2018.

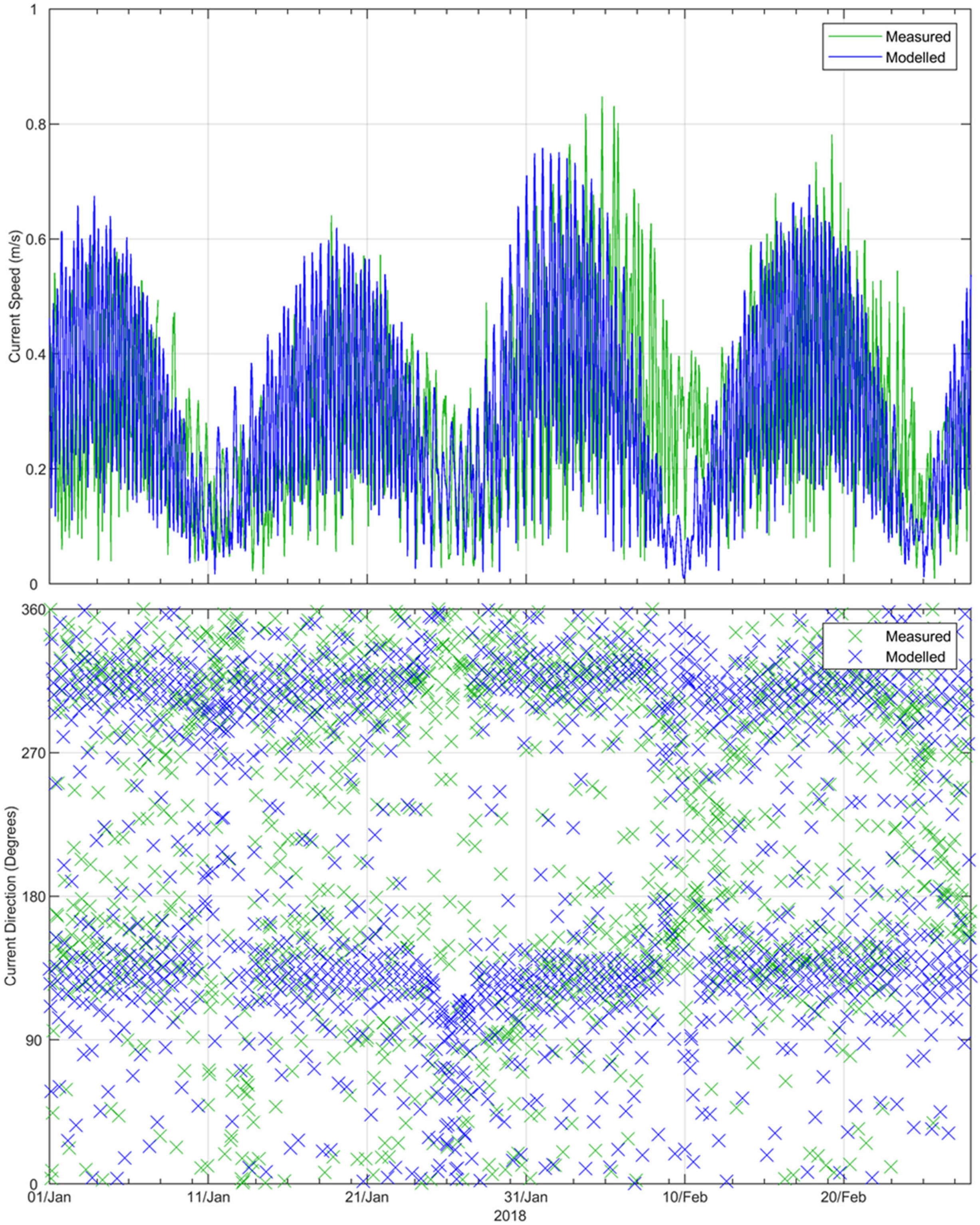

Figure 2.8 **Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 110 m for January and February 2018.**

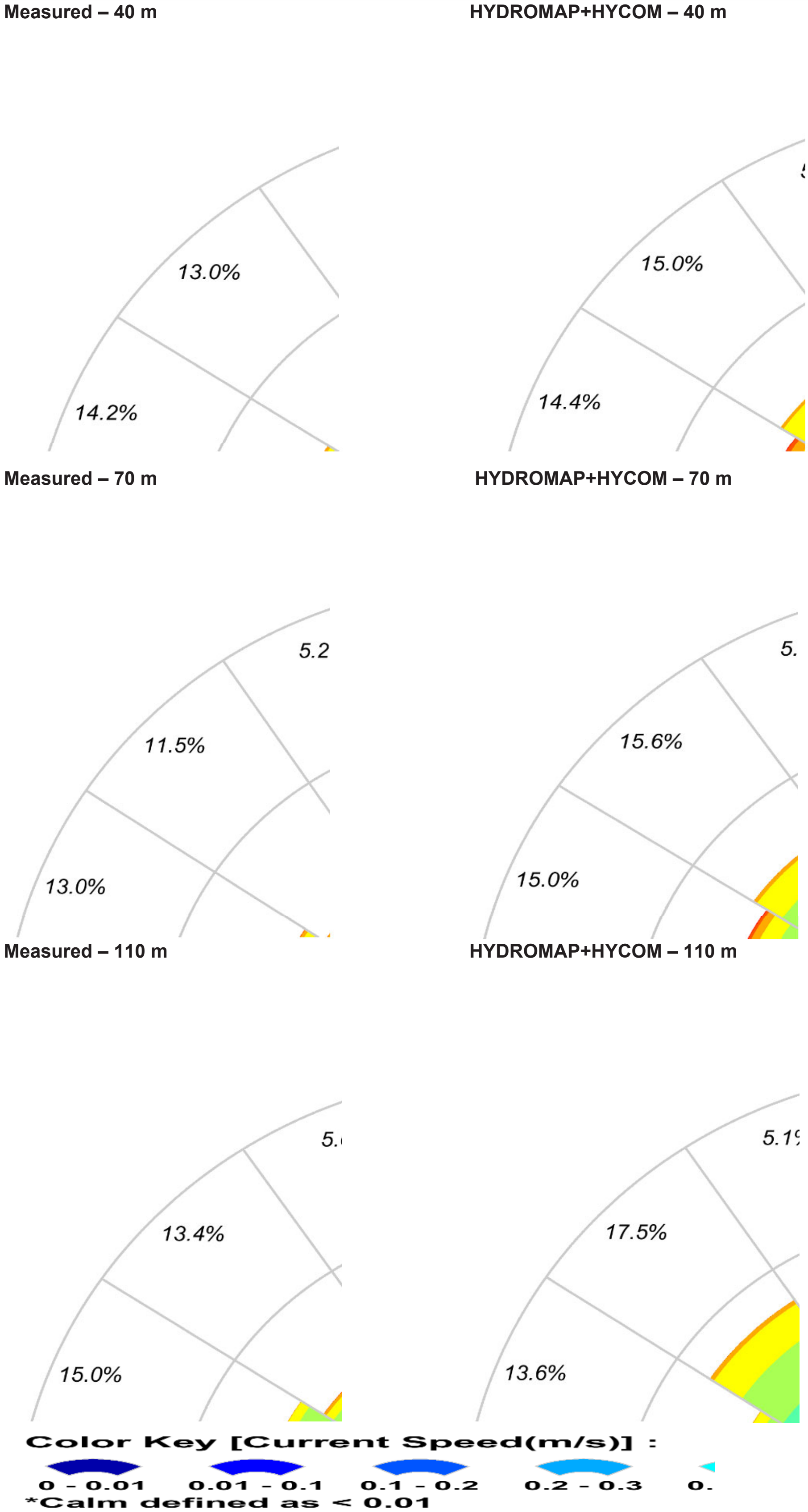

Figure 2.9 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Dorado Development area (2017-2018) at depths of approximately 40 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.4 Surface Currents

Table 2.3 displays the predicted monthly average and maximum surface current speeds adjacent to the release site, while Figure 2.10 and Figure 2.11 show monthly, seasonal and total surface current rose distributions from 2009 – 2018 (inclusive). The currents are from the combination of HYCOM large-scale ocean currents and HYDROMAP tidal currents to account for the total drift throughout the model domain.

Note the convention for defining current direction is the direction the current flows **towards**, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow to the corresponding direction.

The surface modelled current data indicated a consistent monthly average of approximately 0.3 m/s and a dominant current direction towards the northwest and east-southeast to southeast throughout the year, while maximum current speeds varied between 0.70 m/s (November) to 1.42 m/s (October).

Table 2.3 Predicted average and maximum surface current speeds adjacent to the release locations. Data derived by combining HYCOM ocean data and HYDROMAP tidal data from 2009-2018 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.30	0.86	East-southeast (variable)
	February	0.31	1.32	Northwest
	March	0.32	1.41	Northwest
Transitional	April	0.31	1.07	Northwest and West-northwest
Winter	May	0.30	0.91	West-northwest
	June	0.29	0.81	West-northwest
	July	0.31	0.88	West-northwest and northwest
	August	0.31	0.89	Northwest
Transitional	September	0.32	0.91	Northwest and Southeast
Summer	October	0.29	1.42	Northwest
	November	0.26	0.70	Northwest
	December	0.26	0.72	East-southeast (variable)
	Minimum	**0.26**	**0.70**	
	Maximum	**0.32**	**1.42**	

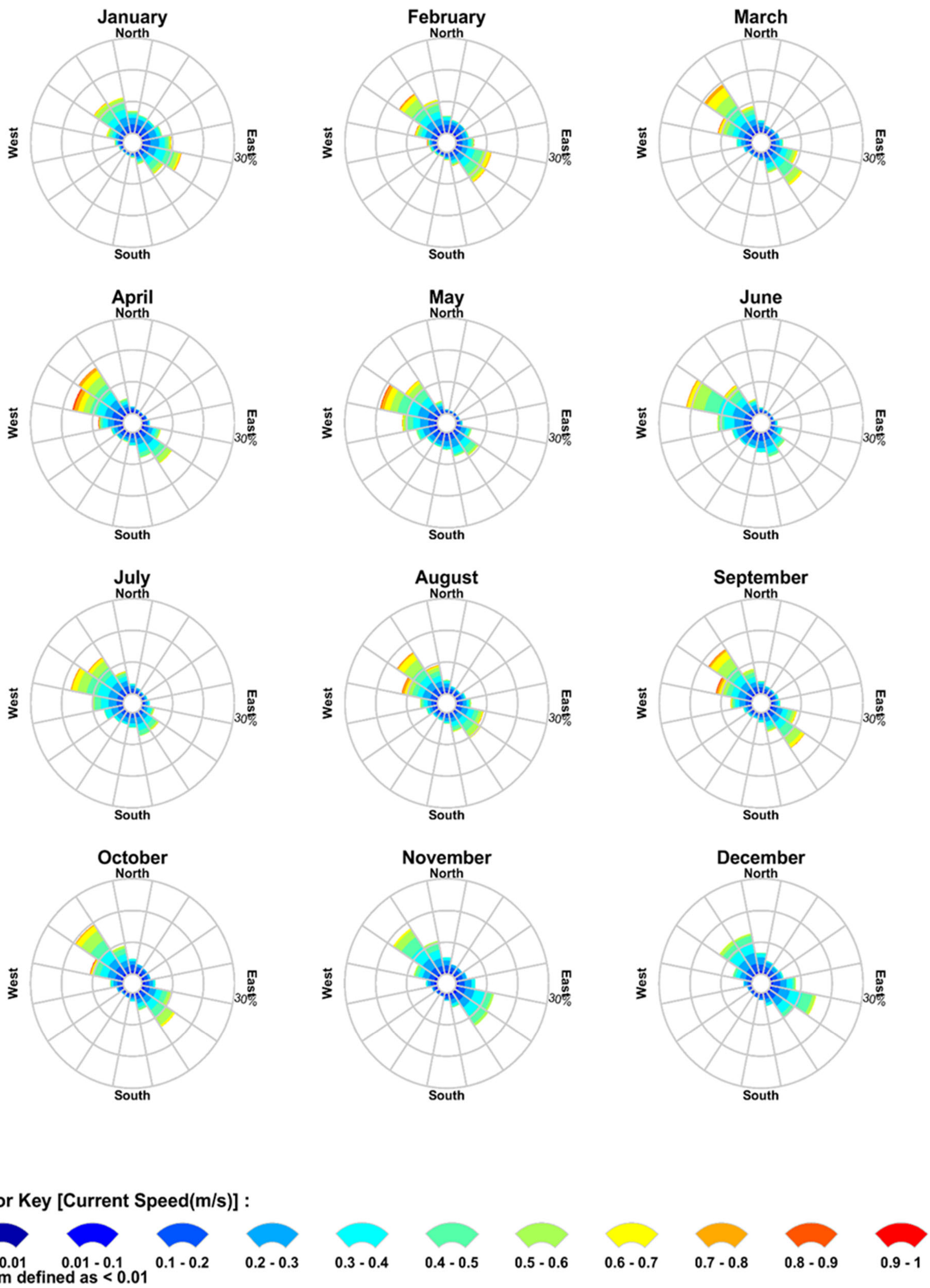

Figure 2.10 Monthly current distribution (2009-2018, inclusive) derived from the HYCOM database near the release site. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

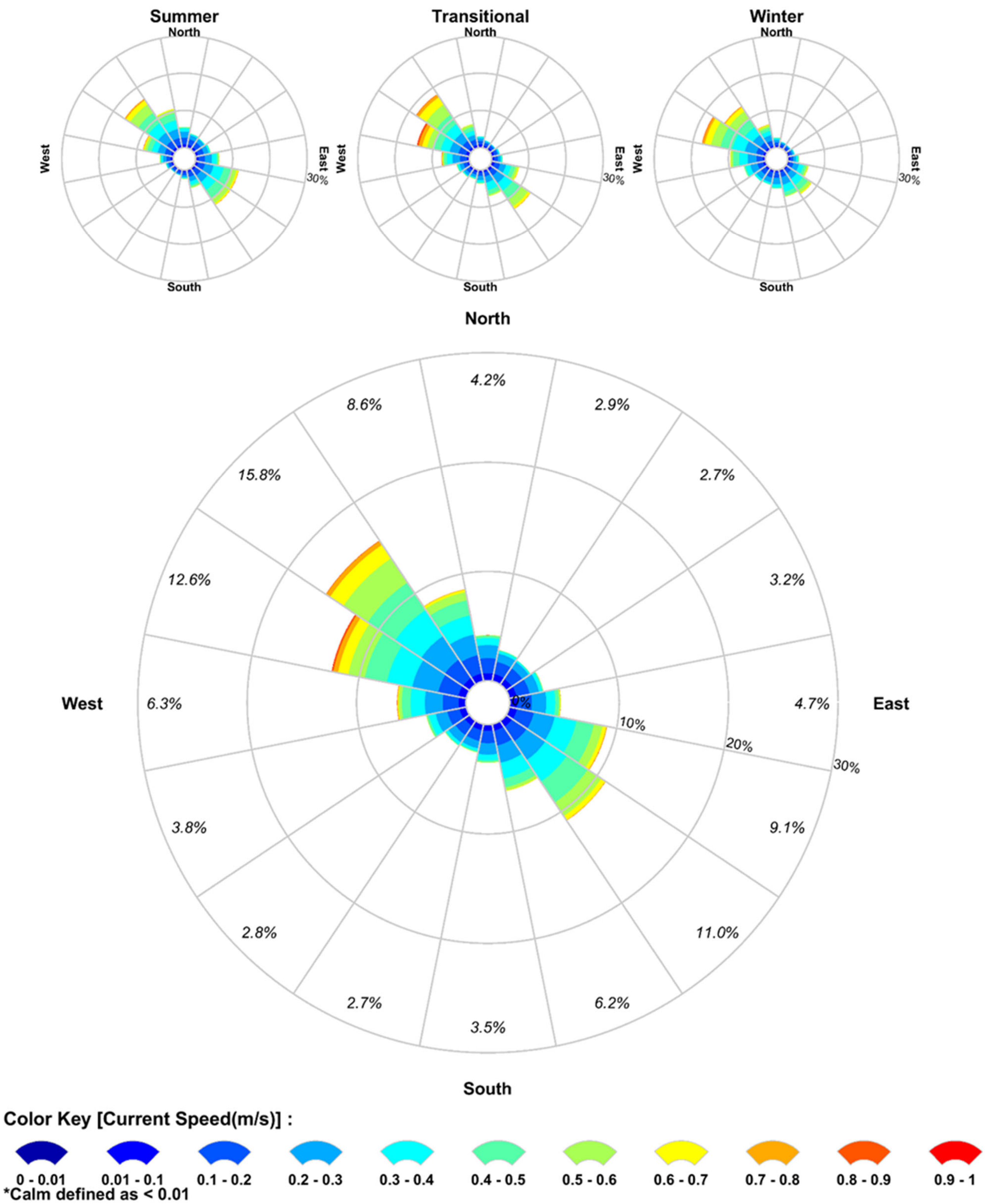

Figure 2.11 Seasonal (top) and total (bottom) current distribution (2009-2018, inclusive) derived from the HYCOM database near the Dorado Development area. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

While the site is dominated by the tide, it can be episodically affected by the ocean currents. Therefore, in order to examine the potential range of variability, the study considered the interannual variability. The Southern Oscillation Index (SOI) data sourced from the Australian Bureau of Meteorology was used to identify interannual trends over the same 10 years as the current data set (2009 – 2018 (inclusive)). The SOI broadly defines Neutral, El Niño (sustained negative values of the SOI below −8 often indicate El Niño episodes) and La Niña (sustained positive values of the SOI above +8 are typical of La Niña episodes) conditions based on differences in the surface air-pressure between Tahiti on the eastern side of the Pacific Ocean and Darwin (Australia), on the western side (Rasmusson and Wallace, 1983; Philander, 1990). El Niño episodes are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean and a decrease in the strength of the Pacific trade winds. La Niña episodes are usually associated with converse trends (i.e. increase in strength of the Pacific trade winds). The three phases (Neutral, El Niño and La Niña) are referred to as the El Nino-Southern Oscillation (ENSO) events.

Figure 2.12 shows the SOI monthly values for 2009 – 2018 (inclusive). Based on the SOI assessment, 2010 was selected as a representative El Niño year, 2012 was selected as a representative Neutral year, and 2015 was selected as a La Niña year.

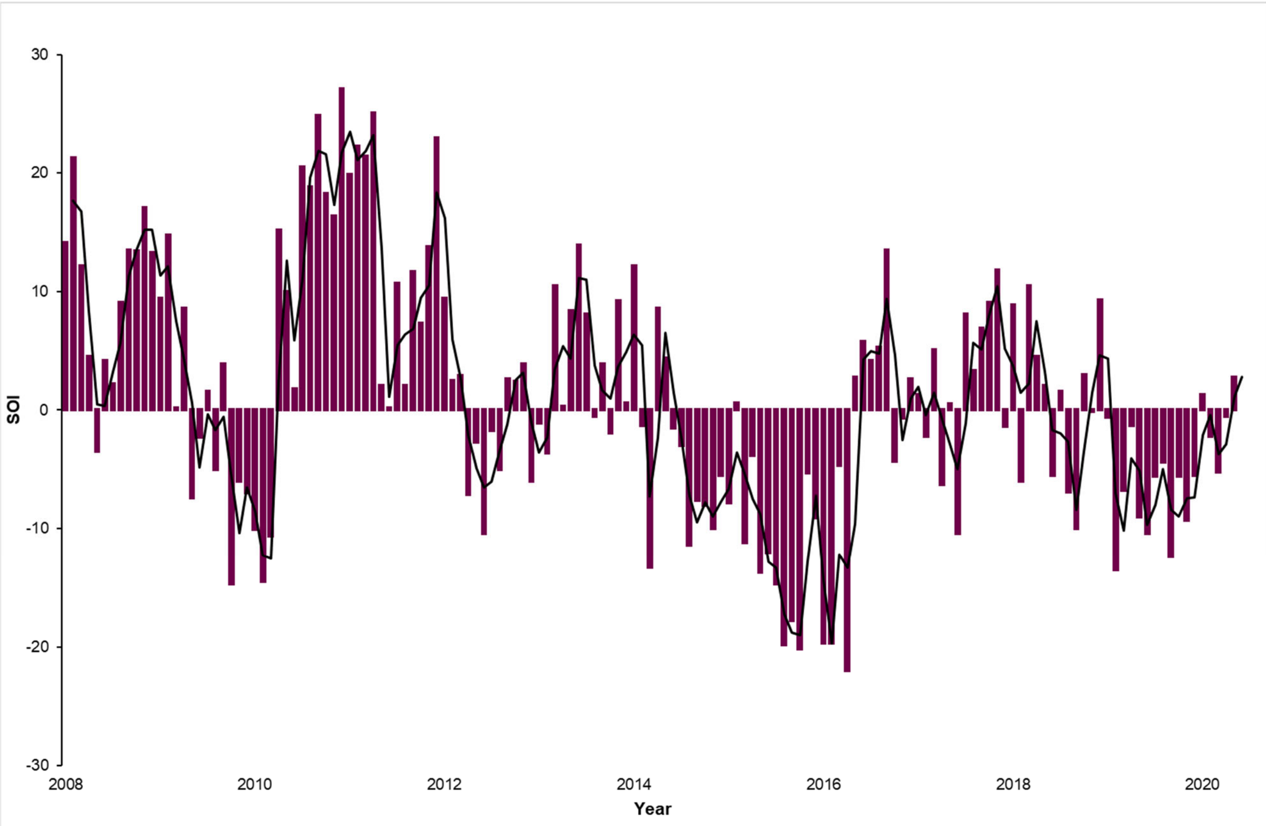

Figure 2.12 Monthly values of the SOI 2008-2020 (inclusive). Sustained positive values indicate La Niña conditions, while sustained negative values indicate El Niño conditions (sourced from Australian Bureau of Meteorology, 2020).

3 MODELLING METHODS

3.1 Sediment Dispersion Model: MUDMAP

MUDMAP is a three-dimensional plume model used by industry and regulators to aid in assessing the potential environmental effects from discharges such as drill cuttings and drilling fluids. The model has been applied to hundreds of assessments in over 35 countries, including Australia.

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near-field (i.e. the immediate area of the discharge) and the far-field (the wider region). Figure 3.1 shows a conceptual diagram of the dispersion and fates of drill cuttings and fluids discharge to the ocean.

Settling under currents is selective for particle size, with the larger particles (rocks, gravel to sand) tending to settle quickly, forming a pile that aligns with the predominant current axis. Smaller particles (especially silts and clays) tend to remain suspended for exponentially longer time periods and will therefore be dispersed more widely by local currents. Dispersion of the finer discharged material will tend to be enhanced with increased current speeds and water depth, and with greater variation in current direction over time and depth.

MUDMAP can simulate up to six classes of discharged drilling material (each with up to 6 sub-categories, for a total of 36 sub-categories). Each material class can be set up with a unique density and particle-size distribution. During the dispersion stage, particles are transported in three dimensions according to the current data and horizontal and vertical dispersion coefficients at each time step, following the governing equations.

MUDMAP has been extensively validated and applied for discharge operations in Australian coastal and ocean waters, and around the world (e.g. Burns et al., 1999; Spaulding, 1994; King & McAllister, 1997, 1998).

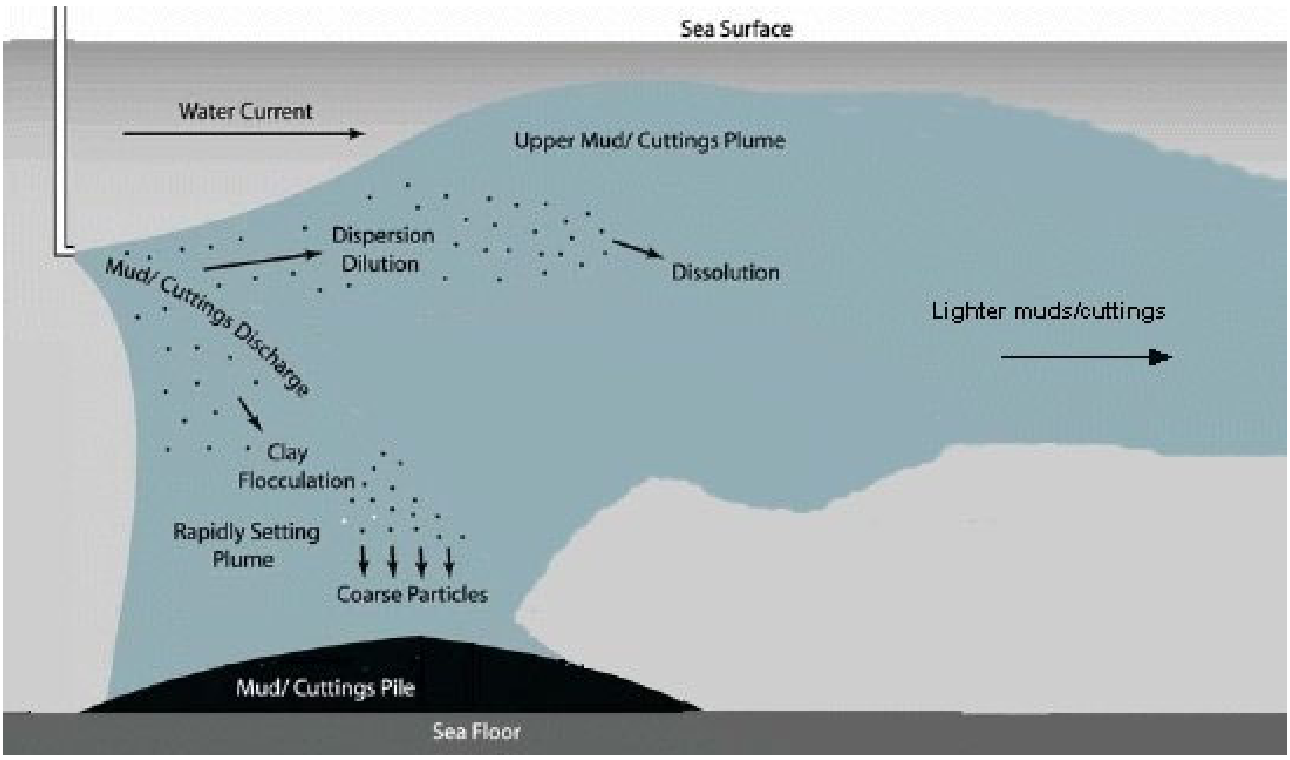

Figure 3.1 Conceptual diagram showing the general behaviour of cuttings and muds discharged to the ocean (modified from Neff, 2005).

3.2 Discharge Program

Santos indicated that the Dorado Development is expected to comprise of five drilling intervals: Conductor, Surface Hole, Intermediate Hole, 12 ¼” Production Hole and 8 ½” Production Hole. Santos has indicated that the 12 wells will be drilled using a conventional monobore design.

Drilling operations will be conducted as two separate stages:

- Conductor and surface hole sections; and
- Intermediate and production hole sections

Conductor and surface hole sections for the 12 wells will be batch drilled in the first stage.

Following the drilling of the Conductor and Surface Hole sections (12 wells), the wells will be drilled sequentially in 3 intervals (Intermediate, 12 ¼” Production and 8 ½” Production).

The Conductor and Surface well intervals (36” and 26” bore diameter) will be drilled using Seawater+Pre-Hydrated Gel Sweeps. The extracted drill cuttings and drilling muds will be discharged directly to the seafloor during the Conductor well interval, while the cuttings and drilling muds for the Surface interval will be brought up to the surface (diverter expected to be used). A riser will then be installed for the remainder of the drilling to circulate the cuttings and muds to the drilling rig, where cuttings will be separated before cuttings and muds are discharged through a vertically orientated pipe above the sea surface. With the riser in place, Water Based Mud (WBM) will be used in the drilling of the Intermediate Hole (17.5” bore diameter), Production Hole (12.25” bore diameter) and Production Hole (8.5” bore diameter) intervals.

Table 3.1 Summary of the estimated volumes of discharged drill cuttings and unrecoverable mud solids for each well interval for a single well.

Well Interval	Hole Diameter (inches)	Discharge Method	Cuttings Volume Discharged (m^3)	Muds (Solids Only)		Discharge Duration (days)
				Type	Volume Discharged (m^3)	
Conductor	36	Returned directly to the seafloor	82	Seawater/Gel	23	1
Surface Hole	26	Cuttings brought to surface (diverter expected to be used)	385	Seawater/Gel	108	2
Intermediate Hole	17.5	Cuttings brought to drilling rig, then discharged to surface	330	WBM	97	5
12.25” Production Hole	12.25	Cuttings brought to drilling rig, then discharged to surface	214	WBM	112	7
8.5” Production Hole	8.5	Cuttings brought to drilling rig, then discharged to surface	46	WBM	57	3
Totals			**1,057**	**-**	**397**	**18**

Note: Only discharged solids used as model input.

WBM – Water Based Mud.

Table 3.2 provides a summary of the proposed drilling schedule, provided by Santos, which was modelled.

Table 3.2 Summary of the proposed drilling schedule.

Activity	Discharge Duration	Total duration
Batch drilling 36" hole section for all 12 wells	1 day of cuttings discharge every 2 days	23 days
Batch drilling 26" hole section for all 12 wells	2 days of cuttings discharge every 4 days	52 days
Well 1		
Drill 17.5" intermediate hole section	5 days of cuttings discharge, then no discharge for 5 days (running casing etc)	10 days
Drill 12.25" production hole section	7 days of cuttings discharge, then no discharge for 6 days (running casing etc)	13 days
Drill 8.5" production hole section	3 days cuttings discharge, then no discharge for 18 days (running casing, wireline logs etc)	21 days
Well 2		
Drill 17.5" intermediate hole section	5 days of cuttings discharge, then no discharge for 5 days (running casing etc)	10 days
Drill 12.25" production hole section	7 days of cuttings discharge, then no discharge for 6 days (running casing etc)	13 days
Drill 8.5" production hole section	3 days cuttings discharge, then no discharge for 18 days (running casing, wireline logs etc)	21 days
Well 3		
Drill 17.5" intermediate hole section	5 days of cuttings discharge, then no discharge for 5 days (running casing etc)	10 days
Drill 12.25" production hole section	7 days of cuttings discharge, then no discharge for 6 days (running casing etc)	13 days
Drill 8.5" production hole section	3 days cuttings discharge, then no discharge for 18 days (running casing, wireline logs etc)	21 days
Well 4		
Drill 17.5" intermediate hole section	5 days of cuttings discharge, then no discharge for 5 days (running casing etc)	10 days
Drill 12.25" production hole section	7 days of cuttings discharge, then no discharge for 6 days (running casing etc)	13 days
Drill 8.5" production hole section	3 days cuttings discharge, then no discharge for 18 days (running casing, wireline logs etc)	21 days

Repeat of each well through to 12 Wells…

3.3 Discharge Input Data

The input data used to set up the dispersion model included:

- Volumes and discharge durations of the cuttings and unrecoverable drilling muds;
- Particle size distributions measured during a recent drilling campaign, and associated settling velocities;
- Bulk density of the released material;
- Temperature and salinity profiles of the receiving waters;
- The height of the discharge points relative to mean sea level;
- Current data to represent local physical forcing.

Table 3.3 provides a summary of the discharge configuration and the estimated volumes of cuttings and muds used as input into the discharge model.

As per the proposed drilling schedule, modelling was first carried out for the Conductor hole sections which will incorporate 984 m^3 of drill cuttings and 274 m^3 of drilling muds discharged at the seabed over 12 days (23 days of operation). Followed by the Surface hole sections which will also be batch drilled with 4,620 m^3 of drill cuttings and 1,296 m^3 of drilling muds discharged at the seabed over 24 days (52 days of operation). Lastly, modelling was carried out for the remaining hole sections (Intermediate, 12 ¼" Production and 8 ½" Production) for the 12 wells which will be drilled sequentially and comprised of a total of 7,080 m^3 of drill cuttings and 3,192 m^3 of drilling muds were discharged from the surface over 180 days (528 days of operation).

Table 3.3 Key inputs to the drill cuttings and unrecoverable mud solids dispersion modelling.

Parameter	Dorado Development wells
Volume of cuttings discharged (m^3) (1 Well)	1,057
Volume of muds discharged (m^3) (1 Well)	397
Volume of cuttings discharged (m^3) (12 Wells)	12,684
Volume of muds discharged (m^3) (12 Wells)	4,764
Density of drill cuttings (kg/m^3)	2,601
Density of drilling WBM (kg/m^3)	4,200
Discharge duration (days) (1 Well)	18
Discharge duration (days) (12 Wells)	216
Depth of seafloor discharges	2 m above the seabed
Depth of surface discharges	at the surface
Sea surface discharge pipe orientation	Vertical
Sea surface discharge pipe diameter (inches)	8" [0.203 m]

3.4 Geotechnical Information

The drill cuttings material was based on samples collected by Santos for each of the hole sizes. A large proportion of the material sampled across the various hole sizes consisted of coarse material (>250 µm). The collected samples were sieved to separating the cuttings that were <250 µm which were then placed into a Particle Size Distribution (PSD) machine.

The most critical geotechnical information required as input into the modelling is PSD data for the finer material. The resultant PSDs for each hole size have been redistributed to match the material size classes and used in the MUDMAP model, as shown in Table 3.4.

For the top two intervals (36" and 26"), most of the material is medium and coarse sand/gravel sized (94.11%) with the remaining distributed between the clay to fine sand classes. The proportion of coarse sand/gravel steadily reduces over the next three hole sections with more material distributed between the clay to fine sand classes.

Table 3.4 Drill cuttings PSD's broken down into material classes for each well interval.

Sediment Grain Size Class	Size Range (µm)	Conductor (36") (%)	Surface Hole (26") (%)	Intermediate Hole (17 ½") (%)	Production (12 ¼") (%)	Production (8 ½") (%)
Medium Clay	0.06-0.63	0.45	0.45	1.20	0.00	0.00
Coarse Clay	0.63-2	2.75	2.75	7.38	1.24	2.06
Fine Silt	2-6.3	0.98	0.98	2.58	2.91	6.05
Medium Silt	6.3-20	0.41	0.41	1.03	8.87	20.35
Coarse Silt	20-63	0.63	0.63	1.70	10.58	27.18
Fine sand	63-250	0.66	0.66	1.70	30.33	27.38
Medium sand	250-500	2.31	2.31	6.13	22.80	9.22
Coarse sand	500-2000	91.80	91.80	78.28	23.27	7.77

The drilling muds material was also based on samples collected and supplied by Santos. The PSD data indicated that all the solids material in the drilling muds consisted on fines (<250 µm). The geotechnical information for the PSDs of each sample was again redistributed to match defined sediment grain size classes and then averaged across all samples (Table 3.5).

Most of the material is fine to coarse silt sized (87.22%) with the remaining material distributed across the finer (clay) and coarser (fine sand) ends of the supplied PSDs. The same distribution of muds was assumed across all the well intervals.

Table 3.5 Drilling muds PSD's broken down into material classes for each well.

Sediment Grain Size Class	Size Range (µm)	Conductor (36") (%)	Surface Hole (26") (%)	Intermediate Hole (17 ½") (%)	Production (12 ¼") (%)	Production (8 ½") (%)
Medium Clay	0.06-0.63	1.04	1.04	1.04	1.04	1.04
Coarse Clay	0.63-2	7.46	7.46	7.46	7.46	7.46
Fine Silt	2-6.3	22.18	22.18	22.18	22.18	22.18
Medium Silt	6.3-20	36.20	36.20	36.20	36.20	36.20
Coarse Silt	20-63	28.84	28.84	28.84	28.84	28.84
Fine sand	63-250	4.53	4.53	4.53	4.53	4.53

3.5 Grid Configuration

A uniformly sized rectangular grid covering a 20 km (longitude, x-direction) by 20 km (latitude, y-direction) region around the well location was employed to calculate the concentration of drill cuttings and muds in the water column and on the seafloor. The resolution of each grid cell was approximately 20 m (x) x 20 m (y) x 5 m (z).

3.6 Mixing Parameters

The horizontal and vertical dispersion coefficients are used in dispersion modelling to represent the mixing and diffusion processes caused by turbulence, which are sub-grid processes at the scale of the hydrodynamic model drivers. The dispersion coefficients are expressed in units of rate of area of change (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations. Increasing the vertical dispersion coefficient spreads the discharge further across the vertical layers.

The horizontal turbulent diffusion of the plume is dependent on the hydrodynamic conditions (i.e. wind, wave and current) and the physical scale of the plume compared to the scales of the oceanic processes that disperse the plume. For a plume of approximately 10-100 m width, dispersion occurs primarily through small-scale horizontal swirling motions and vertical mixing, with a horizontal dispersion rate of the order of 0.1 m^2/s. As the plume grows to a scale of 1-10 km, it begins to be subject to mesoscale eddies and horizontal dispersion rate becomes of the order of a few to tens of m^2/s. At even larger scales, the plume would be larger than the mesoscale eddies and eddy mixing becomes the dominant mechanism, with a rate of horizontal dispersion 100-1,000 m^2/s.

For this project, with an open ocean environment and length scales of 10 m to 1 km, a horizontal diffusion rate of 0.25 m^2/s was applied. A value of 0.10 cm^2/s was set for the vertical dispersion coefficient to account for the influence of turbulence within the water column, as well as wave-induced turbulence. The values are based on previous experience and informed by studies by Copeland (1996).

3.7 Reporting Thresholds

The MUDMAP model predicts sediment concentrations and thicknesses to very low levels that may not be of practical and ecological significance; therefore, a series of minimum detectable levels and impact thresholds were defined for reporting of the model-predicted outcomes.

A study by Glen (1997) found that the maximum natural sedimentation rate for Northwest Australia is 223.21 cm/thousand years (or 0.0061 mm/day). As a conservative measure, the natural threshold thickness of 0.1 mm was calculated daily natural sedimentation rate of 0.0061 mm/day by the discharge duration of a single well (18 days).

The thresholds are supported by studies from Trannum et al. (2009) which found a significant decrease in species count, abundance of individuals, and biomass of marine animals with deposited cuttings 3-24 mm. Furthermore, a study by Kjeilen-Eilertsen et al. (2004) reports that depositional thicknesses greater than 9.6 mm are likely to cause smothering impacts on benthic ecosystems, including corals. It is also worth noting that a study by Smit et al. (2008) established that a thickness threshold of greater than 6.5 mm would be needed before potential harm to benthic macrofauna occur.

Table 3.6 presents a summary of the natural and impact threshold levels used in this study for assessment of sedimentation.

Table 3.6 Natural and impact threshold levels for sediment thickness.

Parameter	Natural Threshold Level (mm)	Impact Threshold Level (mm)	
		Low Exposure	High Exposure
Sediment thickness	0.1	1	10

It is important to note that the predicted deposition is quoted as the level above any background deposition process relevant to the Dorado Development. Moderate levels of sediment mobility are expected in this region due to the drift and tidal current magnitudes, and therefore it is expected that these results are conservative (i.e. more sedimentation predicted than would be the case).

4 MODELLING RESULTS

The modelling results from the discharge of drill cuttings and drilling muds from a single well and all twelve wells for each ENSO event are presented in Section 4.1 and Section 4.2, respectively. Section 4.3 present the integrated combined results for the twelve wells.

4.1 Single Well Results for Each ENSO Events

Figure 4.1, Figure 4.3 and Figure 4.5 show the coverage and sediment thicknesses calculated from drill cuttings and drilling muds discharges from a single well (Well-1) during La Niña, Neutral and predominantly El Niño conditions, respectively.

The modelling results demonstrated that larger particles (greater than 0.25 mm diameter) were predicted to settle typically within 1 km from the well, while the currents transported the smaller sediments (less than 0.25 mm) further away from the well.

Table 4.1 shows the predicted maximum sediment thickness, area of coverage and the maximum distance from well location to each threshold for each ENSO event.

The maximum thickness (or height of mound) was predicted to be 126 mm adjacent to the well location during El Niño conditions. The maximum distance from the well to the natural threshold level (≥0.1 mm) was 1,115 m, occurring during Neutral conditions and the corresponding area of coverage was 0.65 km^2. The maximum distances to the low (1-10 mm) and high (≥10 mm) exposure thresholds was 837 m (Neutral conditions) and 251 m (El Niño conditions), respectively. The greatest areas of coverage on the seafloor at the low and high exposure thresholds, was recorded as 0.29 km^2 and 0.02 km^2, respectively.

Table 4.1 Predicted maximum sediment thickness, area of coverage and maximum distance for each threshold resulting from the drill cuttings and drilling muds discharge for Well-1. The results are presented based on each ENSO event.

ENSO event	Maximum Sediment thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)	0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)
La Niña	91	0.66	0.21	0.02	771	451	190
Neutral	112	0.65	0.29	0.00	1,115	837	40
El Niño	126	0.58	0.16	0.01	863	398	251

Figure 4.2, Figure 4.4 and Figure 4.6 show cross-sections of the predicted maximum concentrations within the water column resulting from the drill cuttings and muds discharge from a single well during La Niña, Neutral and predominantly El Niño conditions, respectively.

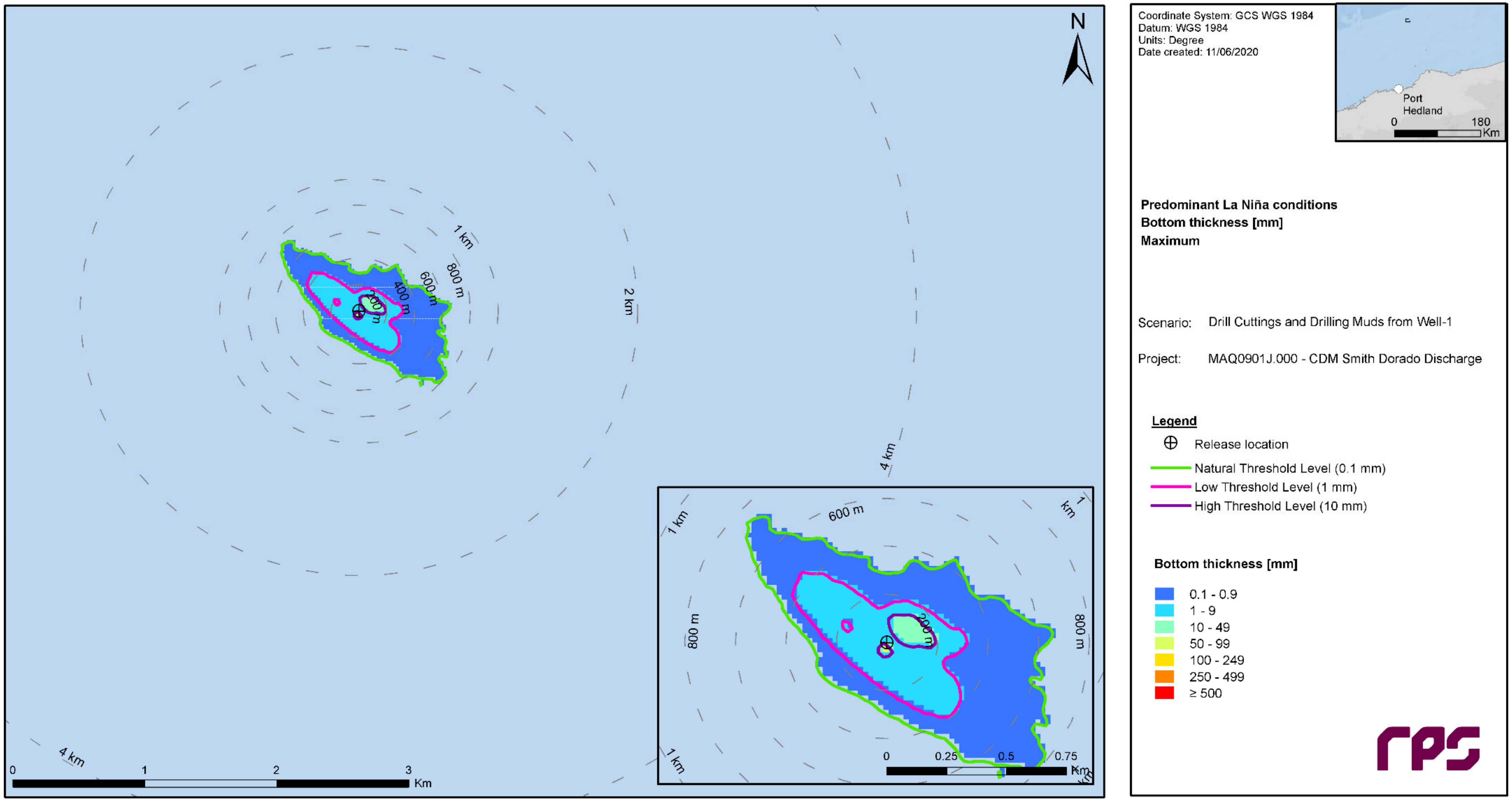

Figure 4.1 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for Well-1 over 18 days commencing in La Niña conditions.

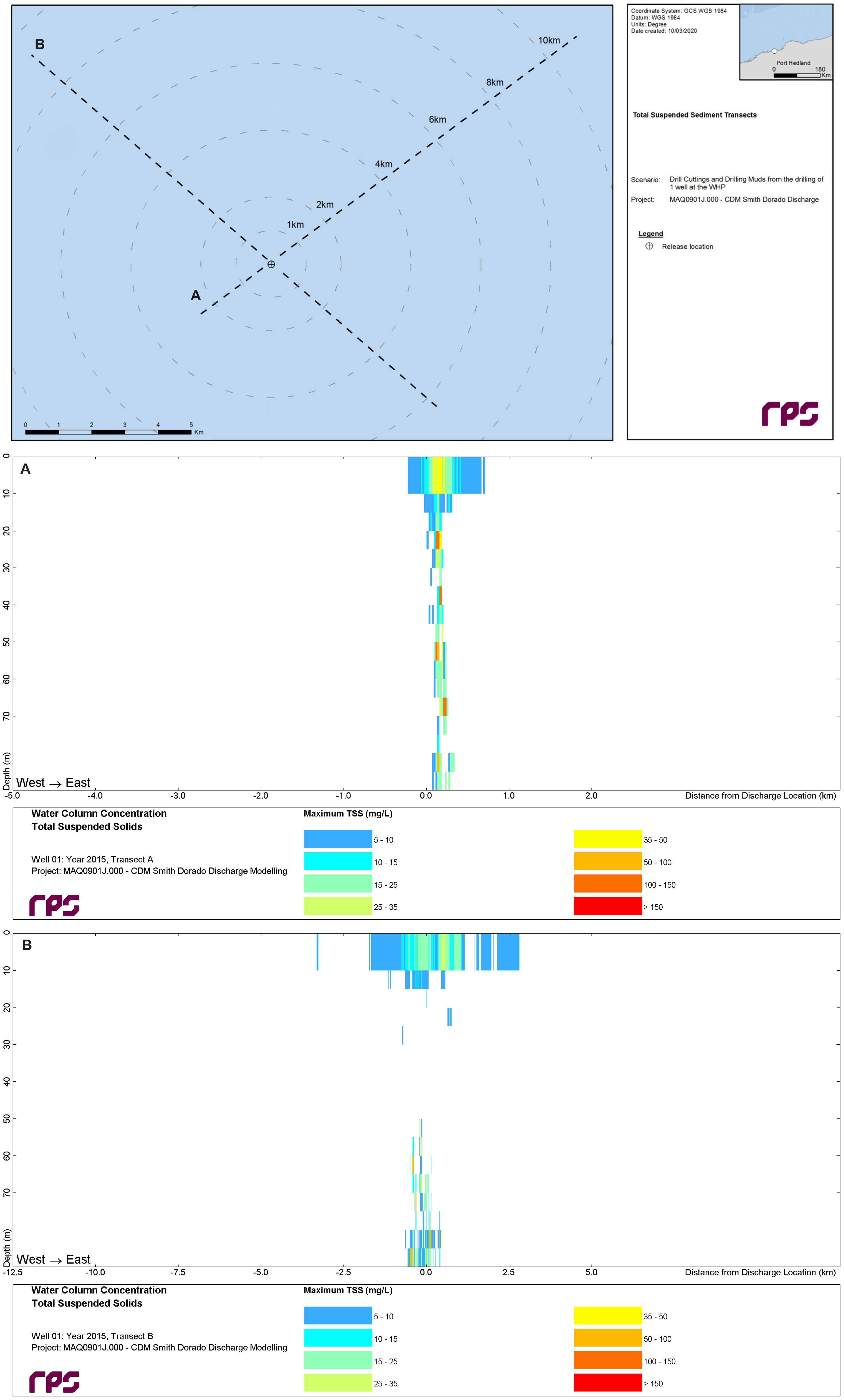

Figure 4.2 Cross-sections (a) east-west and (b) north-south of the predicted maximum suspended sediment concentrations within the water column resulting from the drill cuttings and muds discharges for Well-1 over 18 days commencing in La Niña conditions.

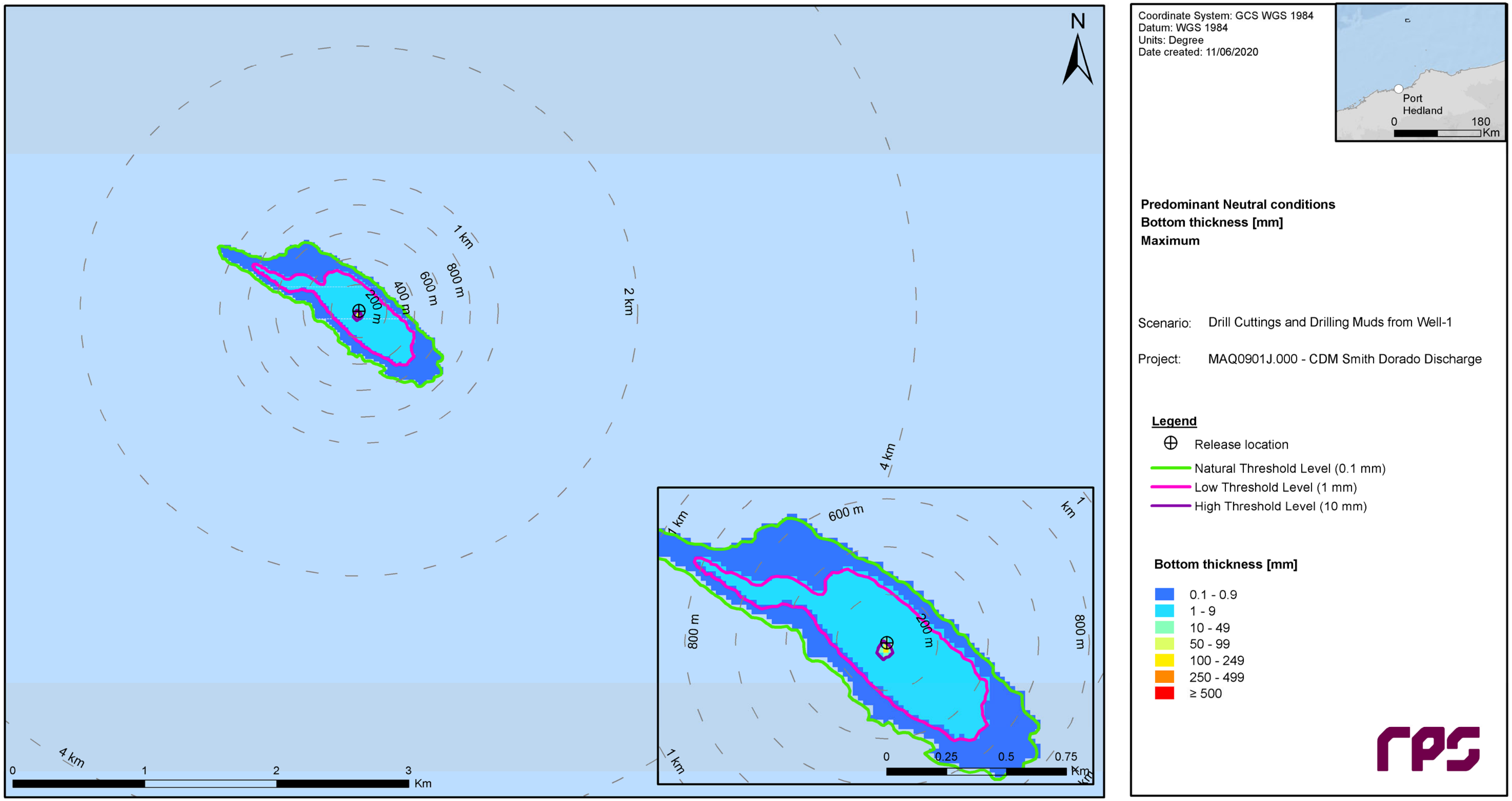

Figure 4.3 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for Well-1 over 18 days commencing in Neutral conditions.

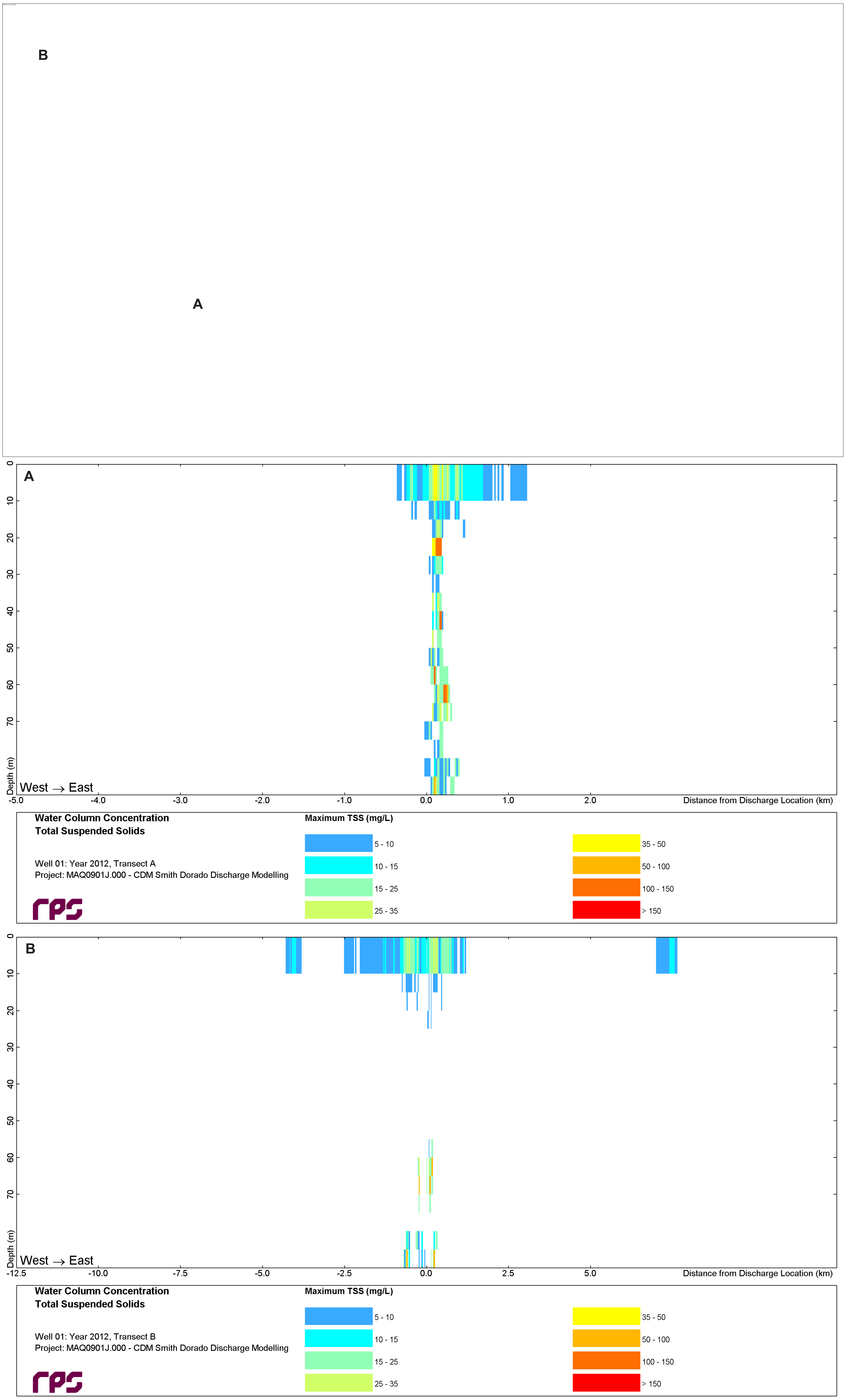

Figure 4.4 **Cross-sections (a) east-west and (b) north-south of the predicted maximum suspended sediment concentrations within the water column resulting from the drill cuttings and muds discharges for Well-1 over 18 days commencing in Neutral conditions.**

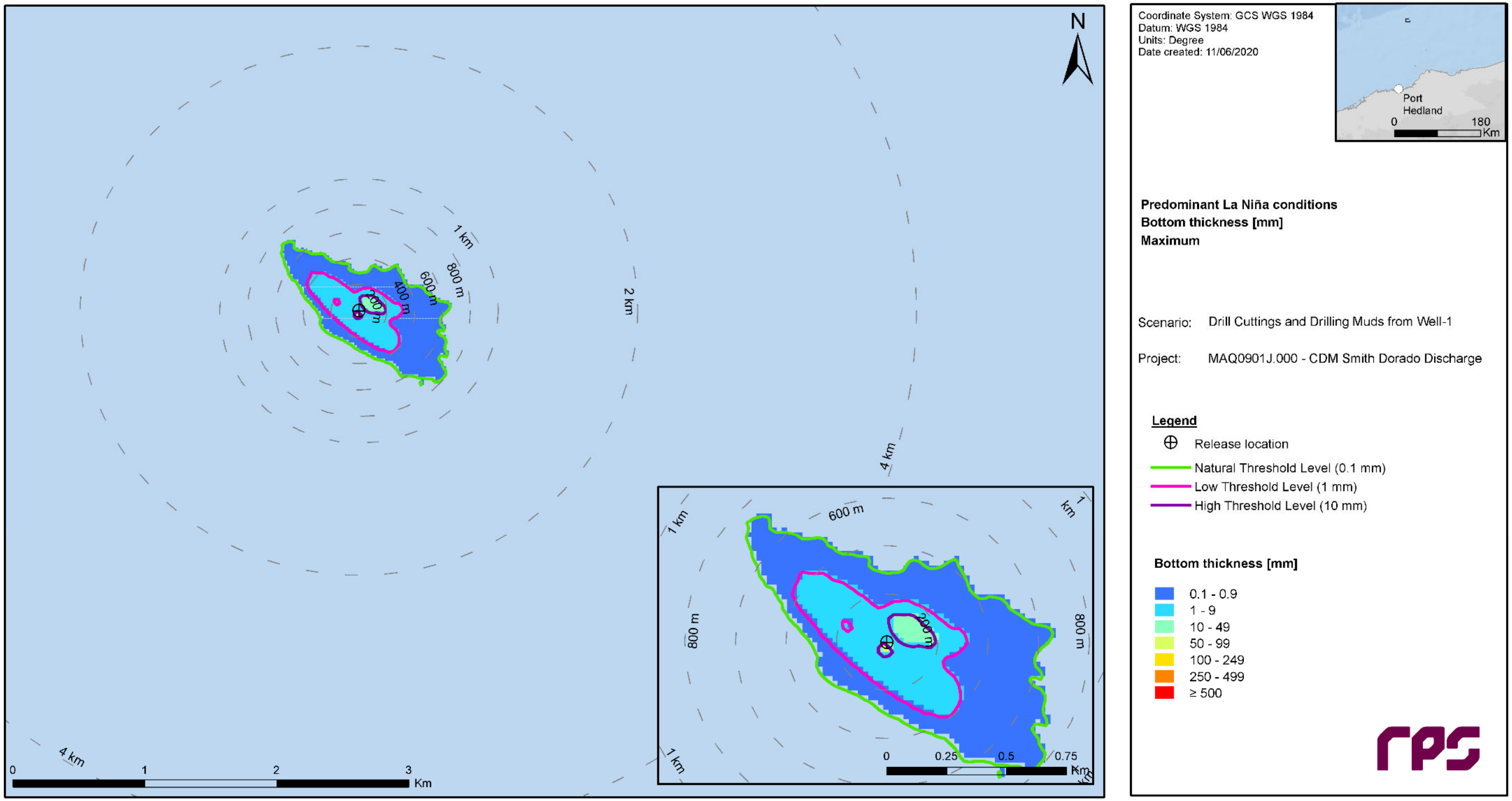

Figure 4.5 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for Well-1 over 18 days commencing in El Niño conditions.

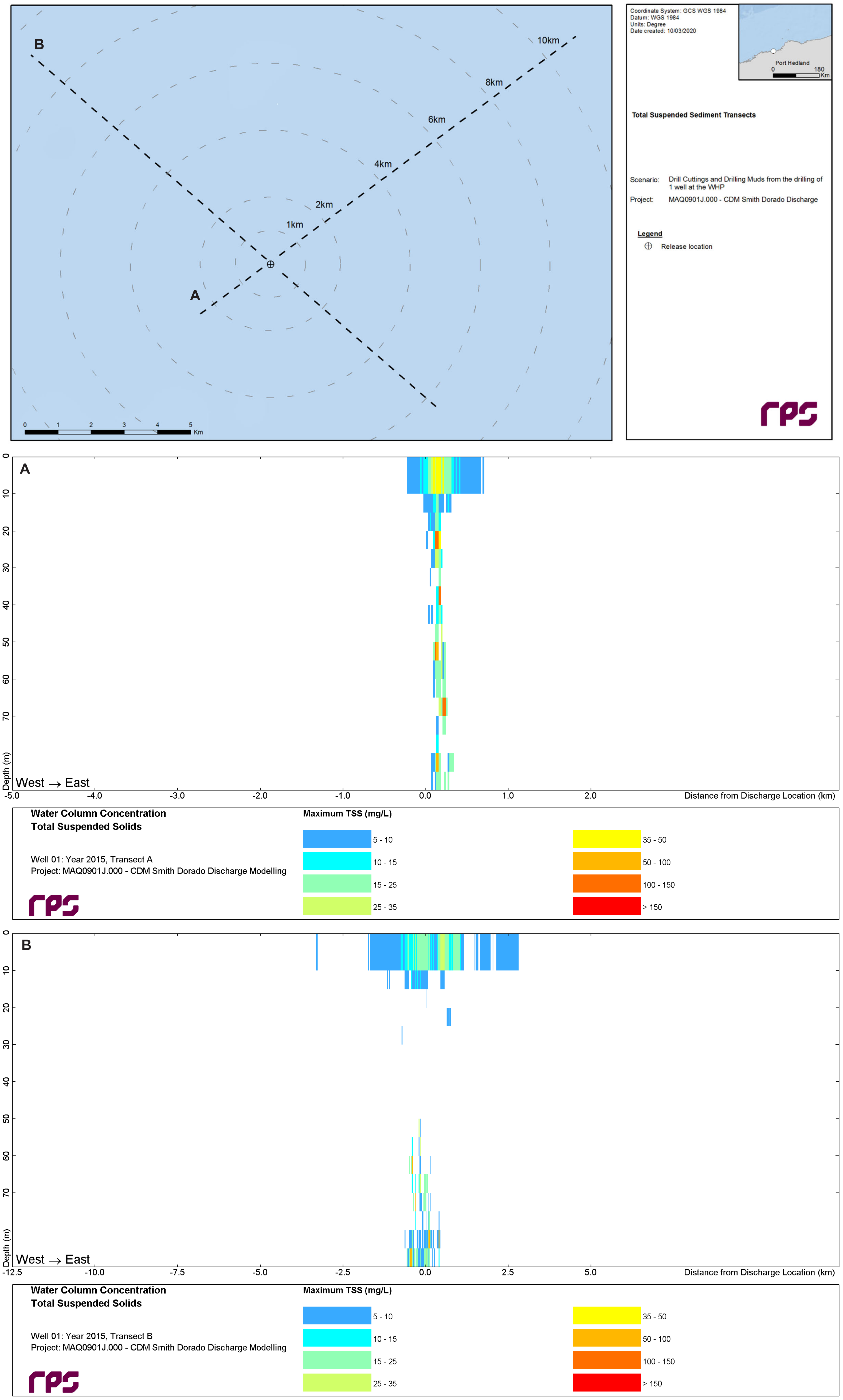

Figure 4.6 **Cross-sections (a) east-west and (b) north-south of the predicted maximum suspended sediment concentrations within the water column resulting drill cuttings and muds discharges for Well-1 over 18 days commencing in El Niño conditions.**

4.2 Twelve Wells Results for Each ENSO Events

The results for the twelve wells were integrated and Figure 4.7, Figure 4.8 and Figure 4.9 show the distribution of sediment thickness calculated for the discharge of drill cuttings and drilling muds commencing in La Niña, Neutral and El Niño conditions, respectively.

Table 4.2 the predicted maximum sediment thickness, area of coverage and the maximum distance from well location to each threshold for each ENSO event.

The maximum thickness (or height of mound) was predicted to be 1,315 mm (during Neutral conditions) adjacent to the well location (Table 4.2).

Modelling predicted a zone of potential influence at the natural threshold level, with thicknesses of 0.1 mm or greater expected up to 2,871 m from the well location while covering an area of 8.39 km^2 (during predominantly El Niño conditions). The low and high exposure thresholds were more localised and not expected beyond 758 m and 391 m, respectively. Greatest areas of coverage on the seafloor at the low and high exposure thresholds were 0.78 km^2 and 0.27 km^2, respectively.

Table 4.2 Predicted maximum sediment thickness, area of coverage and maximum distance for each threshold resulting from the drill cuttings and drilling muds discharge for the 12 wells. The results are presented based on each ENSO event.

ENSO event	Maximum Sediment thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)	0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)
La Niña	1,205	7.69	0.78	0.27	2,501	736	426
Neutral	1,315	8.93	0.73	0.25	2,813	954	447
El Niño	1,224	8.39	0.73	0.23	2,871	758	391

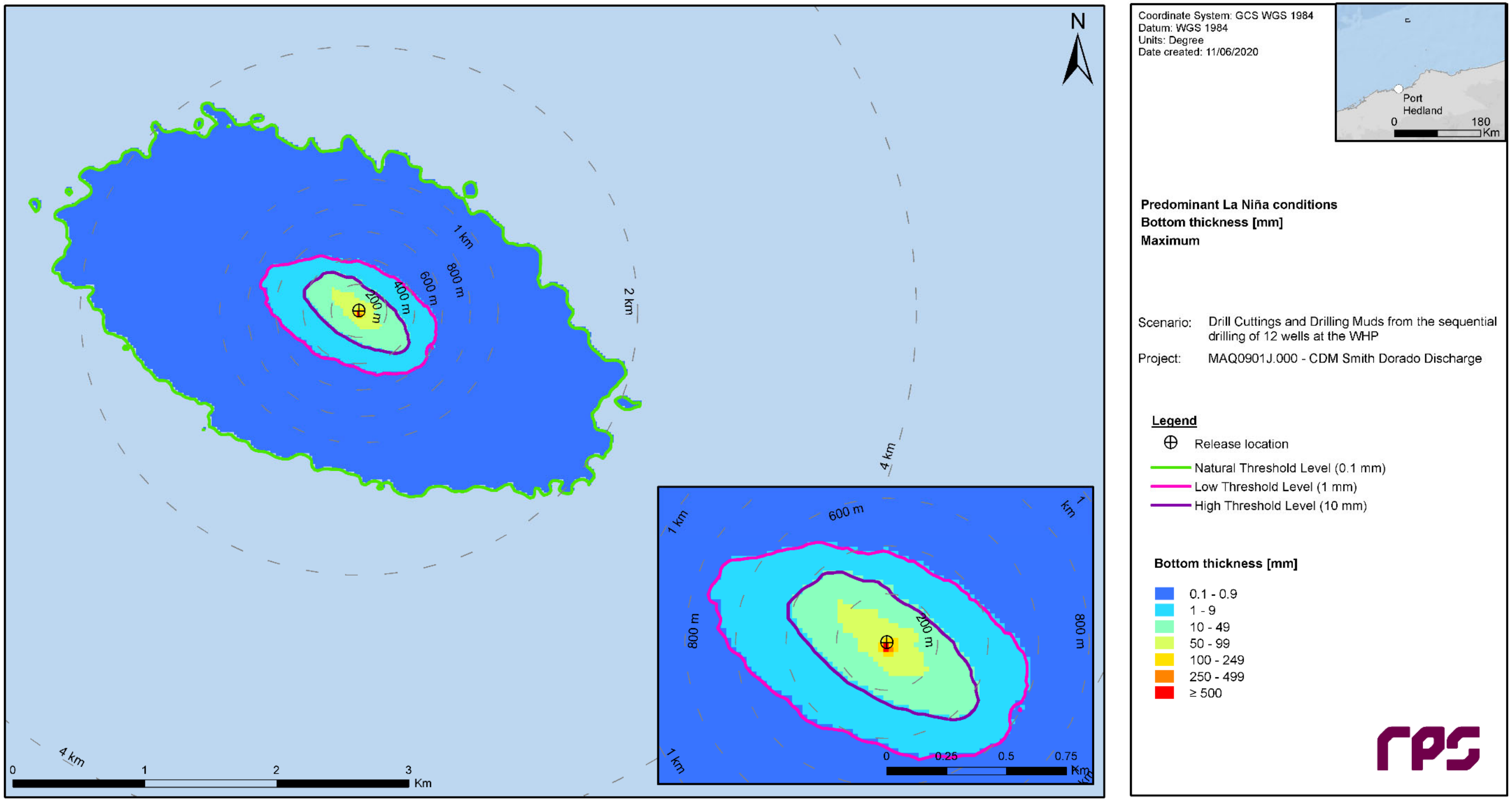

Figure 4.7 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for all 12 wells over 528 days, commencing in La Niña conditions.

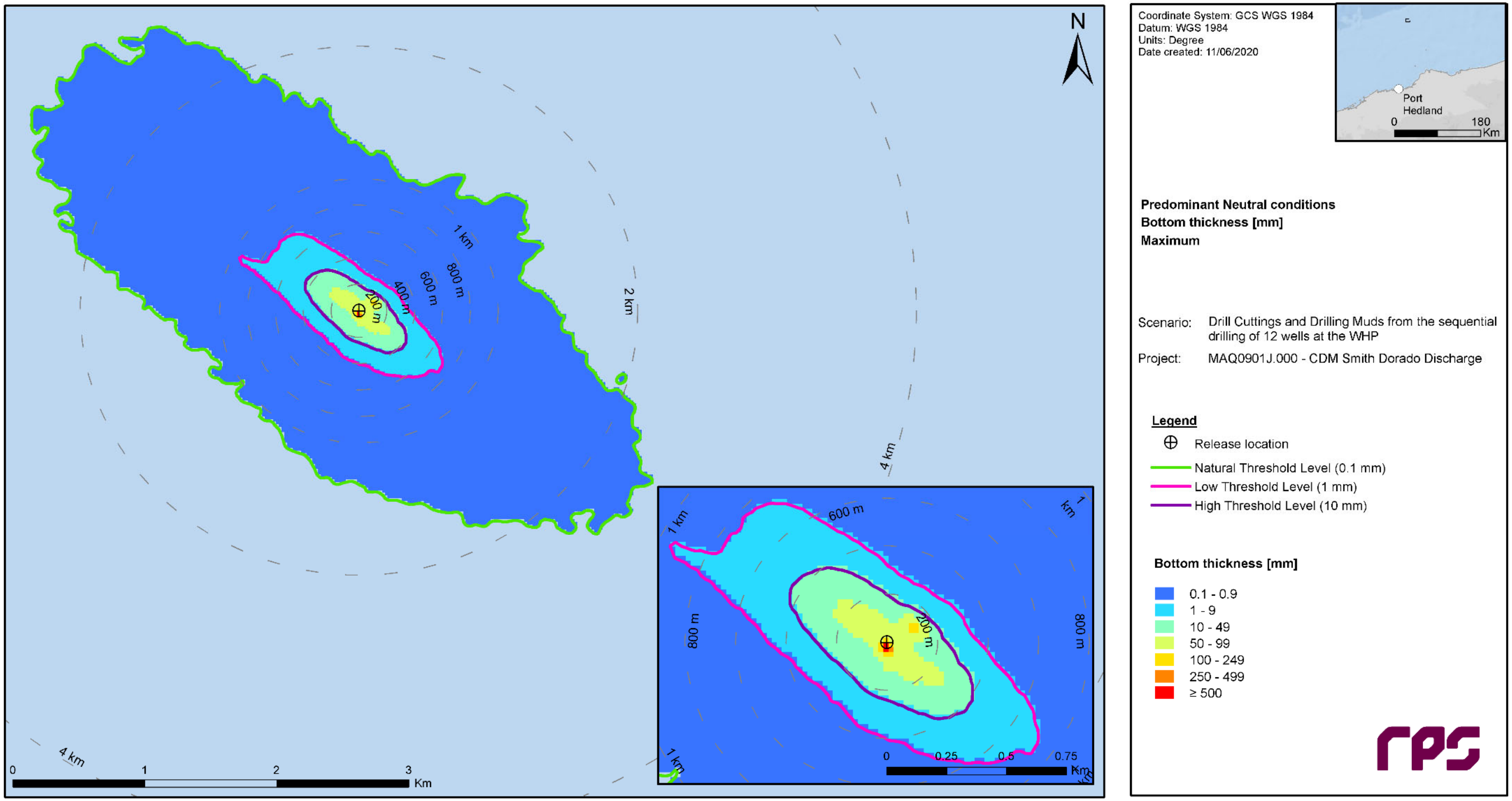

Figure 4.8 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for all 12 wells over 528 days, commencing in Neutral conditions.

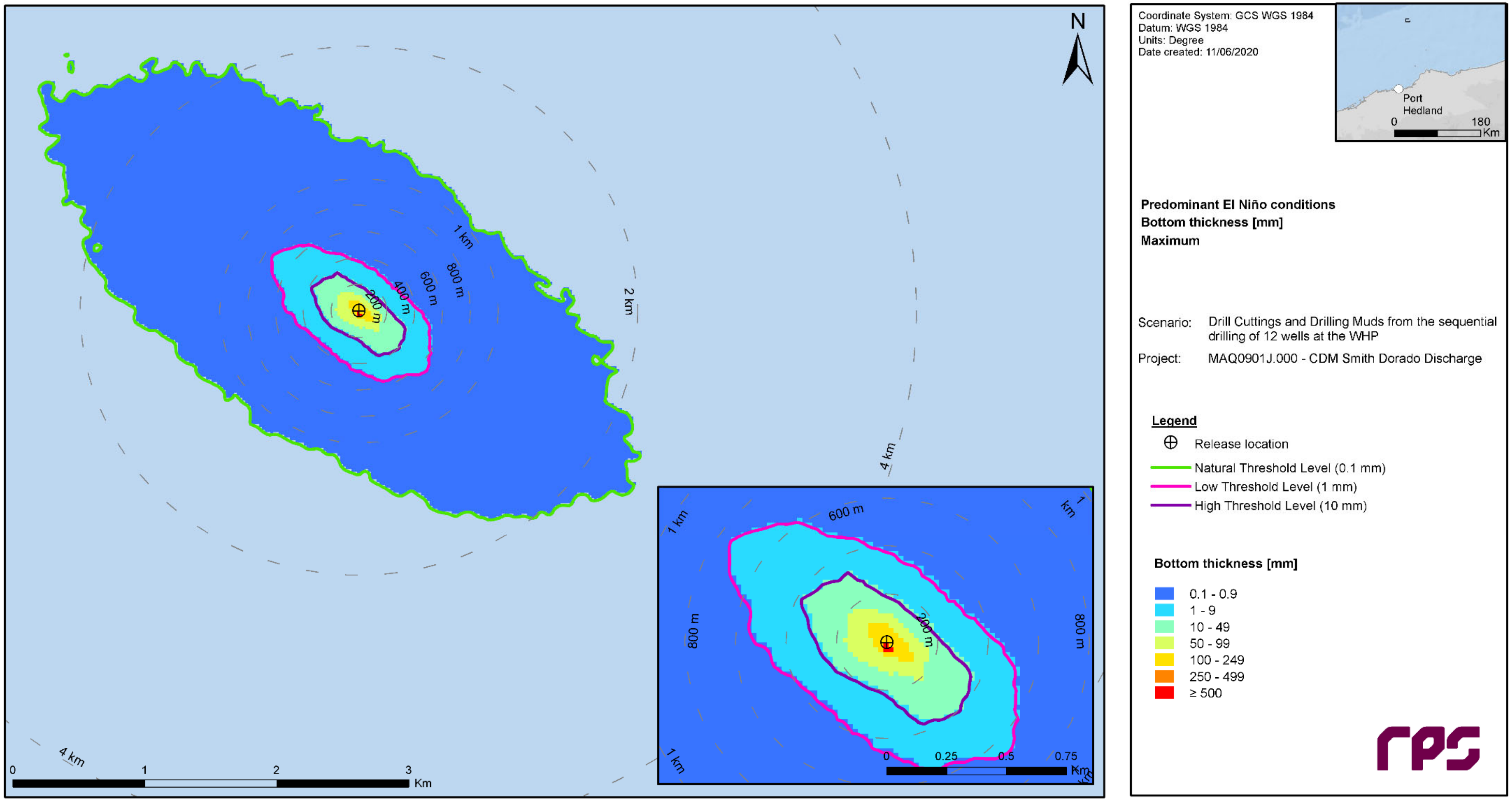

Figure 4.9 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for all 12 wells over 528 days, commencing in El Niño conditions.

4.3 Combined Overall Results

The combined results show the maximum likely extent of the drill cuttings and muds on the seabed, the results for the twelve wells and the three ENSO conditions were combined and are presented in Figure 4.10.

Table 4.3 shows the predicted maximum sediment thickness, area of coverage and the maximum distance from the well location to each threshold.

In all instances the modelling results demonstrated that the settlement of the cuttings and drilling muds were generally spread along the northwest–southeast axis, coinciding with the dominant tidal current directions. The maximum thickness (or height of mound) was predicted to be 1,315 mm adjacent to the well location (within 20 m).

The minimum or natural threshold was predicted to extend up to 2,871 m from the well location and cover an area of 9.81 km^2. The maximum distances from the release site to the low and high exposure thresholds were 954 m and 447 m, respectively.

Table 4.3 Predicted maximum sediment thickness, area of coverage and maximum distances to each threshold from the discharge drill cuttings and drilling muds for the proposed Dorado Development. The combined results are calculated from the amalgamation of all 12 wells and the three ENSO conditions.

Maximum Sediment thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
	0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)	0.1 - 1 mm (natural threshold)	1-10 mm (low exposure)	≥10 mm (high exposure)
1,315	9.81	0.92	0.28	2,871	954	447

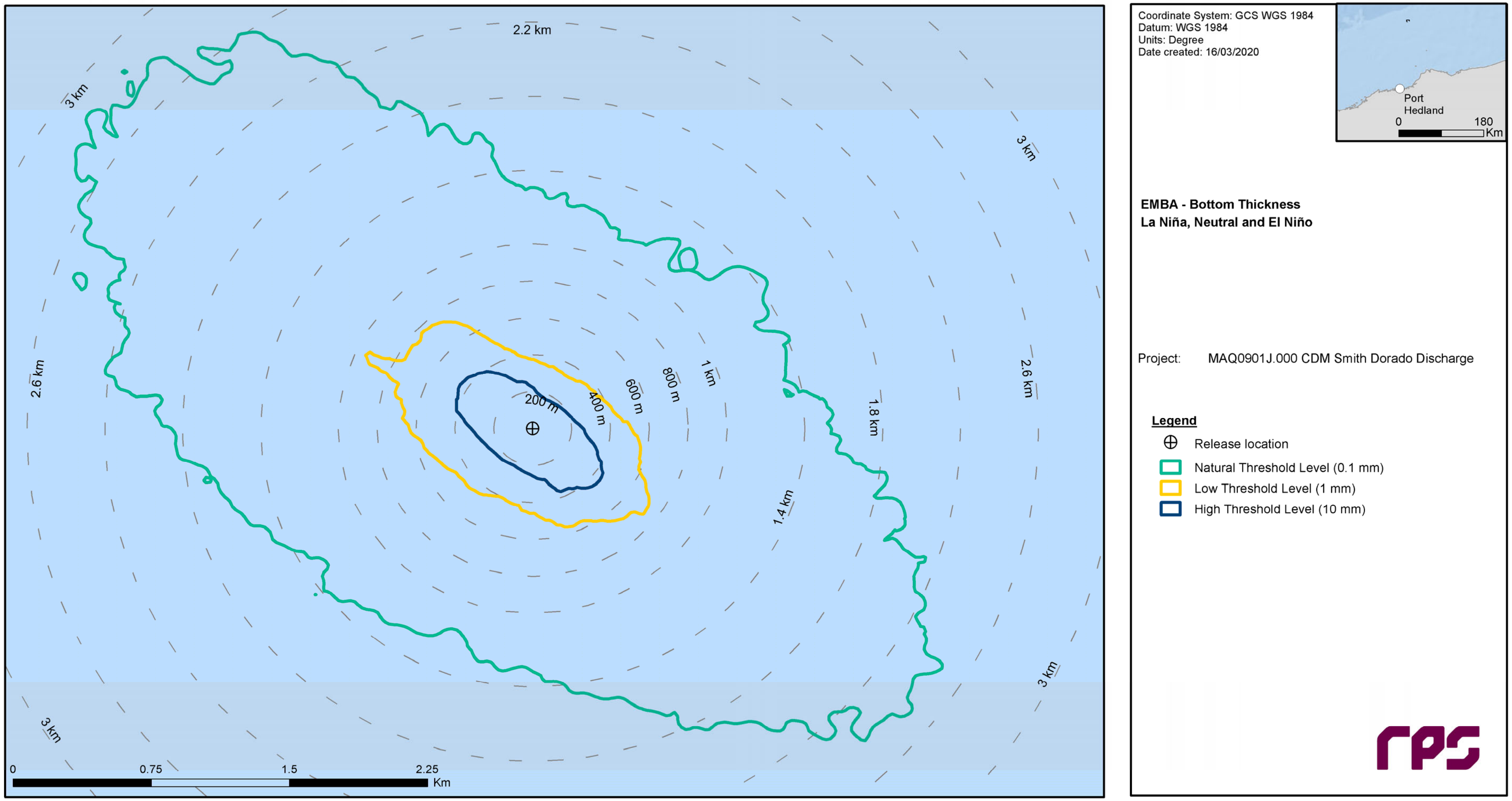

Figure 4.10 Predicted coverage and sediment thicknesses from the drill cuttings and muds discharges for all 12 wells and the three ENSO conditions

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Attachment 7 Produced Water Modelling

PRODUCED WATER DISCHARGE MODELLING – DORADO FIELD

Report

MAQ0901J
CDM Smith Dorado Discharge Modelling - Produced Water Report
Final
26 August 2020

www.rpsgroup.com/mst

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EXECUTIVE SUMMARY

Santos Limited (Santos) is planning for the Dorado Development located in the Bedout Basin offshore north-west Western Australia, approximately 140 km north of Port Hedland. The Dorado Development will target the Dorado oil field with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading (FPSO) facility.

To inform the impact assessment and support the preparation of the Offshore Project Proposal (OPP), a detailed produced water (PW) discharge modelling study was commissioned.

The principal aim of the study was to determine change in temperature and dilution for a continuous PW flow rate of 4,350 m^3/d released at the Dorado FPSO for a range of discharge heights (Case 1 - 10 m above mean sea level (AMSL), Case 2 - 0 m below mean sea level (BMSL) and Case 3 - 10 m BMSL).

The dilution and extent of the PW discharge was assessed on a seasonal basis ((i) summer (October to March); (ii) transitional periods (April and September); and (iii) winter (May to August)). An annualised aggregation of seasonal outcomes was also compiled.

To accurately determine the dilution of the PW discharge and the total potential area of influence, the effect of near-field mixing was considered first, followed by an investigation of the far-field mixing. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales. Given the field is not in production, it is not possible to undertake ecotoxicological tests on the PW stream, so the modelling results have been presented as a range of dilutions.

The main findings of the study are as follows:

Near-Field Modelling

- A discharge from 10 m AMSL was predicted to plunge up to 4.4 m BMSL when the current speed was low before rising and collapses under the water surface while being diverted by the prevailing current. The plunge depth was calculated to decrease under medium (2.6 m) and strong (1.3 m) currents, while the maximum distance of the near-field dilution zone was forecast to increase under high current speed conditions to 13.9 m, compared to 7.2 m for the weak current.
- Calculations for the discharge at 0 m BMSL indicated lower penetration depths (~ 1.5 m maximum) and shorter distances (up to 3.9 m) before all near-field mixing ceases compared to discharge at 10 m AMSL. Lower average dilution rates (up to 1:15) were calculated at the completion of the near-field mixing processes compared to the 10 m AMSL discharge (1:68).
- Discharge at 10 m BMSL was forecast to result in a relatively short plunge distance due to momentum (< 2 m maximum) but provided a greater vertical distance for the plume to rise under buoyancy and entrain with the ambient waters. The additional distance to surface, and the effect on dilution, was calculated to compound with increased current speed. Highest near-field average dilutions overall are calculated for this discharge configuration (up to 1:981 at 129.7 m from the release site).
- Overall, the results indicated a strong effect by the discharge height and current speed. Lowest dilutions were calculated during a weak current and higher dilutions were predicted for medium and high current speeds.

Far-Field Modelling

- The results indicated rapid dispersion of the PW discharge within the ambient environment and dilutions of up to 1:1,000 were within 902 m (based on the 99th percentile analysis) from the discharge location for all three cases.
- At the 95th percentile, the maximum extents to the 1:1,000 dilution contour were 298 m, 608 m and 255 m for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.

- Based on the 95th percentile analysis, the total areas of influence to achieve a 1:1,000 dilution were 0.102 km^2, 0.136 km^2 and 0.072 km^2 for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.
- Maximum depths to the 1:1,000 dilution level were predicted as 4 m, 3 m and 4 m for 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.

1 INTRODUCTION

1.1 Background

Santos Limited (Santos) is planning for the Dorado Development located in the Bedout Basin offshore north-west Western Australia, approximately 140 km north of Port Hedland. The Dorado Development will target the Dorado oil field with reservoir fluid being collected on a wellhead platform (WHP) and transported by infield flowlines for processing on a floating production storage and offloading (FPSO) facility.

The Dorado Development will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations), administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk.

To inform the impact assessment and support the preparation of the OPP, CDM Smith (on behalf of Santos) has commissioned RPS to undertake a detailed produced water (PW) discharge modelling study.

The PW will be generated during the project and will be discharged into the open ocean. The PW stream is generally characterised as having a naturally high temperature due to exposure to geothermal heat in the reservoir and may contain a mixture of constituents including dissolved and dispersed hydrocarbons at levels exceeding the receiving marine waters.

The principal aim of the study was to determine change in temperature and dilution for a continuous PW flow rate of 4,350 m^3/d released at the Dorado FPSO (Figure 1.1) for a range of discharge heights (Case 1 - 10 m above mean sea level (AMSL), Case 2 - 0 m below mean sea level (BMSL) and Case 3- 10 m BMSL).

The dilution and extent of the PW discharge was assessed on a seasonal basis ((i) summer (October to March); (ii) transitional periods (April and September); and (iii) winter (May to August)). An annualised aggregation of seasonal outcomes was also compiled.

Table 1.1 Coordinates of the proposed Dorado FPSO used as the release site for the PW dispersion modelling assessment.

Release site	Latitude (°S)	Longitude (°E)	Water depth (m)
Dorado FPSO	19° 02' 49.546"	118° 44' 36.744"	90

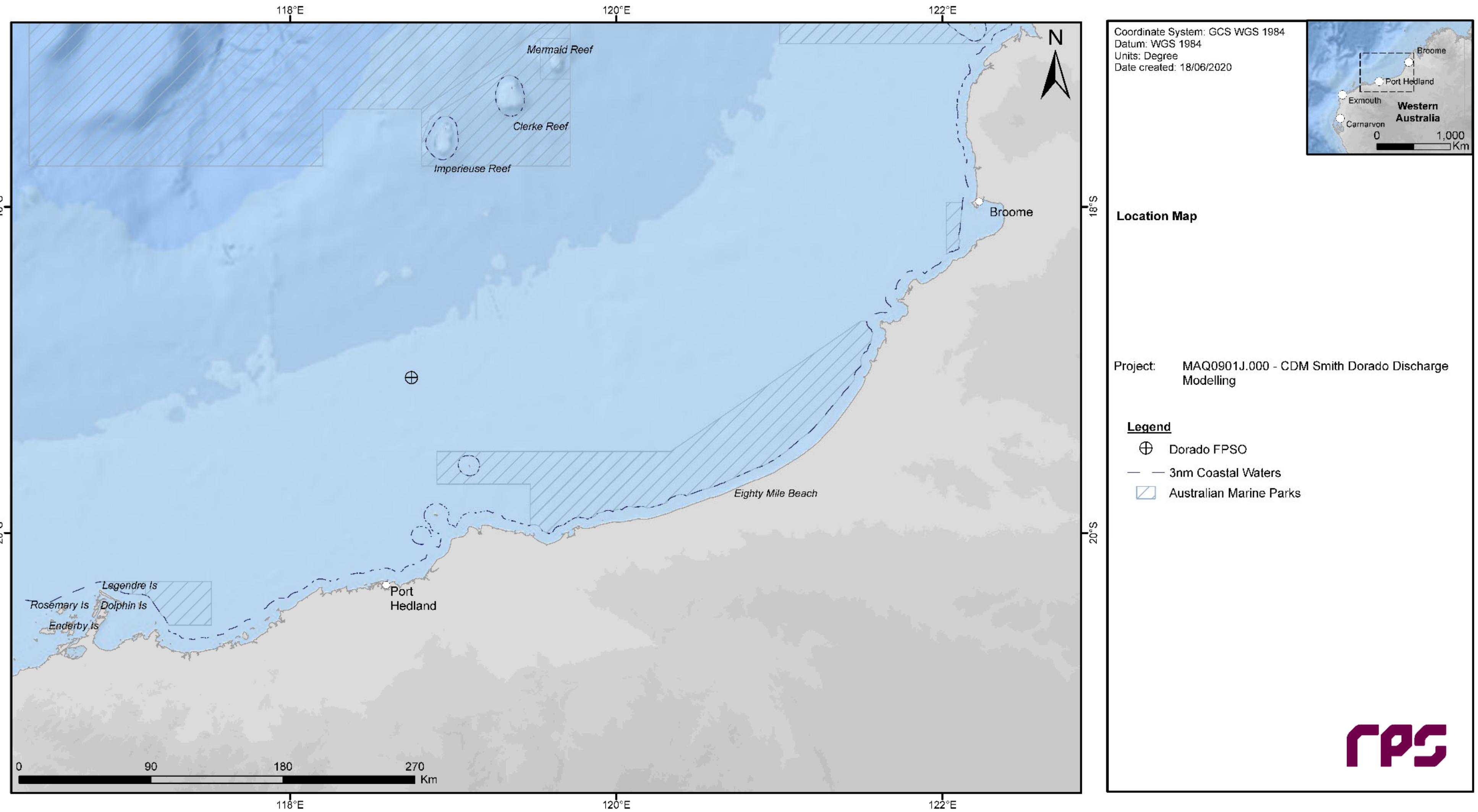

Figure 1.1 Location of the proposed Dorado FPSO used as the release site for the PW dispersion modelling assessment.

1.2 Modelling Scope

The scope of the modelling includes the following components:

1. Generate ten-years (2009-2018) of three-dimensional current data, that includes the combined influence of drift and tidal currents and is suitably long to be indicative of interannual variability in ocean currents.
2. Assess the near-field mixing and dilution for the PW discharge for each case under weak, medium and strong seasonal and annualised current strengths;
3. Establish a far-field dispersion model to calculate dispersive mixing and dilution of the PW discharge for each case, randomly sampling a wide range of current conditions from the ten-year time series of current data.
4. Determine the maximum distances and total areas of influence in which a 1:1,000 dilution is achieved for each case.

The physical mixing of the PW discharge can be separated into two distinct zones: (a) near-field; and (b) far-field. The limits of the near-field zone are defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from the density difference. When the plume encounters a boundary such as the water surface, seabed or density stratification layer, the near-field mixing is complete and the far-field mixing begins. During the far-field phase, the plume is transported and mixed by the ambient currents.

Therefore, to accurately determine the dilution and the mixing zone of the PW stream, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing. In this report the near-field and far-field modelling results are presented.

2 REGIONAL OCEAN CURRENTS

2.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have an influence upon the net trajectory of discharges over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model (HYCOM), with estimates of the tidal currents generated by an RPS model set up for the study area (HYDROMAP).

2.2 Ocean Currents

The large scale drift currents were derived from the output of the global circulation model the Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet et al., 2007, 2009), created by the National Ocean Partnership Program (NOPP), as part of the US Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates ocean observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite observations, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density and sea height variations and the rotation of the earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (approximately 7 km at mid-latitudes) and a temporal resolution of one day.

A hindcast data set of HYCOM currents was obtained for a ten-year period spanning 2009 to 2018 (inclusive).

2.3 Tidal Currents

2.3.1 Description of Tidal Model: HYDROMAP

As the HYCOM model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA) (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

2.3.2 Tidal Grid Setup

The same tidal model grid used in the oil spill study was used for this study. The grid extends approximately 3,870 km east-west by 3,220 km north-south over the eastern Indian Ocean. Figure 2.1 shows a subset of the grid between Exmouth and Derby.

The tidal domain is sub-gridded down to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over more complex bathymetry

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office (see Figure 2.2). Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

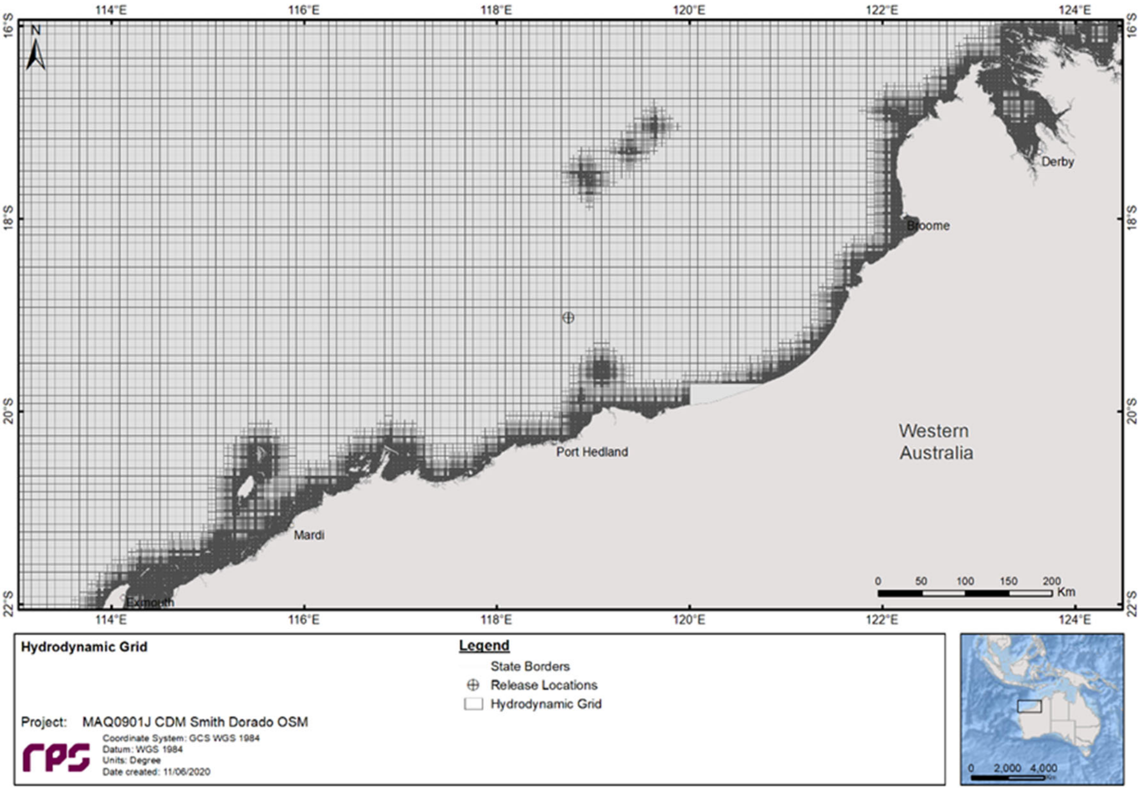

Figure 2.1 Subset of the model grid (grey wire mesh) used to generate the tidal currents. Higher-resolution areas are indicated by the denser mesh zones.

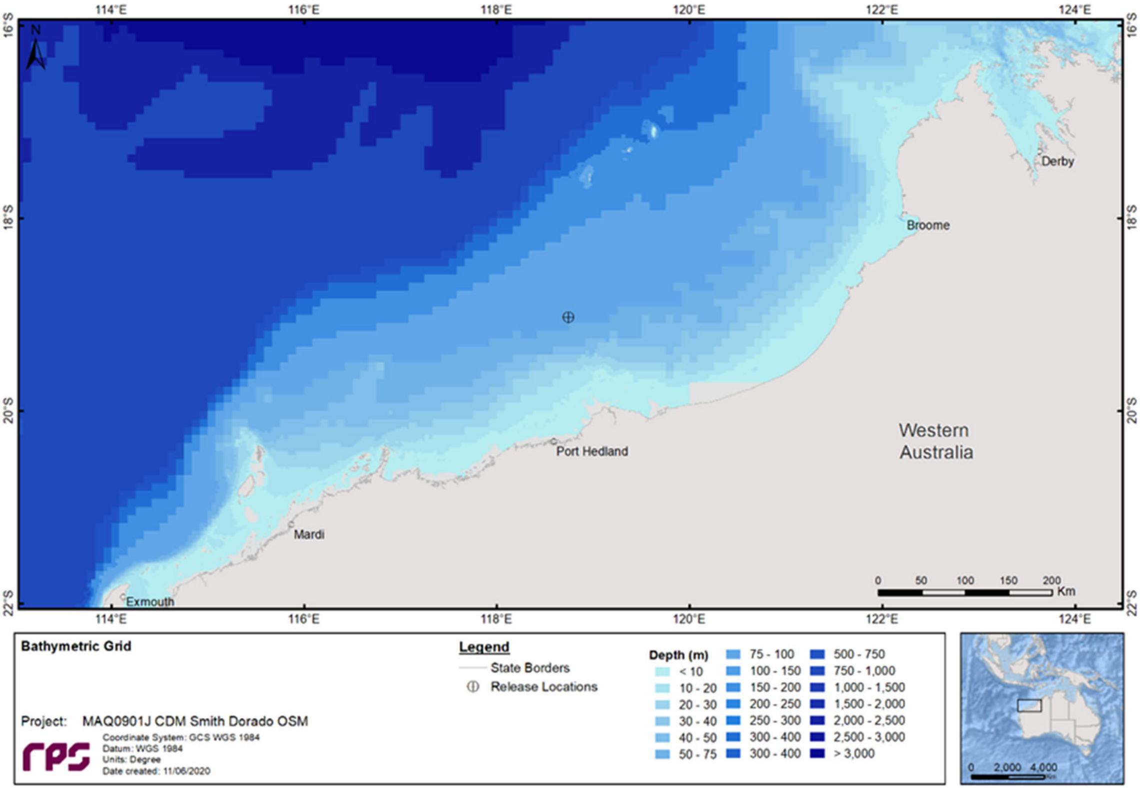

Figure 2.2 Subset of the bathymetry data used generate the tidal currents.

2.3.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

2.3.4 Tidal Model Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at five locations (see Figure 2.3).

Figure 2.4 and Figure 2.5 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graphs, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles.

To provide a statistical measure of the model performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is simply the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error (Willmott and Matsuura, 2005) and more readily understood.

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: X represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of 0 (Willmott, 1981). Willmott et al. (1985) also suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

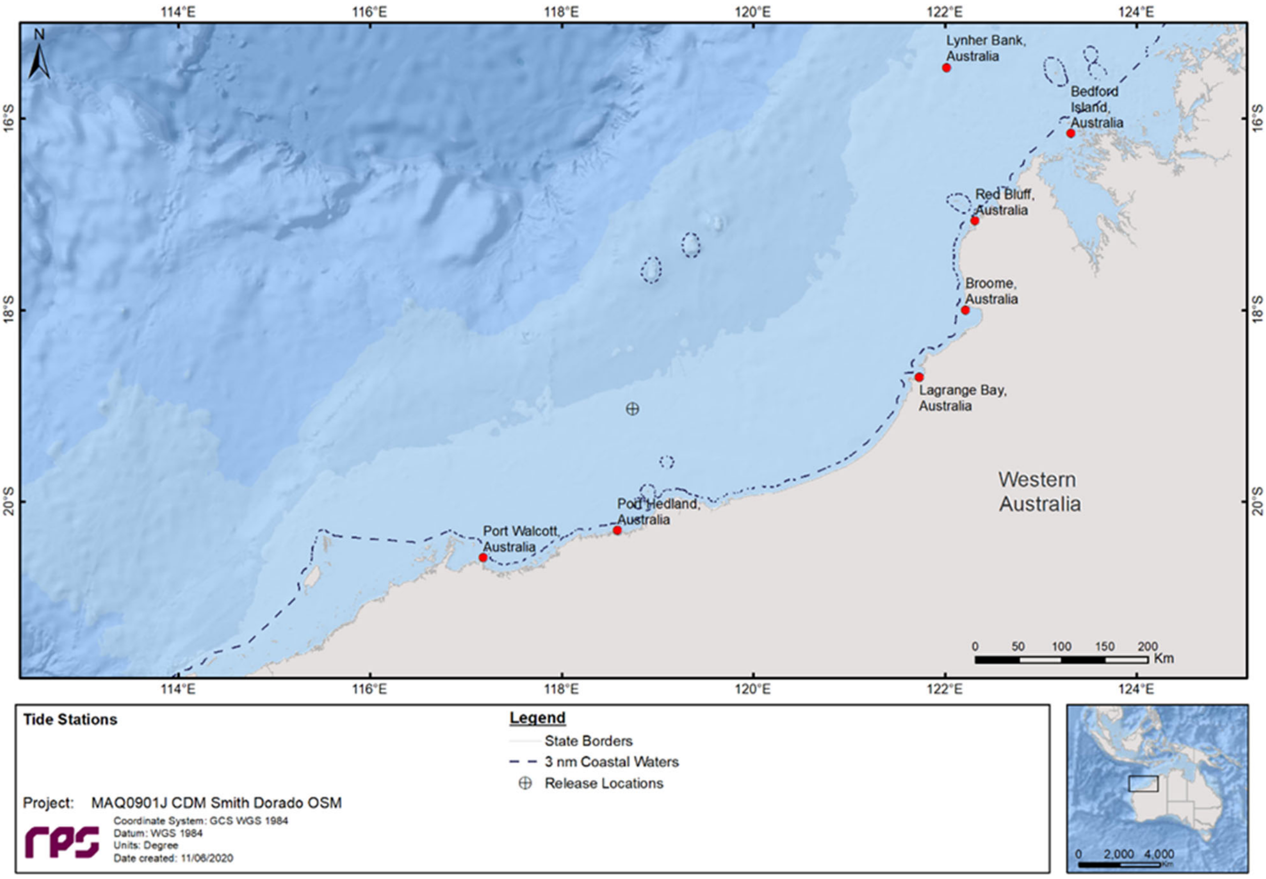

Figure 2.3 Tide stations used to validate surface elevation within the model.

Table 2.1 Statistical comparison between the observed and predicted surface elevations.

Tide Station	IOA	MAE (m)
Broome	0.90	1.11
Lagrange Bay	0.96	0.71
Lynher Bank	0.98	0.31
Port Hedland	0.98	0.33
Port Walcott	0.99	0.20
Red Bluff	0.98	0.46

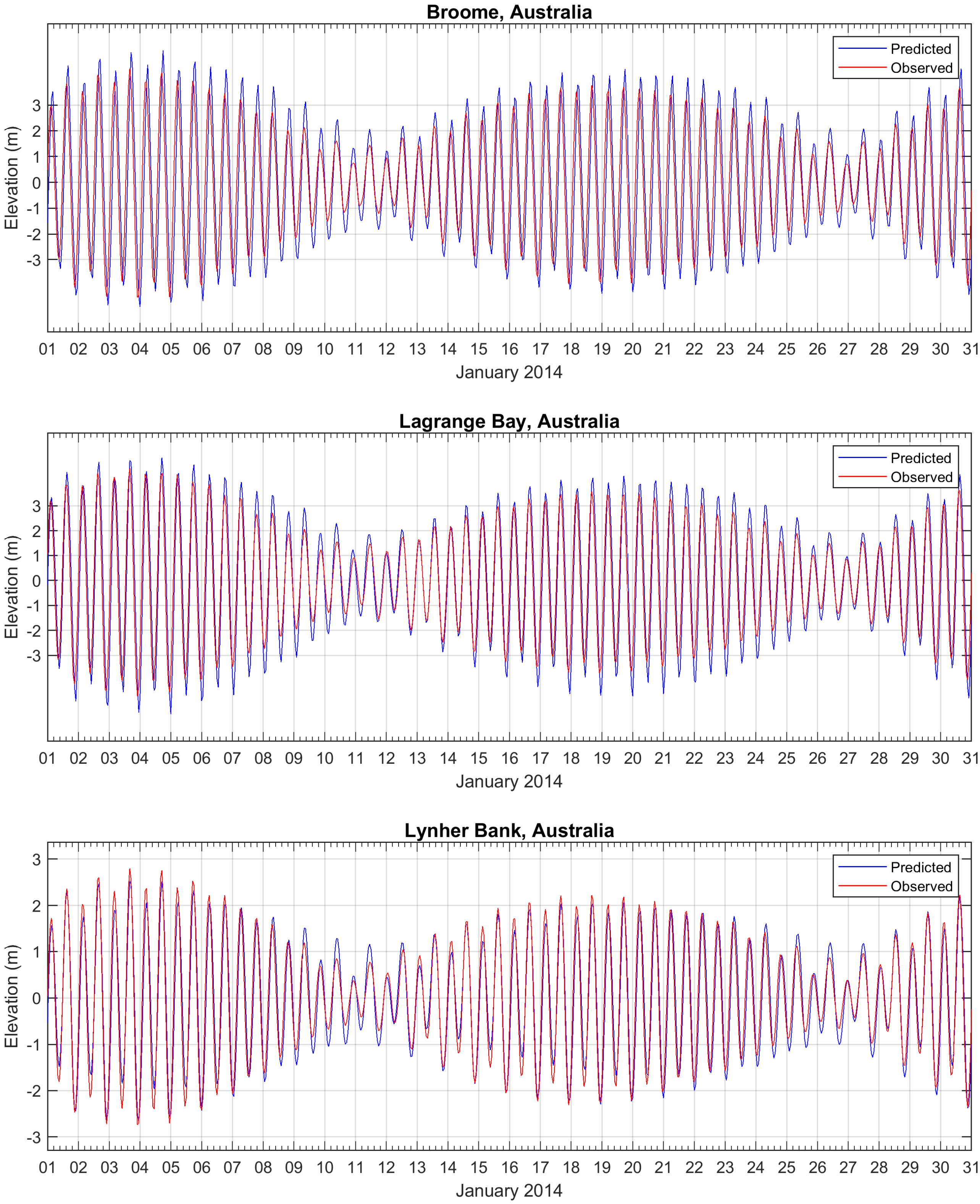

Figure 2.4 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

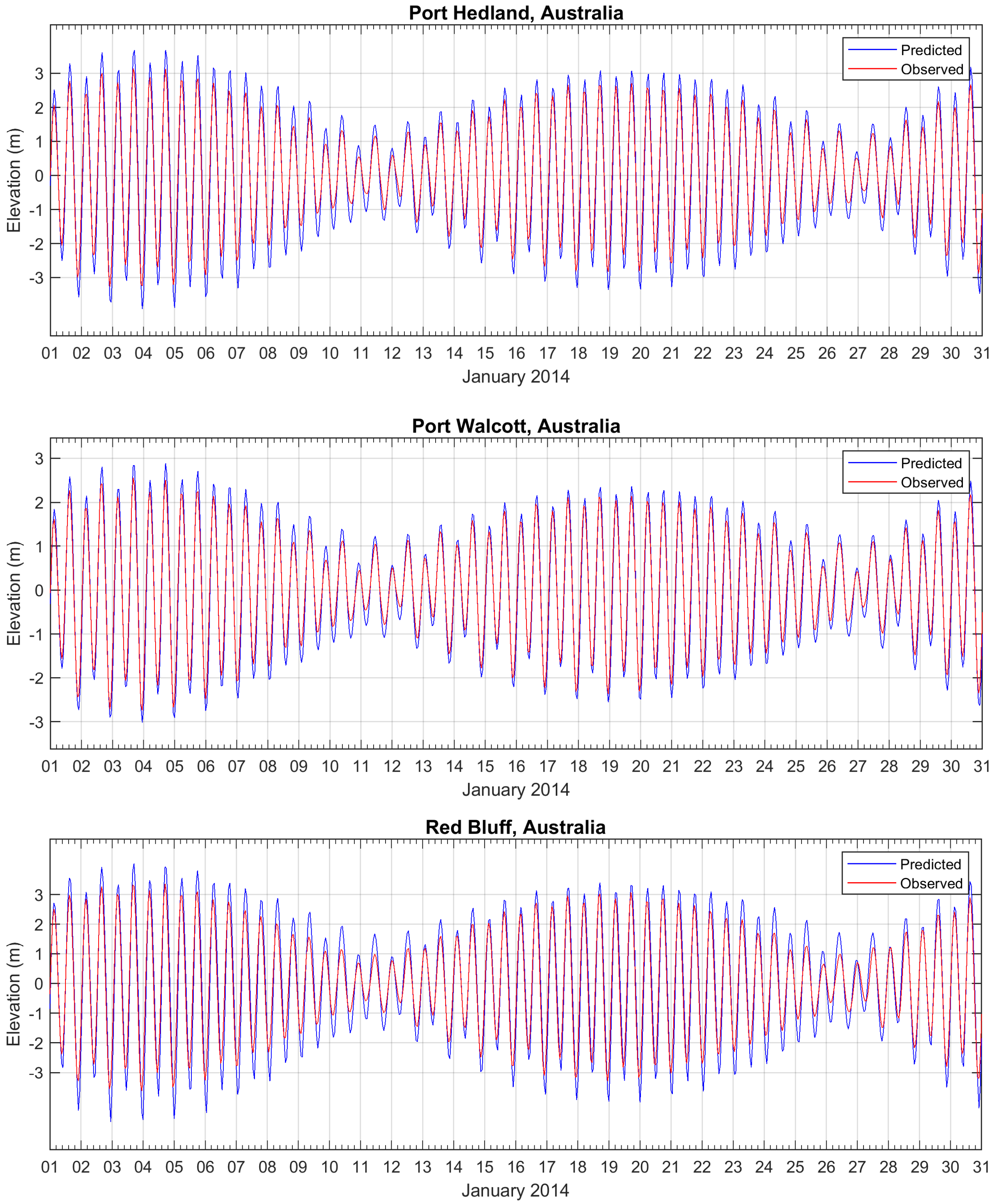

Figure 2.5 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

2.3.5 Current Model Validation

Generated current data were compared against current measurements within the Dorado Development area, using quantitative and visual comparisons at a range of depths.

Time series comparisons of the predicted and measured current speed and direction components at water depths of 40 m, 70 m and 110 m are presented in Figure 2.6, Figure 2.7 and Figure 2.8, respectively, for a two month period (January and February 2018). The time series comparisons reveal that the predicted currents offer a good match with the measured current speed and direction components at all water depths, with the magnitudes and timings of the peaks and troughs matching well.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001). The RMAE is relatively low in all depth layers indicating that the magnitude and range of current speeds match well, however, a slight overprediction of the predicted current magnitude is evident at times.

To compare directionality, roses for the predicted and measured currents at 40 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.9. The roses show that the predicted current direction is a good match with the measured direction. Both the predicted model direction and the measured data direction were in good alignment at each depth layer, portraying a dominant current direction along a northwest/southeast axis. The range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Dorado Development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Dorado Development.

Table 2.2 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds and directions at various depths at the Dorado Development area (January and February 2018).

Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
40 m	0.26	0.71	36.7	Good
70 m	0.26	0.80	29.9	Very good
110 m	0.26	0.85	27.9	Very good

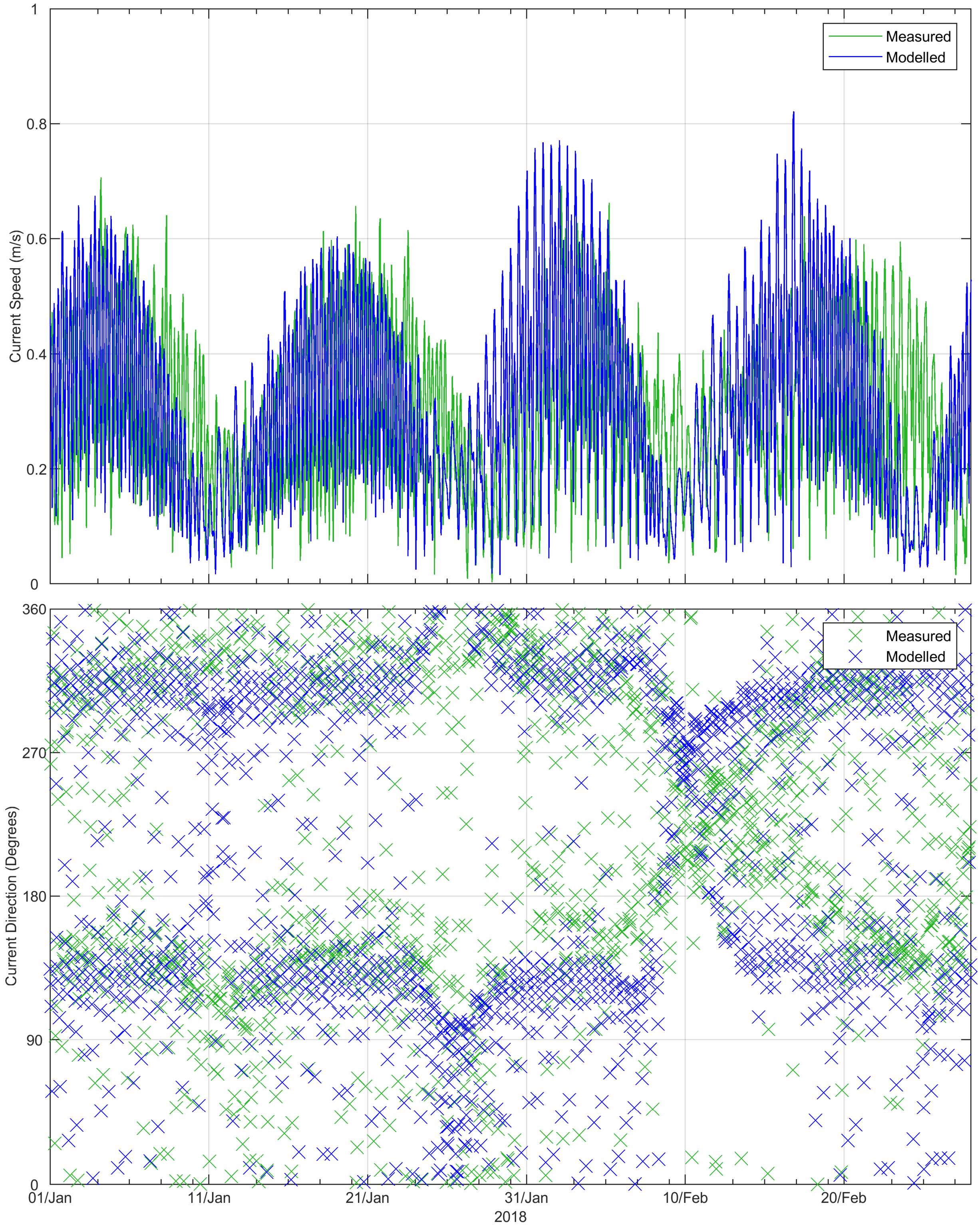

Figure 2.6 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 40 m for January and February 2018.

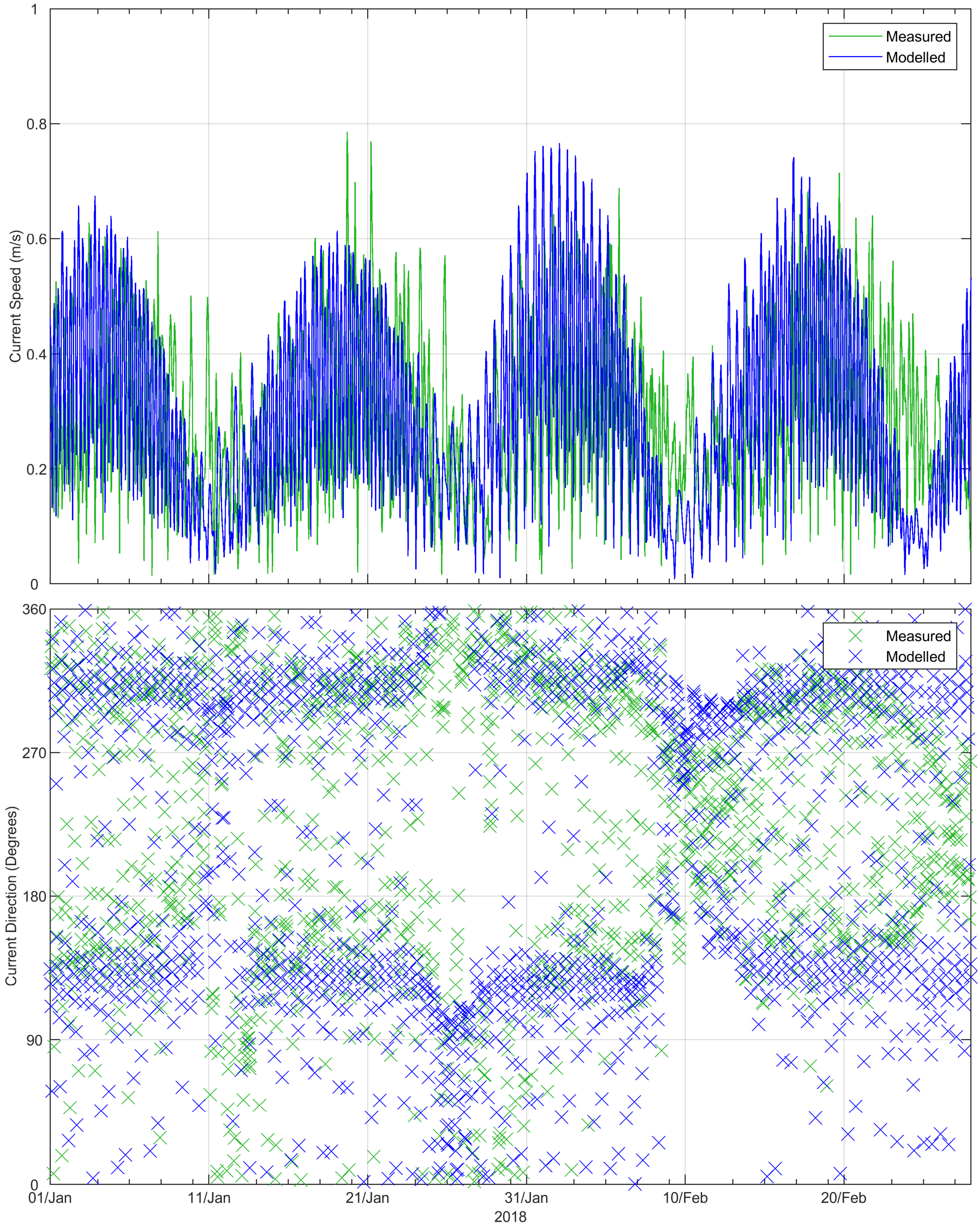

Figure 2.7 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 70 m for January and February 2018.

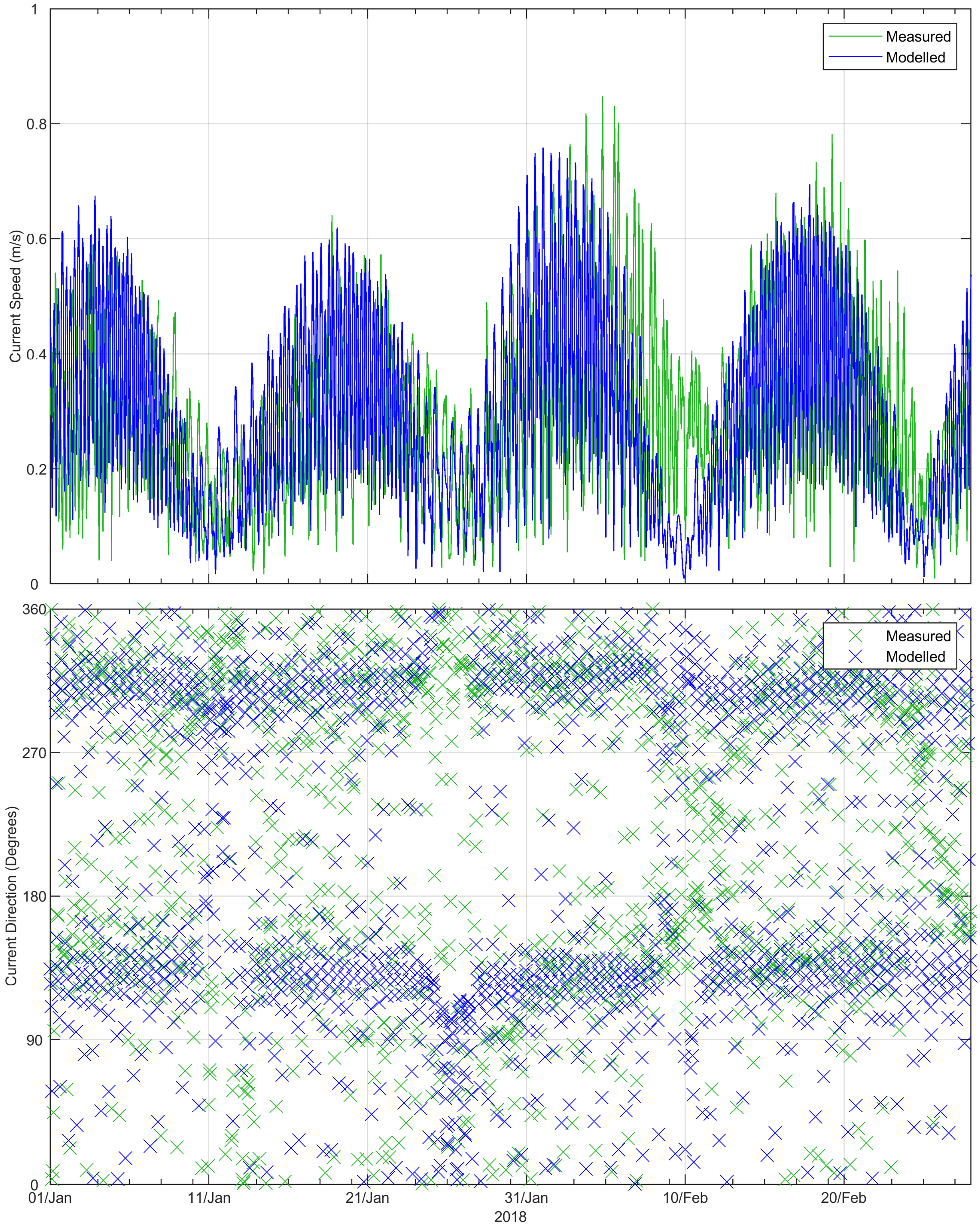

Figure 2.8 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current speeds (top) and current directions (bottom) at the Dorado Development area at a depth of approximately 110 m for January and February 2018.

Figure 2.9 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Dorado Development area (2017-2018) at depths of approximately 40 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.4 Surface Currents

Table 2.3 displays the predicted monthly average and maximum surface current speeds adjacent to the release site, while Figure 2.10 and Figure 2.11 show monthly, seasonal and total surface current rose distributions from 2009-2018 (inclusive). The currents are from the combination of HYCOM large-scale ocean currents and HYDROMAP tidal currents to account for the total drift throughout the model domain.

Note the convention for defining current direction is the direction the current flows **towards**, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow to the corresponding direction.

The surface modelled current data indicated a consistent monthly average of approximately 0.3 m/s and a dominant current direction towards the northwest and east-southeast to southeast throughout the year, while maximum current speeds varied between 0.70 m/s (November) to 1.42 m/s (October).

Table 2.3 Predicted average and maximum surface current speeds adjacent to the release locations. Data derived by combining HYCOM ocean data and HYDROMAP tidal data from 2009-2018 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.30	0.86	East-southeast (variable)
	February	0.31	1.32	Northwest
	March	0.32	1.41	Northwest
Transitional	April	0.31	1.07	Northwest and West-northwest
Winter	May	0.30	0.91	West-northwest
	June	0.29	0.81	West-northwest
	July	0.31	0.88	West-northwest and northwest
	August	0.31	0.89	Northwest
Transitional	September	0.32	0.91	Northwest and Southeast
Summer	October	0.29	1.42	Northwest
	November	0.26	0.70	Northwest
	December	0.26	0.72	East-southeast (variable)
	Minimum	**0.26**	**0.70**	
	Maximum	**0.32**	**1.42**	

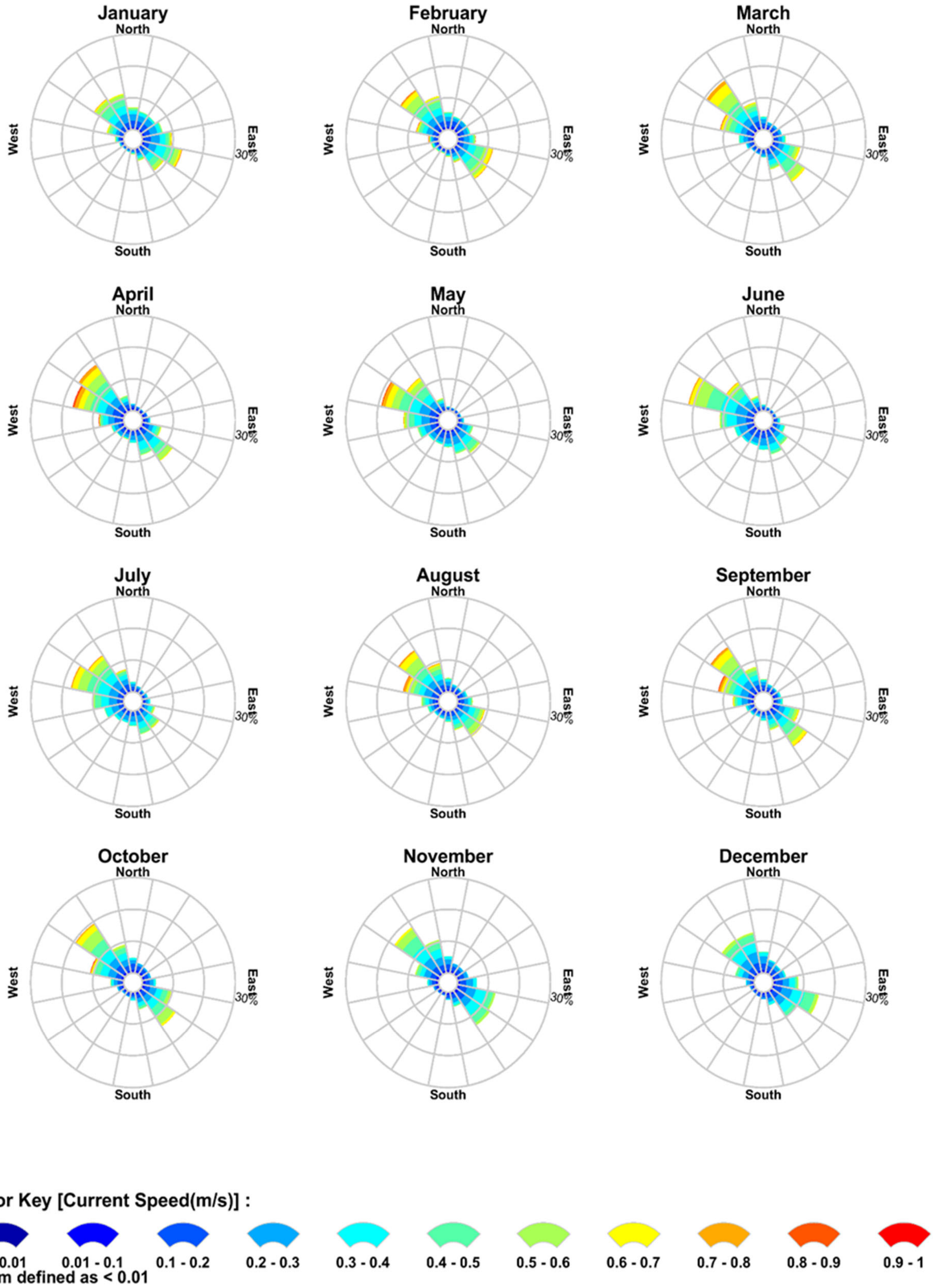

Figure 2.10 Monthly current distribution (2009-2018, inclusive) derived from the HYCOM database near the release site. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

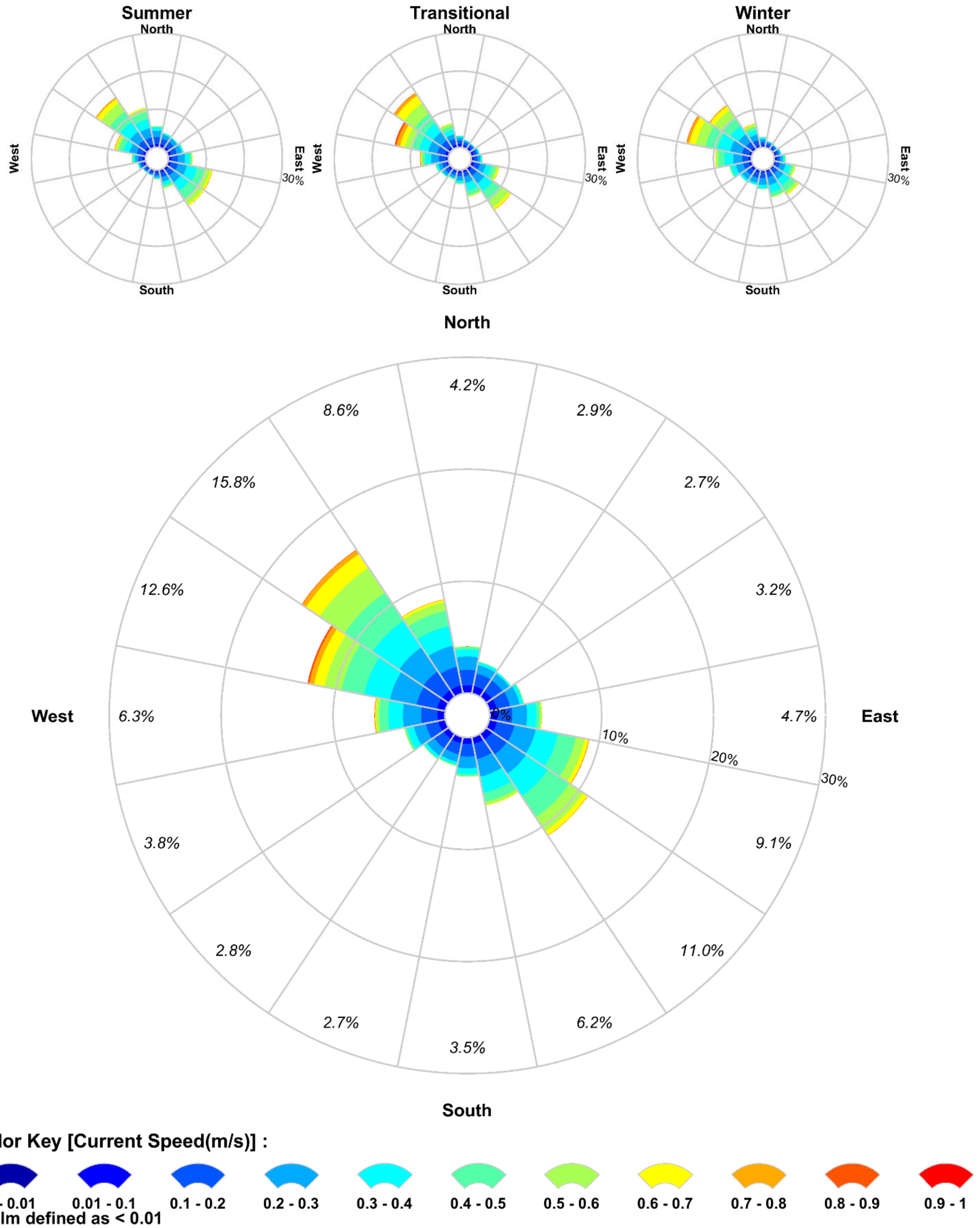

Figure 2.11 Seasonal (top) and total (bottom) current distribution (2009-2018, inclusive) derived from the HYCOM database near the Dorado Development area. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 ENVIRONMENTAL REPORTING CRITERIA

The following environmental criteria were used for the modelling study.

Temperature

A temperature differential of 3 ˚C within 100 m from the release location was assessed in the PW modelling study. This criterion represents a commonly adopted industry standard as part of the International Finance Corporation (IFC) Industry Environmental, Health and Safety Guideline for Offshore Oil and Gas Development (IFC 2015) for cooling water discharges and is therefore not directly applicable to PW. However, it has been used as a guide in the absence of any formally recognised criterion for PW discharges.

Maximum extent of the plume

As the field is not yet producing, it is not possible to undertake ecotoxicological tests on the PW stream. Therefore, the far-field modelling results are presented as a range of dilution contour maps. CDM Smith requested that dilutions up to 1:5,000 be considered in the modelling as a potential upper criterion, while dilutions up to 1:1,000 be presented in the analysis of results. The 1:1,000 dilution is expected to result in the PW discharge reaching the 99% species protection limits for potential contaminants (e.g. metals and hydrocarbons) at concentrations typically recorded in PW in Australian waters. This dilution is also consistent with ecotoxicity testing results of PW from many facilities, which typically show the 99% species protection limit is reached in < 1:500 dilutions While a dilution of 1:5,000 provides continency data if the concentrations of potential contaminants within the PW discharge are found to be unusually high.

This approach allows a direct comparison of the minimum dilutions for various chemicals (or whole stream) once ecotoxicological testing has been undertaken.

4 MODELLING METHODOLOGY

4.1 Near-Field Modelling

4.1.1 Overview

The dispersion of the PW discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. CORMIX calculates the nearfield behaviour due to:

1. Mixing generated as the jet penetrates the receiving water body and moves under momentum, resulting in turbulence;
2. Subsequent entrainment of ambient water as the plume bends in response to buoyancy differences between the plume and ambient water as well as the prevailing current;
3. For buoyant plumes, spreading and dilution that is generated as the plume layer impinges onto the water surface and widens.

As the discharges mix with the ambient waters, the influences of these processes are eroded, and dispersion by currents and turbulence in the water column, referred to as far-field dispersion processes, become dominant processes.

The shape and orientation of the PW, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically-representative range of current speeds representative of the Dorado Development area.

4.1.2 Description of the Near-Field Model: CORMIX

The near-field mixing and dispersion of the PW discharge was simulated using the three-dimensional flow model, CORMIX. CORMIX is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones. CORMIX contains a series of elements for the analysis and design of single or multi-port discharges. Discharges may be submerged or above surface, buoyant or denser than receiving water and the receiving water may be stratified or unstratified. The emphasis of the model is the influence of the geometry and dilution characteristics on the initial mixing zone (Doneker and Jirka, 1990; Jirka et al., 1991). CORMIX is widely applied worldwide and has been validated in many independent studies (http://www.cormix.info/validations.php).

CORMIX is a collection of analytic solutions to simplified forms of the mathematical equations describing transport and dispersion of water borne constituents. The simplifications come about through a range of assumptions about the source configuration, source characteristics (discharge and buoyancy) and the ambient environment. These assumptions effectively limit the domain within which the analytic solutions apply. For the typical outfall source flow, two main zones can be defined as described in Figure 4.1.

Although CORMIX does calculate far-field dispersion, the assumptions of the algorithms limit application to homogeneous environments with no eddies in the ambient flow and little recirculation. For this reason, the CORMIX component of the calculations for this study were limited to the near-field zone.

CORMIX specifies the average dilution or bulk dilution (flux averaged) as 1.7 times the centreline dilution. The centreline is defined by the points of maximum concentration (maximum temperature, minimum dilution etc) at each vertical section along the longitudinal axis. Accordingly, centreline depth is defined as the depth of the maximum concentration point (maximum temperature, minimum dilution) along the longitudinal axis.

4.1.2.1 Discharges above mean sea level

Large-scale plunging jets impacting a free surface of water, such as the discharge of a PW stream above the sea surface through a downward-pointing pipe, is a complex problem subject to contemporary research. For jet diameters of more than ~10 cm, studies include those of Guyot et al. (2016). Jet dynamics under these circumstances involve a range of physical properties: acceleration due to gravity, liquid surface tension, viscosity, air-entrainment caused by transition between confined and unconfined flows, and density contrast between the air and receiving water (Eggers & Villermaux, 2008). Flow states may range from laminar to turbulent. Laminar flows will reduce in diameter as they free-flow between the discharge pipe and the water surface, without entrainment of air bubbles into the stream, which will maximise the momentum of the stream on reaching the sea, and hence the depth to which the discharge will plunge below the surface due to momentum. In contrast, a turbulent flow will widen and entrain air bubbles, reducing the depth of penetration. Figure 4.1 shows a conceptual diagram of a turbulent and laminar flow case to illustrate the different outcomes.

Flow of a circular water stream is laminar if the Reynolds number (a unitless measure of the ratio between the inertial forces and viscous forces in a fluid), is less than 2,000. Flow is considered turbulent if the Reynolds number exceeds 4,000. Between these limits, transitional flow conditions occur. The Reynolds number is calculated as follows:

$$Re = \frac{\rho_l V_0 D_0}{\mu}$$

Where: *Re* is the Reynolds number, ρ_l is the volumetric mass density of the liquid, V_0 is the average velocity at the outlet, D_0 is the outlet diameter and μ is the dynamic viscosity of the liquid.

A relatively high Reynolds number (339,000) is calculated for the above-sea discharge indicating that the discharge stream would be turbulent, which has implications for the width and momentum of the plume at the point of impacting the sea surface.

Air entrainment of a plunging jet occurs when the confined flow of a jet breaks the free-surface of the water causing air-disturbed flows (Guyot et al., 2016). This produces air bubbles under the free surface with an ascent velocity which can further impact on the penetration depth of the plume. The following empirical formula proposed by Nakasone (1987), found to be in good agreement with the experimental results detailed in Guyot et al. (2016), was used to calculate the penetration depth in this study:

$$H = \frac{2}{3} * H_C$$

Where: *H* is the penetration depth and H_c is the height of the discharge.

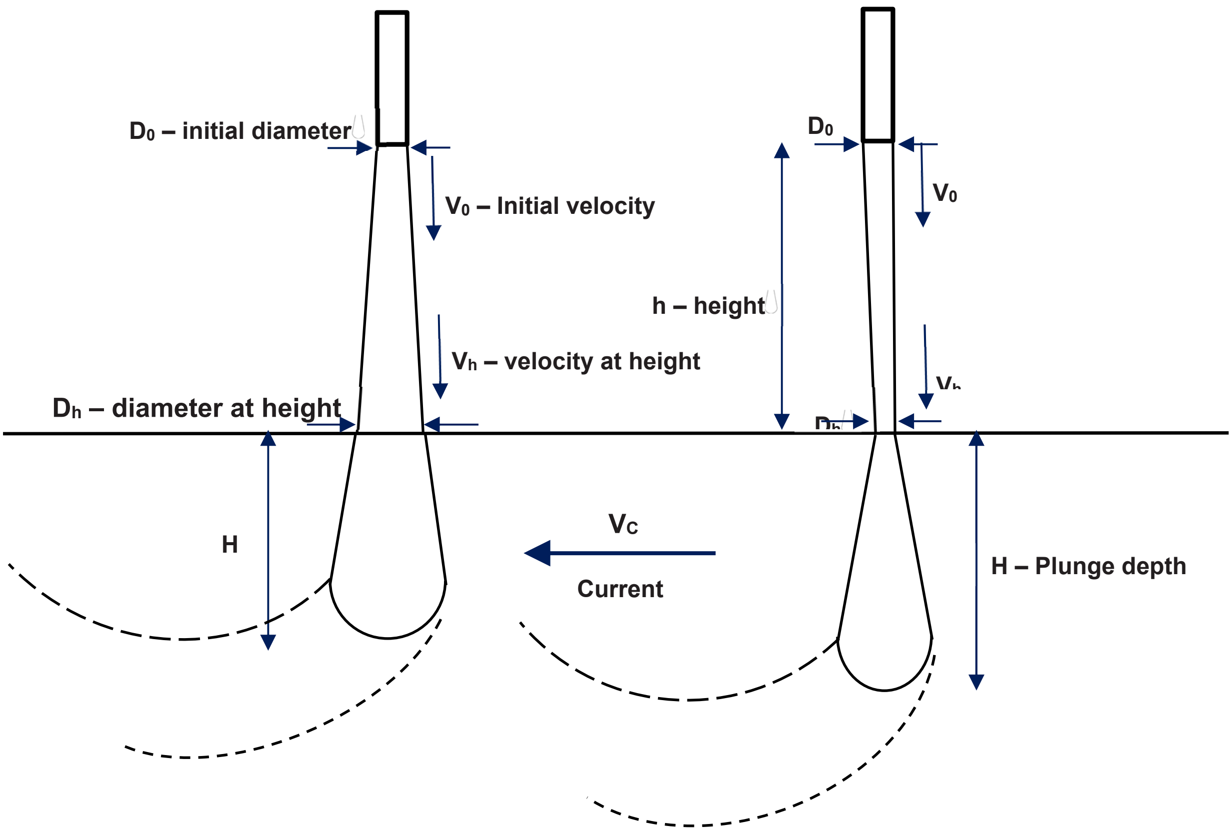

Figure 4.1 Conceptual diagram of the continuous turbulent (left) and laminar (right) flow cases of a largescale plunging jet from a height.

4.1.2.2 Discharges at or below mean sea level

The physical mixing and dilution of PW discharged directly into receiving waters occurs through a series of processes. Initial mixing is generated during what is referred to as the "near-field" mixing zone. As the discharge is ejected from the pipe as a jet, turbulence occurs due to the momentum of the jet displacing ambient water. This process occurs within metres of the discharge pipe and within seconds to minutes. As the plume descends, momentum is lost due to the energy required to displace receiving water. If there is a lateral current, the centreline of the plume will bend in the direction of the current flow. Once downward momentum is lost, the fate of the plume will depend upon plume density.

If the plume remains buoyant relative to receiving water (i.e. warmer and/or at lower salinity than the receiving water), the plume will rise, undergoing further mixing by entrainment of ambient water, until either neutral density is reached or the plume collapses into a layer below the water surface. At this point, the plume enters the "far-field" mixing zone, where subsequent mixing is generated by water currents and turbulence in the water column.

Figure 4.2 shows a conceptual diagram of the dispersion and fates of a positively buoyant discharge below sea level and the idealised representation of the discharge phases.

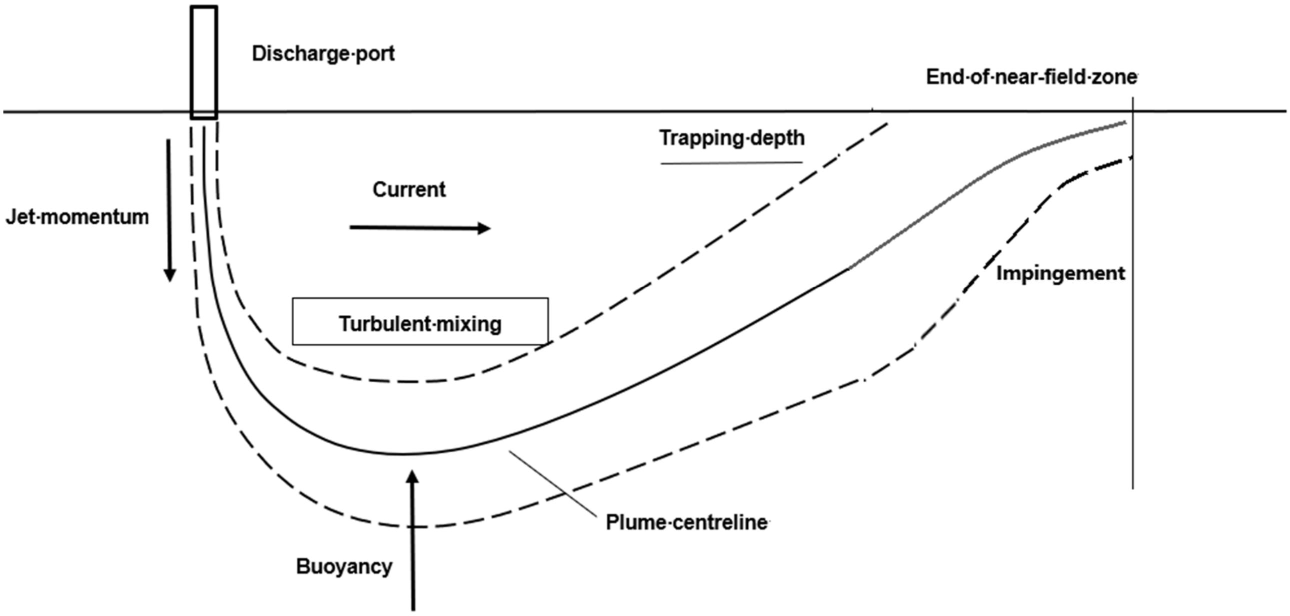

Figure 4.2 Conceptual diagram showing the general behaviour of a positively-buoyant discharge occurring vertically downward into receiving water that is moving due to current. Cormix follows processes until the end of the surface-impingement phase.

4.1.3 Setup of the Near-Field Model

4.1.3.1 Discharge Characteristics

The PW discharge characteristics used in the modelling study are summarised in Table 4.1.

The same discharge rate, pipe diameter and pipe orientation were applied to all cases, with varying discharge heights. The pipe diameter and discharge specified indicate a relatively low discharge velocity (~ 0.5 m/s).

Table 4.1 Summary of the PW discharge near-field characteristics.

Parameter	Case 1 - 10 m AMSL	Case 2 - 0 m BMSL	Case 3 - 10 m BMSL
Flow rate (m^3/d)		4,350	
Location		Dorado FPSO	
Duration (min)		Continuous	
Outlet pipe internal diameter (m) [in]		0.35 [13.78]	
Number of ports		1	
Flow velocity on exit		0.52 m/s	
Outlet pipe orientation		Vertical (downwards)	
Discharge height/depth	10 m AMSL	0 m BMSL	10 m BMSL
Discharge salinity (ppt)		25.5	
Discharge temperature (°C)		50	

4.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the CORMIX model included a vertical profile of temperature and salinity, along with constant current speeds and general direction (per simulation). The temperature and salinity profiles are required to accurately account for the relative buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the PW plumes. These inputs are described in the following sections.

4.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Centers for Environmental Information (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Center for Oceanography (Levitus et al., 2013). The WOA13 data was found to compare very well to measurements carried out in the Dorado Development area.

Table 4.2 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 70 m near the Dorado FPSO location.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth (3 ˚C between the surface and bottom waters). Salinity levels are generally most consistent with depth and indicate a vertically well-mixed water body (34.7-34.8 practical salinity unit, PSU), irrespective of season or depth. The data is considered representative of seasonal conditions near the release site.

Table 4.2 Average temperature and salinity levels adjacent to the Dorado FPSO location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.1	34.7
	10	27.0	34.8
	40	25.6	34.7
	70	24.1	34.8
Transitional	0	26.6	34.7
	10	26.5	34.7
	40	26.2	34.7
	70	24.8	34.8
Winter	0	25.8	34.8
	10	25.8	34.8
	40	25.6	34.8
	70	25.2	34.8
Annual	0	26.6	34.7
	10	26.5	34.7
	40	25.7	34.7
	70	24.6	34.8

Data source: WOA13 database produced by the National Centers for Environmental Information.

4.1.3.2.2 Ambient Current

The ten-year data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds at varying depths for each season and across an annual period (Table 4.3) for input to the near-field model to reflect contrasting dilution and advection cases:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 4.3 Adopted ambient current conditions adjacent to the proposed Dorado FPSO location.

Season	Depth (m)	5th percentile (weak) current speed (m/s)	50th percentile (medium) current speed (m/s)	95th percentile (strong) current speed (m/s)
Summer	0	0.082	0.333	0.733
	10	0.079	0.314	0.716
	40	0.076	0.306	0.708
	70	0.077	0.305	0.710
Transitional	0	0.077	0.347	0.805
	10	0.076	0.334	0.766
	40	0.072	0.326	0.752
	70	0.071	0.328	0.752
Winter	0	0.088	0.343	0.738
	10	0.081	0.318	0.691
	40	0.078	0.303	0.676
	70	0.081	0.300	0.673
Annual	0	0.083	0.339	0.748
	10	0.079	0.318	0.718
	40	0.076	0.308	0.707
	70	0.077	0.307	0.707

4.2 Far-Field Modelling

4.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, with the potential for localised build-up when current speeds are low (e.g. at the turning of the tide) and recirculation of the plume back to the discharge location might occur. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

4.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

4.2.3 Stochastic Modelling

A stochastic procedure was applied for the far-field modelling to sample a representative set of conditions that could affect the mixing and dispersion of the PW discharge. This approach involved running 50 simulations per season per case (i.e. 150 simulations in total per case), with each simulation representing discharge for 10 days under a different, randomly selected start times and in turn sequence of current speeds and directions from the ten-year database. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents that occur at the discharge location.

4.2.4 Setup of Far-Field Model

4.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 5.1.

The PW discharge characteristics are summarised in Table 4.4. The discharges were assumed to occur at 10 m AMSL, 0 m BMSL and 10 m BMSL, with a continuous flow rate of 4,350 m^3/d released at the Dorado FPSO. The initial dilution and shape of the discharge was set by the results of the near-field results described in Section 5.1.

The PW discharge cases were modelled as continuous discharges using 50 simulations for each season under time-varying current assuming the initial dilution and density change imposed by the near-field mixing. Once the simulations were complete, they were combined and reported for three distinct seasons: (i) summer (October to March); (ii) transitional periods (April and September); and (iii) winter (May to August). An annualised aggregation of seasonal outcomes was also compiled.

The seasonal results are presented in Appendix B.

Table 4.4 Summary of the PW far-field discharge characteristics.

Parameter	10 m AMSL	0 m BMSL	10 m BMSL
Hindcast modelling period		2009 to 2018	
Seasons		Summer (October to March) Transitional (April and September) Winter (May to August) Annual	
Location		Dorado FPSO	
Flow rate (m^3/d)		4,350	
Initial depth of centreline (m)	1	0.5	1.5
Initial buoyancy (aqueous component)		Neutral	
Number of simulations per case		150 (50 per season)	
Simulated discharge type		Continuous	
Simulated discharge period (days)		10	

4.2.4.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.25 m^2/s and 0.0001 m^2/s were used to control the spreading of the PW plume in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in-situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a conservative result for concentration extents.

4.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale influences of the discharge, it was necessary to use a fine grid with a resolution of 20 m x 20 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 20 km (longitude or x-axis) by 20 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m. It is important to note, that the 20 m grid cell sizes were selected following extensive sensitivity testing in order to achieve similar dilution rates at the end of the near-field mixing.

5 MODELLING RESULTS

5.1 Near-Field Modelling

Table 5.1 summarises the nearfield modelling results for the three cases; 10 m AMSL, 0 m BMSL and 10 m BMSL.

The results indicated a strong effect of changing the discharge height and current speed. The 10 m AMSL discharge was predicted to plunge up to 4.4 m BMSL when the current speed was weak, before rising and collapsing under the water surface while being diverted by the prevailing current. The plunge depth was calculated to decrease, and the total length of the near-field dilution zone was forecast to increase under higher current speed. The top of the plume was calculated to rise to the surface within approximately 7.2 m of the discharge under weak current, with distance increasing to 12.4 m under a medium current and 13.9 m under a strong current. Higher rate of dilutions were calculated for the medium and high current speeds (average dilution of 1:68 and 1:43, respectively) compared to the dilutions achieved under the weak current speed (average dilution of 1:34).

Cross sections illustrating the change in dilution with distance for each discharge height (10 m AMSL, 0 m BMSL and 10 m BMSL) are shown spatially in Figure 5.1 (weak current), Figure 5.2 (medium current) and Figure 5.3 (strong current). Highest concentrations were observed through the centreline of the vertical cross-sections.

By discharging at 0 BMSL, the modelling showed reduced plunge depths (~ 1.5 m maximum) and shorter distances before the plume begins impinging onto the water surface and shorter distances before all near-field mixing ceases compared to discharge at 10 m AMSL. Lower average dilution rates (< 1:15) were calculated at the completion of the near-field mixing processes compared to the 10 m AMSL case (< 1:68).

A discharge at 10 m BMSL resulted in a relatively short plunge distance (< 2 m maximum) due to momentum but provides a greater vertical distance for the plume to rise under buoyancy, while entraining ambient water. The distance to the surface (10 m plus plunge depth of < 2 m) and the ability for the plume to mix with ambient waters greatly improved the rate of dilution when compared to the other two cases (average dilution < 1:981). While discharge at 10 m BMSL was calculated to potentially achieve a target dilution of 1:1,000 under strong current (occurring ~5% of the time), insufficient dilution is indicated over the wider range of currents for all discharge configurations. This indicates that further dilution under far-field processes would be required to achieve the target dilution.

The seasonal near-field results for the 10 m AMSL, 0 m BMSL and 10 m BMSL discharges are presented in Appendix A.

For all three cases, the temperature of the PW plume was predicted to be within 3 °C of the ambient (background) temperature within 100 m from the release location, therefore meeting the environmental criteria. The temperature of the PW plume generally returned to within 3 °C of ambient water temperature within 15 m horizontally from the release location. Note that for the 0 m BMSL weak and medium current speeds, the temperature of the PW was not predicted to drop below 3 °C of ambient in the near-field.

Table 5.1 Predicted plume characteristics at the end of the near-field mixing zone for each case under weak, medium and strong current speeds during annualised conditions.

Case	Surface current speed (m/s)	Maximum plume diameter (m)	Maximum plunge depth (m) BMSL	Plume temp (°C)	Plume-ambient temp difference (°C)	Plume dilution (1:x)		Maximum horizontal distance
						Minimum (centreline)	Average	
10 m AMSL	Weak (0.08)	1.7	4.4	27.8	1.2	20	34	7.2
	Medium (0.34)	1.7	2.6	27.2	0.6	40	68	12.4
	Strong (0.75)	0.9	1.3	26.8	0.2	25	43	13.9
0 m BMSL	Weak (0.08)	1.0	1.4	34.5	7.9	3	5	3.9
	Medium (0.34)	0.6	0.6	33.0	6.4	4	7	1.0
	Strong (0.75)	0.5	0.5	29.3	2.7	9	15	2.7
10 m BMSL	Weak (0.08)	2.8	11.4	27.0	0.5	50	85	9.9
	Medium (0.32)	4.7	10.2	26.6	0.1	280	476	40.5
	Strong (0.72)	4.6	10.1	26.5	0.1	577	981	129.7

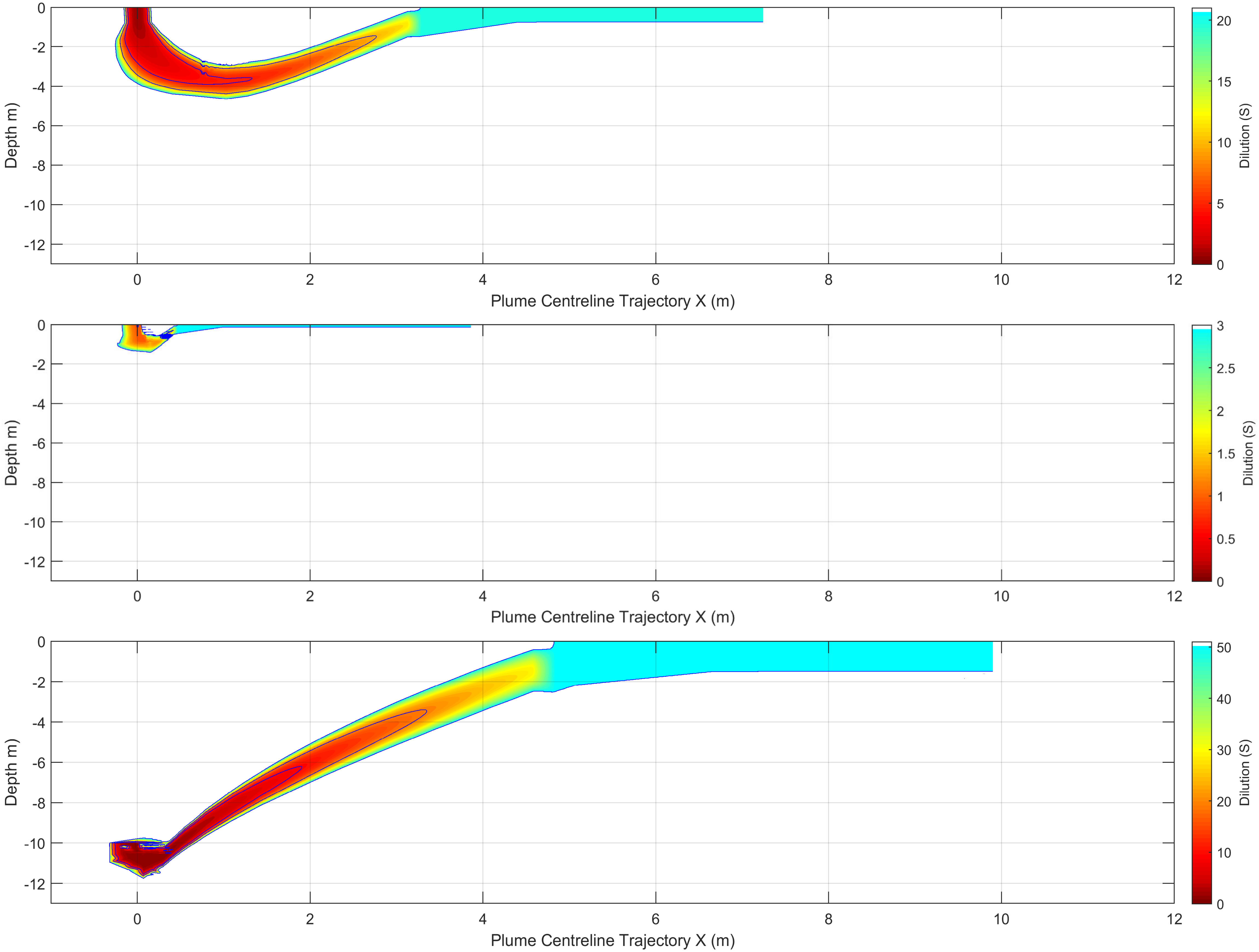

Figure 5.1 Cross-sections of the near-field dilutions for a 4,350 m³/d discharge rate released under weak (annualised) currents at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

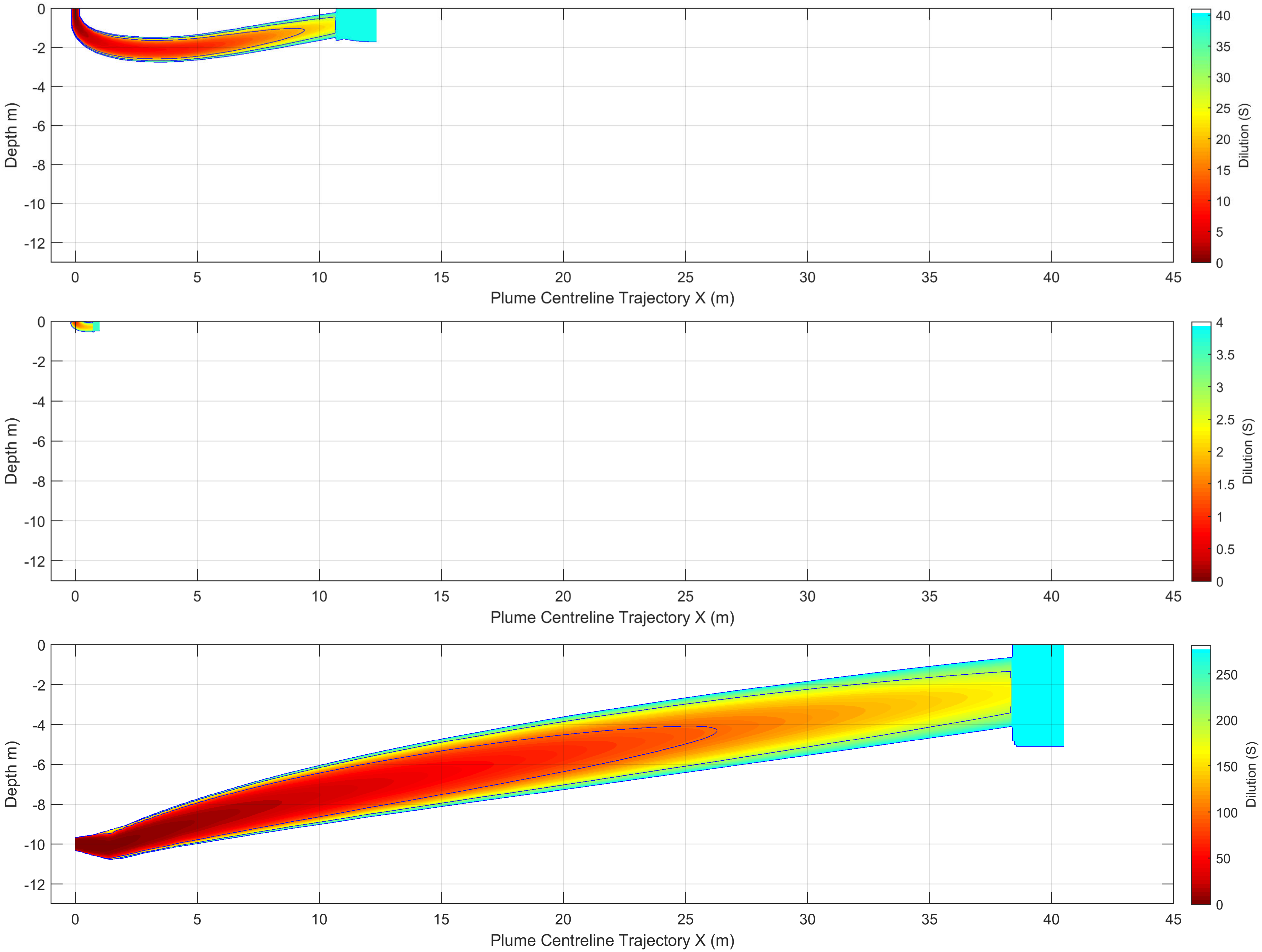

Figure 5.2 Cross-sections of the near-field dilutions for a 4,350 m^3/d discharge rate released under medium (annualised) currents at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

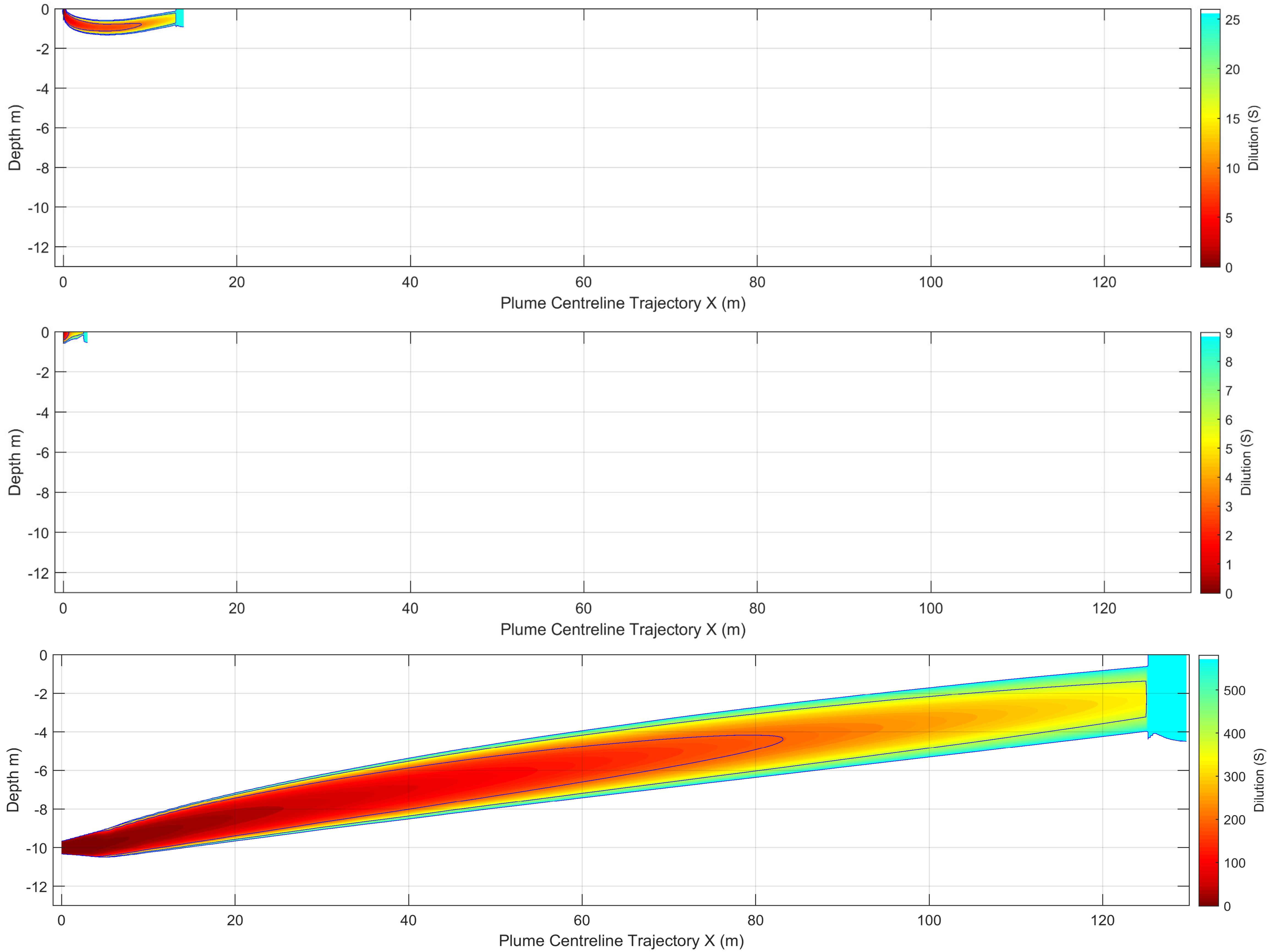

Figure 5.3 Cross-sections of the near-field dilutions for a 4,350 m³/d discharge rate released under strong (annualised) currents at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

5.2 Far-Field Modelling

5.2.1 Overview

Near-field and far-field modelling are used to describe different processes and scales of effect. While the near-field modelling is conducted at fine time and space scales and uses static current, the far-field model considers larger time and space scales and accounts for dispersion under time-changing current. The far-field modelling may capture episodes of pooling of the discharge plume under weak currents, which will result in lower dilution (higher concentrations) patches moving further from the discharge source than is indicated by the near-field modelling.

5.2.2 Interpretation of Percentile Dilution Contours

For each of the modelled discharge cases, the results for all simulations were combined and a statistical analysis performed to produce percentile contours of the predicted dilutions. In the following sections, outcomes are presented for mean, 95th percentile and 99th percentile dilutions. The mean statistic is calculated to represent the central tendency, while calculation of 95th percentile and 99th percentile statistics captures outcomes that might be expected for the most ephemeral and extreme forcing conditions.

Note that the percentile figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that dilution values occur across all replicate simulations and time steps. For example, if the lowest 95th percentile dilution at a location in the model domain is predicted as a value of 100, this means that for 95% of the time the dilution level will be higher than 100 and for 5% of the time the dilution level will be lower than 100.

Dilutions were calculated from the ratios of the initial concentrations of the contaminant to the initial concentrations in the receiving waters. Note that this assumes the background concentration of the contaminant in the receiving waters is zero and there is no significant biodegradation.

Table 5.2 summarises the expected initial concentrations of Total Petroleum Hydrocarbons (TPH) as dispersed oil-in-water and the equivalent concentrations required to yield particular dilution levels. These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 5.2 Initial concentrations of TPH and equivalent concentrations at example dilution levels.

Parameter	TPH in mg/L of dispersed oil-in-water)	
Initial concentration in discharge	15.0	30.0
Initial concentration in receiving waters	0.0	
Concentration at 1:50 dilution	0.3	0.6
Concentration at 1:75 dilution	0.2	0.4
Concentration at 1:100 dilution	0.15	0.3
Concentration at 1:150 dilution	0.1	0.2
Concentration at 1:200 dilution	0.075	0.15
Concentration at 1:300 dilution	0.05	0.1
Concentration at 1:500 dilution	0.03	0.06
Concentration at 1:1,000 dilution	0.015	0.03

5.2.3 Timeseries Observations

Figure 5.4 to Figure 5.6 show snapshots of predicted dilutions for single simulations at 3-hour intervals for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively. Note the periods chosen for each simulation and the intention of the simulations selected was to show the spatially-varying orientation of the plume and the rapidly-varying nature of the dilutions that could be observed under typical conditions. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

The snapshots illustrated that the dilutions (and in turn concentrations) became more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) were predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume had a more continuous appearance, with higher-concentrated patches moving as a unified group.

The snapshots in Figure 5.4 to Figure 5.6 show a relatively thin and discontinuous plume emanating from the discharge location interspersed with patches of lower dilutions of the plume which separated over time from the connecting plume. This pattern is attributable to periodic tide reversals which cause the existing plume to repeatedly pass over the discharge location.

These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

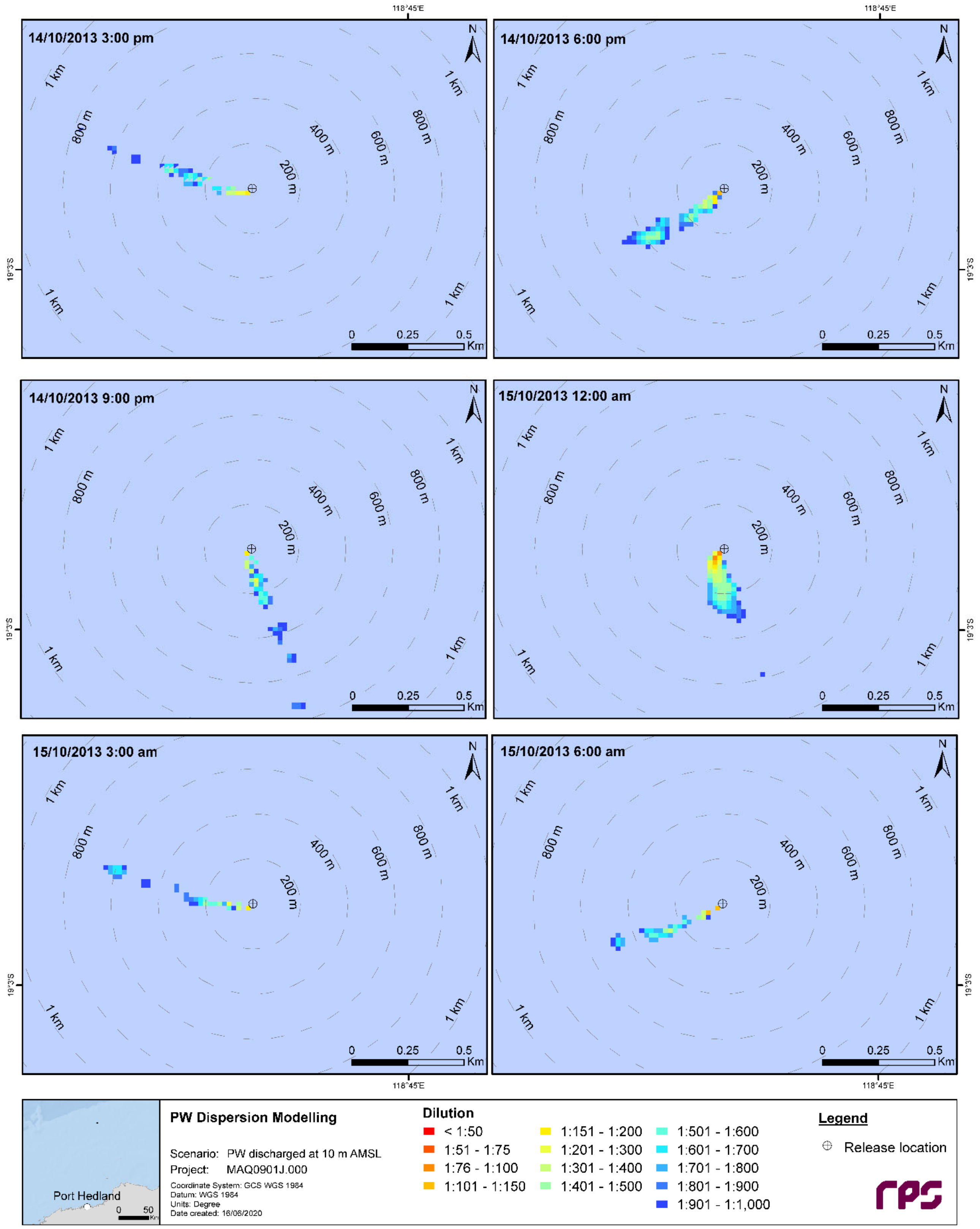

Figure 5.4 Snapshots of predicted maximum dilution levels, at 3-hour intervals from 3.00 pm on the 14th of October 2013 to 6.00 am on the 15th of October 2013 for a discharge of 4,350 m³/day occurring at 10 m AMSL.

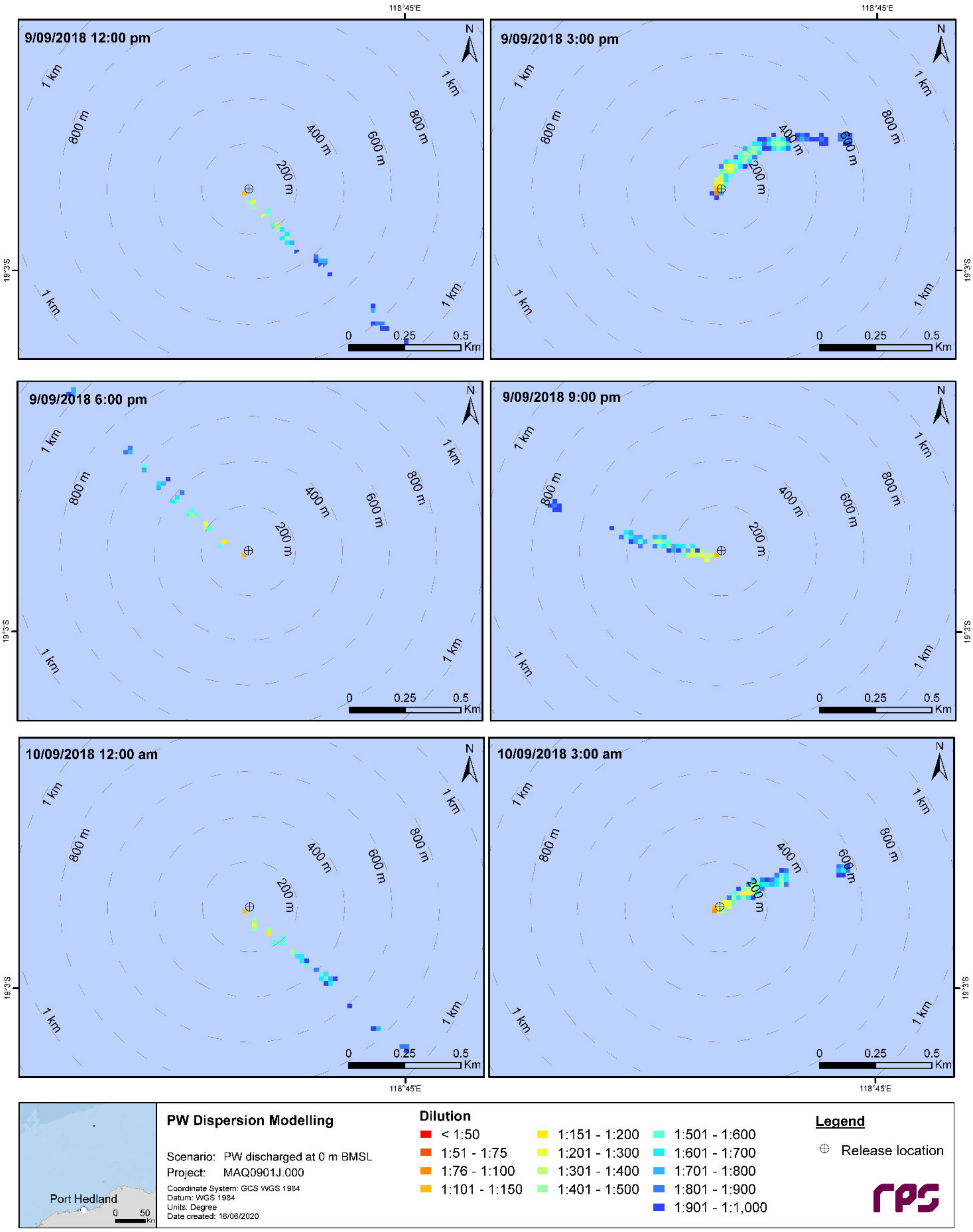

Figure 5.5 Snapshots of predicted maximum dilution levels, at 3-hour intervals from 12.00 pm on the 9th of September 2018 to 3.00 am on the 10th of September 2018 for a discharge of 4,350 m^3/day occurring at 0 m BMSL.

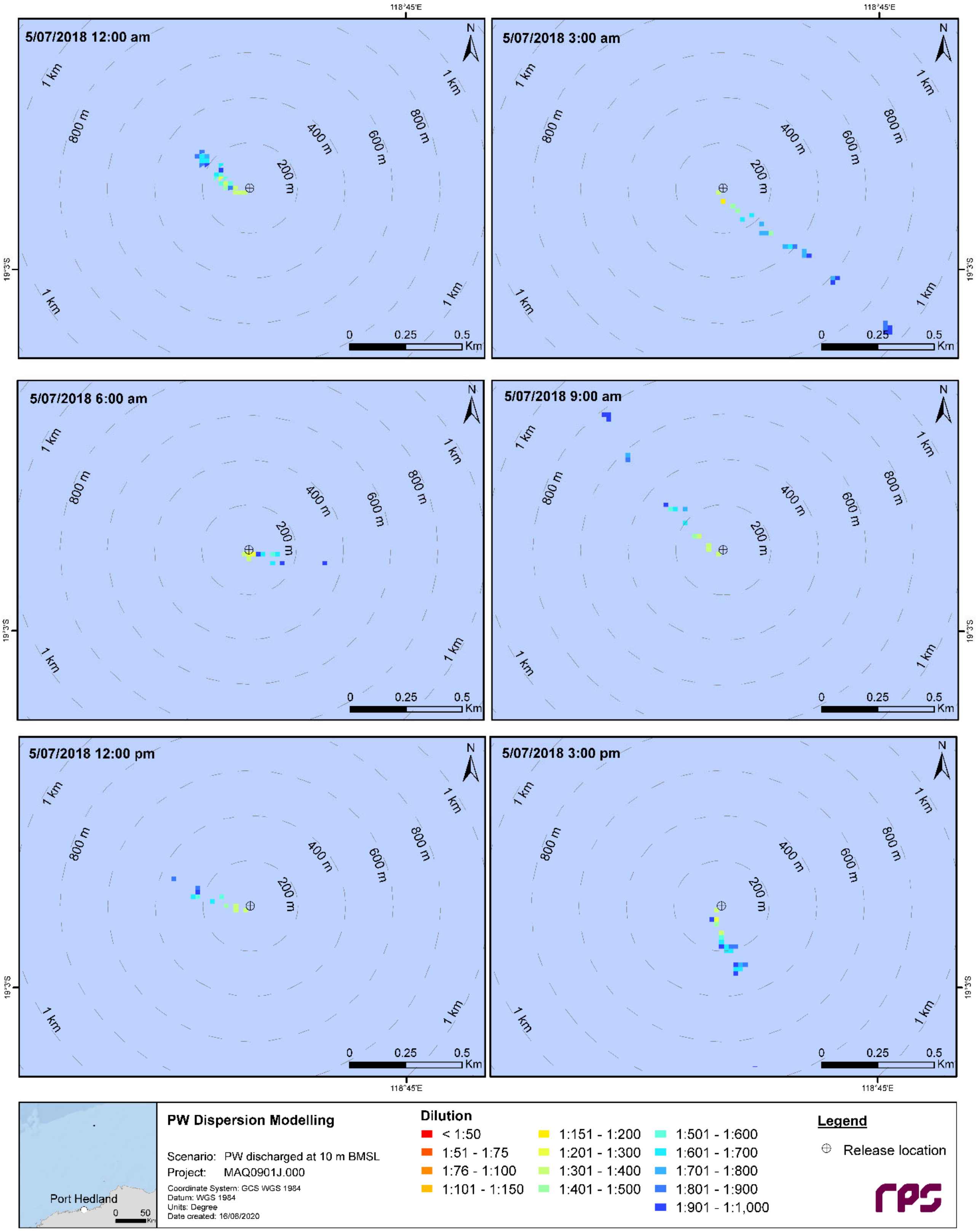

Figure 5.6 Snapshots of predicted maximum dilution levels, at 3-hour intervals from 12.00 am on the 5th of July 2018 to 3.00 pm on the 5th of July 2018 for a discharge of 4,350 m^3/day occurring at 10 m BMSL.

5.2.4 Annualised Analysis

The model outputs for the 150 simulations per case were combined and presented on an annualised basis.

Table 5.3 summarises the annualised maximum distances from the discharge location to achieve 1:50, 1:100, 1:200, 1:300, 1:400, 1:500, 1:600, 1:700, 1:800, 1:900; and 1:1,000 dilutions for each case. The results indicate that the release of effluent under all conditions results in rapid dispersion within the ambient environment. At the 95th percentile, the maximum spatial extents to the 1:1,000 dilution contour were 298 m, 608 m and 255 m for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.

Table 5.4 summarises the total area of influence for the 1:1,000 dilution contour for each statistic for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL. At the 95th percentile, the maximum areas of exposure to the specified dilution contour were 0.102 km^2, 0.136 km^2 and 0.072 km^2 for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.

Table 5.5 summarises the maximum depths from the discharge location to achieve 1:1,000 dilutions for each season and statistic. Maximum depths were predicted as 4 m, 3 m and 4 m for 10 m AMSL, 0 m BMSL and 10 m BMSL, respectively.

Figure 5.7 to Figure 5.15 show mean, 95th and 99th percentile dilutions for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column for the particular statistic and does not consider frequency or duration.

Comparison figures of the maximum spatial extents to the 1:1,000 dilution contour for discharges at 10 m AMSL, 0 m BMSL and 10 m BMSL are presented in Figure 5.16 (mean), Figure 5.17 (95th percentile) and Figure 5.18 (99th percentile).

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

The seasonal far-field results for the 10 m AMSL, 0 m BMSL and 10 m BMSL discharges are presented in Appendix B.

Table 5.3 Maximum distances from the PW discharge location to achieve given dilution factors for each case. Findings are based on the combined annualised results (150 simulations per case).

Dilution	Maximum distance (m) from discharge location to achieve given dilutions								
	Case 1 - 10 m above mean sea level			Case 2 - 0 m below mean sea level			Case 3 - 10 m below mean sea level		
	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile
1:50	-	-	-	-	-	42	-	-	-
1:100	-	42	42	42	42	608	-	-	42
1:200	42	42	86	42	608	608	-	42	58
1:300	42	76	166	42	608	608	42	51	114
1:400	42	95	212	42	608	622	42	76	175
1:500	42	130	283	42	608	624	42	103	220
1:600	42	184	374	42	608	637	42	148	286
1:700	42	198	468	58	608	639	42	184	355
1:800	42	242	566	58	608	709	42	198	438
1:900	58	270	652	58	608	837	42	214	538
1:1,000	58	298	765	58	608	902	42	255	591

Table 5.4 Total area of influence to achieve a dilution factor of 1:1,000 for each case. Findings are based on the combined annualised results (150 simulations per case).

Percentile	Total area (km^2) of influence for given dilution of 1:1,000		
	Case 1 - 10 m above mean sea level	Case 2 - 0 m below mean sea level	Case 3 - 10 m below mean sea level
Mean	0.002	0.003	0.001
95th	0.102	0.136	0.072
99th	0.856	1.369	0.550

Table 5.5 Maximum depth the 1:1,000 dilution was achieved for each case. Findings are based on the combined annualised results (150 simulations per case).

Maximum depth (m) from discharge location to achieve given dilution of 1:1,000		
Case 1 - 10 m above mean sea level	Case 2 - 0 m below mean sea level	Case 3 - 10 m below mean sea level
4	3	4

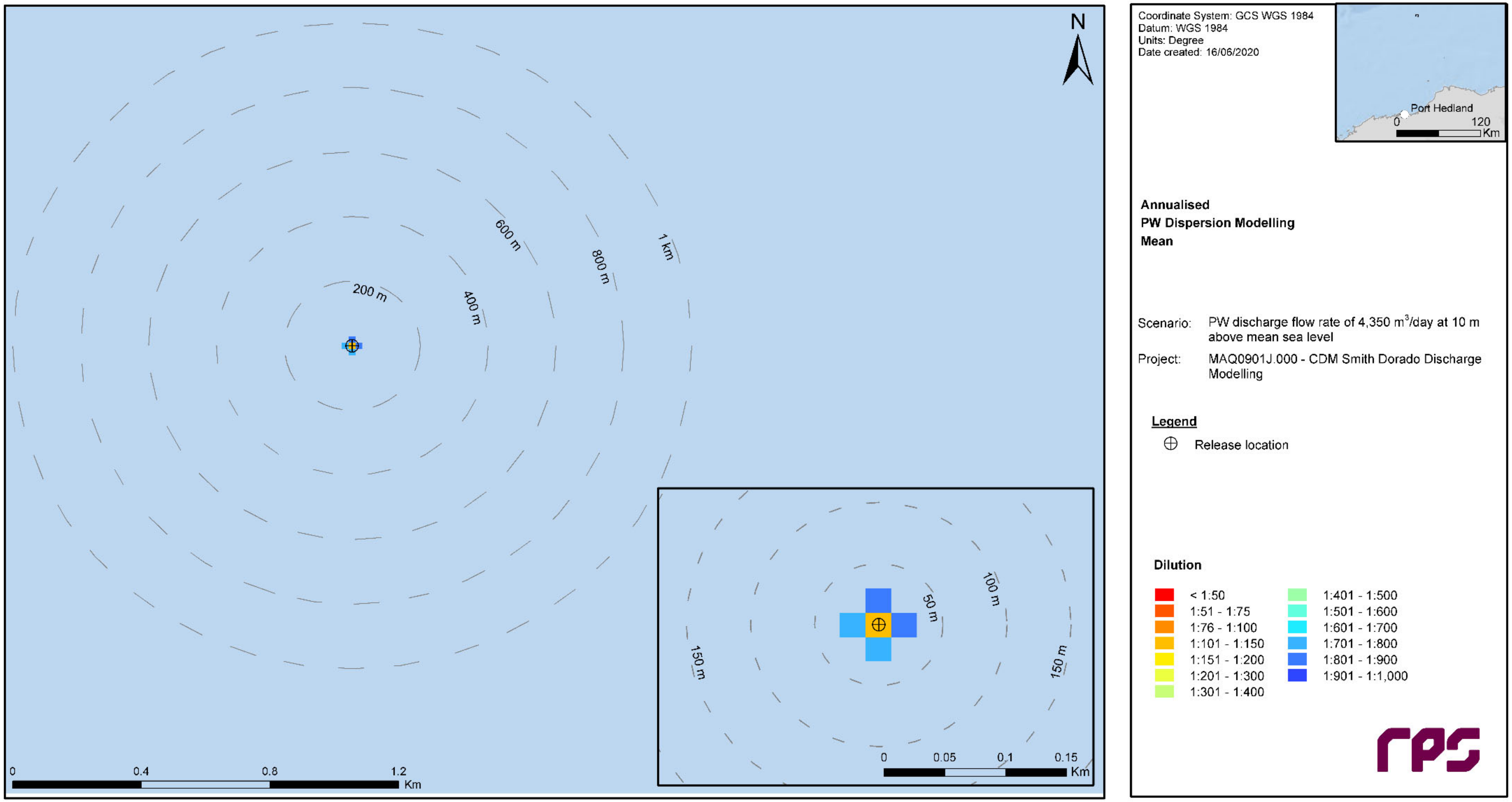

Figure 5.7 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined annualised results (150 simulations).

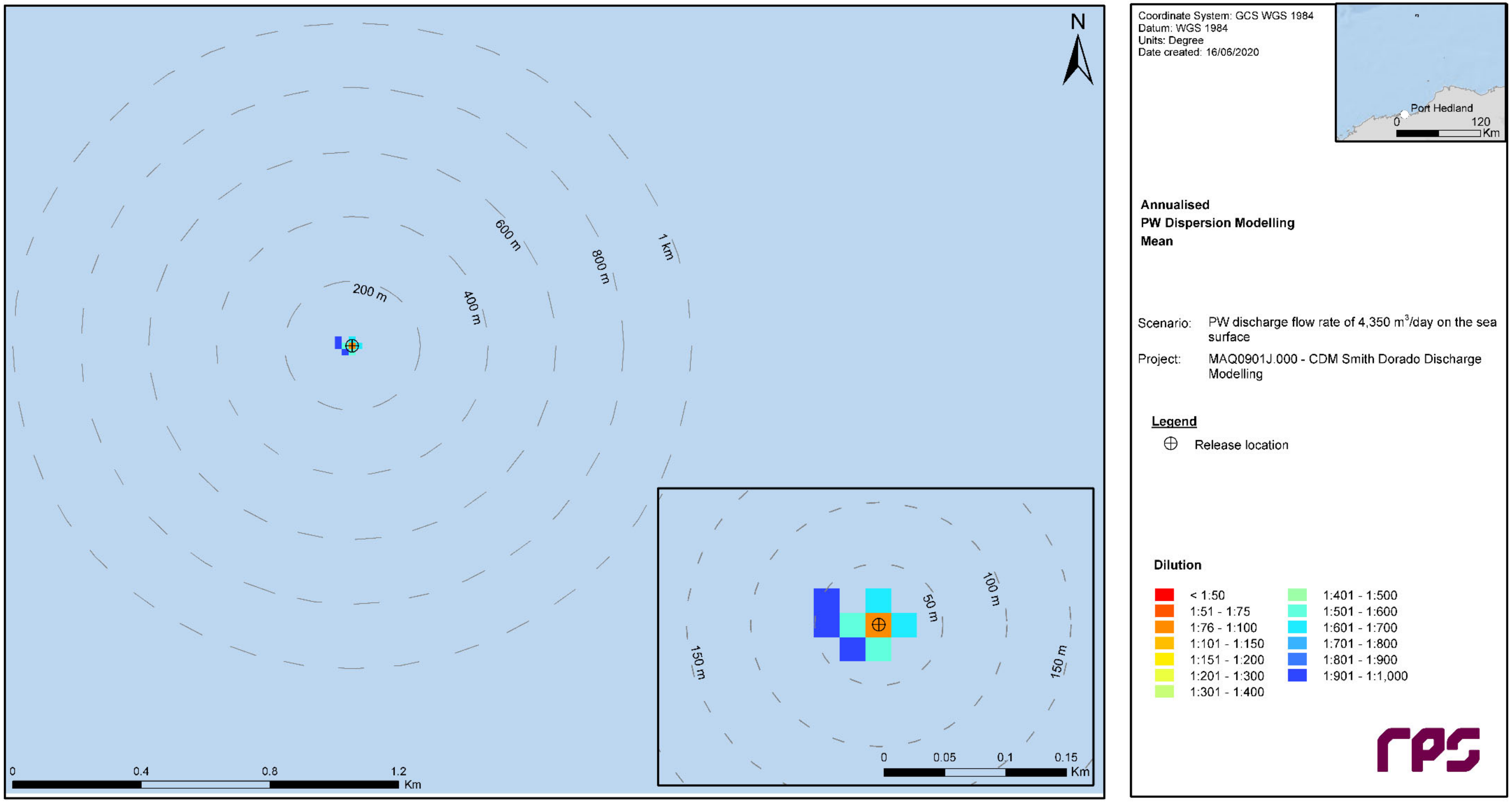

Figure 5.8 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined annualised results (150 simulations).

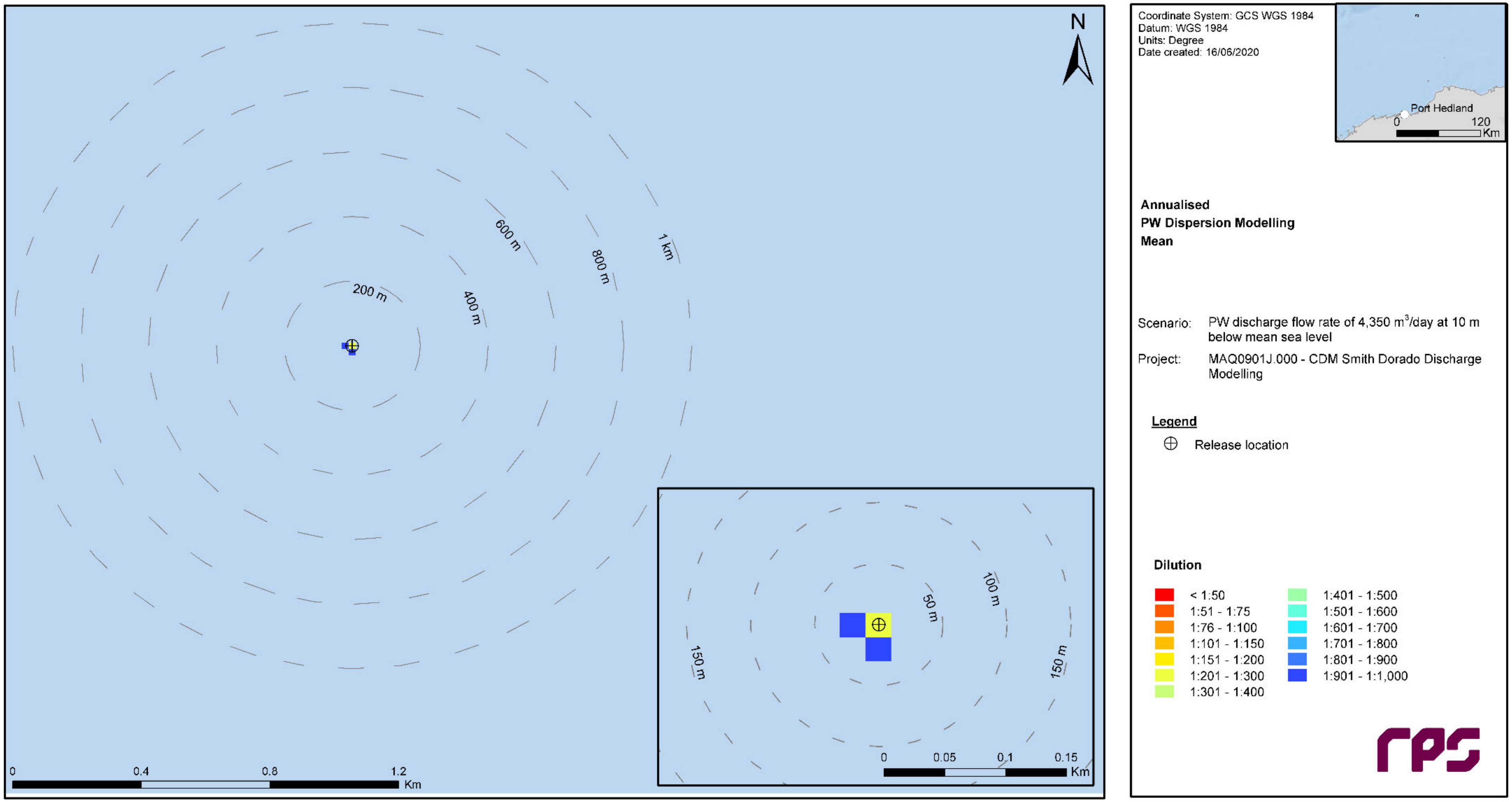

Figure 5.9 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined annualised results (150 simulations).

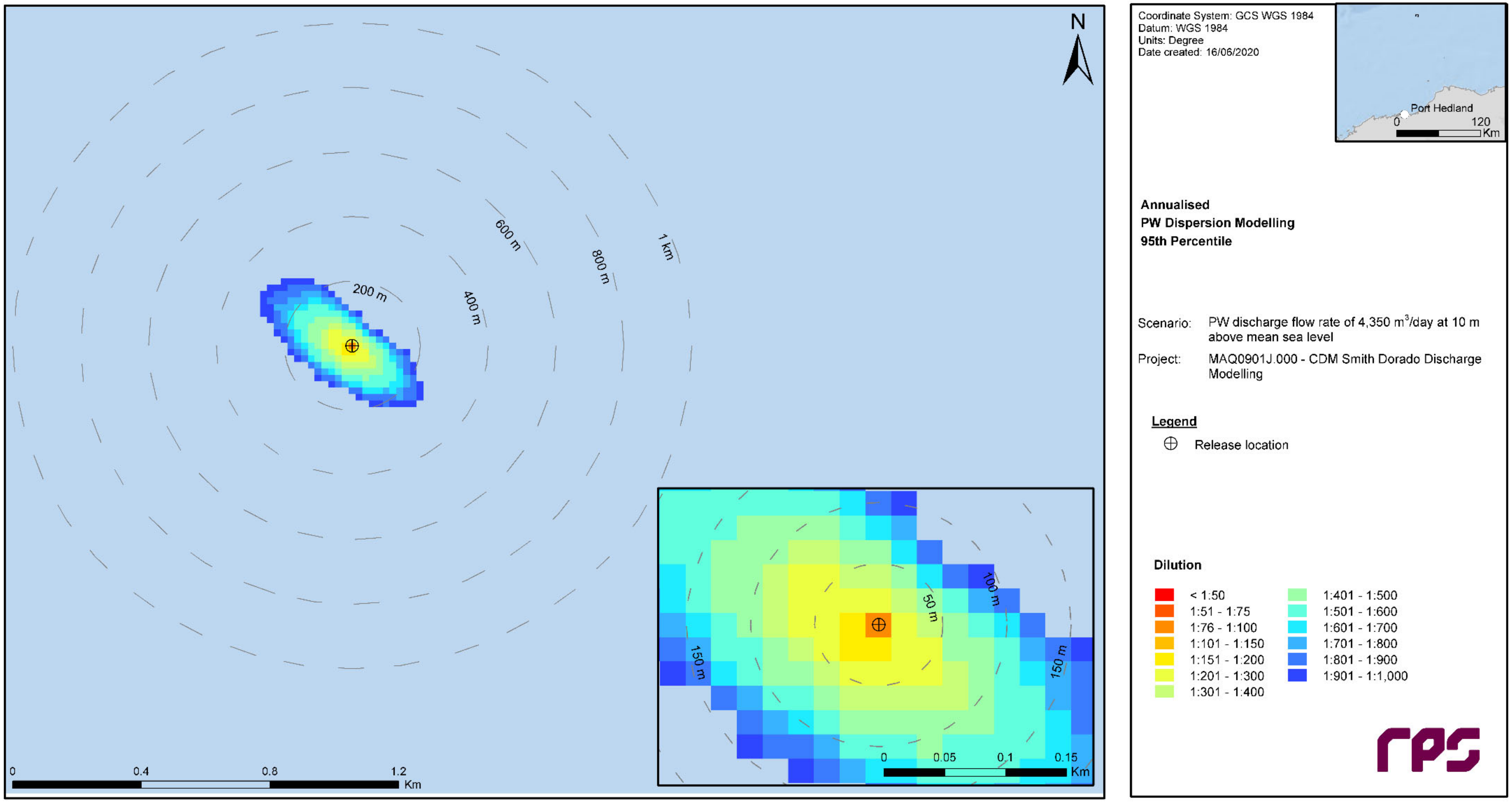

Figure 5.10 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined annualised results (150 simulations).

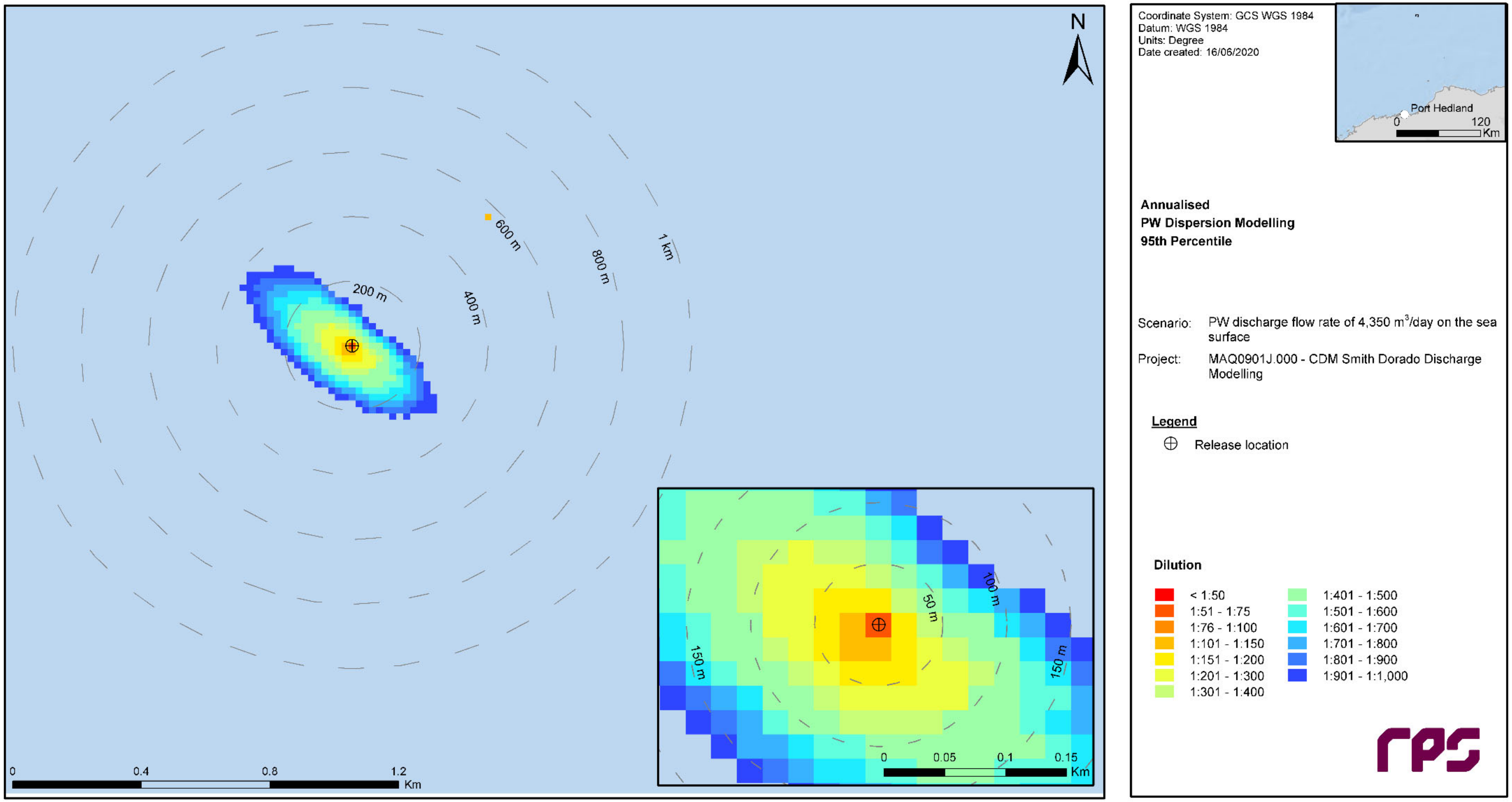

Figure 5.11 Predicted 95th percentile dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined annualised results (150 simulations).

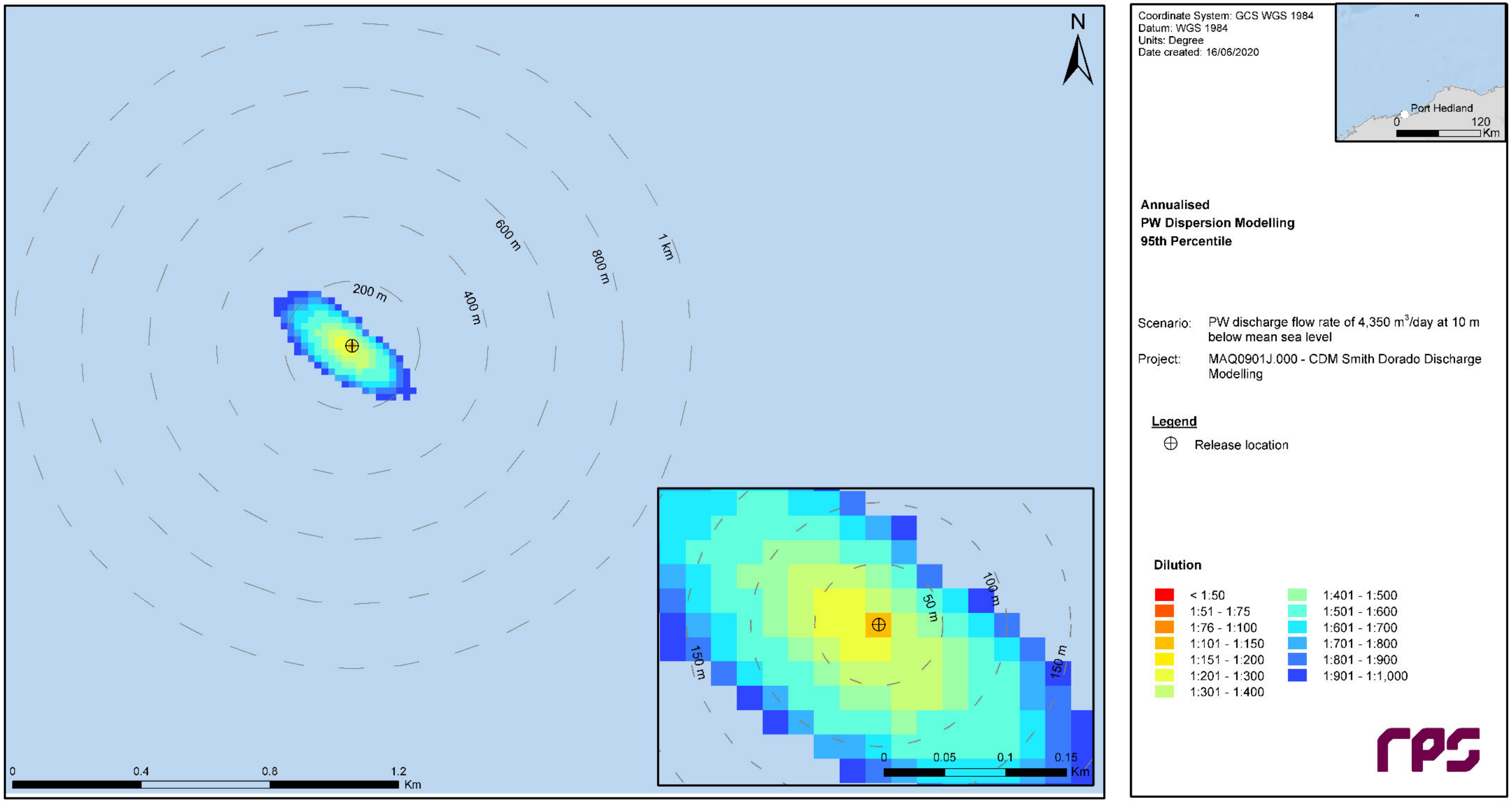

Figure 5.12 Predicted 95th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m BMSL. Findings are based on the combined annualised results (150 simulations).

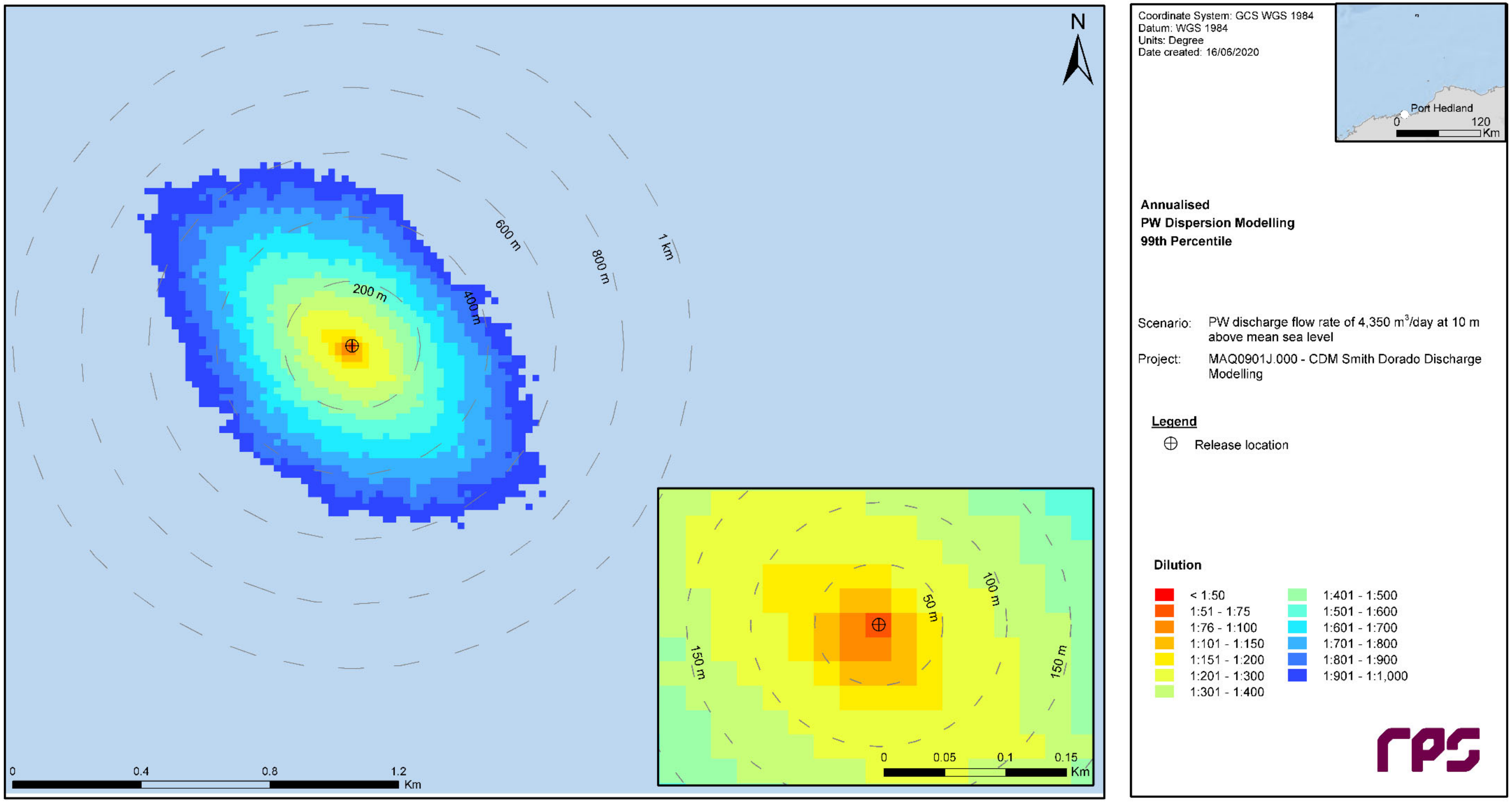

Figure 5.13 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m AMSL. Findings are based on the combined annualised results (150 simulations).

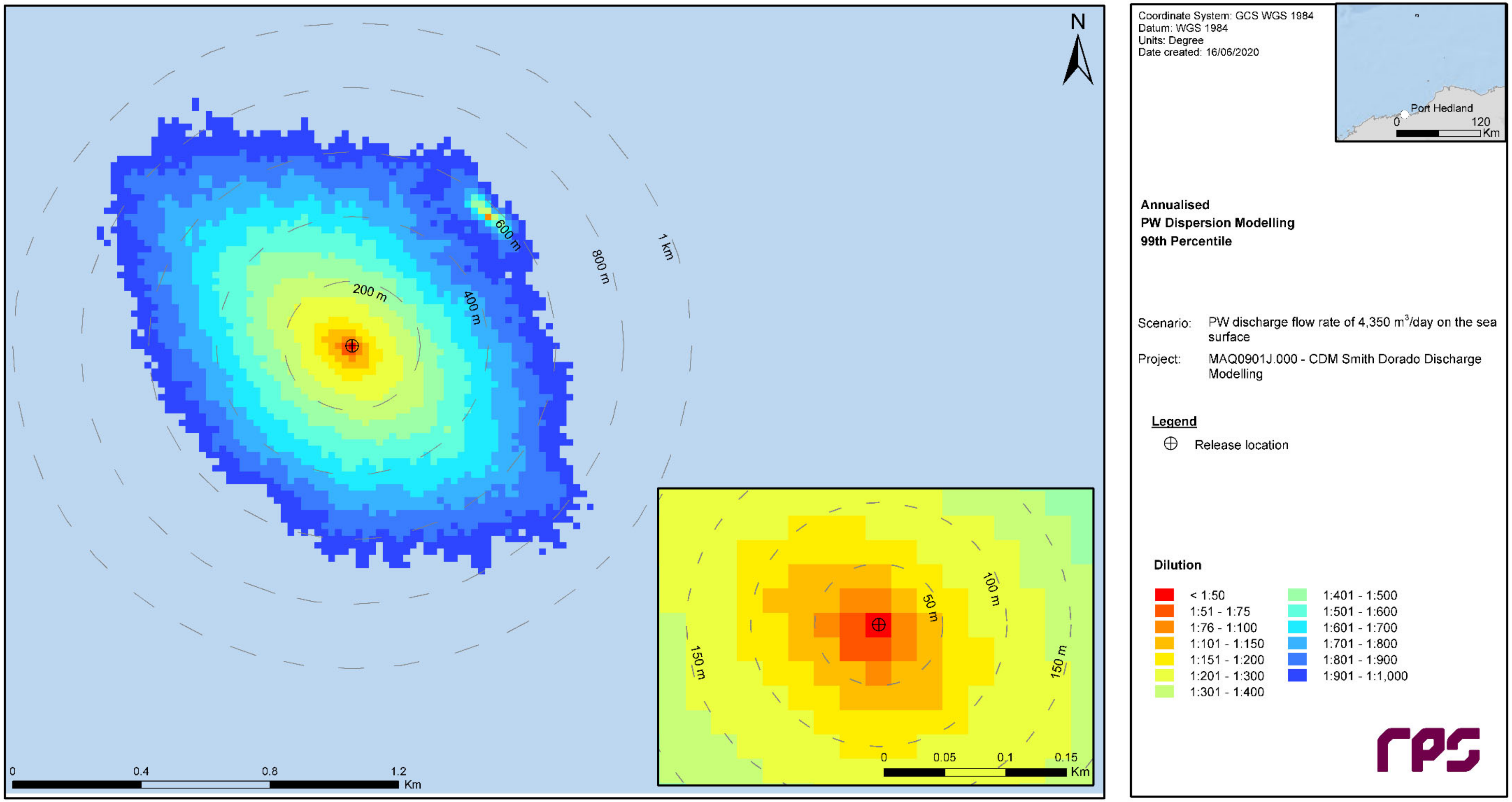

Figure 5.14 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined annualised results (150 simulations).

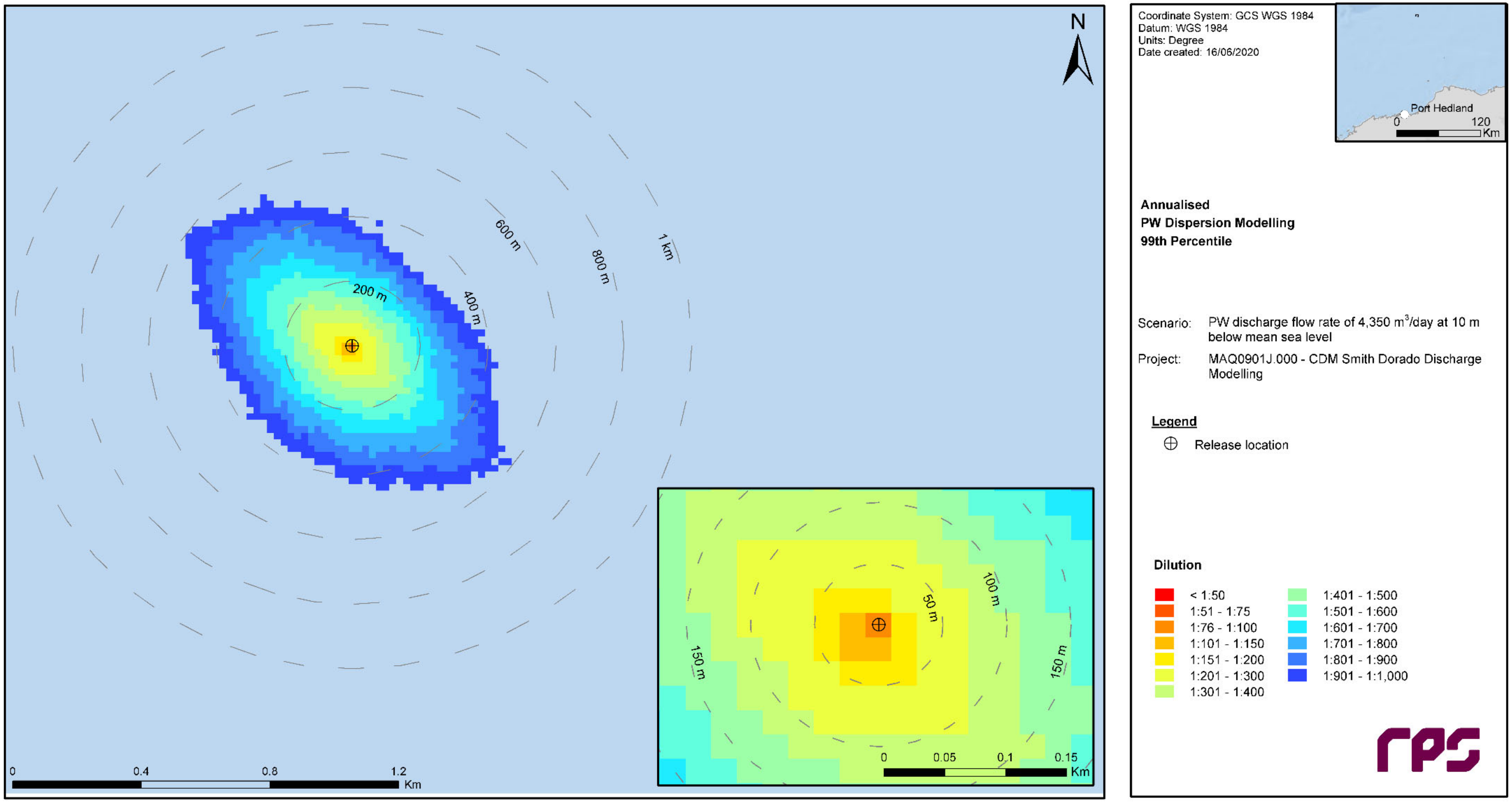

Figure 5.15 Predicted 99th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined annualised results (150 simulations).

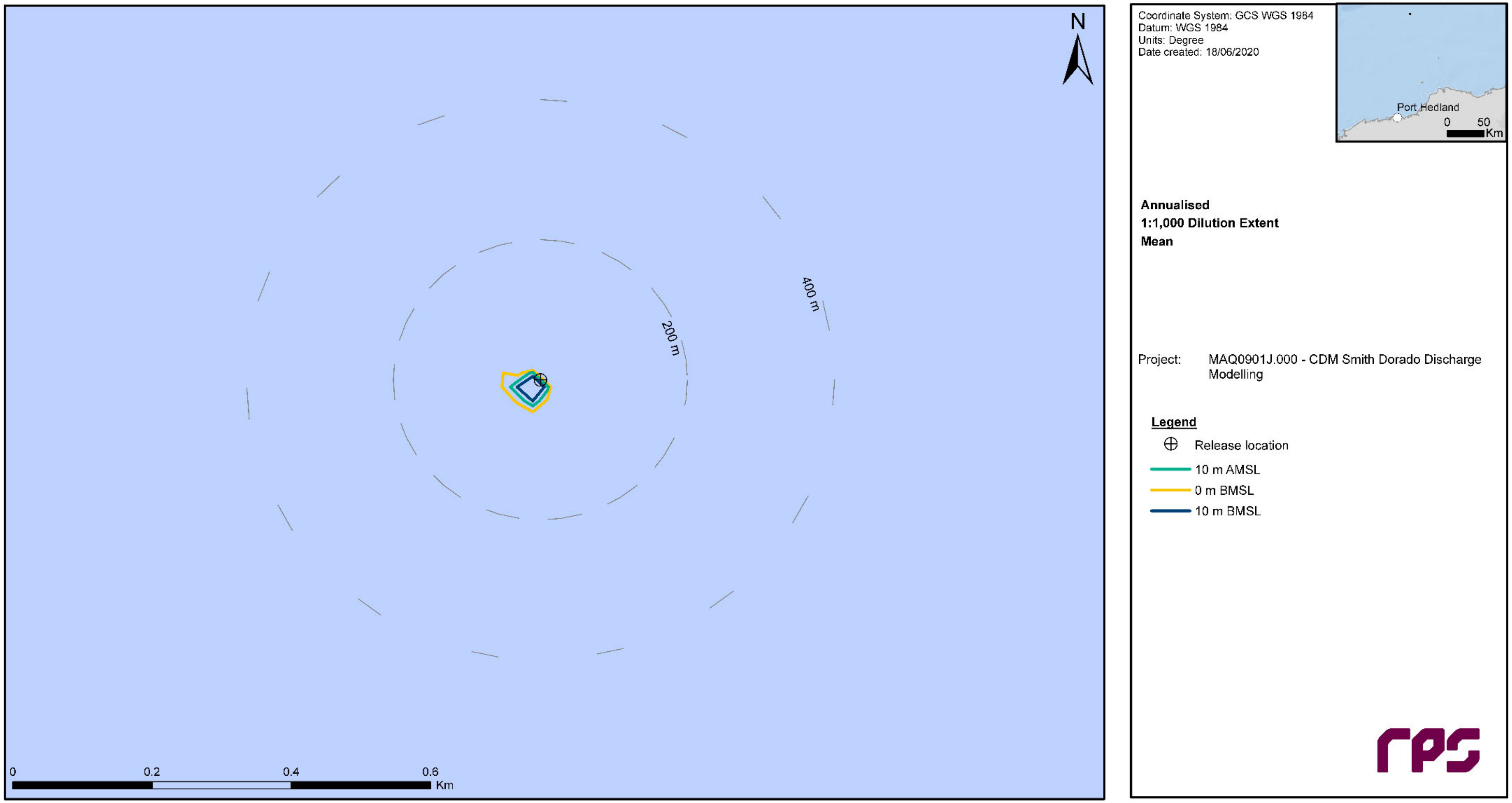

Figure 5.16 Maximum spatial extents to the 1:1,000 dilution contour for a 4,350 m^3/d PW discharge released at 10 m AMSL, 0 m BMSL and 10 m BMSL for the mean percentile. Findings are based on the combined annualised results (150 simulations per case).

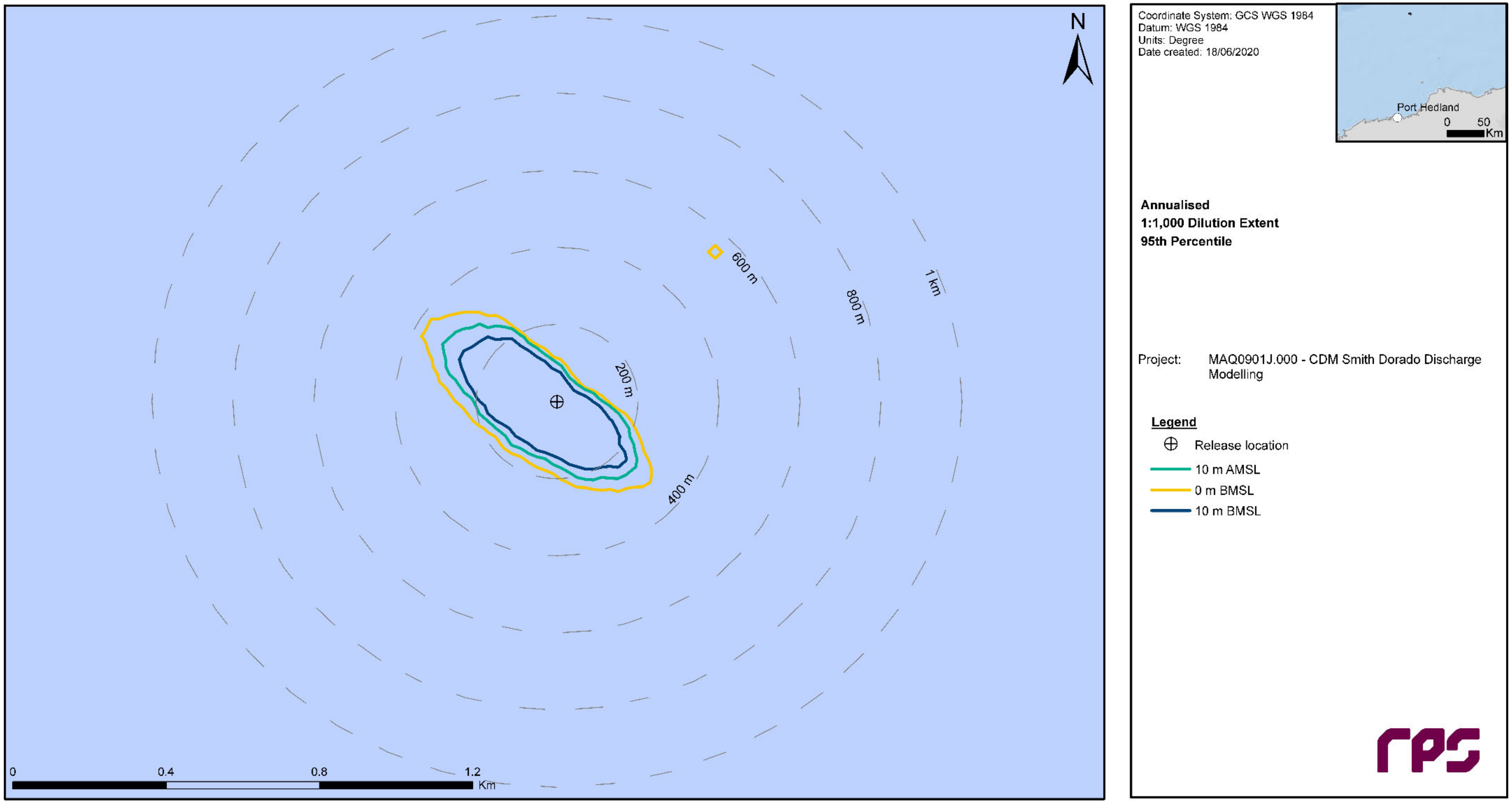

Figure 5.17 Maximum spatial extents to the 1:1,000 dilution contour for a 4,350 m^3/d PW discharge released at 10 m AMSL, 0 m BMSL and 10 m BMSL for the 95th percentile. Findings are based on the combined annualised results (150 simulations per case).

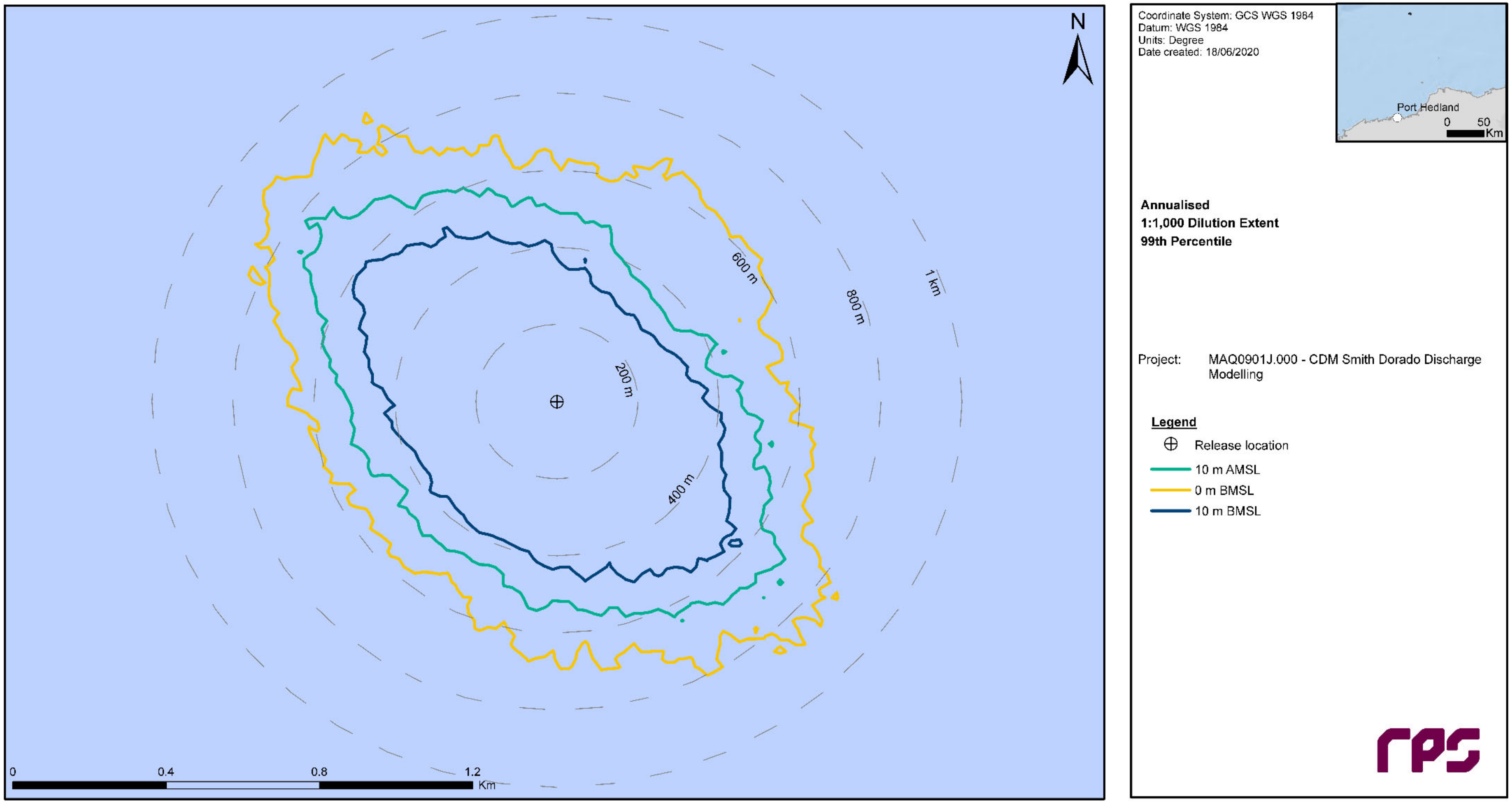

Figure 5.18 Maximum spatial extents to the 1:1,000 dilution contour for a 4,350 m³/d PW discharge released at 10 m AMSL, 0 m BMSL and 10 m BMSL for the 99th percentile analysis. Findings are based on the combined annualised results (150 simulations per case).

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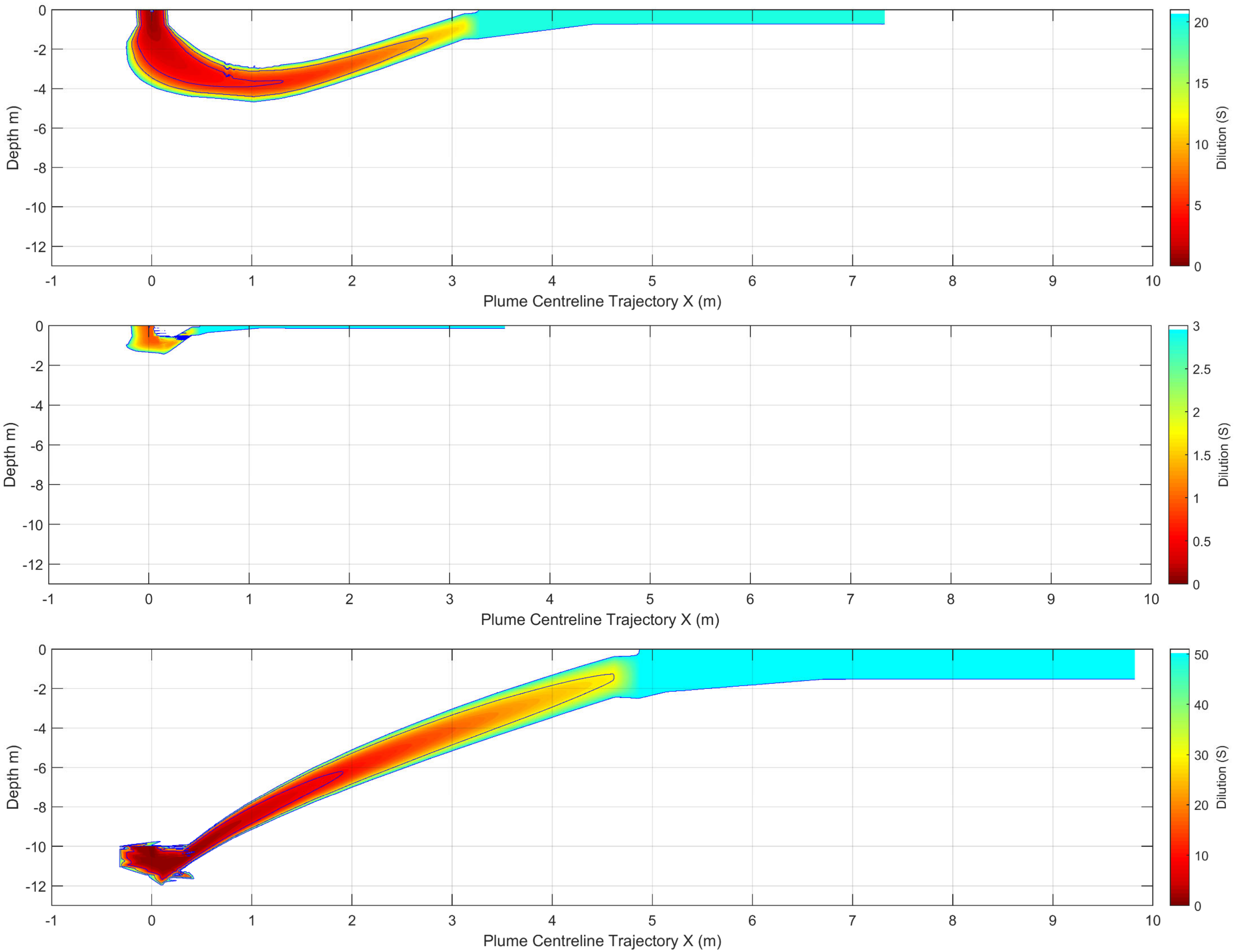
Appendix A

Seasonal Near-Field Results

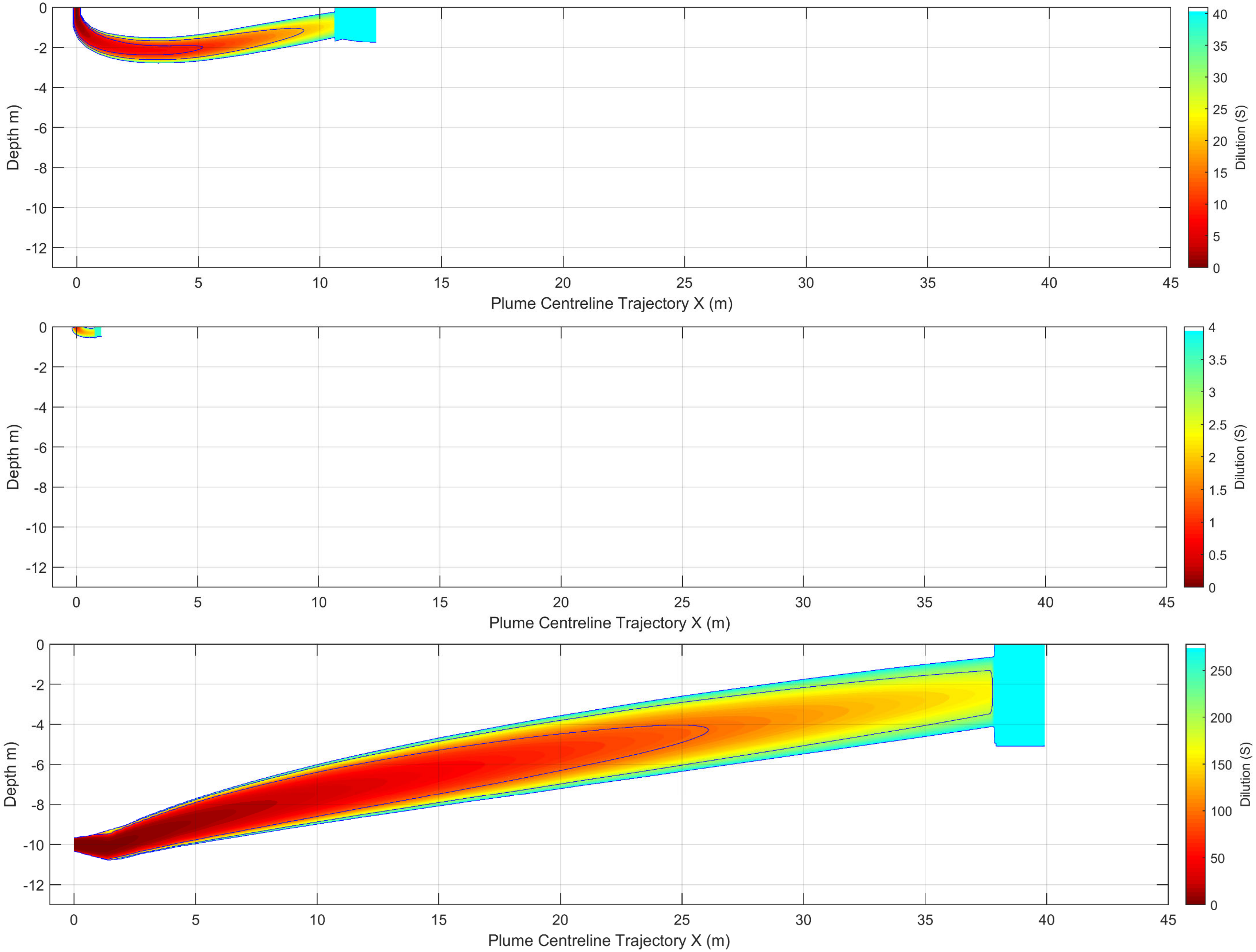
A.1 Summer

Apx Table 1 Predicted plume characteristics at the end of the near-field mixing zone of each case under weak, medium and strong current speeds during summer conditions.

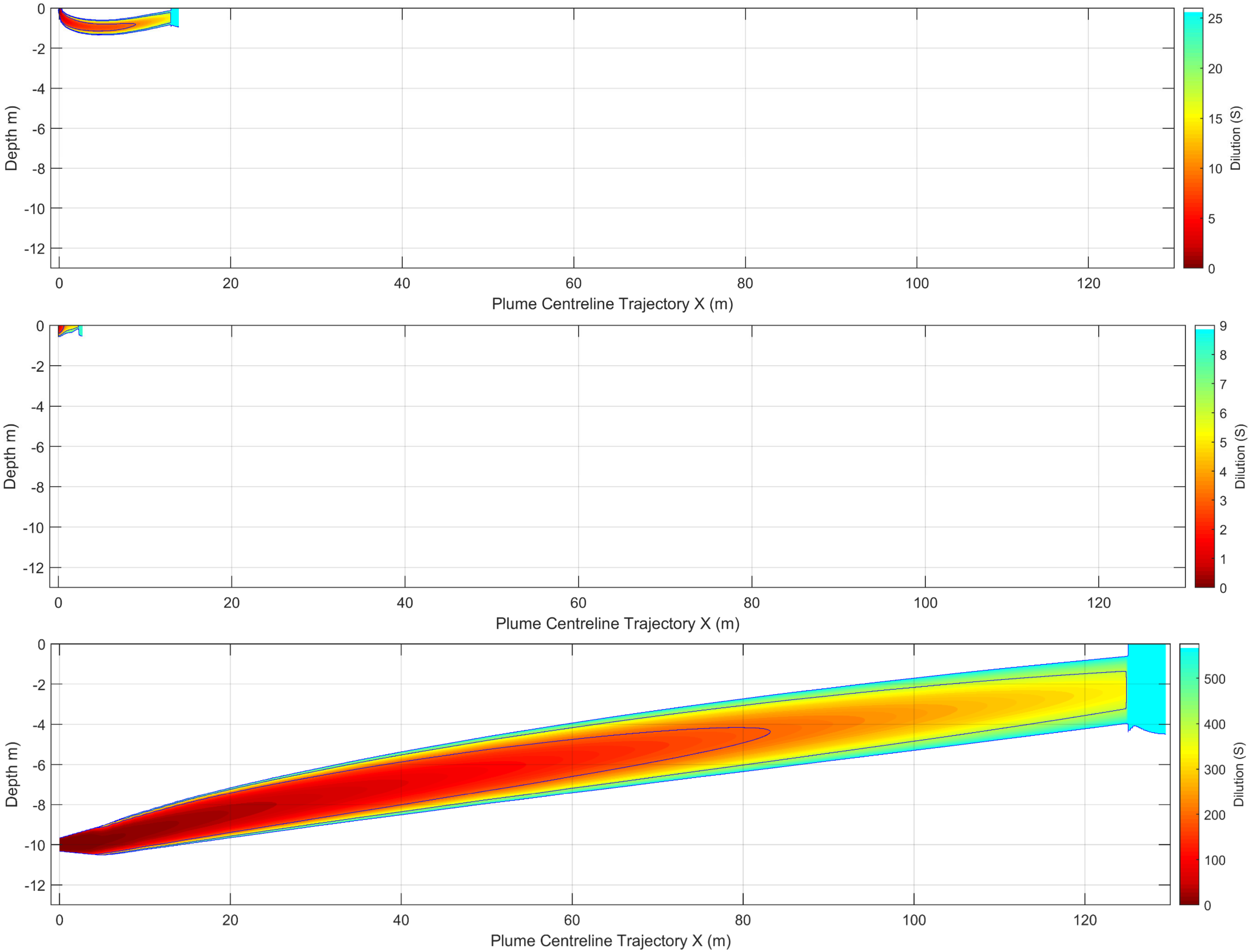
Case	Surface current speed (m/s)	Maximum plume diameter (m)	Maximum plunge depth (m)	Plume temp (°C)	Plume-ambient temp difference (°C)	Plume dilution (1:x)		Maximum horizontal distance
						Minimum (centreline)	Average	
10 m AMSL	Weak (0.08)	1.7	4.4	28.24	1.14	20	34	7.3
	Medium (0.33)	1.7	2.6	28.06	0.96	41	70	12.3
	Strong (0.73)	1.0	1.3	27.99	0.89	26	44	13.9
0 m BMSL	Weak (0.08)	1.0	1.4	34.78	7.68	3	5	3.6
	Medium (0.33)	0.6	0.6	33.32	6.22	4	7	1.0
	Strong (0.73)	0.4	0.5	29.82	2.72	8	14	2.8
10 m BMSL	Weak (0.08)	2.8	11.5	27.46	0.46	50	85	9.8
	Medium (0.31)	4.7	10.2	27.08	0.08	277	471	39.9
	Strong (0.72)	4.6	10.2	27.04	0.04	576	979	129.5



Apx Figure 1 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m^3/d released under weak (summer) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).



Apx Figure 2 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under medium (summer) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

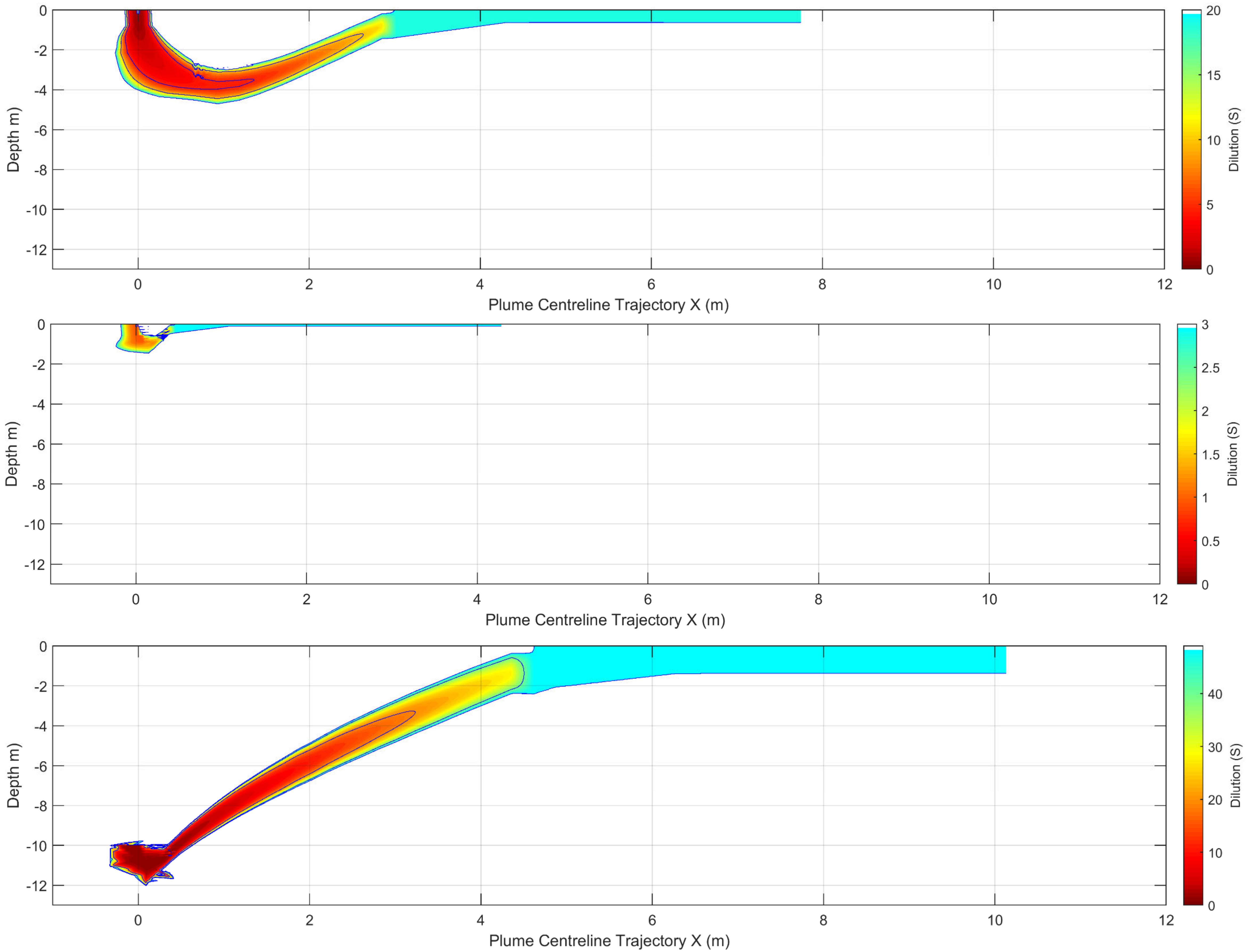


Apx Figure 3 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under strong (summer) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

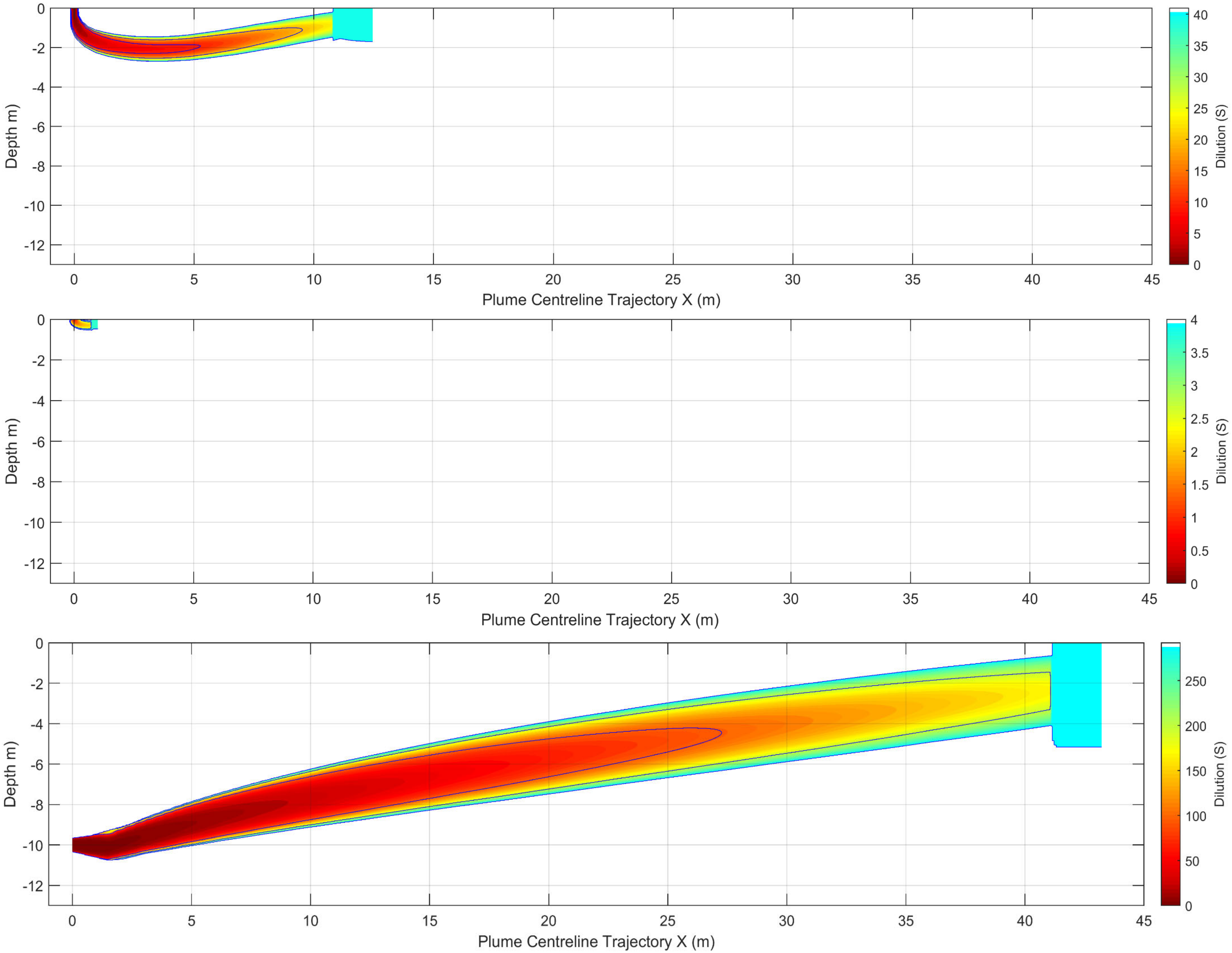
A.2 Transitional

Apx Table 2 Predicted plume characteristics at the end of the near-field mixing zone of each case under weak, medium and strong current speeds during transitional conditions.

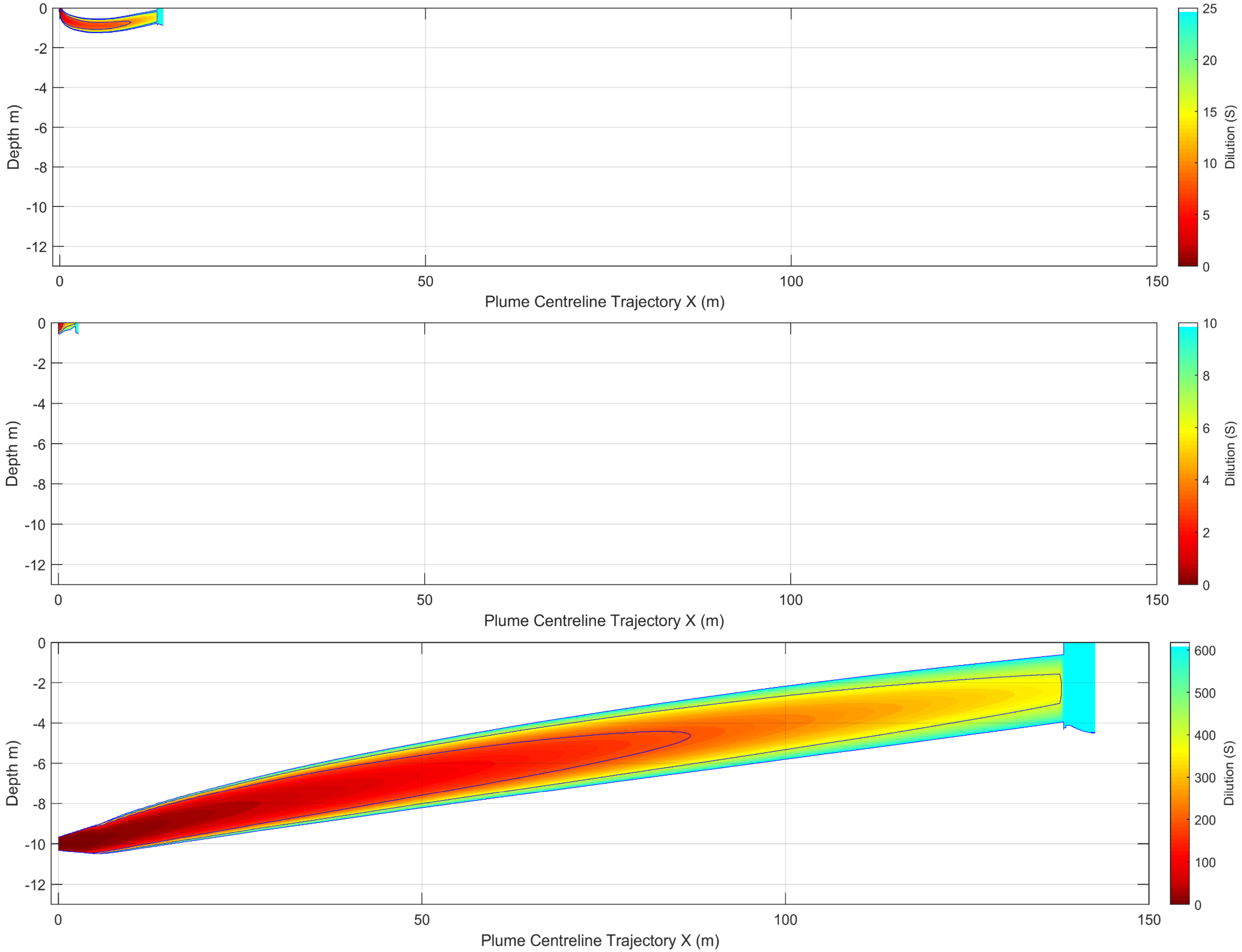
Case	Surface current speed (m/s)	Maximum plume diameter (m)	Maximum plunge depth (m)	Plume temp (°C)	Plume-ambient temp difference (°C)	Plume dilution (1:x)		Maximum horizontal distance
						Minimum (centreline)	Average	
10 m AMSL	Weak (0.08)	1.6	4.4	27.83	1.23	19	32	7.8
	Medium (0.35)	1.7	2.6	27.18	0.58	40	68	12.5
	Strong (0.81)	0.9	1.2	27.57	0.97	24	41	14.2
0 m BMSL	Weak (0.08)	1.0	1.5	34.52	7.92	3	5	4.3
	Medium (0.35)	0.6	0.6	32.98	6.38	4	7	1.0
	Strong (0.81)	0.5	0.5	29.13	2.53	9	15	2.8
10 m BMSL	Weak (0.08)	2.8	1.5	26.98	0.48	49	83	9.9
	Medium (0.33)	4.7	0.6	26.58	0.08	292	496	43.2
	Strong (0.77)	4.6	0.5	26.54	0.04	617	1,048	142.6



Apx Figure 4 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under weak (transitional) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).



Apx Figure 5 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under medium (transitional) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

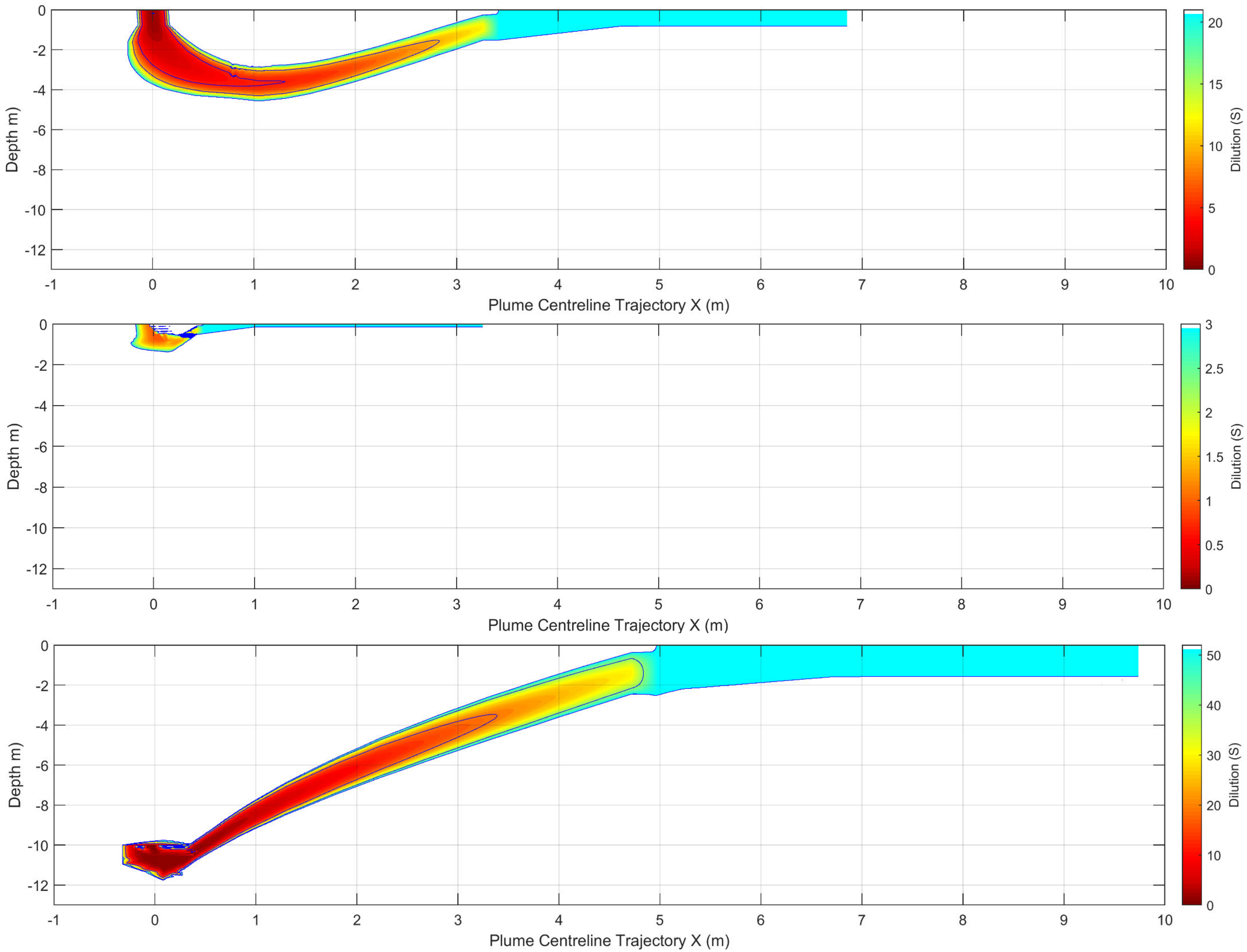


Apx Figure 6 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under strong (transitional) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

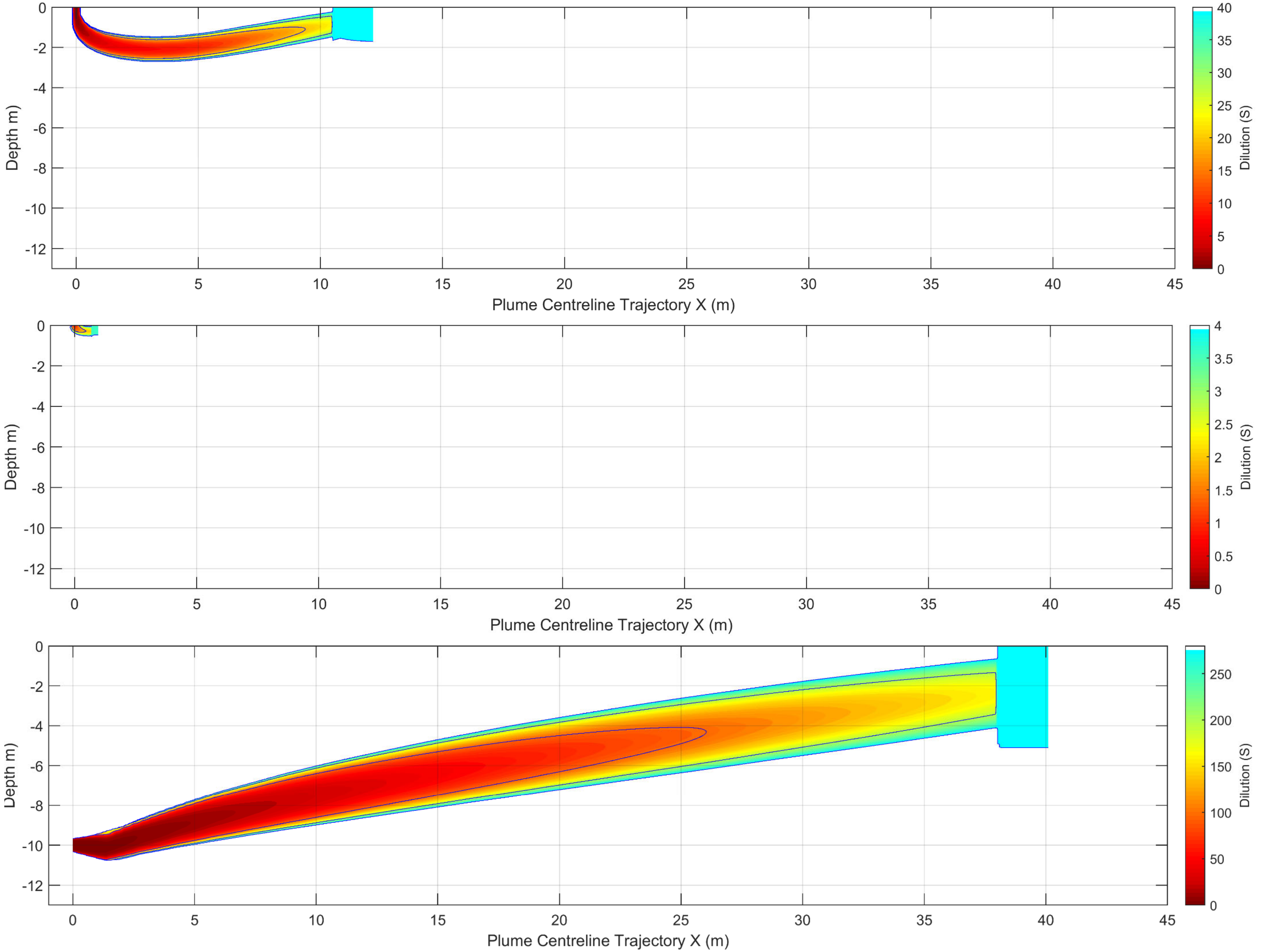
A.3 Winter

Apx Table 3 Predicted plume characteristics at the end of the near-field mixing zone of each case under weak, medium and strong current speeds during winter conditions.

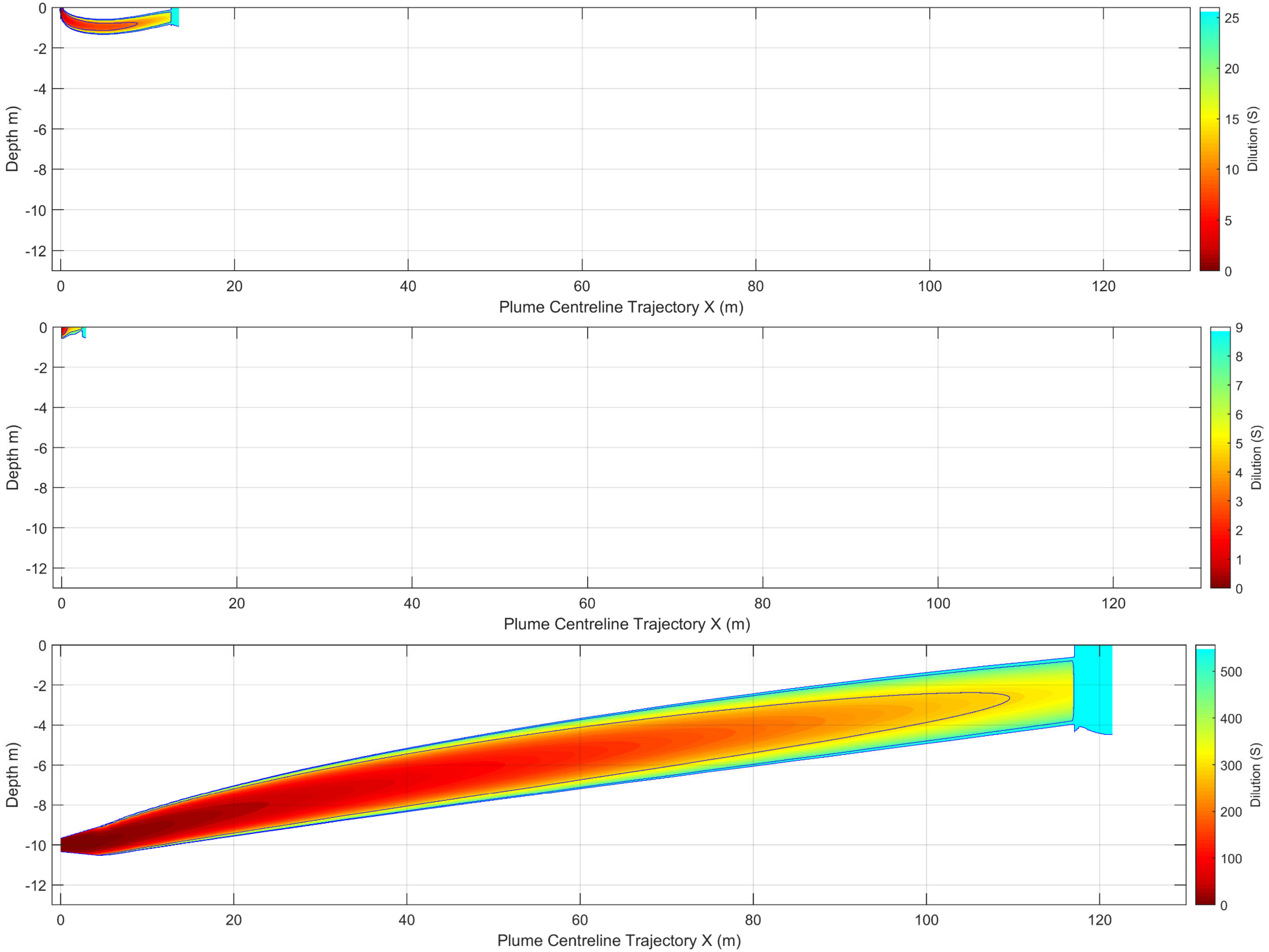
Case	Surface current speed (m/s)	Maximum plume diameter (m)	Maximum plunge depth (m)	Plume temp (°C)	Plume-ambient temp difference (°C)	Plume dilution (1:x)		Maximum horizontal distance
						Minimum (centreline)	Average	
10 m AMSL	Weak (0.09)	1.7	4.3	26.97	1.17	21	36	6.9
	Medium (0.34)	1.7	2.6	26.41	0.61	40	68	12.2
	Strong (0.74)	0.9	1.3	26.76	0.96	25	43	13.6
0 m BMSL	Weak (0.09)	1.0	1.5	33.99	8.19	3	5	3.3
	Medium (0.34)	0.6	0.6	32.49	6.69	4	7	1.0
	Strong (0.74)	0.5	0.5	28.65	2.85	9	15	2.8
10 m BMSL	Weak (0.08)	2.8	11.4	26.27	0.47	51	87	9.7
	Medium (0.31)	4.7	10.8	25.89	0.09	280	476	40.1
	Strong (0.72)	4.6	10.8	25.84	0.04	555	944	121.5



Apx Figure 7 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under weak (winter) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).



Apx Figure 8 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m^3/d released under medium (winter) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).



Apx Figure 9 Cross-sections of the near-field dilutions calculated for discharge at 4,350 m³/d released under strong (winter) currents for discharges released at 10 m AMSL (top pane), 0 m BMSL (middle pane) and 10 m BMSL (bottom pane).

Appendix B

Seasonal Far-Field Results

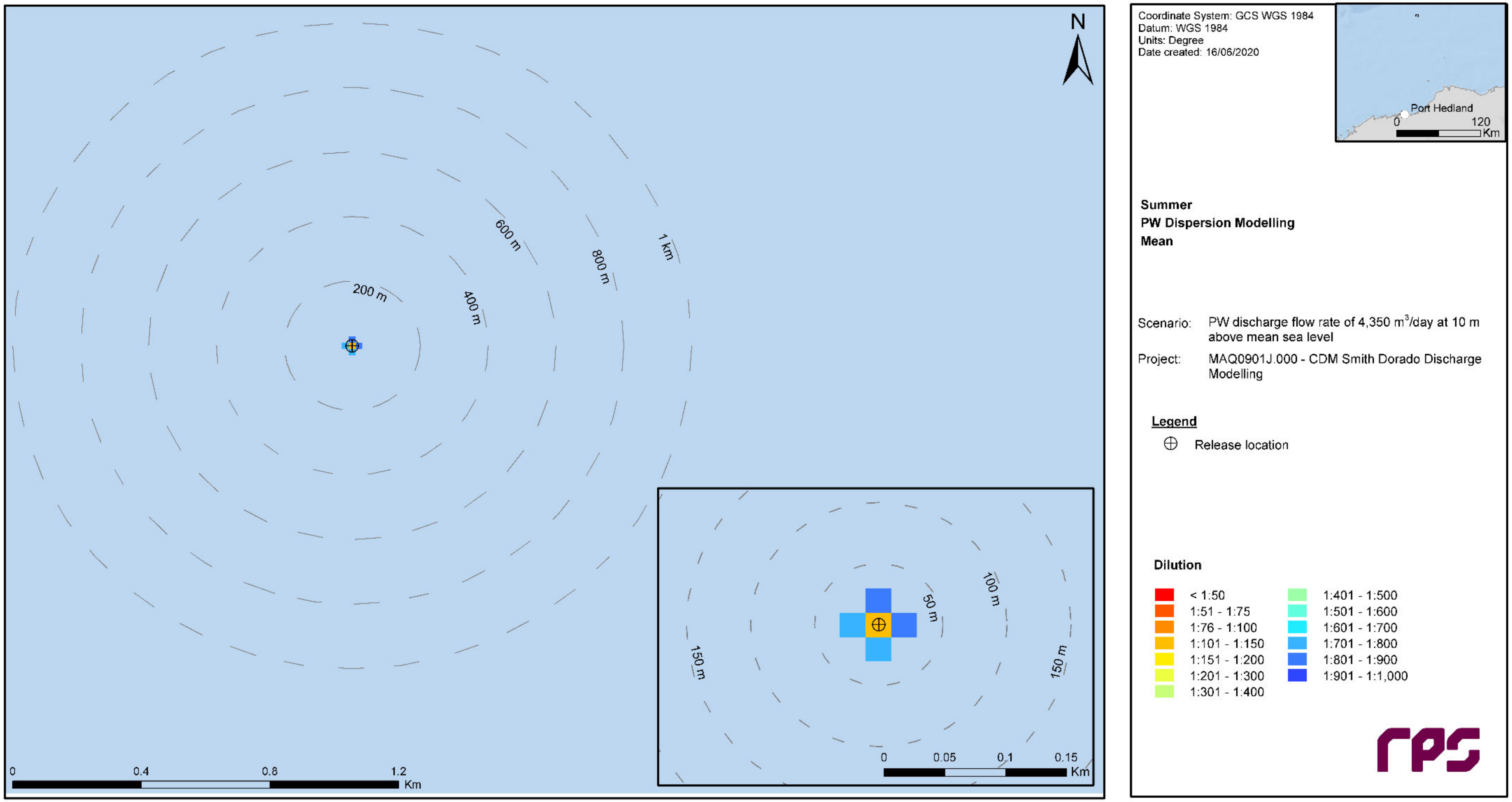
B.1 Summer

Apx Table 4 Maximum distances from the PW discharge location to achieve given dilution factors for each case. Findings are based on the combined summer results (50 simulations per case).

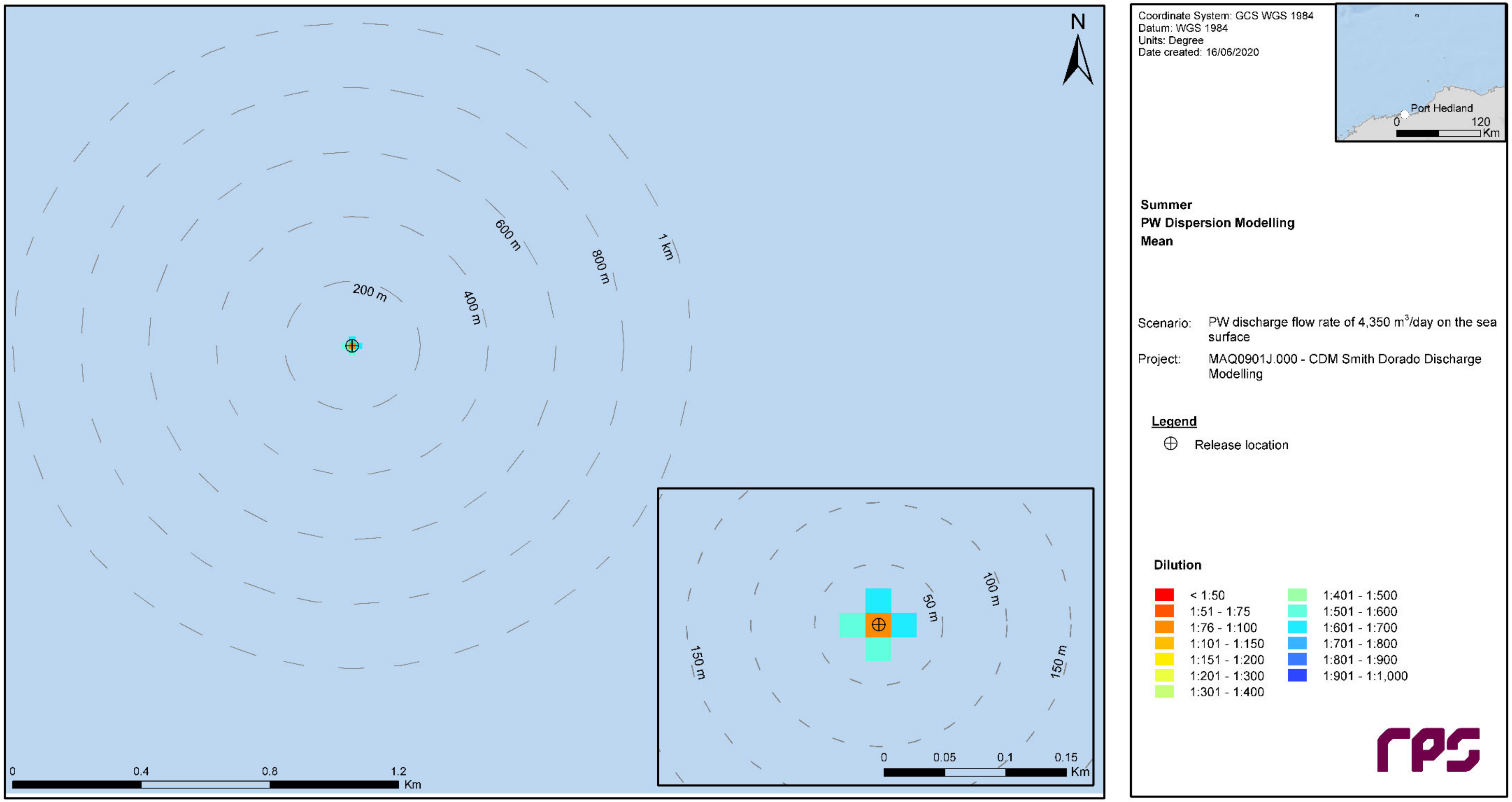
Dilution	Maximum distance (m) from discharge location to achieve given dilutions								
	Case 1 - 10 m above mean sea level			Case 2 - 0 m below mean sea level			Case 3 - 10 m below mean sea level		
	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile
1:50	-	-	-	-	-	42	-	-	-
1:100	-	42	42	42	42	608	-	-	42
1:200	42	42	76	42	608	608	-	42	58
1:300	42	71	166	42	608	608	42	51	103
1:400	42	95	203	42	608	622	42	76	166
1:500	42	121	275	42	608	624	42	103	220
1:600	42	175	347	42	608	637	42	148	274
1:700	42	198	468	58	608	639	42	175	347
1:800	42	219	519	58	608	668	42	192	427
1:900	58	258	608	58	608	787	42	214	515
1:1,000	58	274	731	58	608	900	42	237	591

Apx Table 5 Total area of influence to achieve a dilution factor of 1:1,000 for each case. Findings are based on the combined summer results (50 simulations per case).

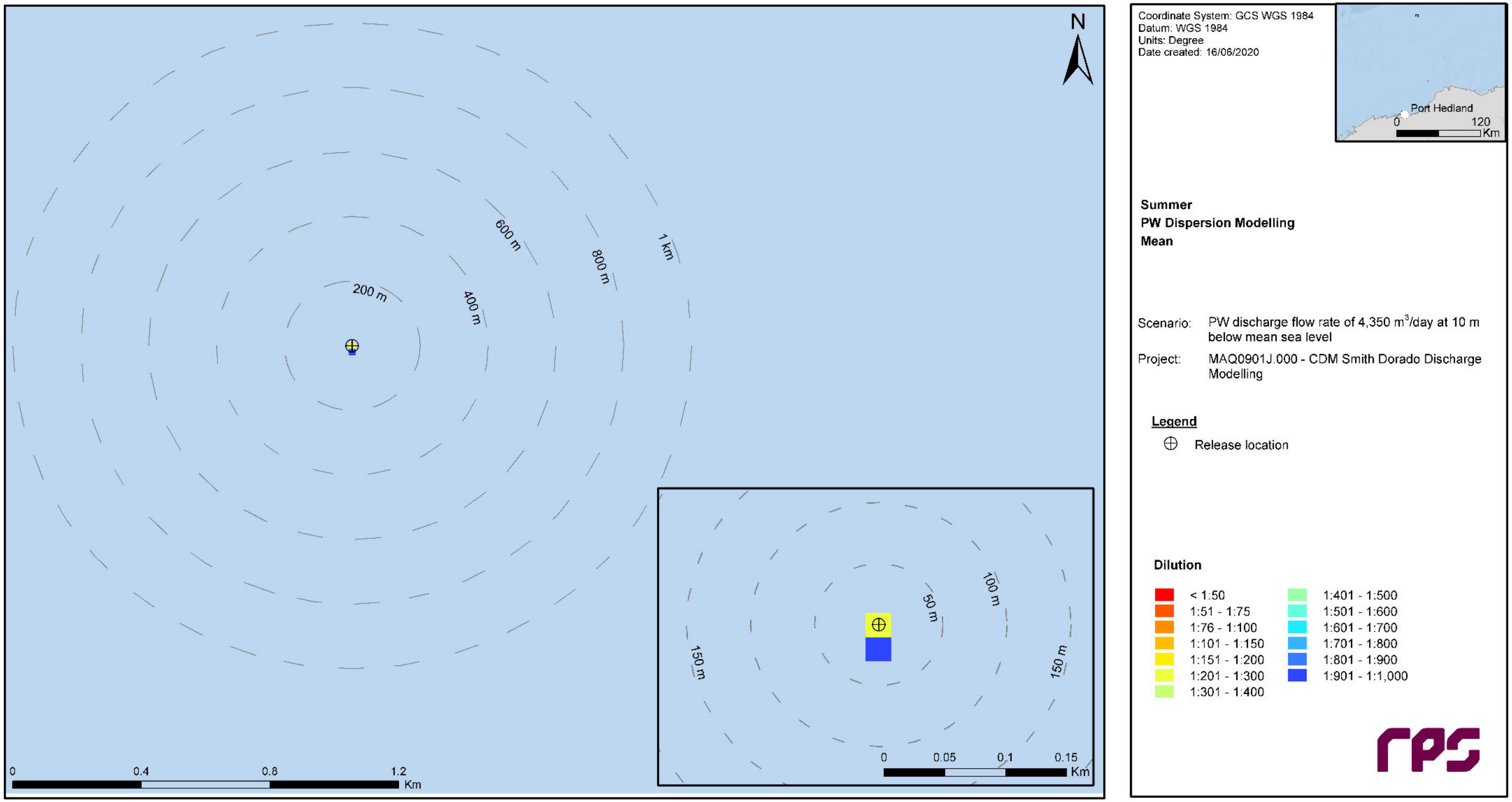
Percentile	Season	Total area (km^2) of influence for given dilution of 1:1,000		
		10 m above mean sea level	0 m below mean sea level	10 m below mean sea level
Mean	Summer	0.002	0.002	0.0008
95th		0.080	0.103	0.058
99th		0.757	1.183	0.489



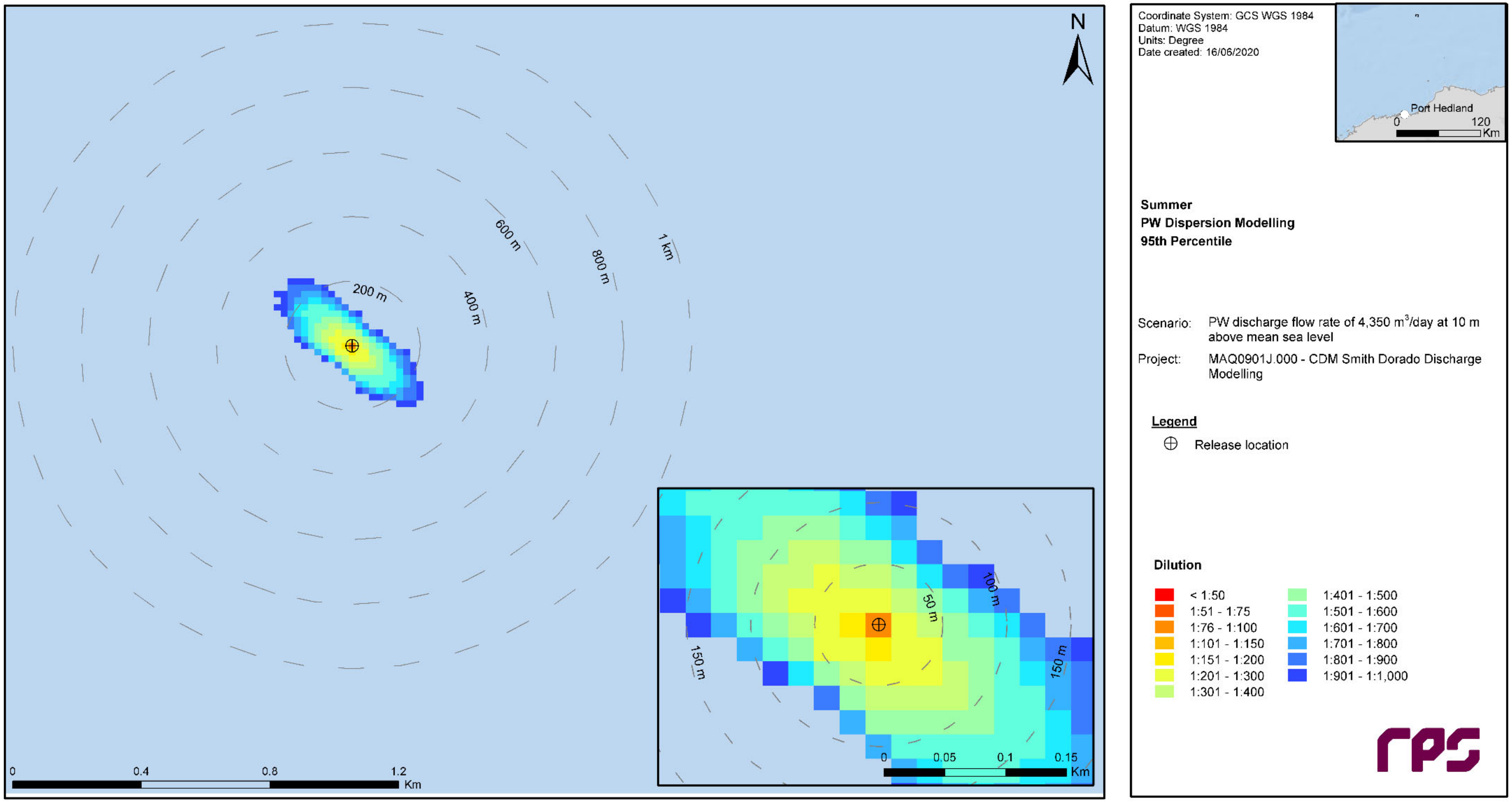
Apx Figure 10 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 10 m AMSL. Findings are based on the combined summer results (50 simulations).



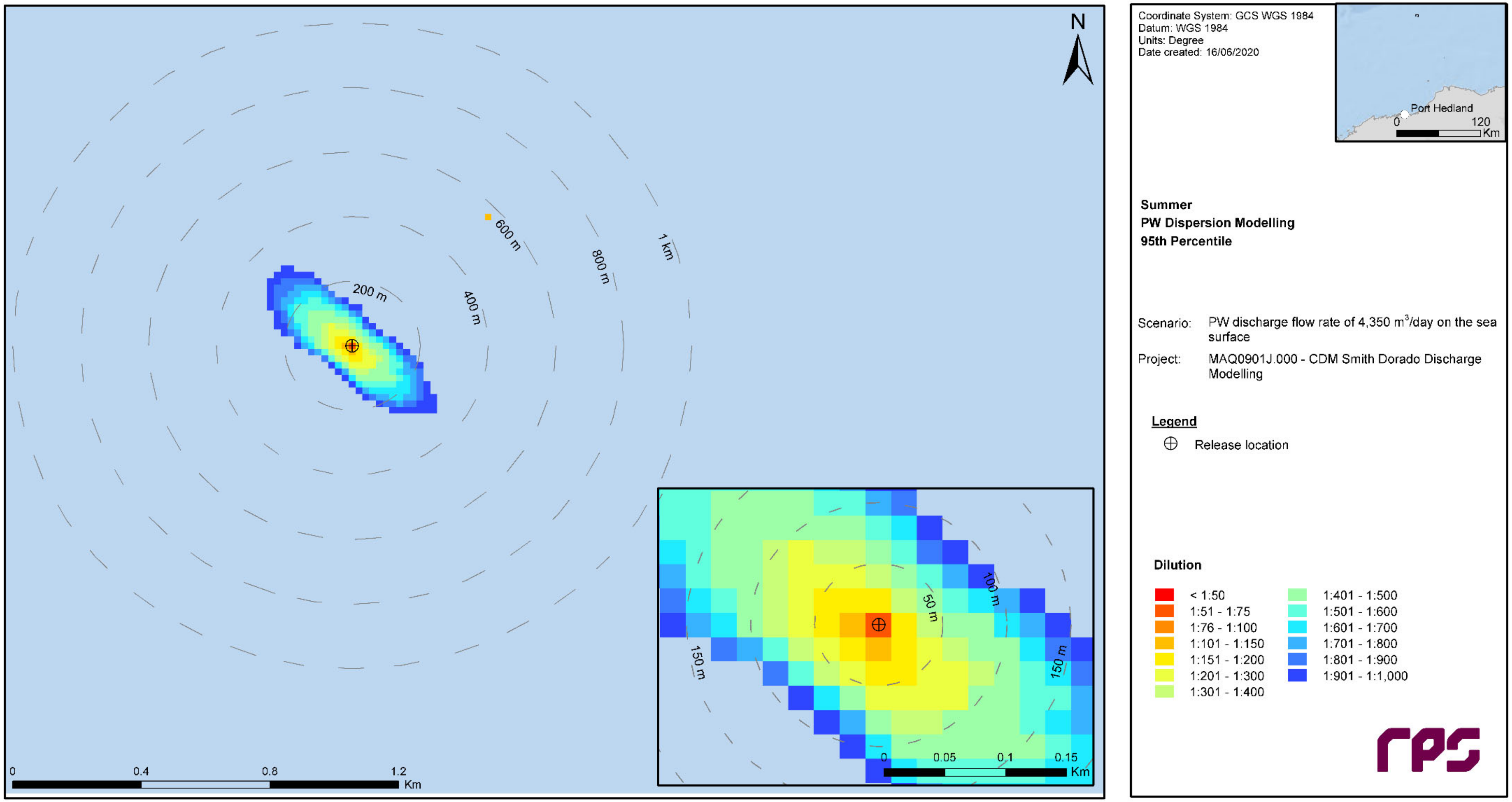
Apx Figure 11 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 0 m BMSL. Findings are based on the combined summer results (50 simulations).



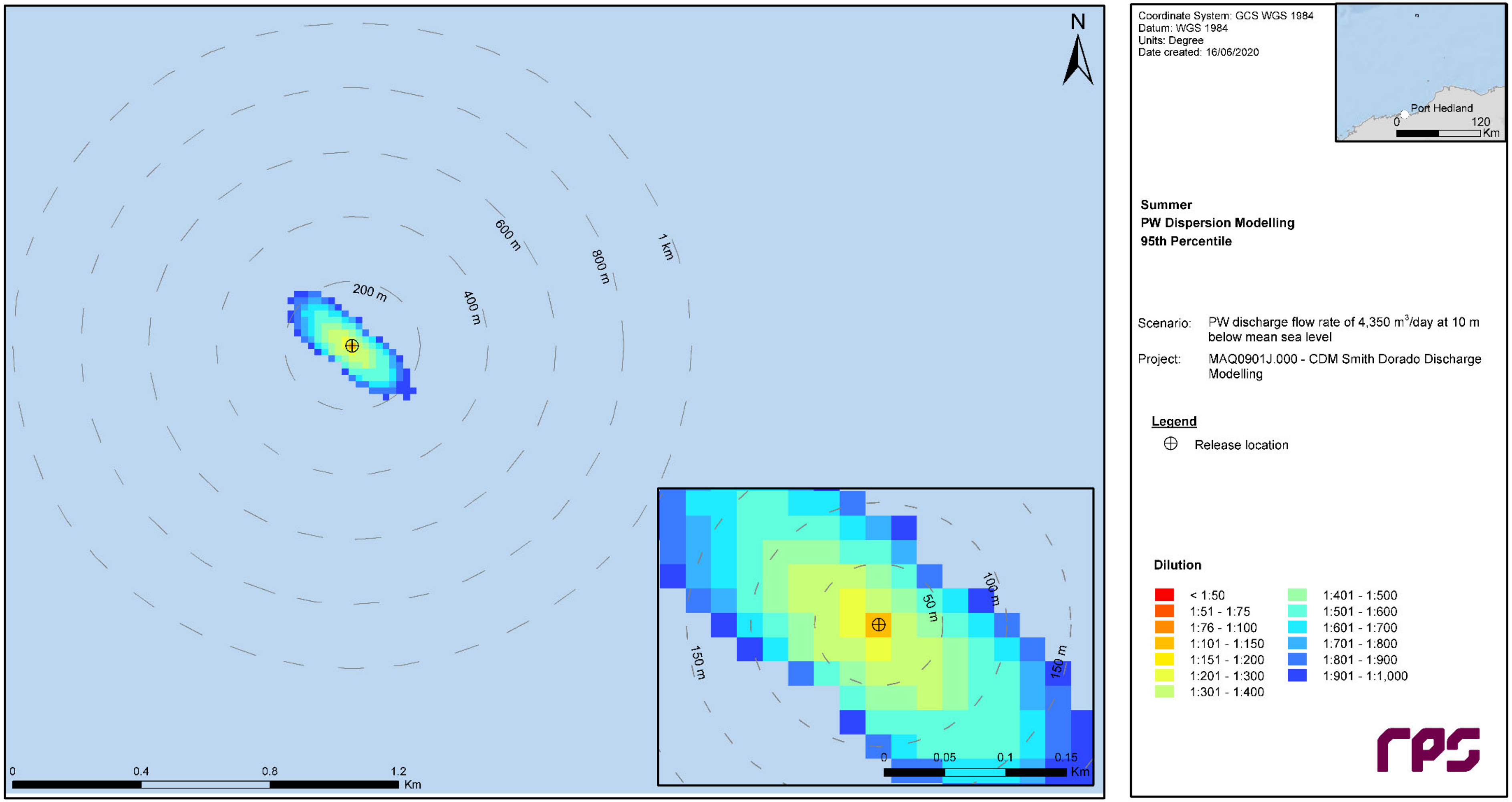
Apx Figure 12 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 10 m BMSL. Findings are based on the combined summer results (50 simulations).



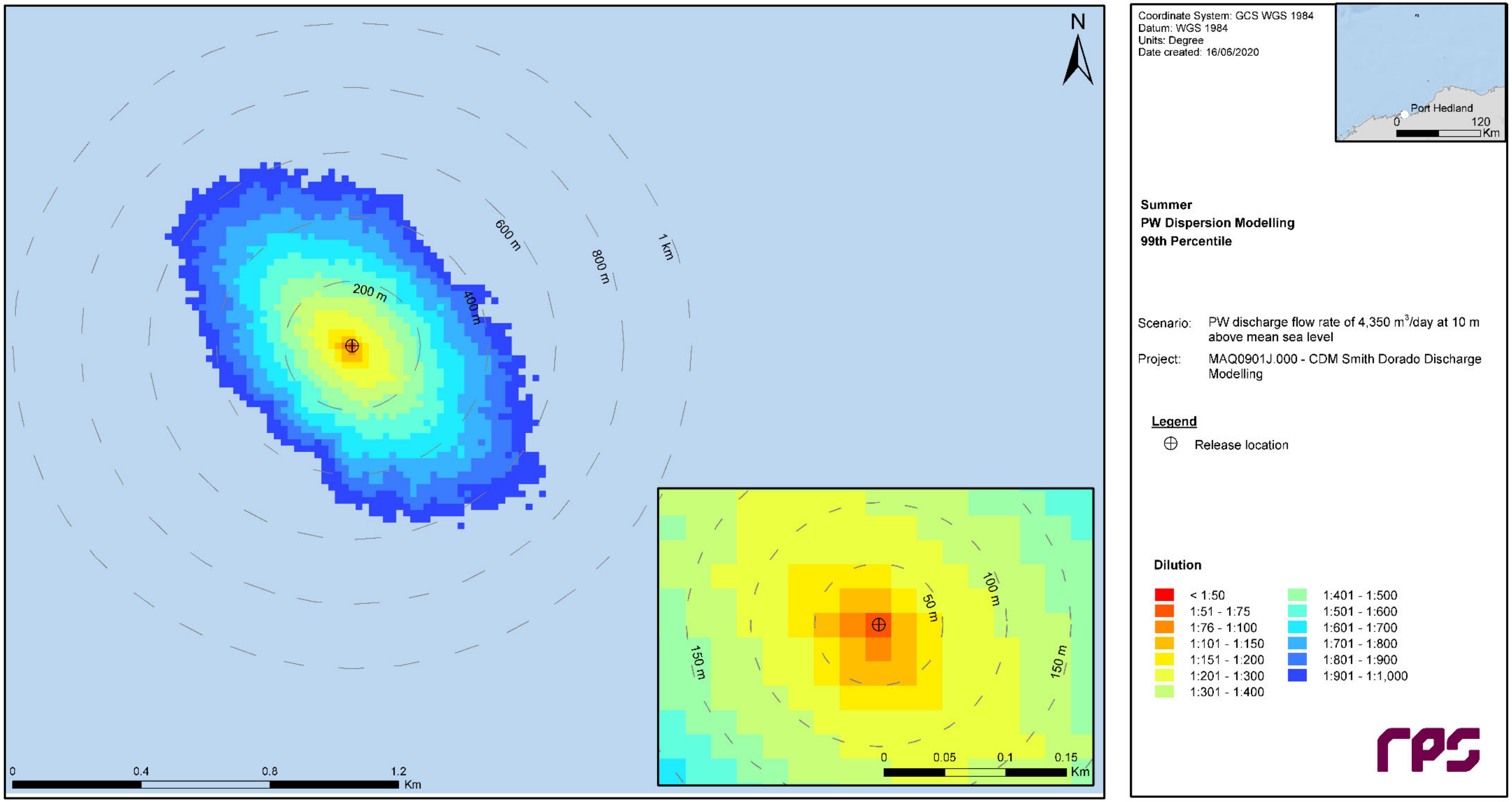
Apx Figure 13 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined summer results (50 simulations).



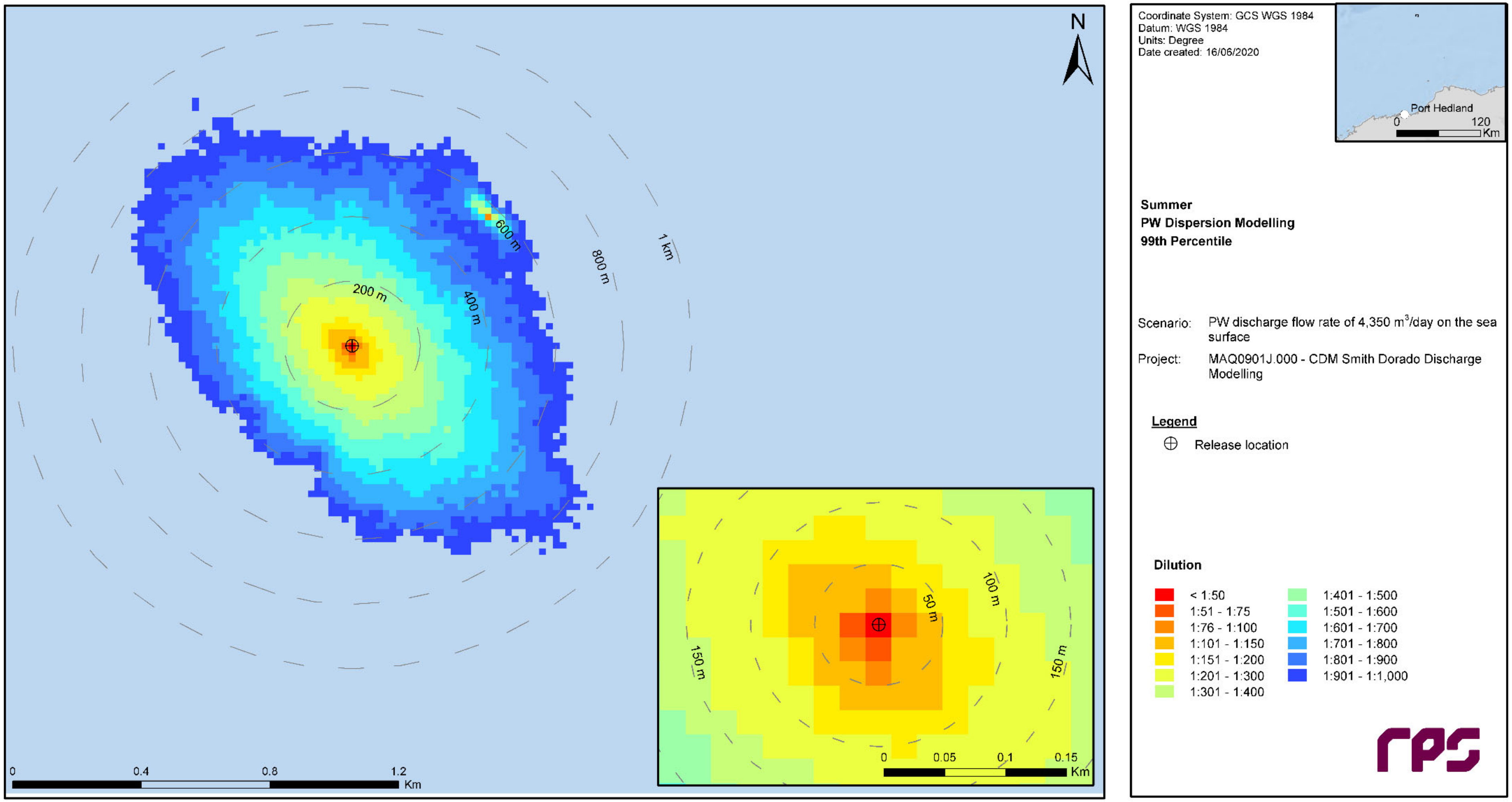
Apx Figure 14 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 0 m BMSL. Findings are based on the combined summer results (50 simulations).



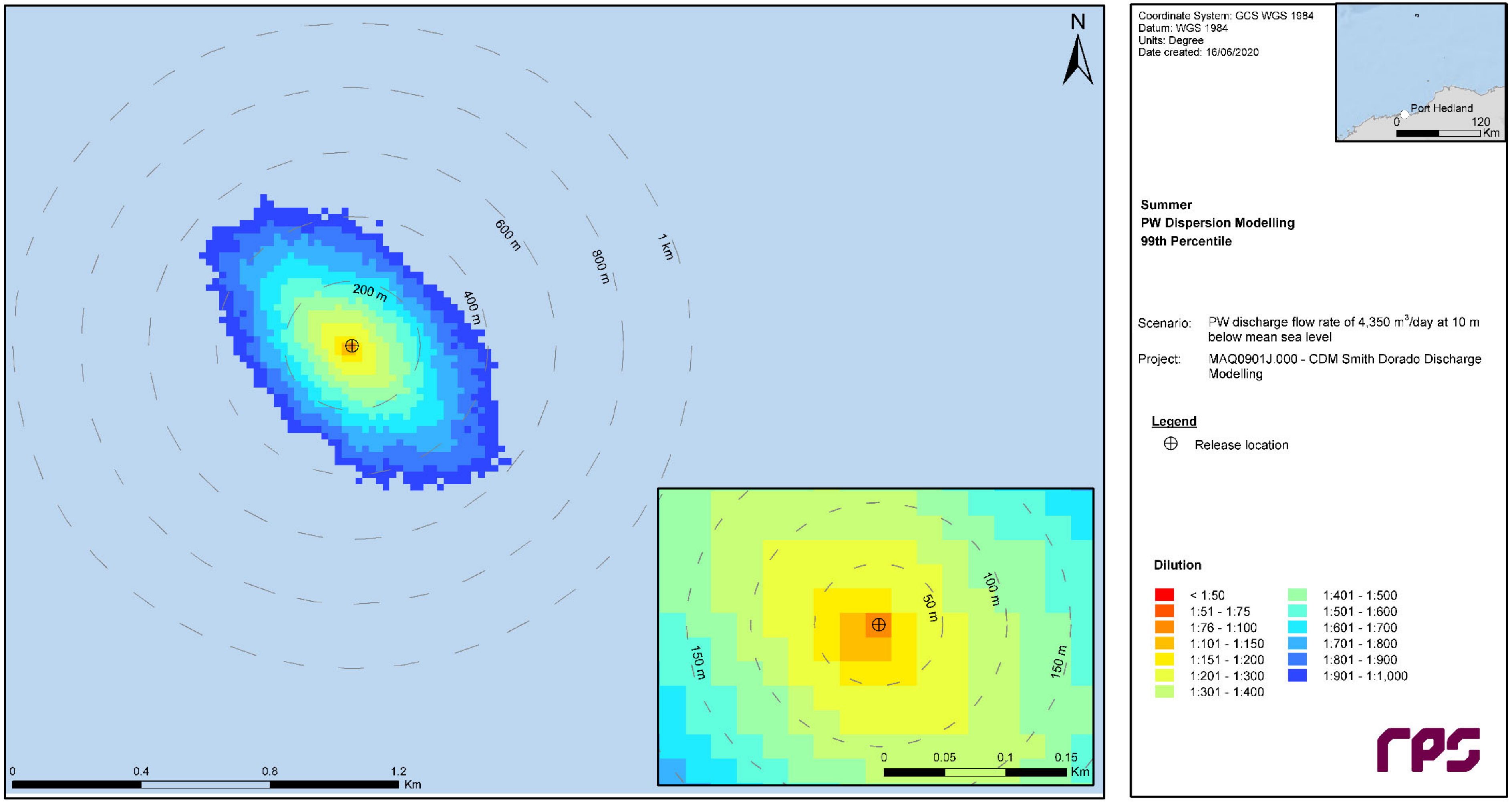
Apx Figure 15 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined summer results (50 simulations).



Apx Figure 16 Predicted 99th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined summer results (50 simulations).



Apx Figure 17 Predicted 99th percentile dilutions for a 4,350 m3/d PW discharge released at 0 m BMSL. Findings are based on the combined summer results (50 simulations).



Apx Figure 18 Predicted 99th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined summer results (50 simulations).

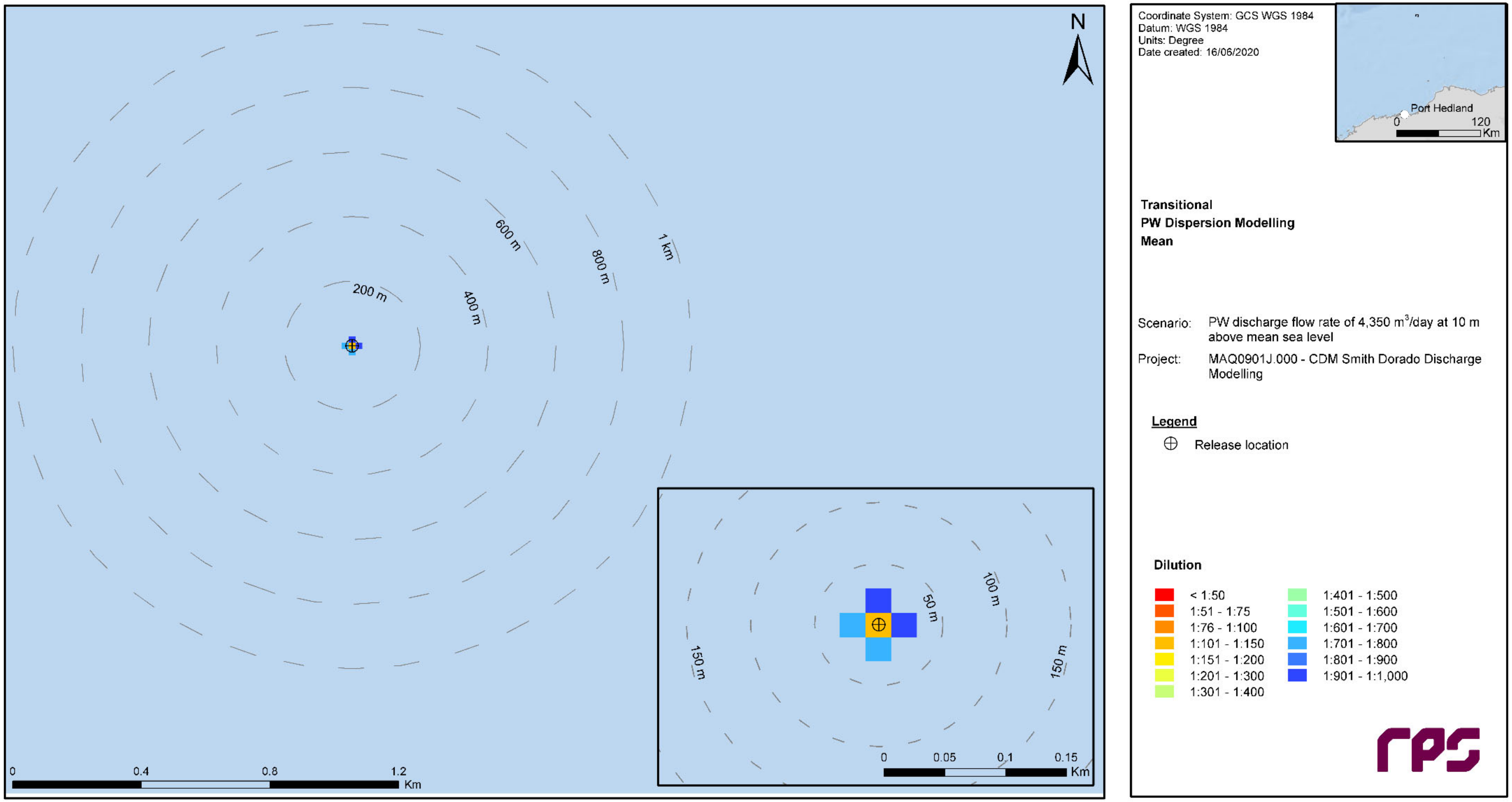
B.2 Transitional

Apx Table 6 Maximum distances from the PW discharge location to achieve given dilution factors for each case. Findings are based on the combined transitional results (50 simulations per case).

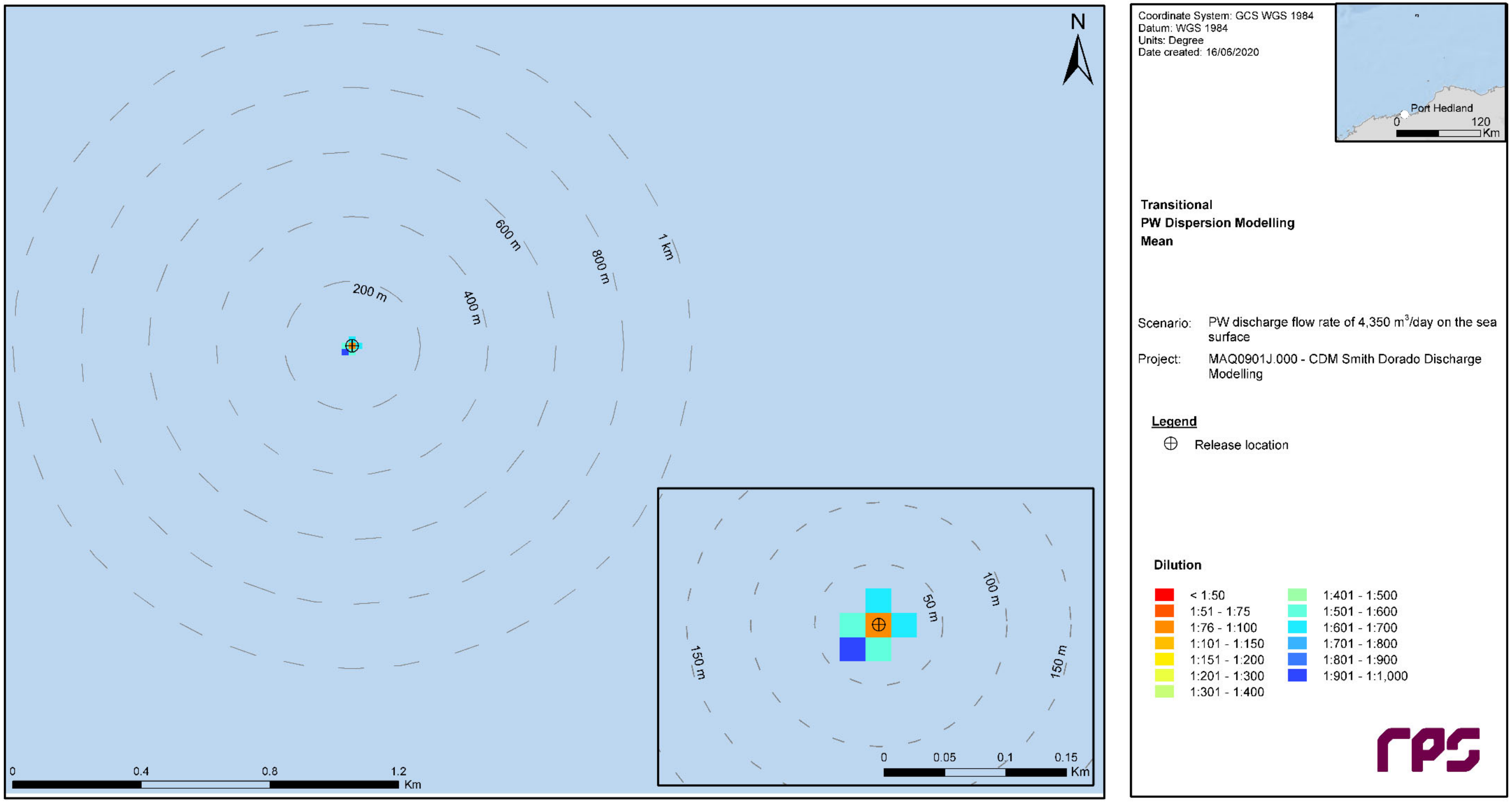
Dilution	Maximum distance (m) from discharge location to achieve given dilutions								
	Case 1 - 10 m above mean sea level			Case 2 - 0 m below mean sea level			Case 3 - 10 m below mean sea level		
	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile
1:50	-	-	-	-	-	42	-	-	-
1:100	-	42	42	42	42	58	-	-	42
1:200	42	42	76	42	58	110	-	42	58
1:300	42	71	147	42	91	192	42	42	103
1:400	42	95	198	42	103	269	42	76	158
1:500	42	114	259	42	158	353	42	103	202
1:600	42	170	347	42	198	453	42	142	283
1:700	42	186	434	58	227	538	42	170	326
1:800	42	212	525	58	258	636	42	186	425
1:900	42	242	583	58	283	795	42	202	498
1:1,000	58	270	707	58	325	902	42	214	555

Apx Table 7 Total area of influence to achieve a dilution factor of 1:1,000 for each case. Findings are based on the combined transitional results (50 simulations per case).

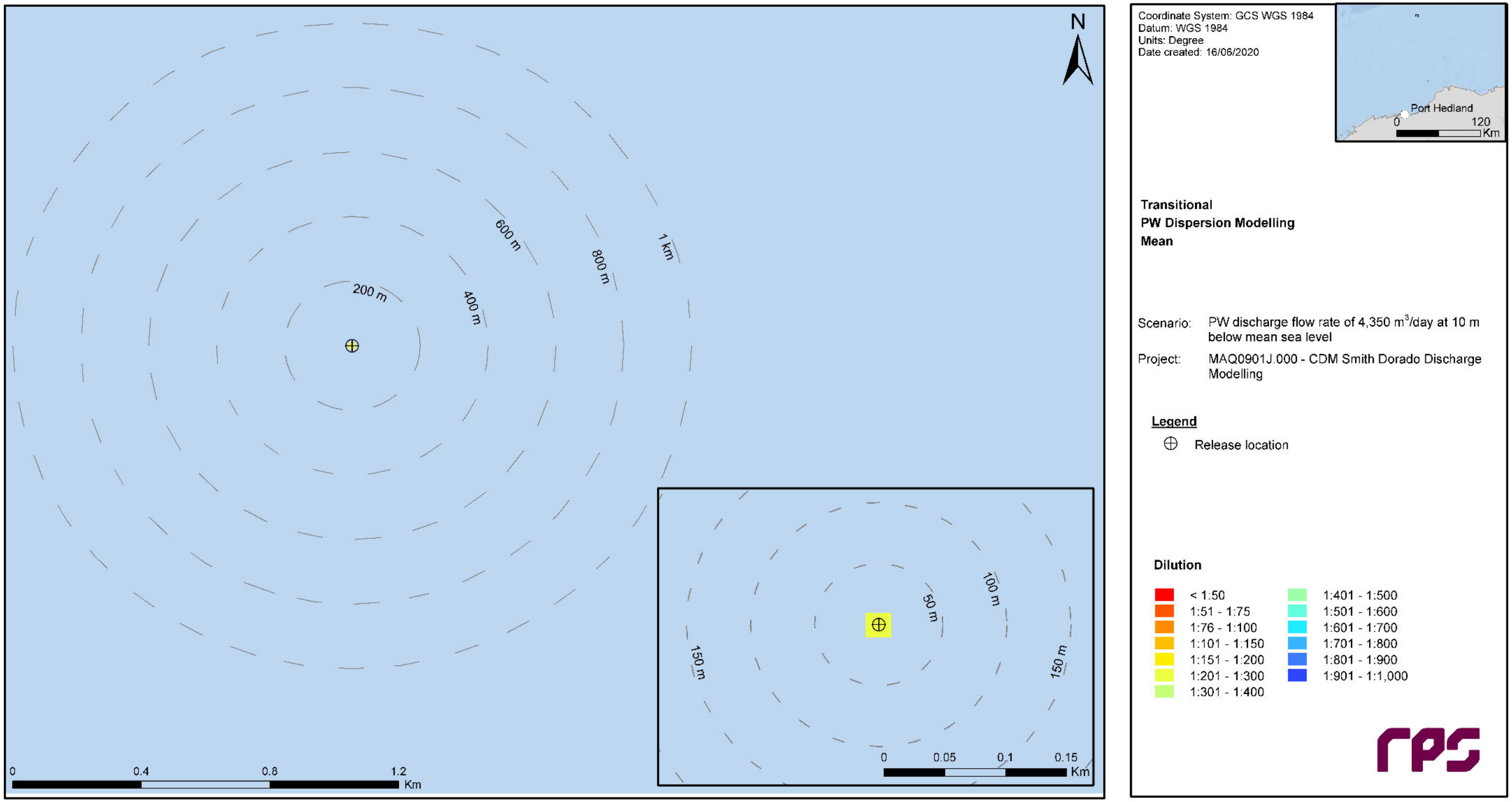
Percentile	Season	Total area (km^2) of influence for given dilution of 1:1,000		
		10 m above mean sea level	0 m below mean sea level	10 m below mean sea level
Mean	Transitional	0.002	0.002	0.0004
95th		0.075	0.107	0.055
99th		0.737	1.120	0.500



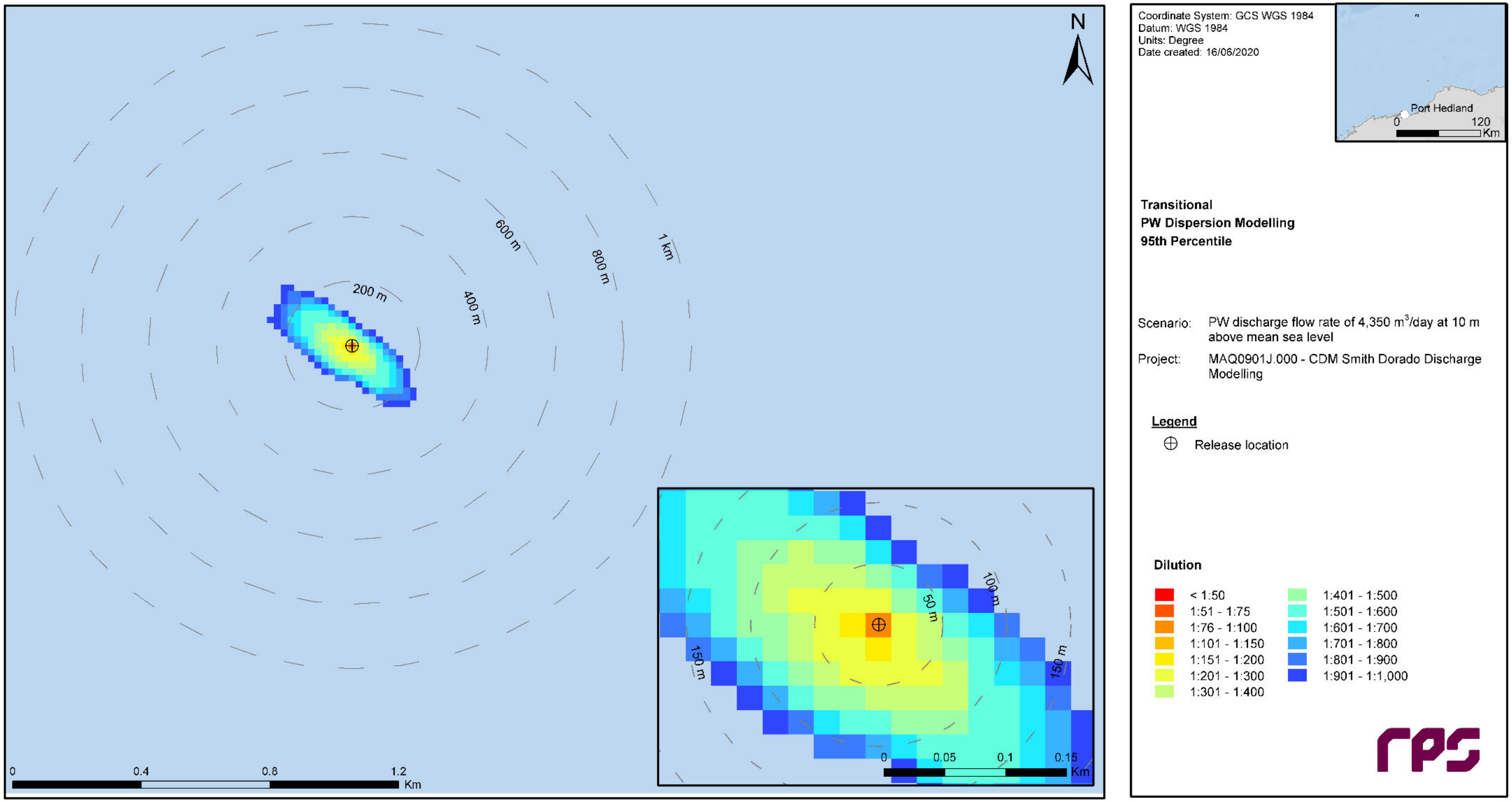
Apx Figure 19 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 10 m AMSL. Findings are based on the combined transitional results (50 simulations).



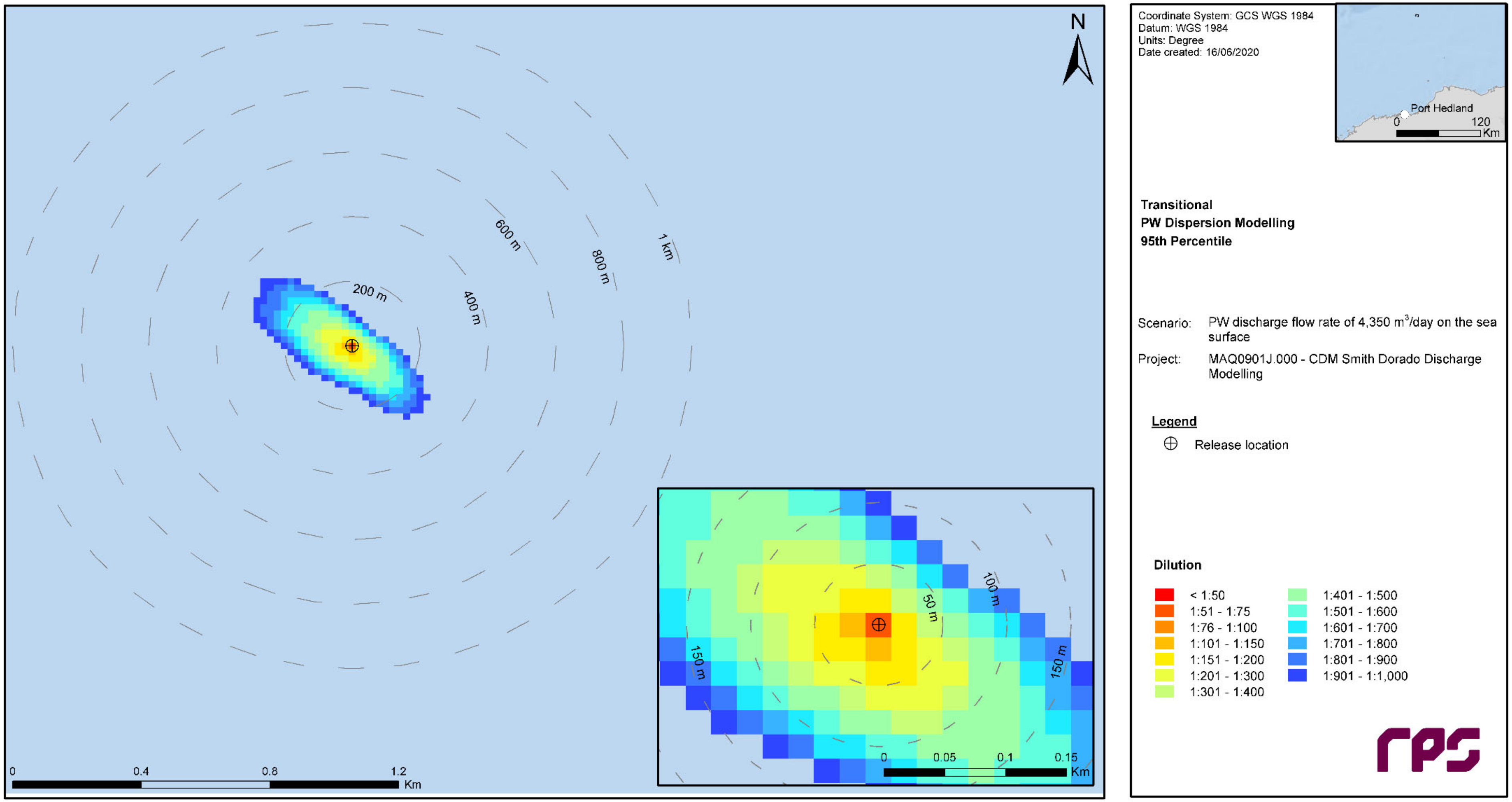
Apx Figure 20 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined transitional results (50 simulations).



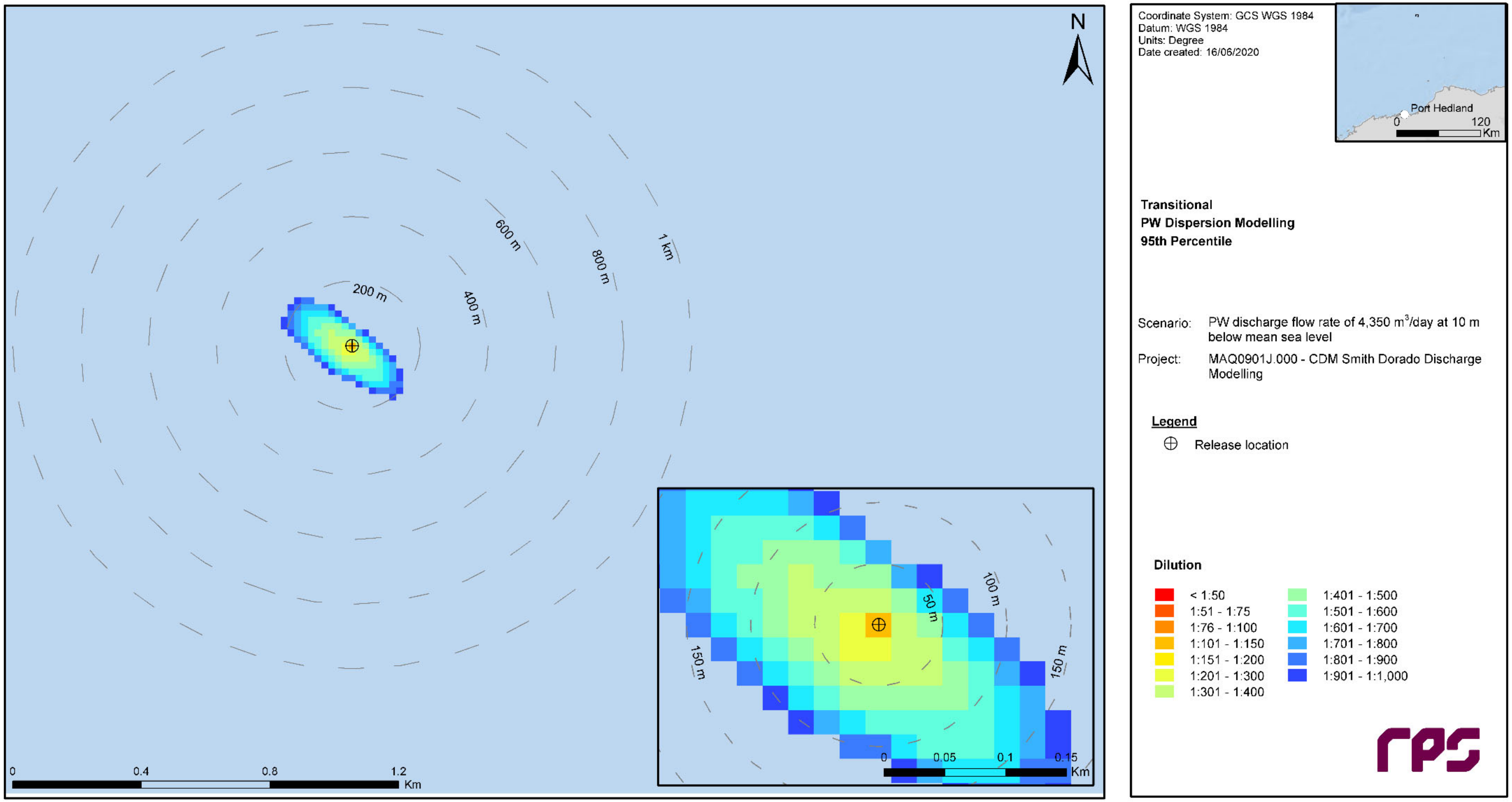
Apx Figure 21 Predicted mean dilutions for a 4,350 m³/d PW discharge released at 10 m BMSL. Findings are based on the combined transitional results (50 simulations).



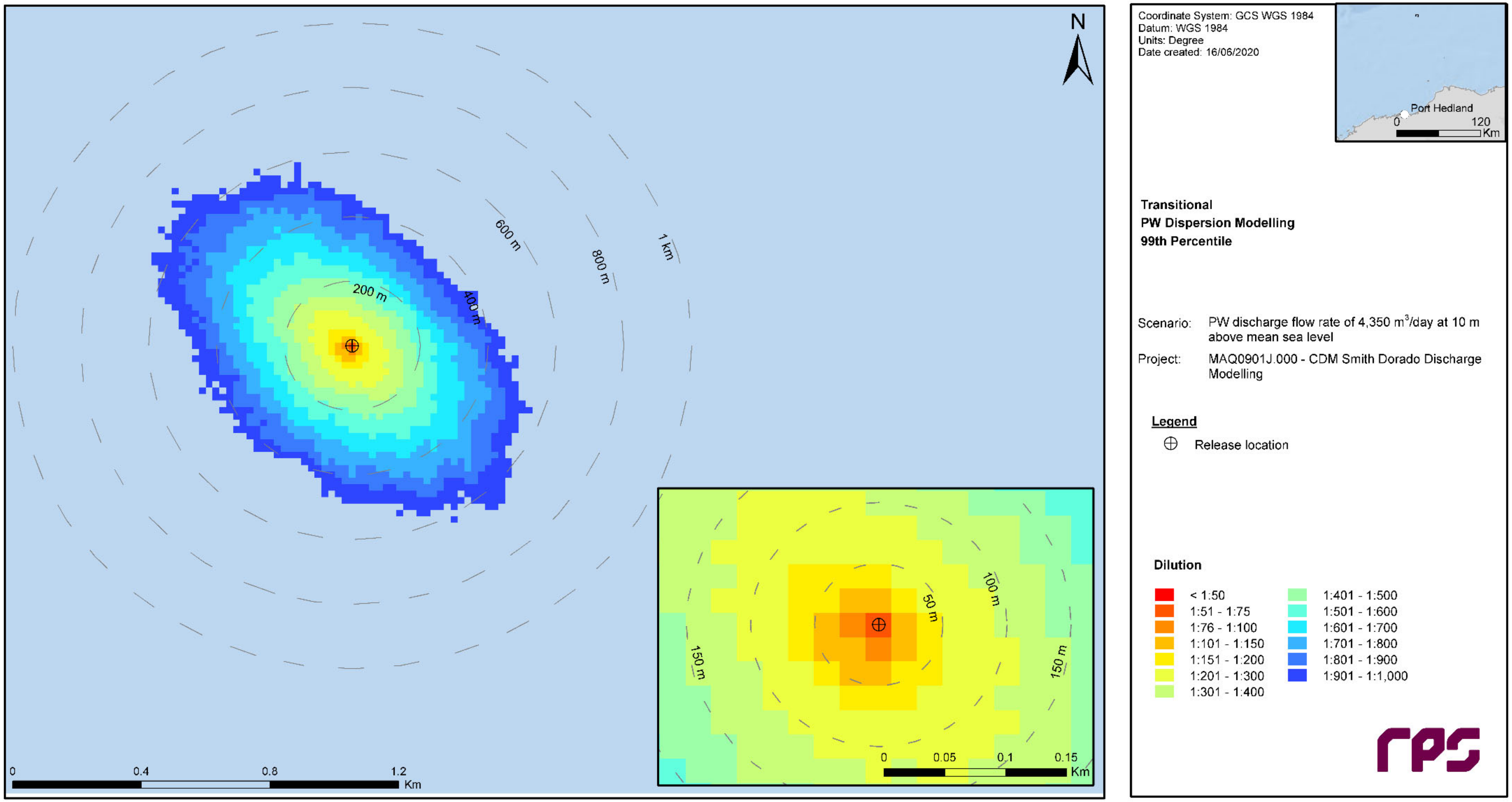
Apx Figure 22 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined transitional results (50 simulations).



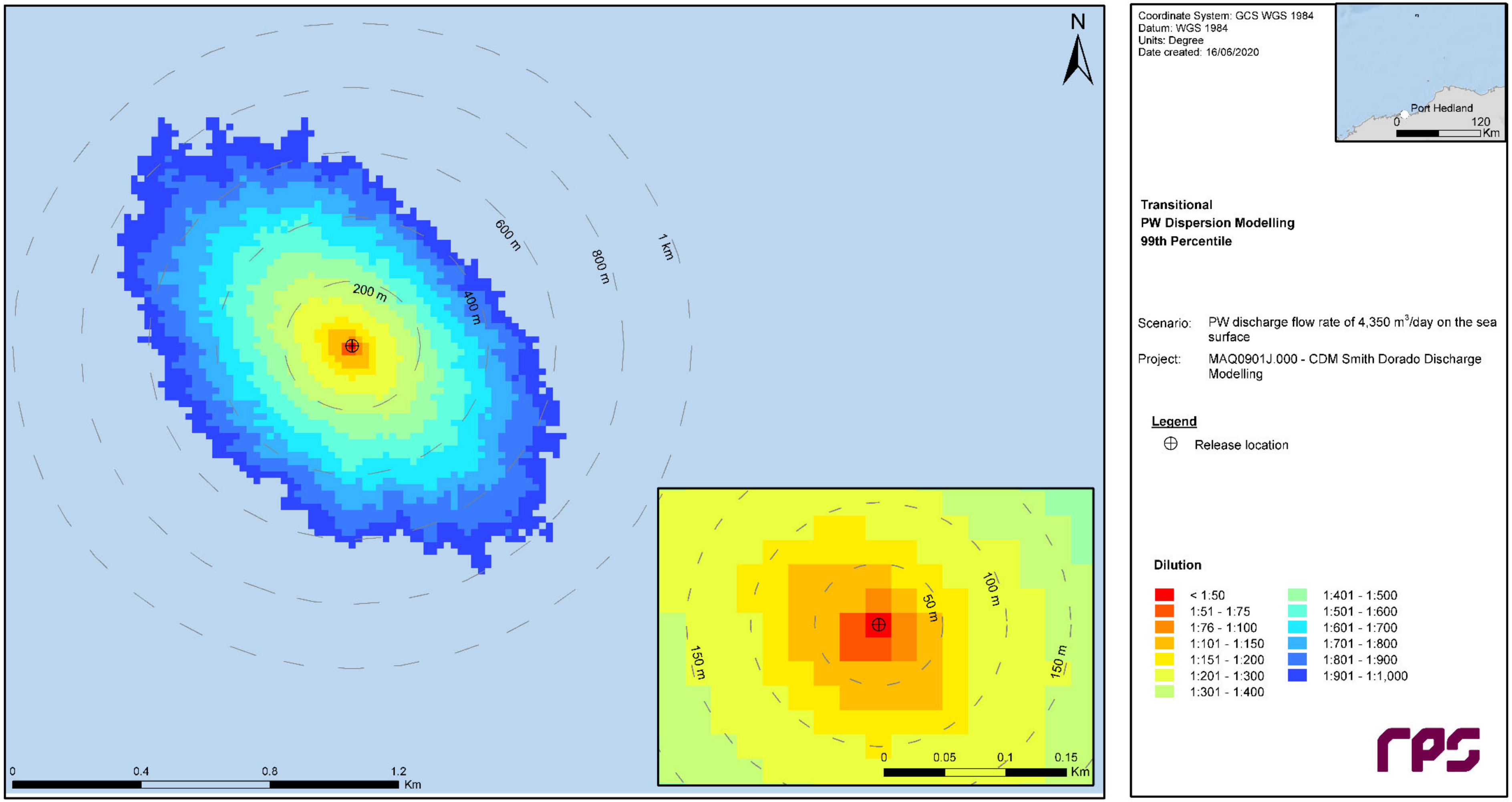
Apx Figure 23 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 0 m BMSL. Findings are based on the combined transitional results (50 simulations).



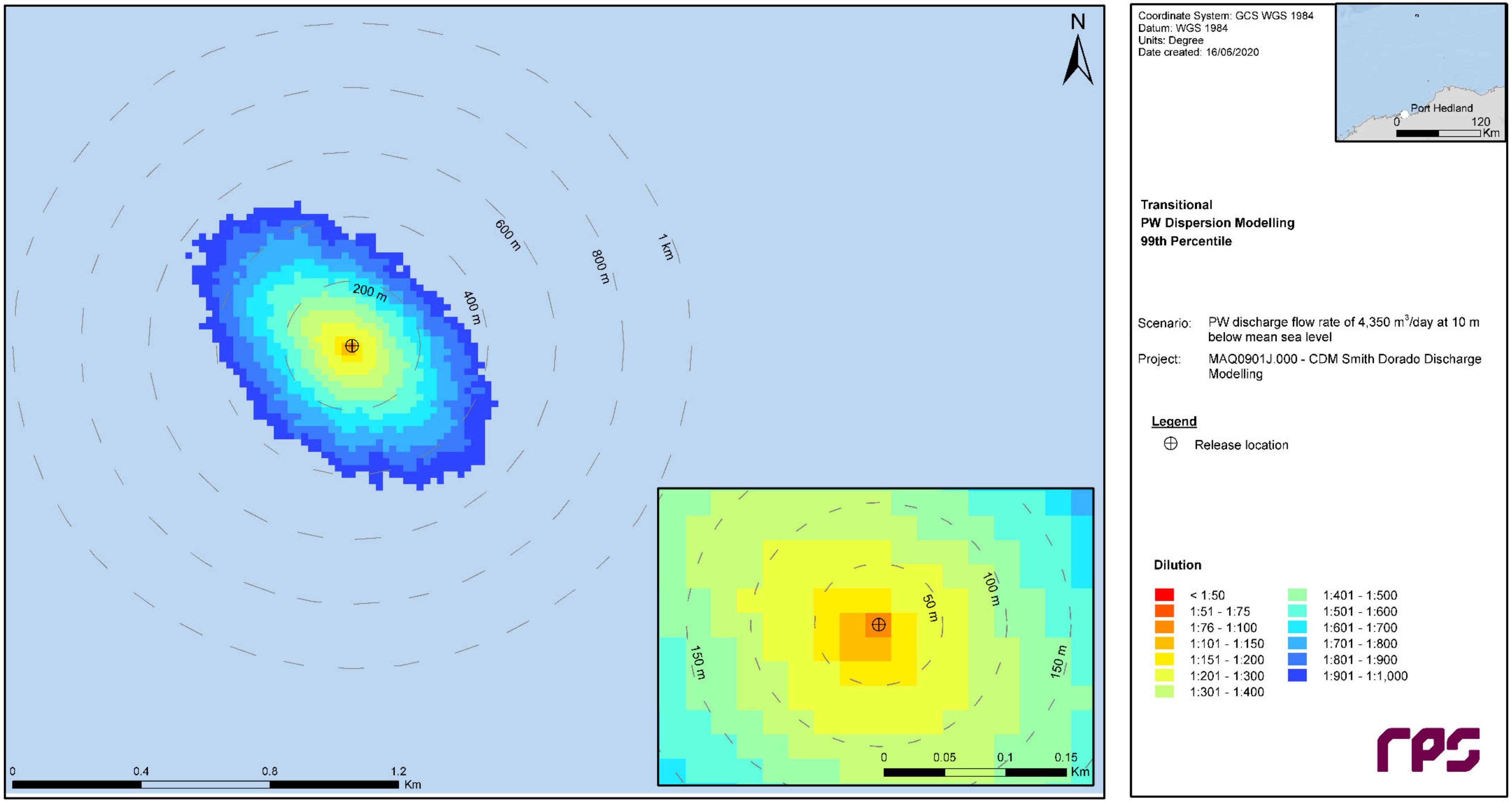
Apx Figure 24 Predicted 95th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m BMSL. Findings are based on the combined transitional results (50 simulations).



Apx Figure 25 Predicted 99th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined transitional results (50 simulations).



Apx Figure 26 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined transitional results (50 simulations).



Apx Figure 27 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m BMSL. Findings are based on the combined transitional results (50 simulations).

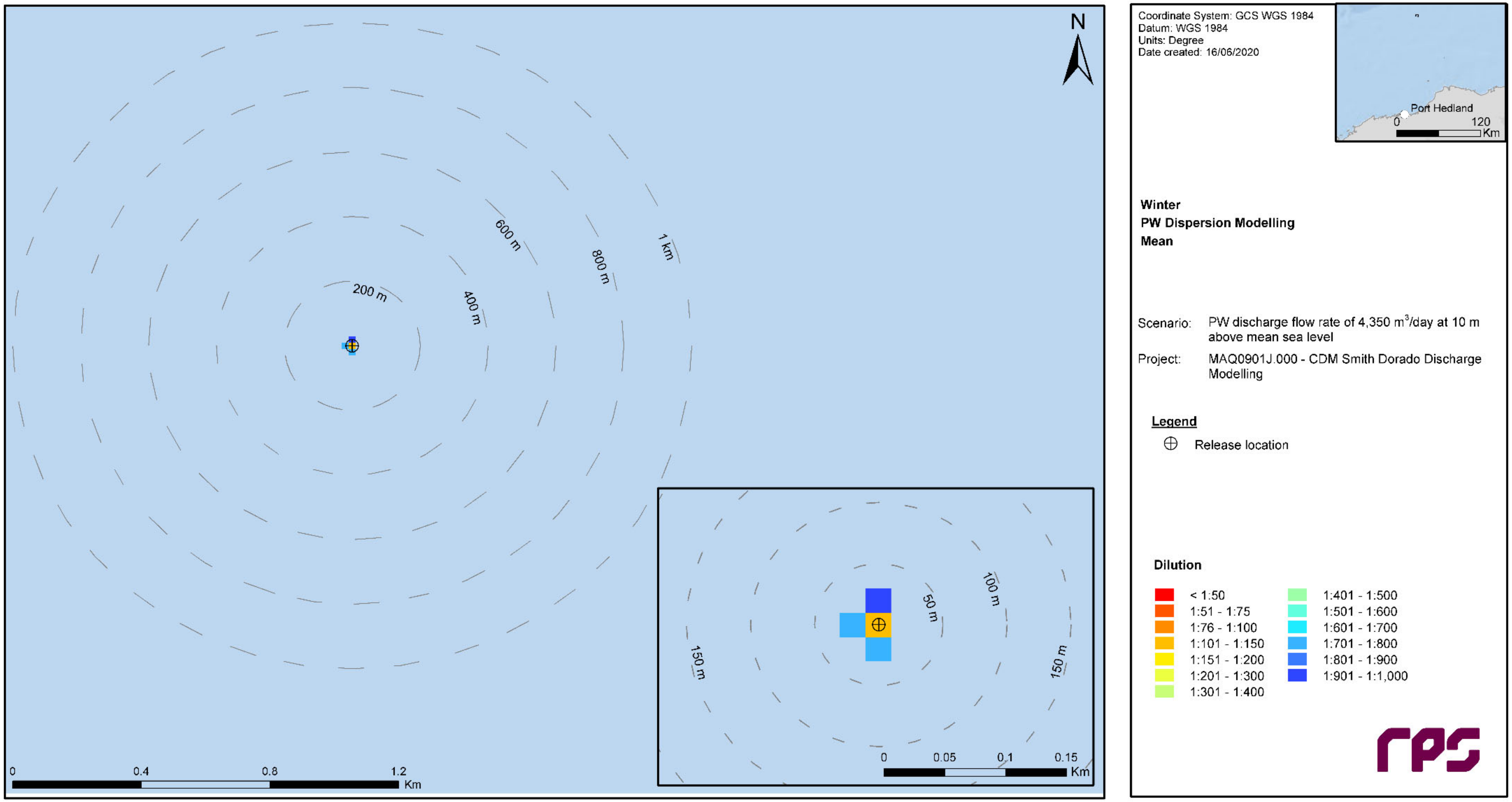
B.3 Winter

Apx Table 8 Maximum distances from the PW discharge location to achieve given dilution factors for each case. Findings are based on the combined winter results (50 simulations per case).

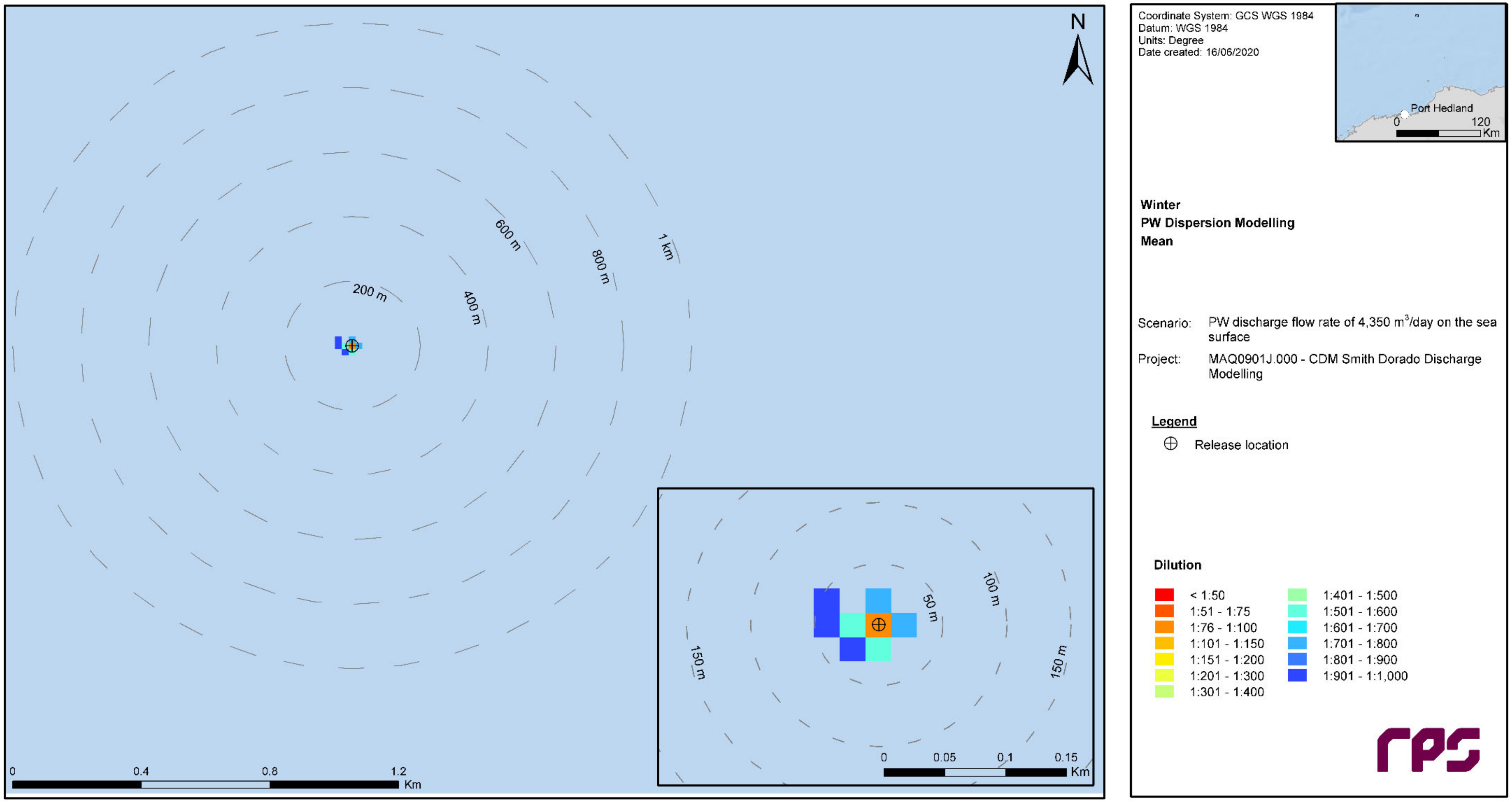
Dilution	Maximum distance (m) from discharge location to achieve given dilutions								
	Case 1 - 10 m above mean sea level			Case 2 - 0 m below mean sea level			Case 3 - 10 m below mean sea level		
	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile	mean	95th percentile	99th percentile
1:50	-	-	-	-	-	42	-	-	-
1:100	-	42	42	42	42	58	-	-	42
1:200	42	42	86	42	58	114	-	42	58
1:300	42	76	158	42	94	202	42	51	114
1:400	42	94	212	42	114	286	42	76	175
1:500	42	130	283	42	170	386	42	103	214
1:600	42	184	374	42	212	474	42	142	286
1:700	42	198	467	42	255	596	42	184	355
1:800	42	242	566	58	283	709	42	198	438
1:900	42	270	652	58	326	837	42	214	538
1:1,000	58	298	765	58	368	893	42	255	583

Apx Table 9 Total area of influence to achieve a dilution factor of 1:1,000 for each case. Findings are based on the combined winter results (50 simulations per case).

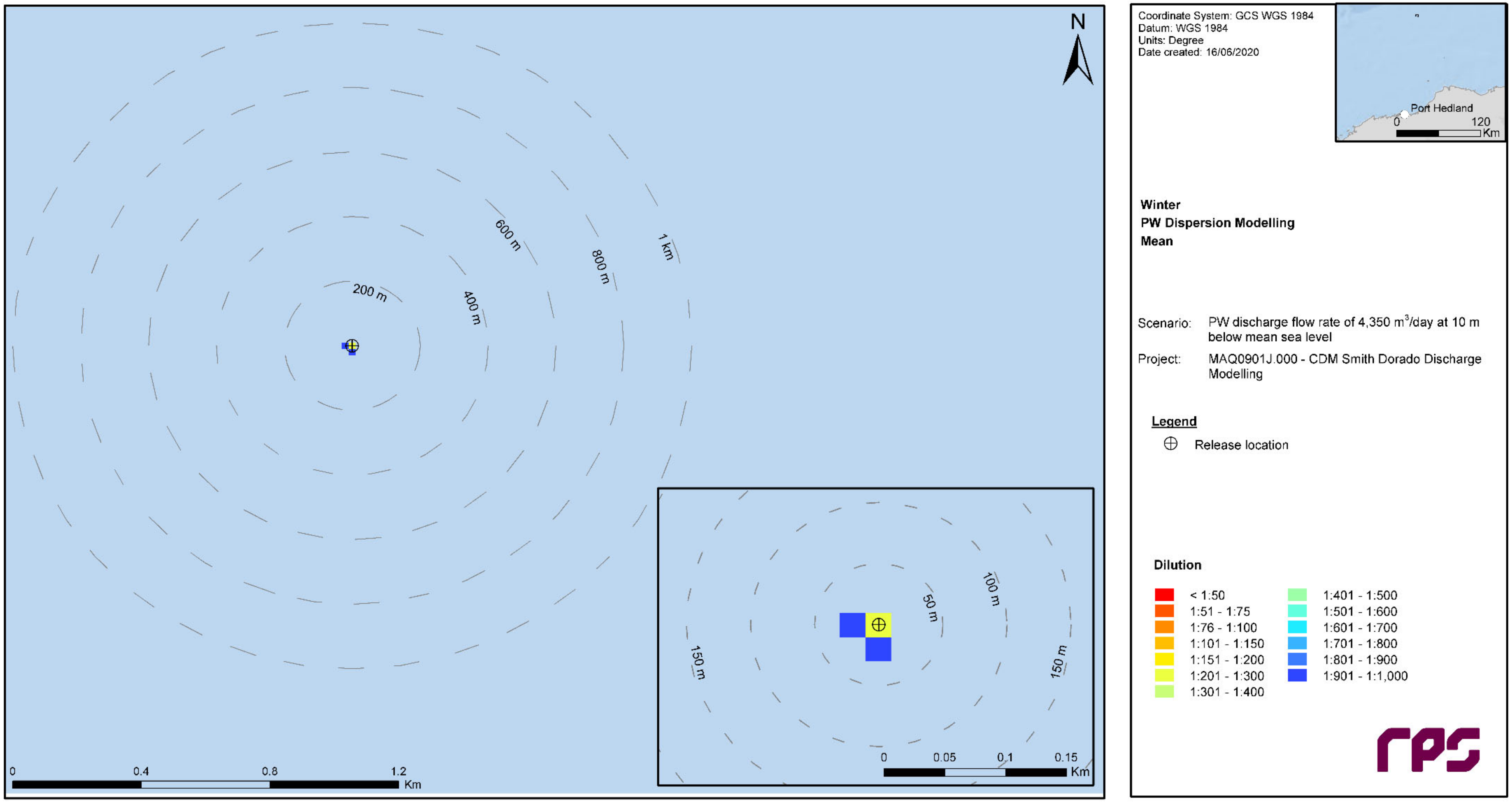
Percentile	Season	Total area (km^2) of influence for given dilution of 1:1,000		
		10 m above mean sea level	0 m below mean sea level	10 m below mean sea level
Mean	Winter	0.002	0.003	0.0012
95th		0.083	0.115	0.061
99th		0.748	1.120	0.477



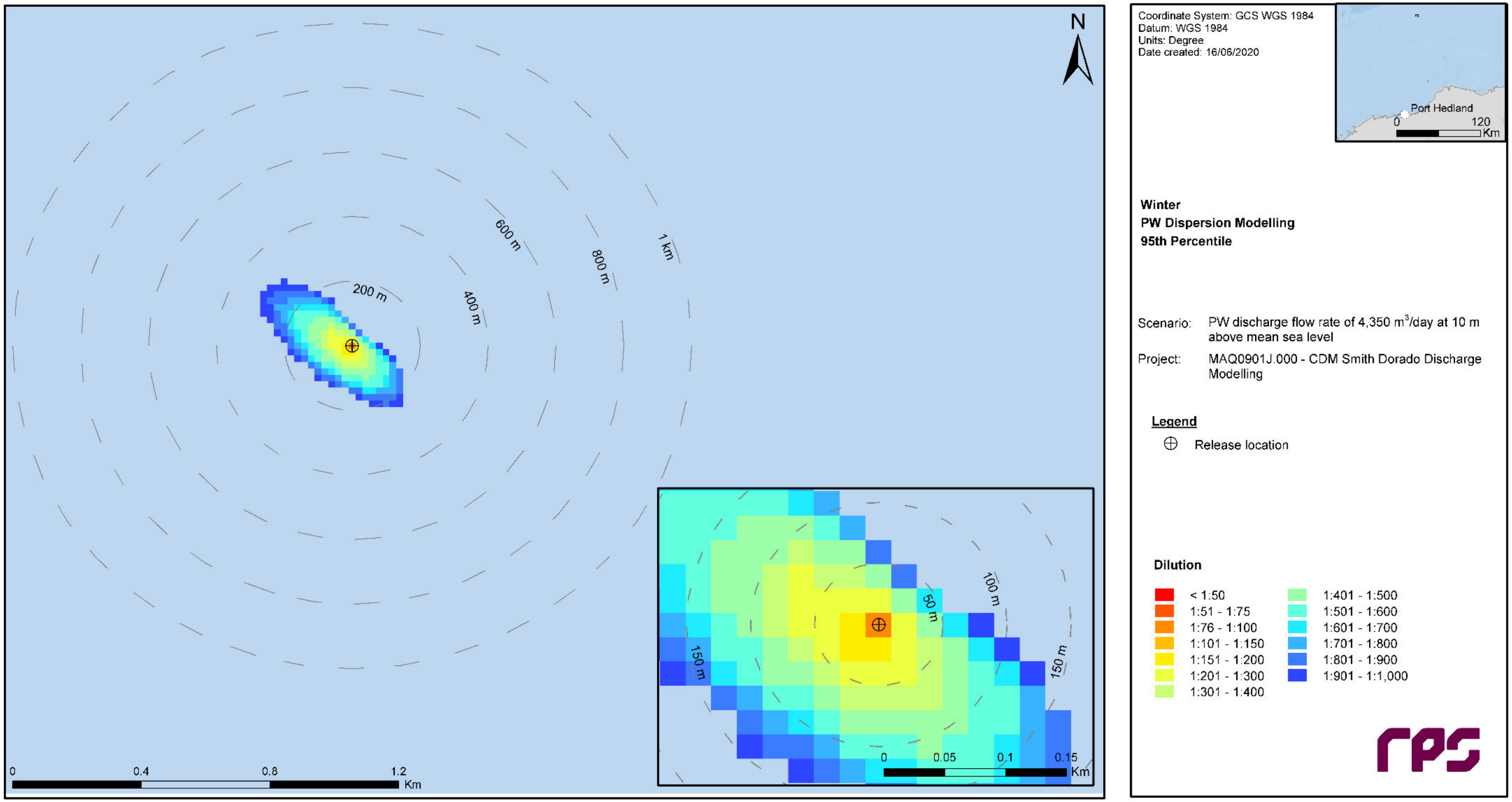
Apx Figure 28 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 10 m AMSL. Findings are based on the combined winter results (50 simulations).



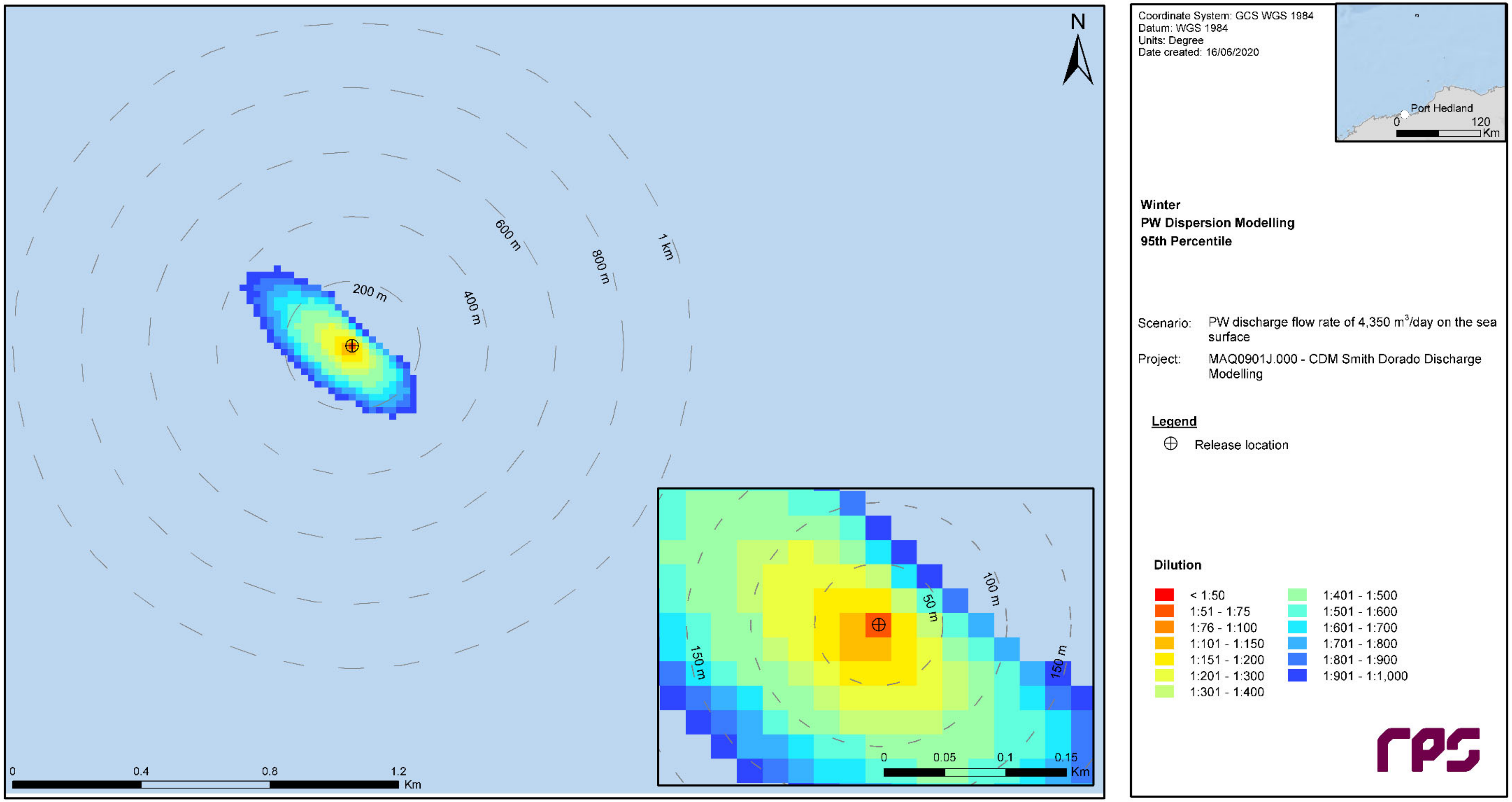
Apx Figure 29 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 0 m BMSL. Findings are based on the combined winter results (50 simulations).



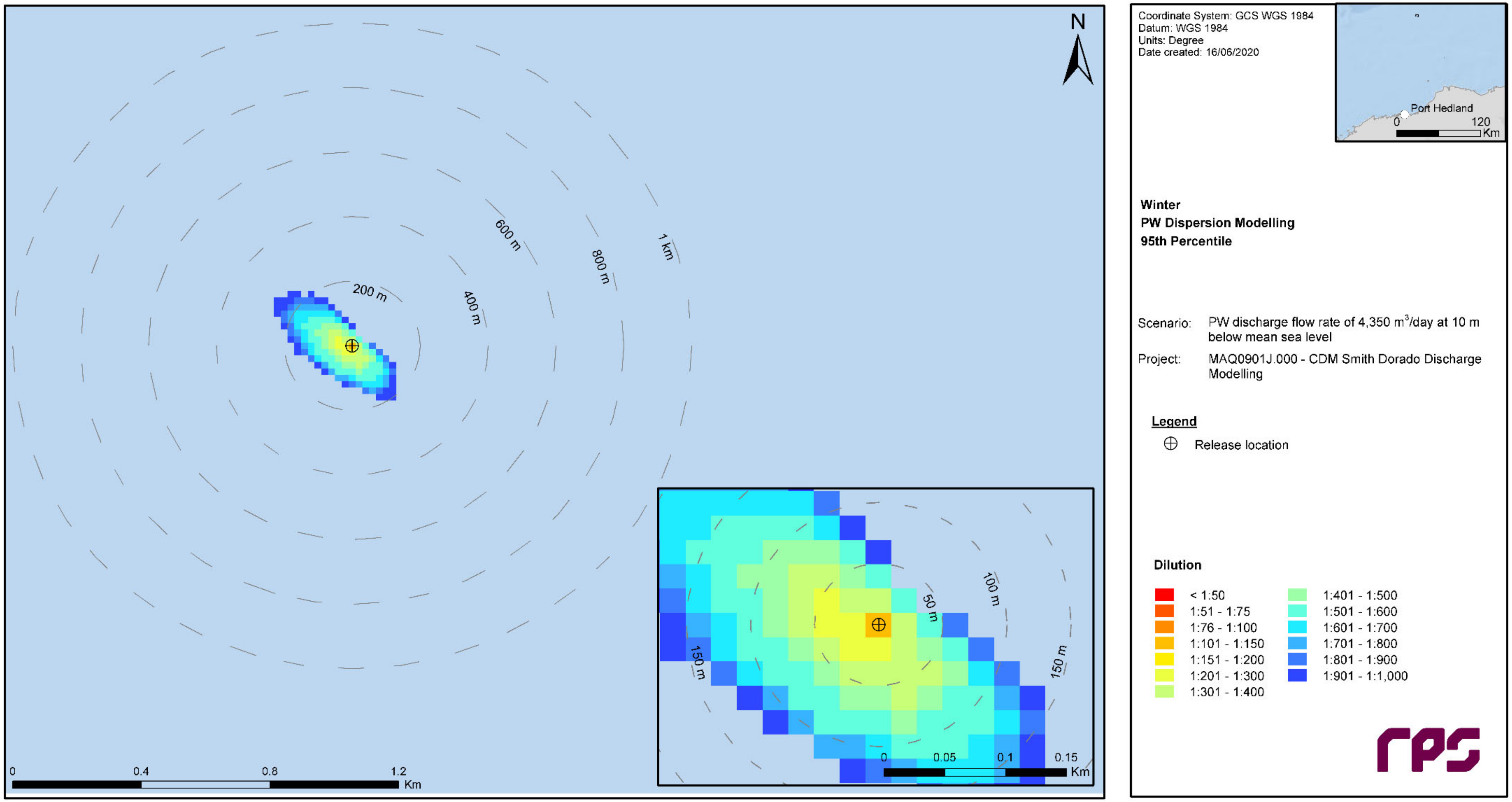
Apx Figure 30 Predicted mean dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined winter results (50 simulations).



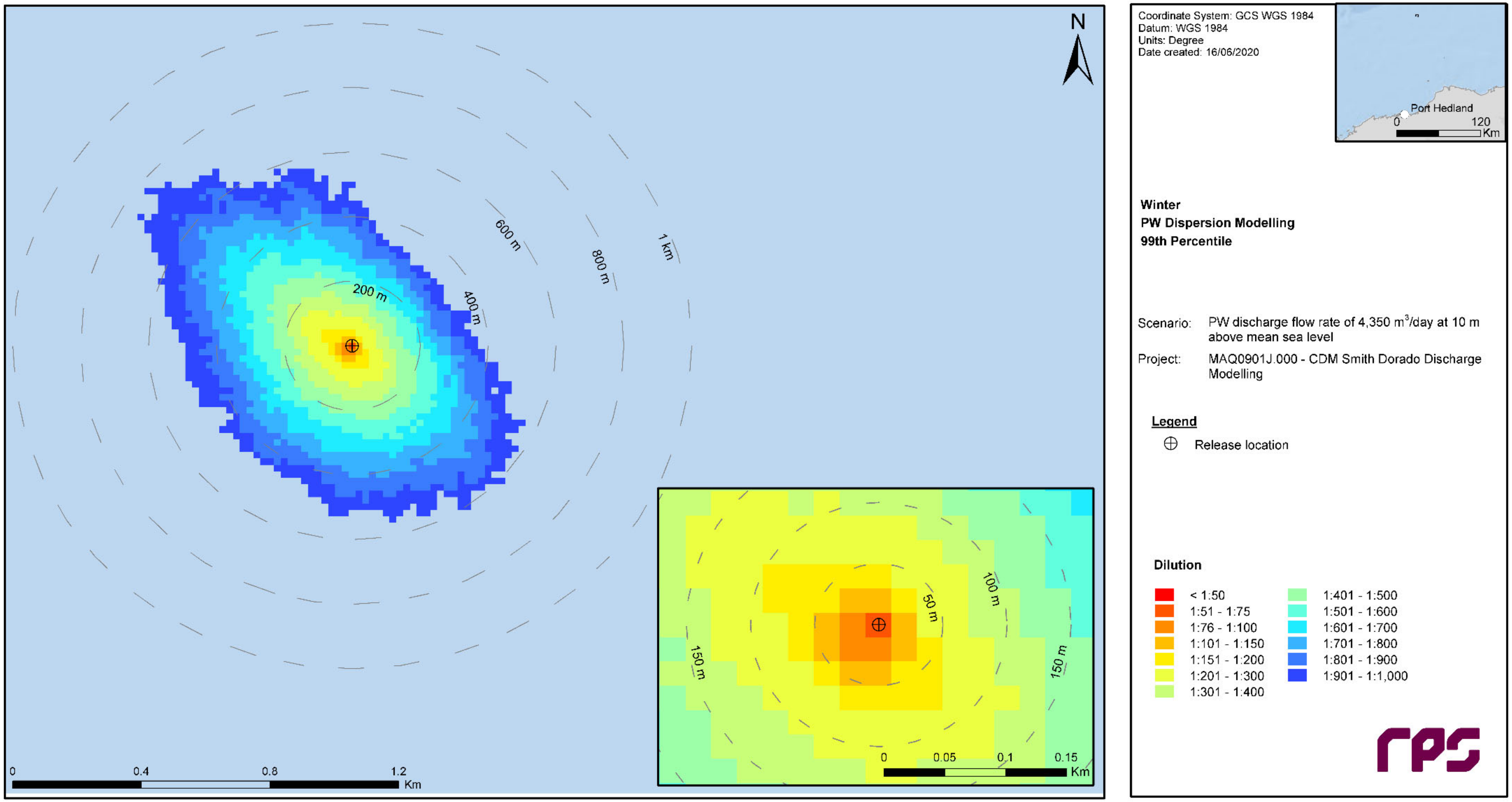
Apx Figure 31 Predicted 95th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m AMSL. Findings are based on the combined winter results (50 simulations).



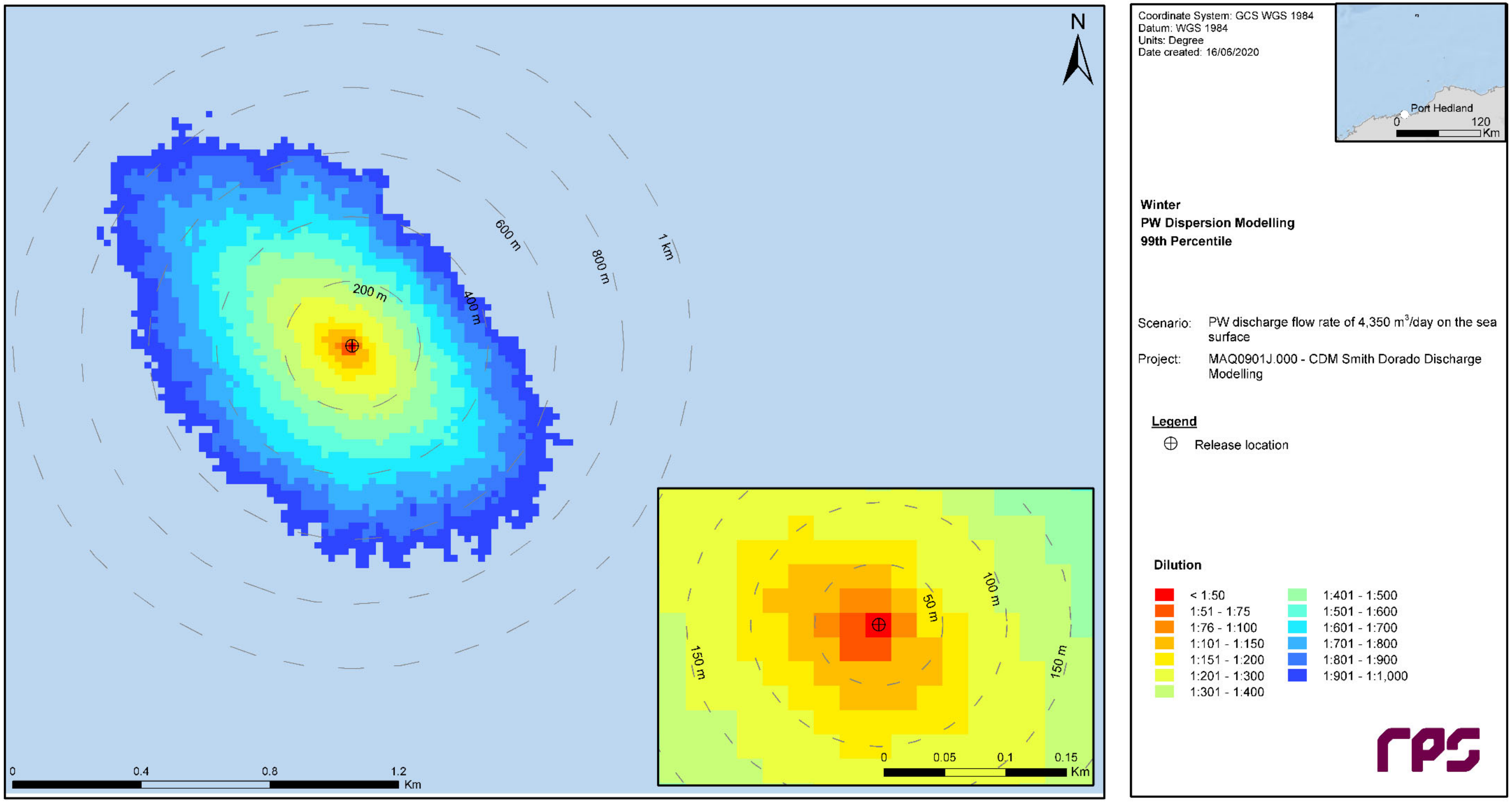
Apx Figure 32 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 0 m BMSL. Findings are based on the combined winter results (50 simulations).



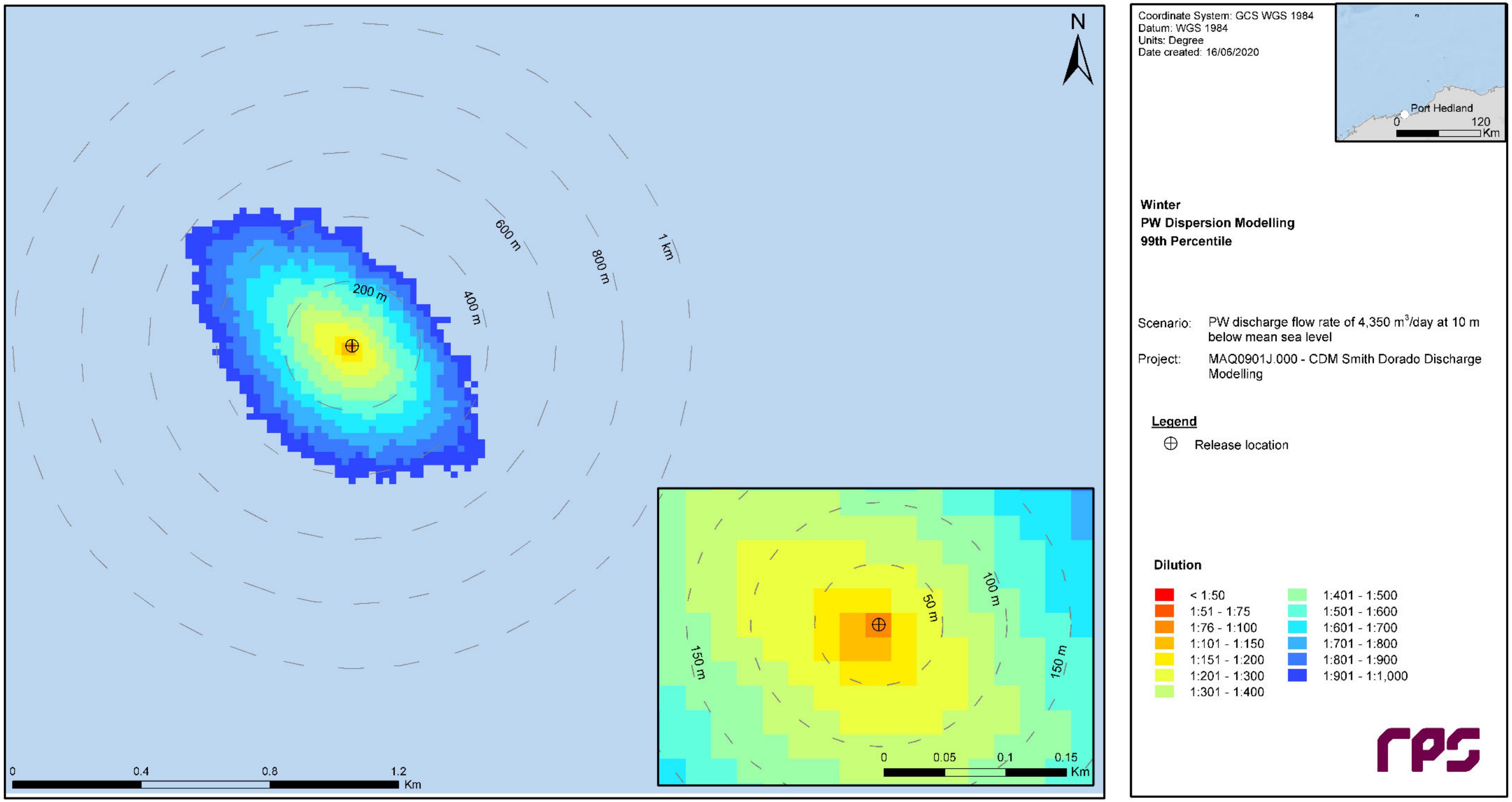
Apx Figure 33 Predicted 95th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined winter results (50 simulations).



Apx Figure 34 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 10 m AMSL. Findings are based on the combined winter results (50 simulations).



Apx Figure 35 Predicted 99th percentile dilutions for a 4,350 m³/d PW discharge released at 0 m BMSL. Findings are based on the combined winter results (50 simulations).



Apx Figure 36 Predicted 99th percentile dilutions for a 4,350 m^3/d PW discharge released at 10 m BMSL. Findings are based on the combined winter results (50 simulations).

Attachment 8 Hydrocarbon Spill Modelling and Consequence Assessment.

Attachment 8-1 Spill Modelling

OIL SPILL MODELLING STUDY – DORADO FIELD

Report

MAQ0901J
CDM Smith Dorado Oil Spill Modelling Report
Final
20 May 2021

rpsgroup.com

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TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
μm	Micrometre (unit of length; 1 μm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ASTM	American Society for Testing and Materials
bbl	Barrel of oil
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
Biodegradation	Decomposition of organic material by microorganism
BTEX	Benzene, toluene, ethylbenzene, and xylenes
°C	degree Celsius (unit of temperature)
CDC	Climate Diagnostics Center
CFSR	Climate Forecast System Reanalysis
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
DEWHA	Department of the Environment, Water, Heritage and the Arts
Dissolved hydrocarbons	Hydrocarbon droplets which are dissolved in water.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
EEZ	Exclusive Economic Zone
Entrained hydrocarbons	Hydrocarbon droplets that are suspended into the water column, though not dissolved.
EP	Environmental plan
Evaporation	The process whereby components of the oil mixture are transferred from the sea-surface to the atmosphere as vapours.
FPSO	Floating production storage and offloading facility
g/m^2	Grams per square meter (unit of surface area density)

GCS WGS 1984	Geographic Coordinate System World Geodetic System 1984 (WGS84); reference coordinate system
GEP	Gas Export Pipeline
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model.
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IBRA	Interim Biogeographic Regionalisation of Australia
Isopycnal layer	Water layer characterised by the same density
ITOPF	International Tankers Owners Pollution Federation
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
KEF	Key Ecological Feature
Knots	unit of speed (1 knot = 0.514 m/s)
KP	Kilometre post. Refers to the surveyed distance along the main line or lateral line of a pipeline.
LC_{50}	Median lethal dose required for mortality of 50% of a tested population after a specified exposure duration.
m	Meter (unit of length)
m/s	Meter per Second (unit of speed)
m^3	Cubic meter (unit of volume)
MAHs	Monoaromatic hydrocarbons
MNP	Marine National Park
MNR	Marine Nature Reserve
MP	Marine Park
MPA	Marine Protected Area
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NCEP	National Centres for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
NRC	National Research Council
OPP	Offshore Project Proposal
PAHs	Polynuclear aromatic hydrocarbons
ppb	parts per billion (concentration)
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics.
PSU	Practical salinity units

Ramsar site	A site listed under the Ramsar Convention on wetlands which is an international intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources.
RSB	Reefs, shoals and banks
Sea surface exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors.
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 1 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as "deterministic modelling" provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of 'worst-case' oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2018). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill.
State waters	Low water mark seaward for three nautical miles
Stochastic Oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the area that maybe affected (EMBA) and also indicates which particular locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations for the Risk EMBA will enclose a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the Risk EMBA contours derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2018). Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment.
Summer	December to the following March
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
Transitional	April and September
Weathered oil	Oil that no longer contains volatile or soluble components
WHP	Well Head Platform
WHS	World Heritage Site
Winter	May to August

EXECUTIVE SUMMARY

Background

Santos Limited (Santos) is planning the development of the Dorado Development (Dorado Project), located in the Bedout Basin offshore north-west Western Australia (WA), approximately 140 km north of Port Hedland. The Dorado Project targets the Dorado reservoir with hydrocarbons being collected on a wellhead platform (WHP) and pumped by infield flowlines for processing on a floating production storage and offloading (FPSO) facility. There is also potential for future development of surrounding fields within the Dorado Project Area. These fields will be developed by drilling additional wells and tied back to the Dorado WHP and/or FPSO via flowlines.

To assess the potential environmental impacts and risks arising from unplanned activities associated with the project a detailed oil spill modelling study was commissioned, which examined the following scenarios:

- Scenario 1: An uncontrolled subsea blowout of crude at the WHP over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) with a decreasing discharge rate;

- Scenario 2: An uncontrolled surface blowout of crude at the WHP over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) with a decreasing discharge rate;

- Scenario 3: A 1,080 m^3 subsea release of crude over 1 hour from the export pipeline, between the FPSO and WHP;

- Scenario 4: An instantaneous surface release of 225 m^3 of crude at the FPSO due to an offtake incident;

- Scenario 5: A tanker colliding with the FPSO and the tanker instantly releasing 1,800 m^3 of heavy fuel oil (HFO) at the surface; and

- Scenario 6: An instantaneous surface release of 10,108 m^3 of crude to represent the loss of contents from the FPSO storage tank.

The potential risk of exposure to the surrounding waters and accumulation to shorelines was assessed over defined seasonal periods: summer (October to March), winter (May to August) and transitional (April and September). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The purpose of the modelling is to further improve the understanding of a conservative ‘outer envelope’ of the potential area that may be affected in the unlikely event of a hydrocarbon release event. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbons may influence based on 300 different spill simulations combined. To understand the potential area that might be affected during an isolated (single) spill event, the results for single deterministic simulations were also presented.

Methodology

The modelling study was carried out in several stages. Firstly, a ten-year current dataset (2009–2018) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, for each scenario modelling was conducted using a stochastic (or statistical) approach, which involved running 100 spill simulations per season (300 total) using the same release information (i.e. spill volume, duration and oil composition), though different start times. This ensured that each simulation was subjected to different wind and current conditions and, in turn, movement and weathering of the oil. Once all 100 simulations were run, the model combined the results to determine the risk and potential exposure/accumulation to the surrounding waters and shorelines and specific sensitive resources over each seasonal period.

This study used thresholds for, shoreline, and in-water (entrained and dissolved) oil, which are consistent with NOPSEMA spill modelling bulletin (NOPSEMA 2019). Reporting thresholds represent potential effects ranging from possible social and economic effects, degradation of water quality (low threshold) as well as possible effects on the behaviour, survival and recruitment success on biota (medium and high thresholds).

Oil Properties

The Caley crude was used as the representative hydrocarbon from the reservoir, given that it is expected to be the most persistent oil from the Archer formation reservoirs and constitutes the largest volume of the extracted hydrocarbons. The physical-chemical properties of Caley crude were based on a detailed assay provided by Santos. It has a density of 773 kg/m^3 (API of 51.4) and a low pour point (-15°C). The low viscosity (1.45 cP) indicates that the crude would rapidly spread and thin out resulting in a large surface area of hydrocarbon available for evaporation. Based upon the Caley crude assay, up to 48% of the hydrocarbon would evaporate over the first few hours or day, with up to 67% evaporated after a few days when on the sea surface. Fifteen percent of the crude is considered persistent, which would eventually breakdown due to the decay. The oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015) guidelines.

Heavy fuel oil (HFO) has a high density of 947.9 kg/m^3 (API of 12.3) and a relatively high pour point (7°C). The high viscosity (3,180 cP) indicates that this oil will not readily spread when released and will form a thick slick on the sea surface, decreasing the rate of evaporation. This oil contains approximately 82.8% (by mass) of hydrocarbon compounds (or residuals) that is expected to become semi-solid to solid at ambient temperatures and is susceptible to decay overtime. The oil is categorised as a group IV oil (heavy-persistent) based on categorisation and classification derived from AMSA (2015) guidelines

Key Findings

Scenario 1: 12,779,600 bbl (2,031,794 m^3) subsea release of crude at the WHP

- The maximum distance from the release location to the low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥ 50 g/m^2) floating oil exposure thresholds was 1,278.2 km west-southwest, 528.3 km west-southwest and 304.5 km west-southwest, respectively, all predicted during summer conditions.

- There are a total of 8 Australian Marine Parks (AMP) and 3 reefs, shoals and banks (RSB) within the low exposure zone across the 3 seasons. While floating oil was predicted to cross WA State Waters during every season with probabilities of 1-12%.

- The probability of hydrocarbon accumulating on any shoreline at, or above, the low threshold (10-100 g/m^2) was 10% and 1% during summer and transitional conditions, with no accumulation at, or above, this threshold predicted in winter months. The minimum time for hydrocarbon accumulating at, or above, the low threshold was approximately 2.88 days and the maximum volume of oil ashore was 64.7 m^3. Port Hedland recorded the highest probability of shoreline accumulation at the low threshold (7%) during summer conditions while the shortest time before shoreline accumulation was predicted during transitional conditions as 2.88 days.

- Twenty AMPs, 8 Key Ecological Features (KEF) and 103 RSB are within the entrained hydrocarbon low exposure zone. Entrained hydrocarbons drifted into state waters during every season with probabilities ranging from 81-94%. One hundred percent exposure was recorded at the Argo-Rowley Terrace AMP during winter.

- Across the 3 seasons, there are 12 AMPs, 4 KEFs and 45 RSBs within the low exposure zone. The probability of dissolved hydrocarbons drifting into WA State Waters ranged from 38-64% and the quickest time for it to reach the boundary was 2.83 days.

Scenario 2: 12,779,600 bbl (2,031,794 m^3) surface release of crude at the WHP

- The maximum distance from the release location to the low, moderate and high floating oil exposure thresholds was 1,201.9 km southwest (summer), 497.3 km west-southwest (transitional) and 304.5 km west-southwest (summer and transitional), respectively.

- Within the floating oil low threshold zone, there are 7 AMPs and 3 RSBs across the 3 seasons. Floating oil was predicted to cross WA State Waters during every season with probabilities of 1-12%. Montebello AMP recorded the highest probability of exposure to floating oil at 18% during summer conditions. The shortest time for floating oil at the low threshold to reach an AMP was recorded at Argo-Rowley Terrace as 7.50 days during summer conditions.

- The probability of hydrocarbon accumulating on any shoreline at, or above, the low threshold was 11% and 1% during summer and transitional conditions, with no accumulation at, or above, this threshold predicted in winter months. The minimum time for hydrocarbon accumulating at, or above, the low threshold was approximately 2.88 days and the maximum volume of oil ashore was 38.1 m^3. Port Hedland recorded the highest probability of shoreline accumulation at the low threshold (9%) during summer conditions and the maximum length of hydrocarbon accumulating on any shoreline (at the low threshold) of 3 km.

- There are 20 AMP in the entrained hydrocarbon low exposure zone and 104 RSB receptors. The highest probability of exposure to an RSB receptor was predicted at Rankin Bank during all three seasons (summer 96%; transitional 94% and winter 97%). While the quickest time to reach an RSB receptor was predicted at Madeleine Shoals (4 days during transitional conditions).

- The dissolved hydrocarbon low exposure zone surrounded 12 AMP and 42 RSB receptors. Dissolved hydrocarbons were predicted to drift into WA state waters during every season with probabilities ranging from 39-64%.

Scenario 3: 1,080 m^3 subsea release of crude from the export pipeline

- The maximum distance from the release location to the low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥ 50 g/m^2) floating oil exposure thresholds was 153.1 km west-southwest (transitional), 40.5 km northeast (winter) and 34.6 km west-northwest (transitional), respectively.

- No floating oil exposure to any of the receptors assessed.

- No shoreline accumulation was predicted above the low threshold (10-100 g/m^2) for this scenario.

- A combined total of 7 AMPs are within the low exposure zone across the 3 seasons, with the Montebello AMP recording the highest probability of exposure of 7% during transitional conditions. The shortest time for exposure at the low threshold to an AMP was recorded at Dampier during transitional conditions at 0.88 days (21 hours). No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold.

- Dissolved hydrocarbons were not predicted to impact any receptors (other than the Northwest Shelf IMCRA, which the release location resides within) at, or above, the low (10-50 ppb) threshold for this scenario.

Scenario 4: 225 m^3 surface release of crude at the FPSO

- The maximum distance from the release location to the low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥ 50 g/m^2) floating oil exposure thresholds was 151.8 km southwest (transitional), 30.2 km north-northeast (winter) and 17.2 km northwest (summer), respectively.

- There was no floating oil exposure to any of the receptors assessed.

- No shoreline accumulation was predicted above the low threshold (10-100 g/m^2) for this scenario.

- No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold. A total of 5 AMPs are within the low exposure zone for the summer and transitional results and the probability of exposure was between 1 – 2%. Rankin Bank was the only RSB predicted to be exposed by entrained hydrocarbons at the low threshold during transitional (2%) and winter (1%) conditions, while Imperieuse Reef was the only receptor exposed during summer conditions (1%).

- Argo-Rowley Terrace AMP was the only AMP to be exposed to dissolved hydrocarbons at the low threshold, with a probability of 1% predicted in summer conditions. And it took 8.17 days for exposure. No KEF or RSB receptors were predicted to be exposed by dissolved hydrocarbons at the low threshold.

Scenario 5: 1,800 m^3 surface release of HFO at the FPSO

- The maximum distance from the release location to the low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥ 50 g/m^2) floating oil exposure thresholds was 2,143.4 km west-northwest (transitional), 1,707.1 km west-northwest (winter) and 1,013.6 km west-southwest (transitional), respectively.

- The floating oil low exposure zone encompasses Nine AMPs are within the predicted zone of floating oil exposure (at the low threshold) during summer conditions, 6 for transitional and 5 for winter conditions. There are 14 RSBs within the low exposure zone across the 3 seasons and 13 during summer. The Imperieuse Reef recorded the highest probability of exposure at 20%, which occurred during transitional conditions, with the minimum time before exposure at 11.6 days. Floating oil was predicted to cross WA state waters during every season with probabilities of 12-69%.

- The probability of hydrocarbon accumulating on any shoreline at, or above, the low threshold (10-100 g/m^2) during summer, transitional and winter seasons was 72%, 31% and 16%, respectively. The minimum time for hydrocarbon accumulating at, or above, the low threshold was approximately 11.67 days and the maximum volume of oil ashore was 1,684.5 m^3. Broome recorded the highest probability of shoreline accumulation at the low threshold (45%) during summer conditions while the shortest time for hydrocarbon accumulating at the low threshold was predicted during transitional conditions (11.67 days at Imperieuse Reef).

- Three AMPs are within the entrained hydrocarbon low exposure zone for summer and 1 AMP (Montebello) during transitional conditions. Montebello AMP recorded the highest probability of exposure of 2%. No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold. was predicted at Rankin Bank only during transitional conditions with a probability of 2%. The quickest time before exposure was 7 days.

- No KEF or RSB receptors were predicted to be exposed by dissolved hydrocarbons at the low threshold.

Scenario 6: 10,108 m^3 surface release of crude from the FPSO

- The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 361.3 km west, 152.3 km west-southwest and 151.5 km west-southwest, respectively, all during transitional conditions.

- Exposure at the low threshold was predicted at 1 AMP (Mermaid Reef) during only the summer season with a probability of 1% and a time of exposure of 24.5 days. Two RSB (Clerke Reef and Mermaid Reef) were exposed by floating oil only during summer conditions and the probability of exposure was 1% at both receptors. The shortest time before exposure was predicted at Clerke Reef, taking 12.71 days.

- No shoreline accumulation was predicted above the low threshold (10-100 g/m^2) for this scenario.

- Ten AMPs are within the entrained hydrocarbon low exposure zone across the three seasons, with the Montebello AMP recording the highest probability of exposure of 20% during winter conditions. Glomar Shoals was the only KEF exposed to entrained hydrocarbons at the low threshold during all 3 seasons with the probability varying from 21 to 24%. The Commonwealth waters adjacent to Ningaloo Reef KEF was the only other receptor exposed to entrained hydrocarbons at the low threshold during transitional conditions only (1% probability).

- Across the 3 seasons, 10 AMPs are within the dissolved hydrocarbon low exposure zone, with Argo-Rowley Terrace AMP recording the highest probability of exposure of 7% during transitional conditions. Dampier AMP was predicted to be exposed quickest at 4.13 days during transitional conditions. Glomar Shoals was the only KEF to be exposed by dissolved hydrocarbons at the low threshold with probabilities between 1 – 6%. Five RSB are within the low exposure zone across the three seasons, with the highest probability predicted at Clerke Reef during transitional conditions (6%).

1 INTRODUCTION

1.1 Background

Santos Limited (Santos) is planning the development of the Dorado Development located in the Bedout Basin offshore north-west Western Australia (WA), approximately 140 km north of Port Hedland. The Dorado Project targets the Dorado reservoir with hydrocarbons being collected on a wellhead platform (WHP) and pumped by infield flowlines for processing on a floating production storage and offloading (FPSO) facility. There is also potential for future development of surrounding fields within the Dorado Project Area.

The Dorado Development will be subject to regulatory assessment as an Offshore Project Proposal (OPP) in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations), administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

The OPP is required to assess all environmental impacts and risks arising from planned and unplanned activities associated with the project appropriate to the nature and scale of each impact or risk.

To suitably inform the impact assessment and support the preparation of the OPP, CDM Smith (on behalf of Santos) has commissioned RPS to undertake a detailed oil spill modelling study.

Santos identified six worst-case credible hydrocarbon spill scenarios that may be associated with the Dorado project:

- Scenario 1: An uncontrolled subsea blowout of crude at the WHP over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) with a decreasing discharge rate;
- Scenario 2: An uncontrolled surface blowout of crude at the WHP over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) with a decreasing discharge rate;
- Scenario 3: A 1,080 m^3 subsea release of crude over 1 hour from the export pipeline, between the FPSO and WHP;
- Scenario 4: An instantaneous surface release of 225 m^3 of crude at the FPSO due to an offtake incident;
- Scenario 5: A tanker colliding with the FPSO and the tanker instantly releasing 1,800 m^3 of heavy fuel oil (HFO) at the surface; and
- Scenario 6: An instantaneous surface release of 10,108 m^3 of crude to represent the loss of contents from the FPSO storage tank.

The coordinates of the release locations are presented in Table 1.1 and graphically in Figure 1.1

Each scenario was modelled and assessed over defined seasonal periods: summer (October to March), winter (May to August) and transitional (April and September).

The purpose of the modelling is to further improve the understanding of a conservative ‘outer envelope’ of the potential area that may be affected in the unlikely event of a hydrocarbon release event. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbons may influence based on 300 different spill simulations combined. To understand the potential area that might be affected during an isolated (single) spill event, the results for single simulations were also presented.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Model Application Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

Note that the oil spill model, the method and analysis presented herein uses modelling algorithms which have been anonymously peer reviewed and published in international journals. Furthermore, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1.1 Coordinates of the Dorado Development hydrocarbon spill modelling release locations.

Scenario	Location	Latitude	Longitude	Water depth (m)
1, 2	WHP	19° 01' 38.001" S	118° 44' 36.744" E	91
4, 5, 6	FPSO (2.2 km directly south of the WHP)	19° 02' 49.546" S	118° 44' 36.744" E	90
3	Export pipeline release location (point between the WHP and FPSO)	19° 02' 13.773" S	118° 44' 36.744" E	90.5

The WGS84 Geographic projection is used throughout the report.

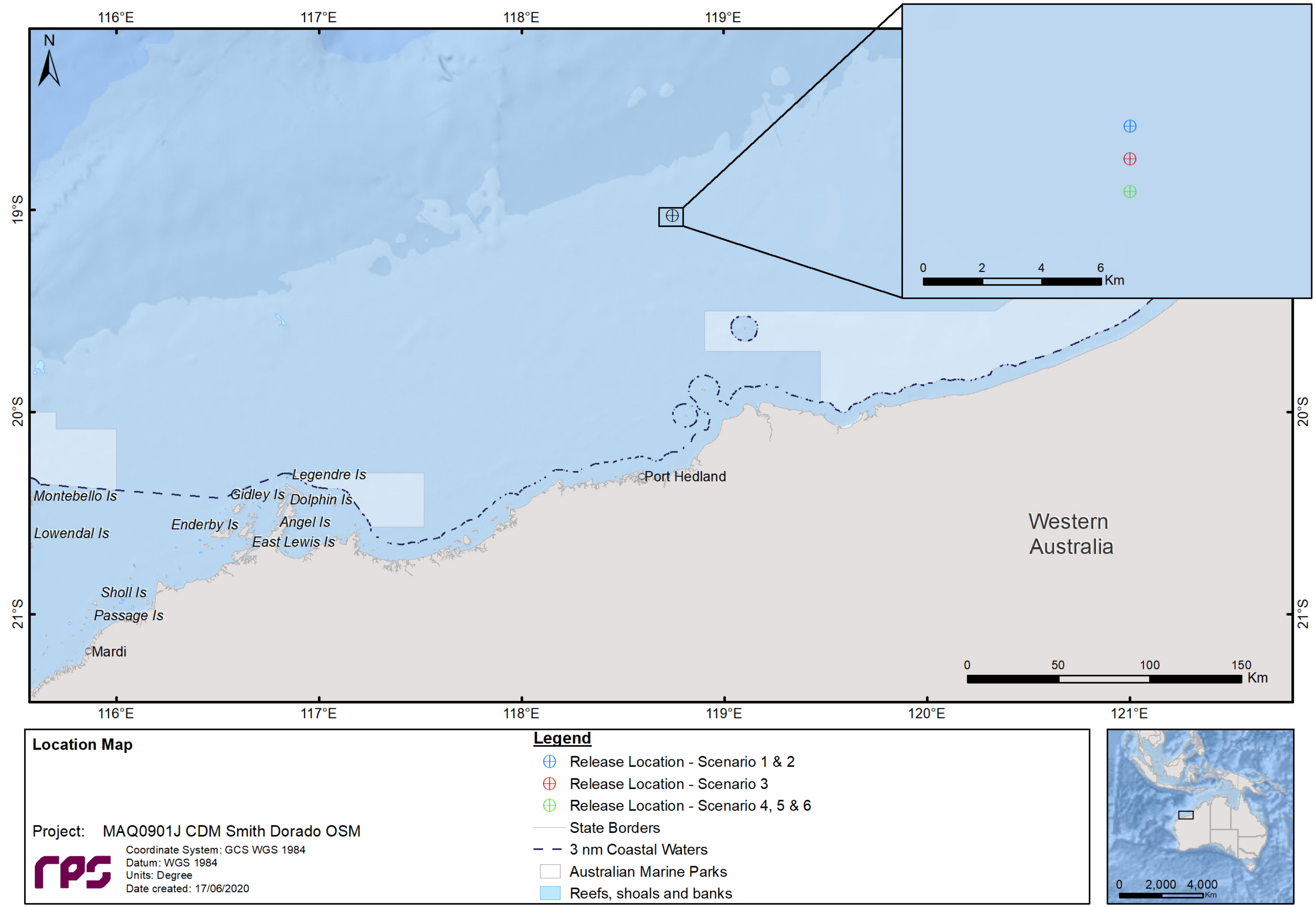


Figure 1.1 Map of the Dorado Development oil spill modelling release locations.

1.2 What is Oil Spill Modelling?

Oil spill modelling is a valuable tool widely used for risk assessment, emergency response and contingency planning where it can be particularly helpful to proponents and decision makers. By modelling a series of the most likely oil spill scenarios, decisions concerning suitable response measures and strategic locations for deploying equipment and materials can be made, and the locations at most risk can be identified. The two types of oil spill modelling often used are stochastic and deterministic modelling.

1.2.1 Stochastic Modelling (Multiple Spill Simulations)

Stochastic modelling involves running numerous individual oil spill simulations to provide insight into the potential area of effect using a range of prevailing wind and current conditions that are historically representative of the location of where the spill event may occur. As part of this study, 300 oil spills were simulated for each scenario using the same spill information (release location, spill volume, duration and oil type) but with varied start dates and times corresponding to the period represented by the available wind and current data. Each season is represented by 100 spill scenarios. Once the simulations were complete, the results were overlaid (NOPSEMA, 2018, Figure 1.2) to understand the range of environments that could be influenced or impacted by a spill (the Environment that May Be Affected - EMBA).

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of accumulation above defined concentrations;
- Volume of oil that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous or over a specified time window) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous or over a specified time window) to entrained hydrocarbons in the water column.

The EMBA that is presented and interrogated in this assessment for the spill scenarios presents the combined boundary of all 300 spill scenarios (each being a “deterministic” run). Each single spill is independent of the other, and will extend within the EMBA (which is all the spills combined).

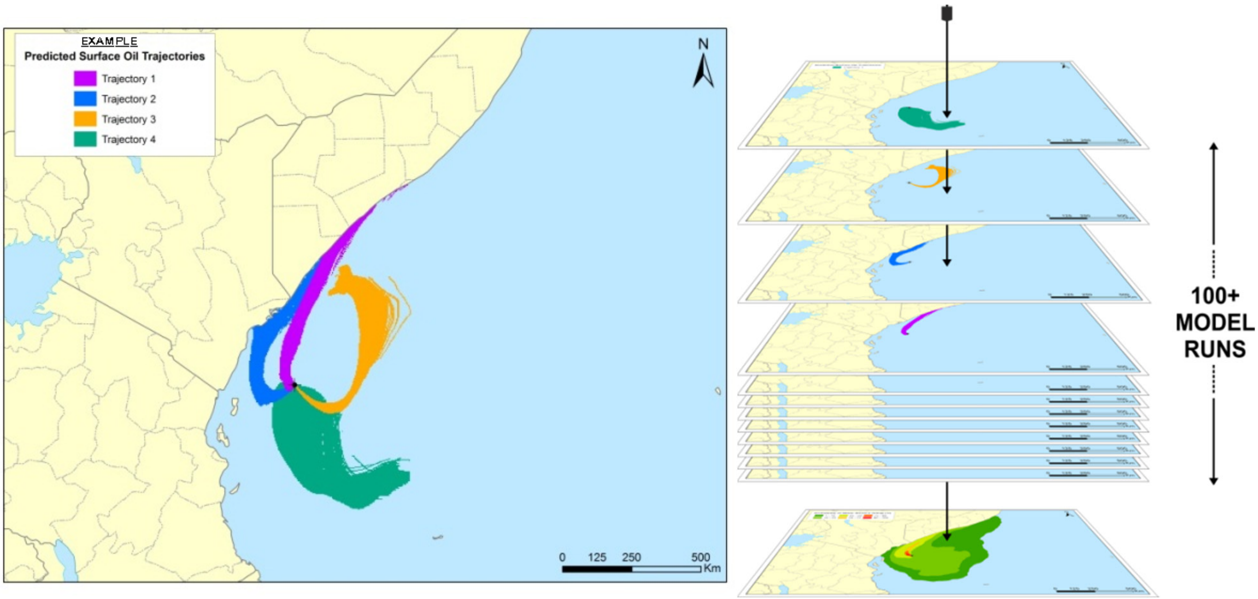


Figure 1.2 Examples of spill trajectories predicted by SIMAP for the same scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability.

1.2.2 Deterministic Modelling (Single Spill Simulation)

Deterministic modelling is the predictive modelling of a single incident subject to a single sample of wind and weather conditions over time (NOPSEMA, 2018; Figure 1.3).

Deterministic modelling is often paired with stochastic modelling to place the large stochastic footprint into perspective. This deterministic analysis is generally a single run selected from the stochastic analysis and serves as the basis for developing the plans and equipment needs for a realistic spill response.

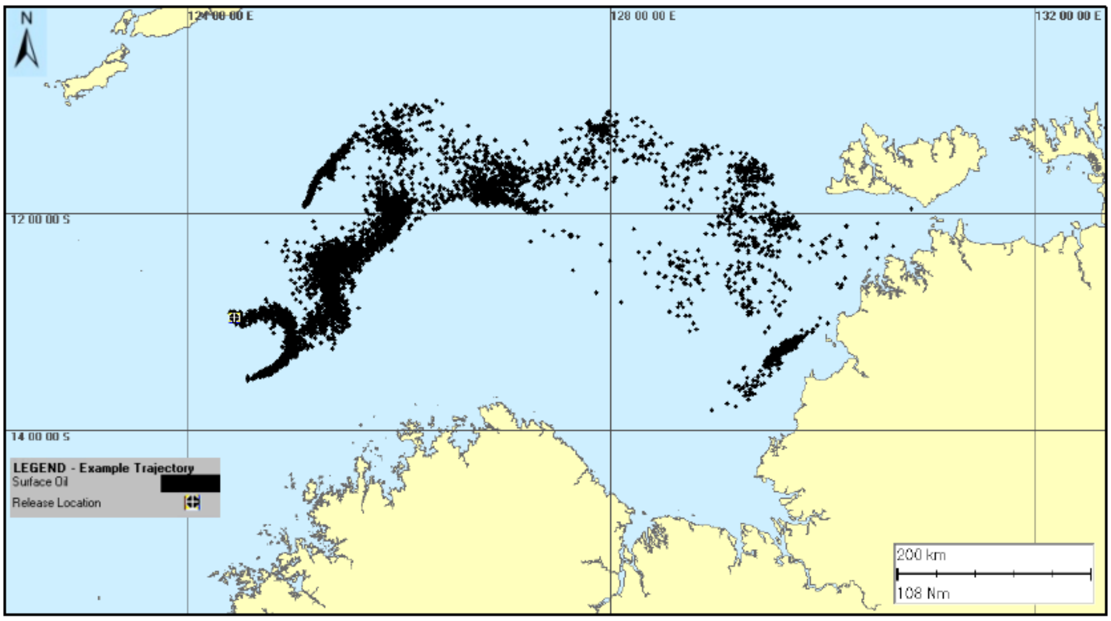


Figure 1.3 Example of an individual spill simulations predicted by SIMAP for a spill scenario.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2009 to 2018 (inclusive)) wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Confirm the suitability of the generated current data by comparing it against measurements within the Dorado project area, collected over a 2-month period (January and February 2018), using quantitative and visual comparisons at water depths of 40 m, 70 m and 110 m;

3. Use 10 years of high-resolution wind, aggregated current data and hydrocarbon characteristics as input into the 3-dimensional oil spill model to represent the movement, spreading, entrainment and weathering of the oil over time;

4. Use SIMAP's stochastic model to calculate exposure to surrounding waters (sea surface and water column) and accumulation on shorelines. This involved running 100 randomly selected single simulations for each season (i.e. 300 simulations per scenario), with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but varying start times. This will ensure that each spill is subjected to unique wind and current conditions.

5. Combine the 100 spill trajectories per season to determine the exposure by floating oil and in the water column, in addition to accumulation on shorelines (for a defined low, moderate and high threshold); and

6. For the scenarios (1, 2 and 5) resulting in shoreline accumulation above impact thresholds, the "worst case" deterministic runs were identified and presented based on the following criteria:

    a. Largest volume of oil ashore; and

    b. Longest length of shoreline upon which oil was predicted to accumulate.

7. For the scenarios (3, 4 and 6) where there was no shoreline accumulation above impact thresholds, the "worst case" deterministic runs were identified and presented based on the following criteria:

    a. Largest swept area of floating oil on the sea surface above 50 g/m^2 (high or actionable floating oil threshold); and

    b. Largest area of entrained hydrocarbon exposure above 10 ppb (low threshold).

3 REGIONAL OCEAN CURRENTS

3.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region (< 100 m water depth). However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have an influence upon the net trajectory of discharges over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location. A comprehensive description of the circulation patterns of the Northwest Shelf is provided in a review by Condie and Andrewartha (2008).

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model (HYCOM), with estimates of the tidal currents generated by an RPS model set up for the study area (HYDROMAP).

3.1.1 Ocean Currents

The large scale drift currents were derived from the output of the global circulation model the Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet et al., 2007, 2009), created by the National Ocean Partnership Program (NOPP), as part of the US Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates ocean observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite observations, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density and sea height variations and the rotation of the earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (approximately 7 km at mid-latitudes) and a temporal resolution of one day.

A hindcast data set of HYCOM currents was obtained for a ten-year period spanning 2009 to 2018 (inclusive).

3.1.2 Tidal Currents

3.1.2.1 Description of Tidal Model: HYDROMAP

As the HYCOM model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA) (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

3.1.2.2 Tidal Grid Setup

A HYDROMAP model was established over a domain that extended approximately 3,870 km east-west by 3,220 km north-south over the eastern Indian Ocean. Figure 3.1 shows a subset of the grid between Exmouth and Derby.

The tidal domain is sub-gridded down to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over more complex bathymetry.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office (see Figure 3.2). Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

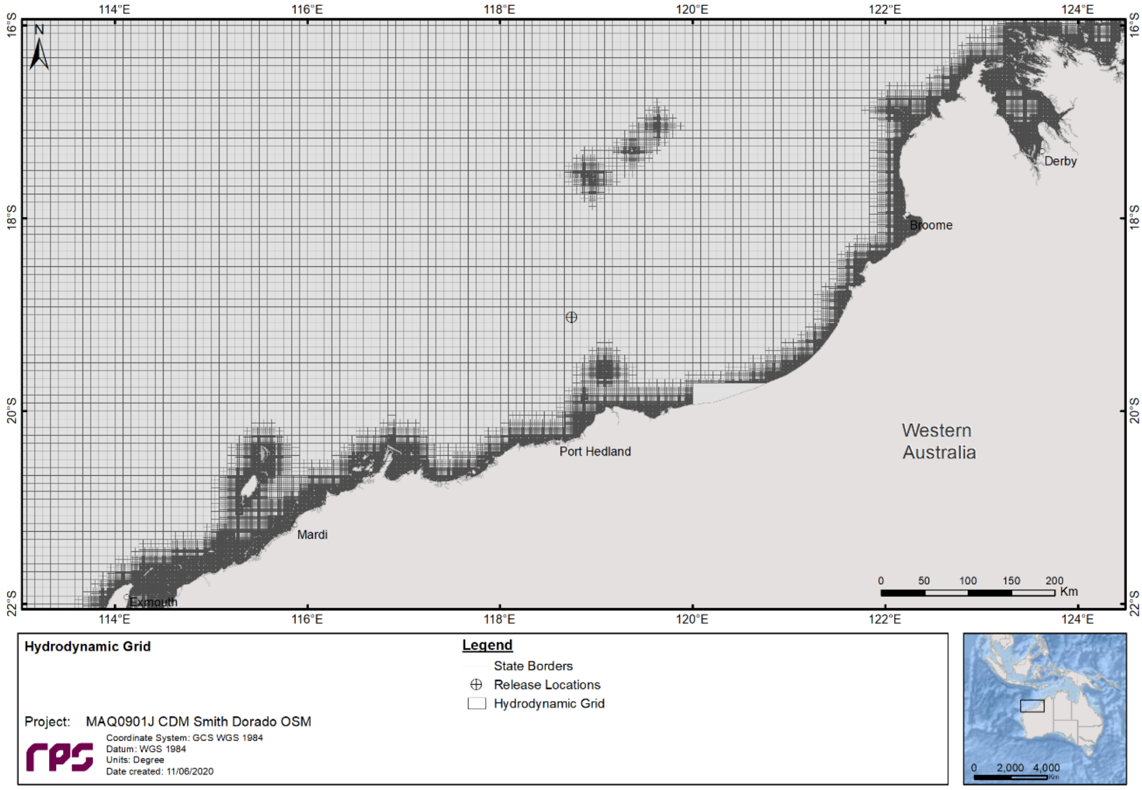


Figure 3.1 Subset of the model grid (grey wire mesh) used to generate the tidal currents. Higher-resolution areas are indicated by the denser mesh zones.

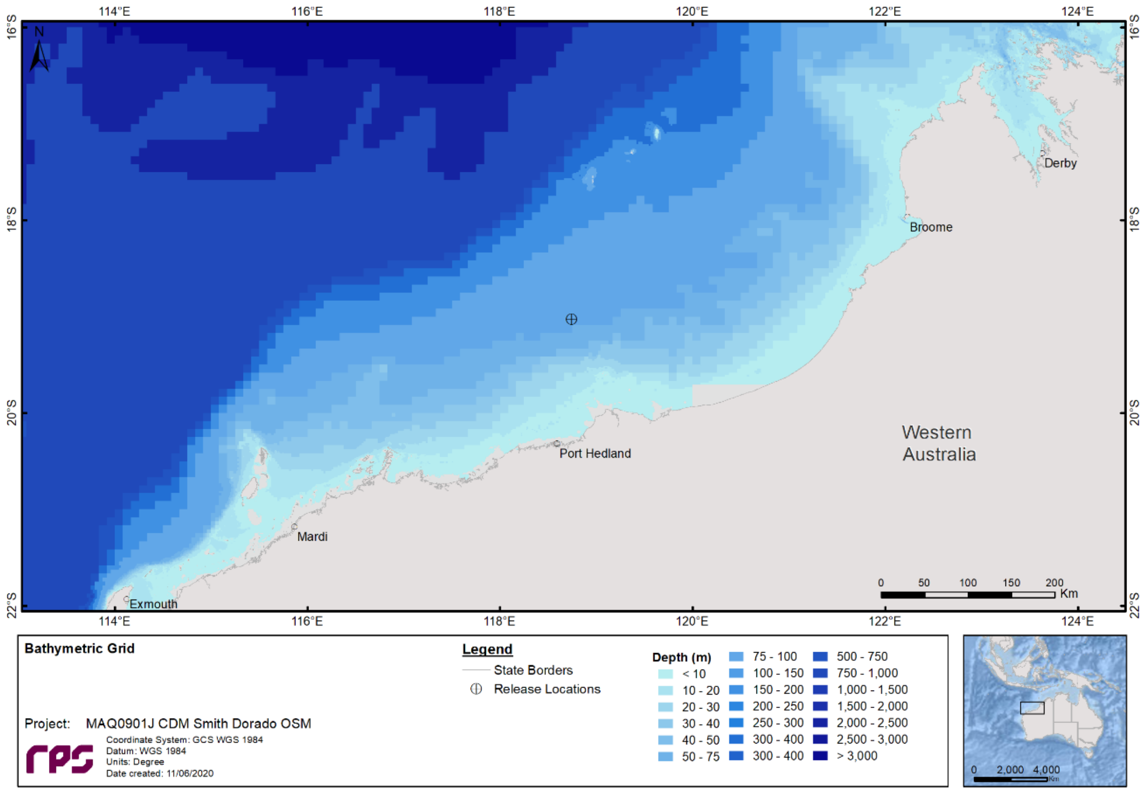


Figure 3.2 Subset of the bathymetry data used to generate the tidal currents.

3.1.2.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K2, S2, M2, N2, K1, P1, O1 and Q1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.1.2.4 Tidal Model Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at five locations (see Figure 3.3).

Figure 3.4 and Figure 3.5 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graphs, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles.

To provide a statistical measure of the model performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is simply the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error (Willmott and Matsuura, 2005) and more readily understood.

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: X represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of 0 (Willmott, 1981). Willmott et al. (1985) also suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

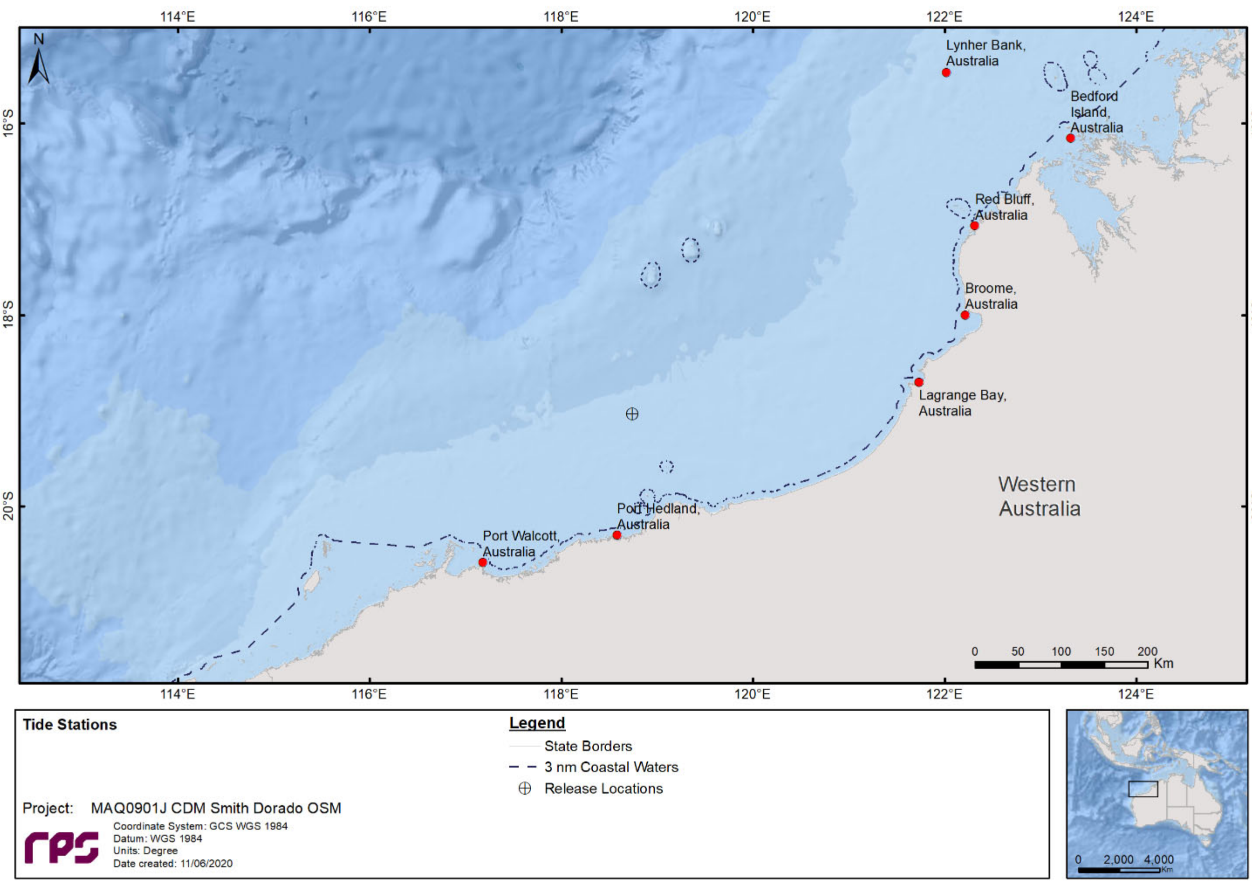


Figure 3.3 Tide stations used to validate surface elevation within the model.

Table 3.1 Statistical comparison between the observed and predicted surface elevations.

Tide Station	IOA	MAE (m)
Broome	0.90	1.11
Lagrange Bay	0.96	0.71
Lynher Bank	0.98	0.31
Port Hedland	0.98	0.33
Port Walcott	0.99	0.20
Red Bluff	0.98	0.46

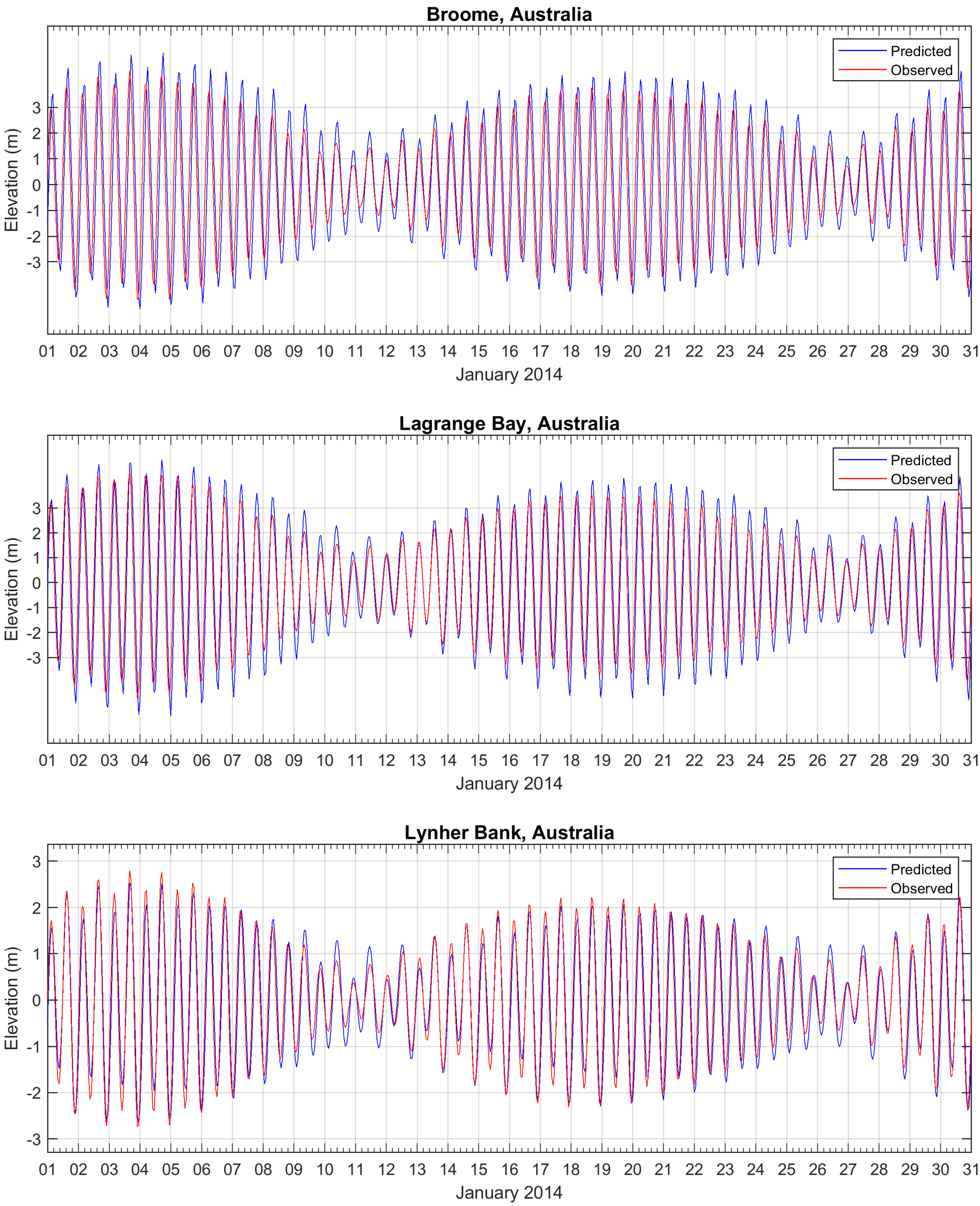


Figure 3.4 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

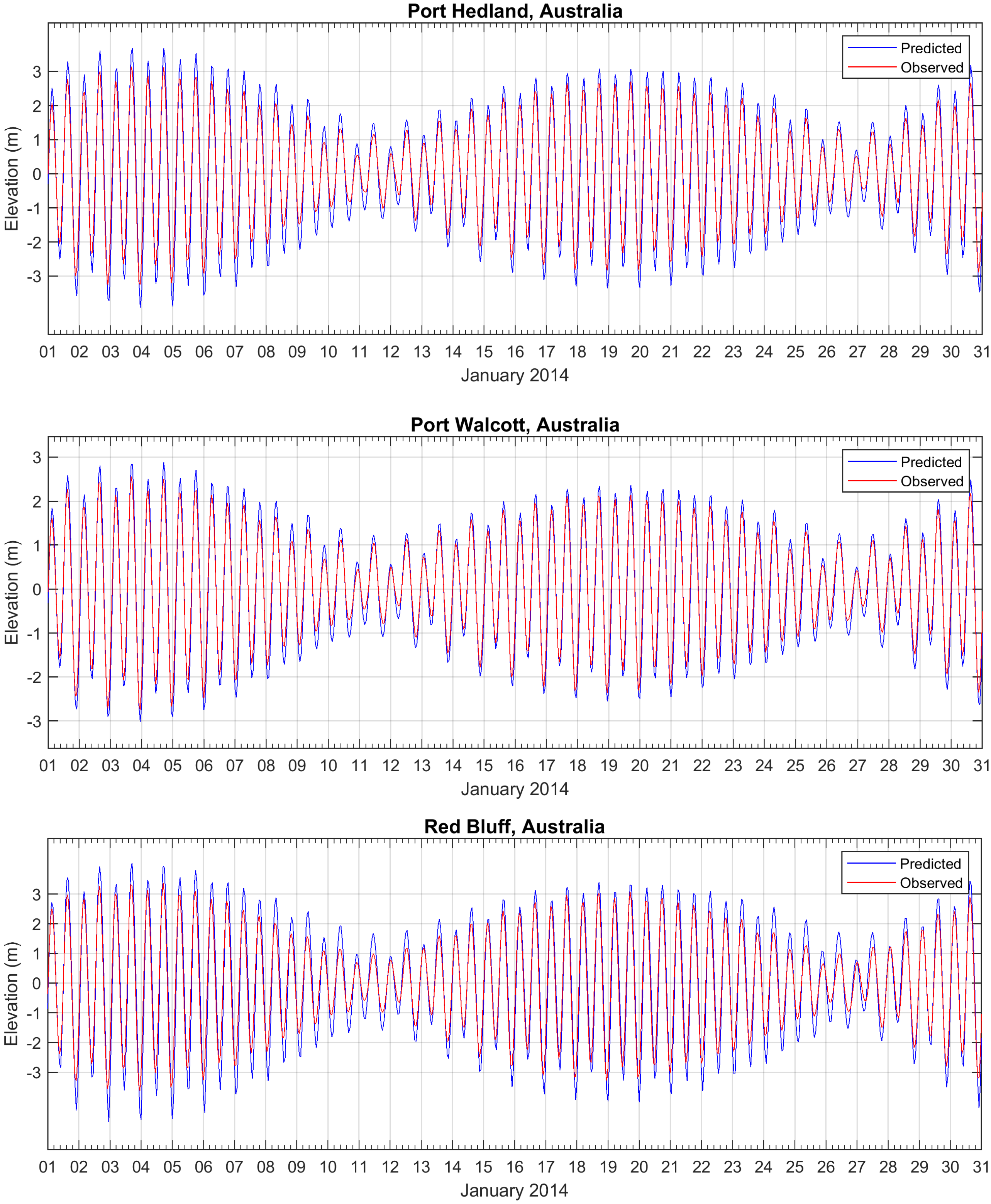


Figure 3.5 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

3.1.3 Current Model Validation

To confirm the suitability of the generated current data, it was compared against current measurements within the Dorado project area, using quantitative and visual comparisons at a range of depths.

Time series comparisons of the predicted and measured current speed and direction components at water depths of 40 m, 70 m and 110 m are presented in Figure 3.6, Figure 3.7 and Figure 3.8, respectively, for a two month period (January and February 2018). The time series comparisons reveal that the predicted currents offer a good match with the measured current speed and direction components at all water depths, with the magnitudes and timings of the peaks and troughs matching well.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001). The RMAE is relatively low in all depth layers indicating that the magnitude and range of current speeds match well, however, a slight overprediction of the predicted current magnitude is evident at times.

To compare directionality, roses for the predicted and measured currents at 40 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 3.9. The roses show that the predicted current direction is a good match with the measured direction. Both the predicted model direction and the measured data direction were in good alignment at each depth layer, portraying a dominant current direction along a northwest/southeast axis. The range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Dorado Project area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Dorado Project.

Table 3.2 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds and directions at various depths at the Dorado Project area (January and February 2018).

Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
40 m	0.26	0.71	36.7	Good
70 m	0.26	0.80	29.9	Very good
110 m	0.26	0.85	27.9	Very good

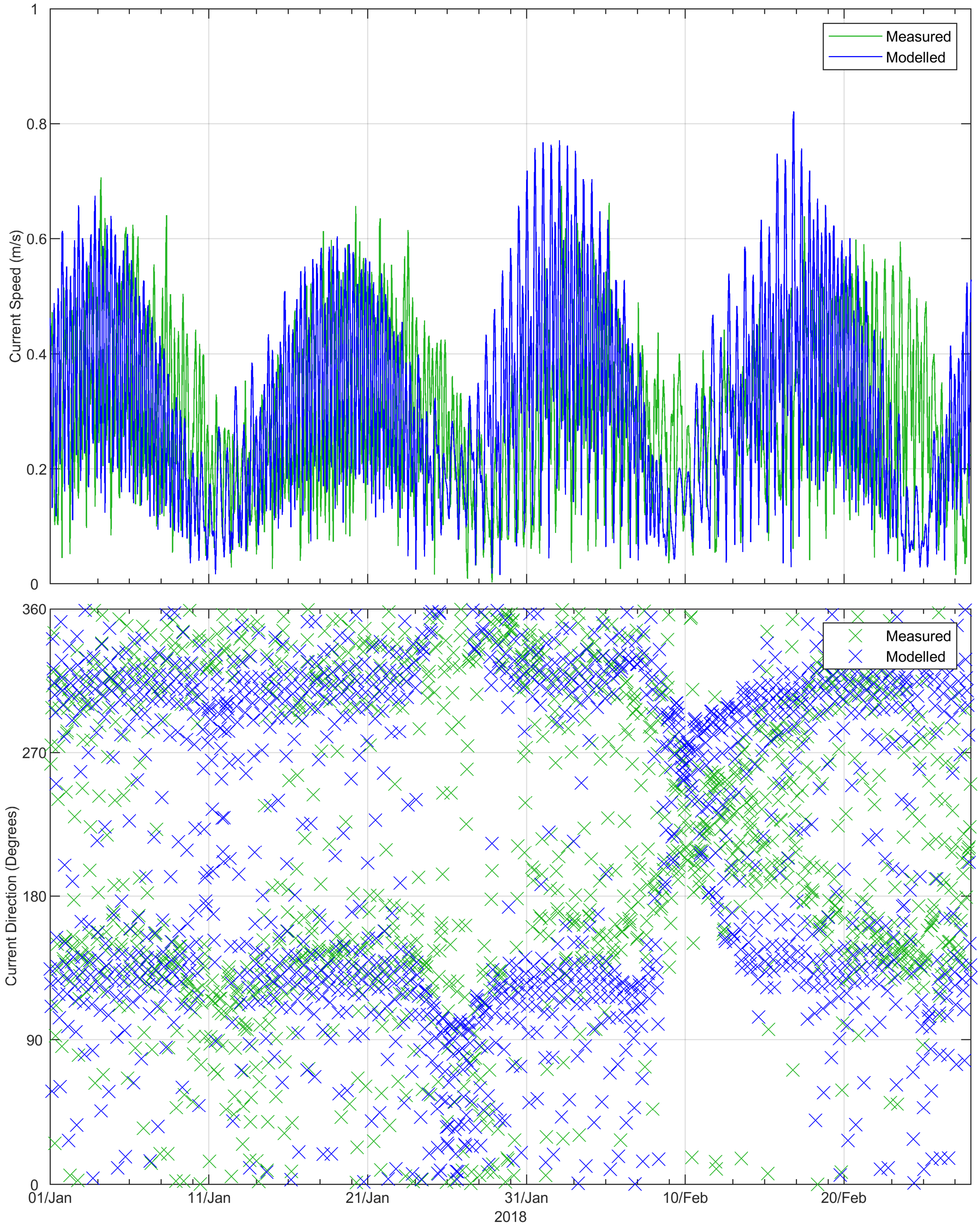


Figure 3.6 Time series comparisons between predicted (HYDROMAP+HYCOM, blue line) and measured (green line) current speeds (top) and current directions (bottom) at the Dorado Project area at a depth of approximately 40 m for January and February 2018.

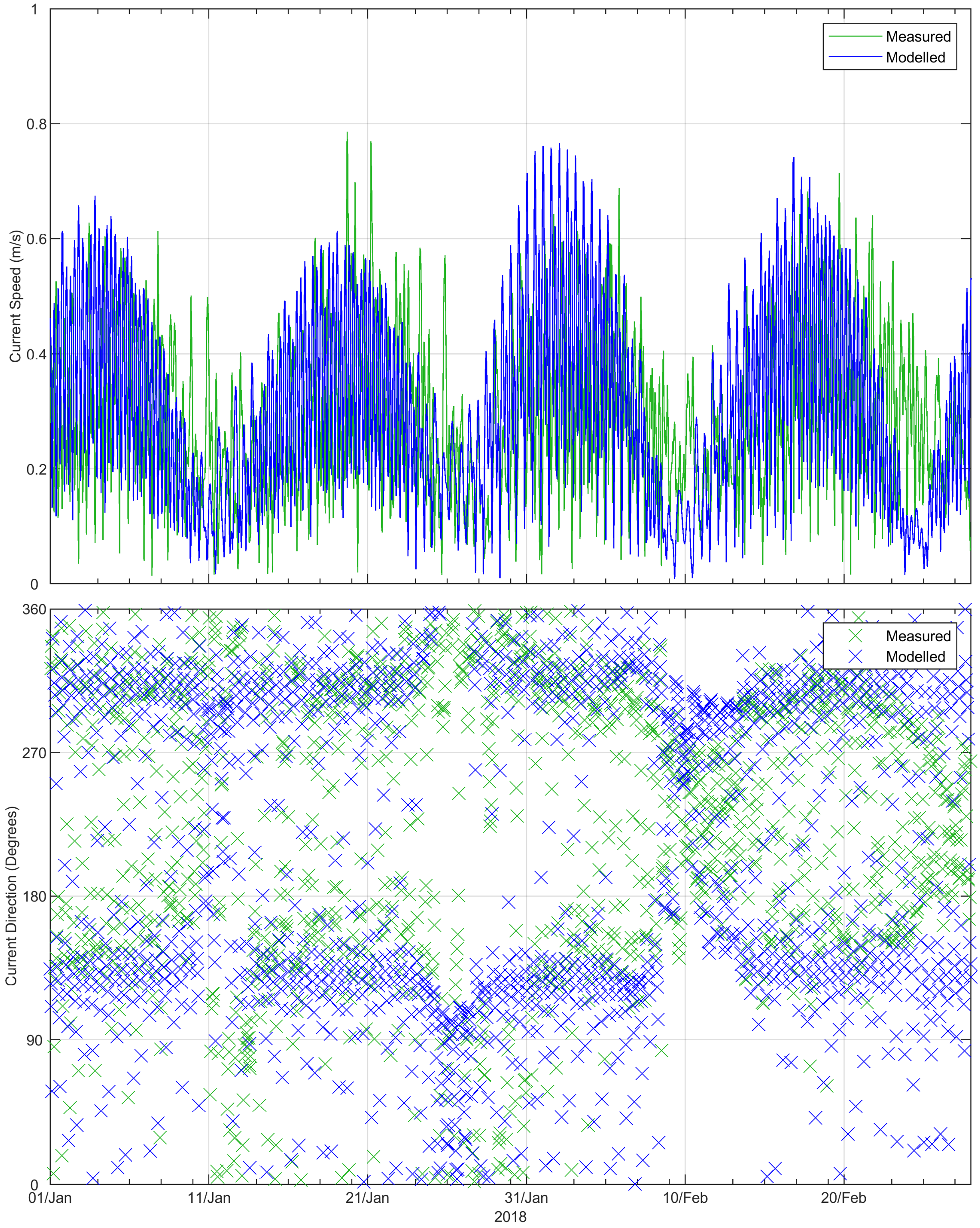


Figure 3.7 Time series comparisons between predicted (HYDROMAP+HYCOM, blue line) and measured (green line) current speeds (top) and current directions (bottom) at the Dorado Project area at a depth of approximately 70 m for January and February 2018.

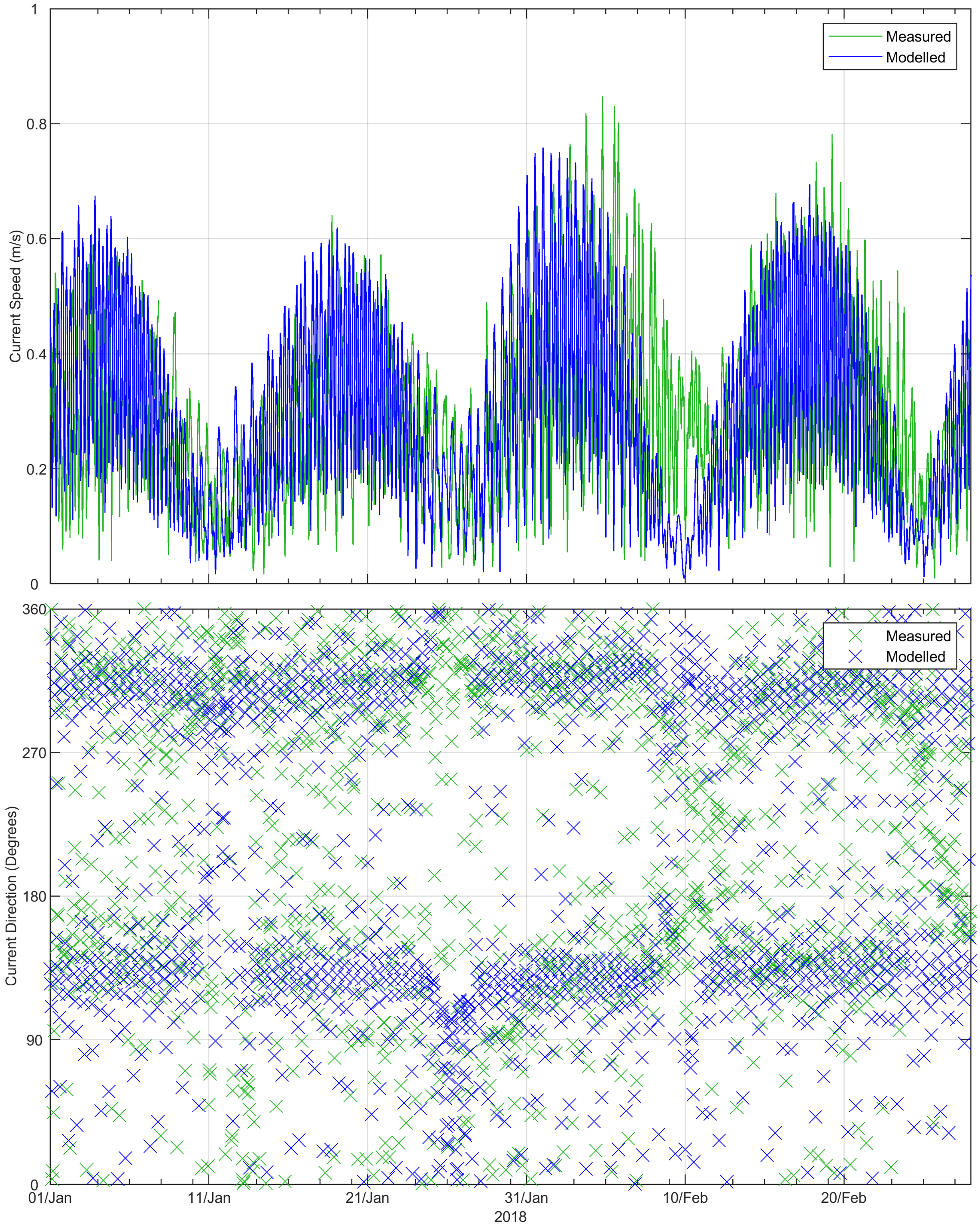


Figure 3.8 Time series comparisons between predicted (HYDROMAP+HYCOM, blue line) and measured (green line) current speeds (top) and current directions (bottom) at the Dorado Project area at a depth of approximately 110 m for January and February 2018.

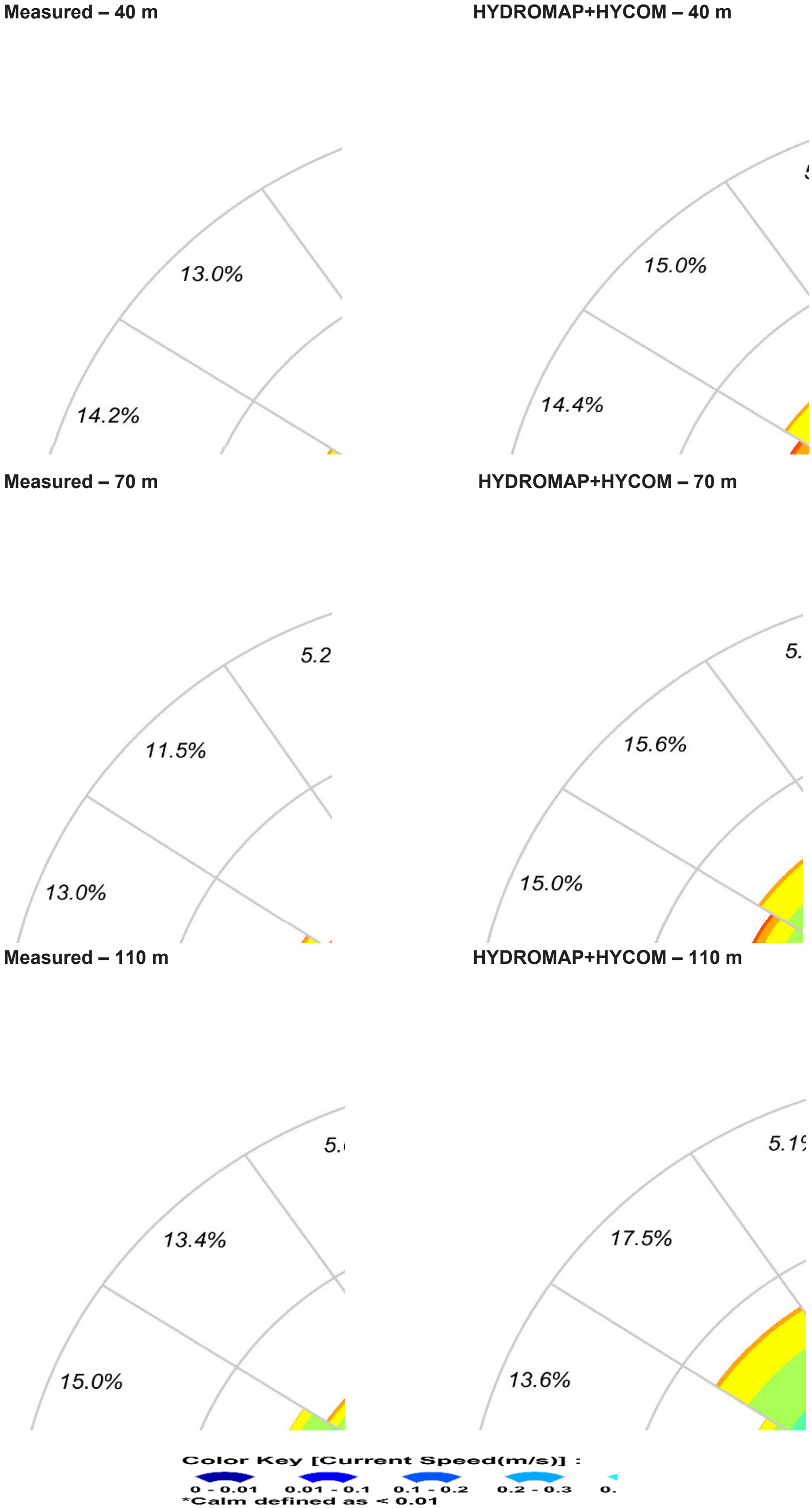


Figure 3.9 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Dorado Project area (2017-2018) at depths of approximately 40 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3.2 Surface Currents

Table 3.3 displays the predicted monthly average and maximum surface current speeds adjacent to the release locations, while Figure 3.10 and Figure 3.11 show monthly, seasonal and total surface current rose distributions from 2009 – 2018 (inclusive). The currents are from the combination of HYCOM large-scale ocean currents and HYDROMAP tidal currents to account for the total drift throughout the model domain.

Note the convention for defining current direction is the direction the current flows **towards**, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow to the corresponding direction.

The surface modelled current data indicated a consistent monthly average between of approximately 0.3 m/s and a dominant current direction towards the northwest and east-southeast to southeast throughout the year, while maximum current speeds varied between 0.70 m/s (November) to 1.42 m/s (October).

Table 3.3 Predicted average and maximum surface current speeds adjacent to the release locations. Data derived by combining HYCOM ocean data and HYDROMAP tidal data from 2009-2018 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.30	0.86	East-southeast (variable)
	February	0.31	1.32	Northwest
	March	0.32	1.41	Northwest
Transitional	April	0.31	1.07	Northwest and West-northwest
Winter	May	0.30	0.91	West-northwest
	June	0.29	0.81	West-northwest
	July	0.31	0.88	West-northwest and northwest
	August	0.31	0.89	Northwest
Transitional	September	0.32	0.91	Northwest and Southeast
Summer	October	0.29	1.42	Northwest
	November	0.26	0.70	Northwest
	December	0.26	0.72	East-southeast (variable)
	Minimum	**0.26**	**0.70**	
	Maximum	**0.32**	**1.42**	

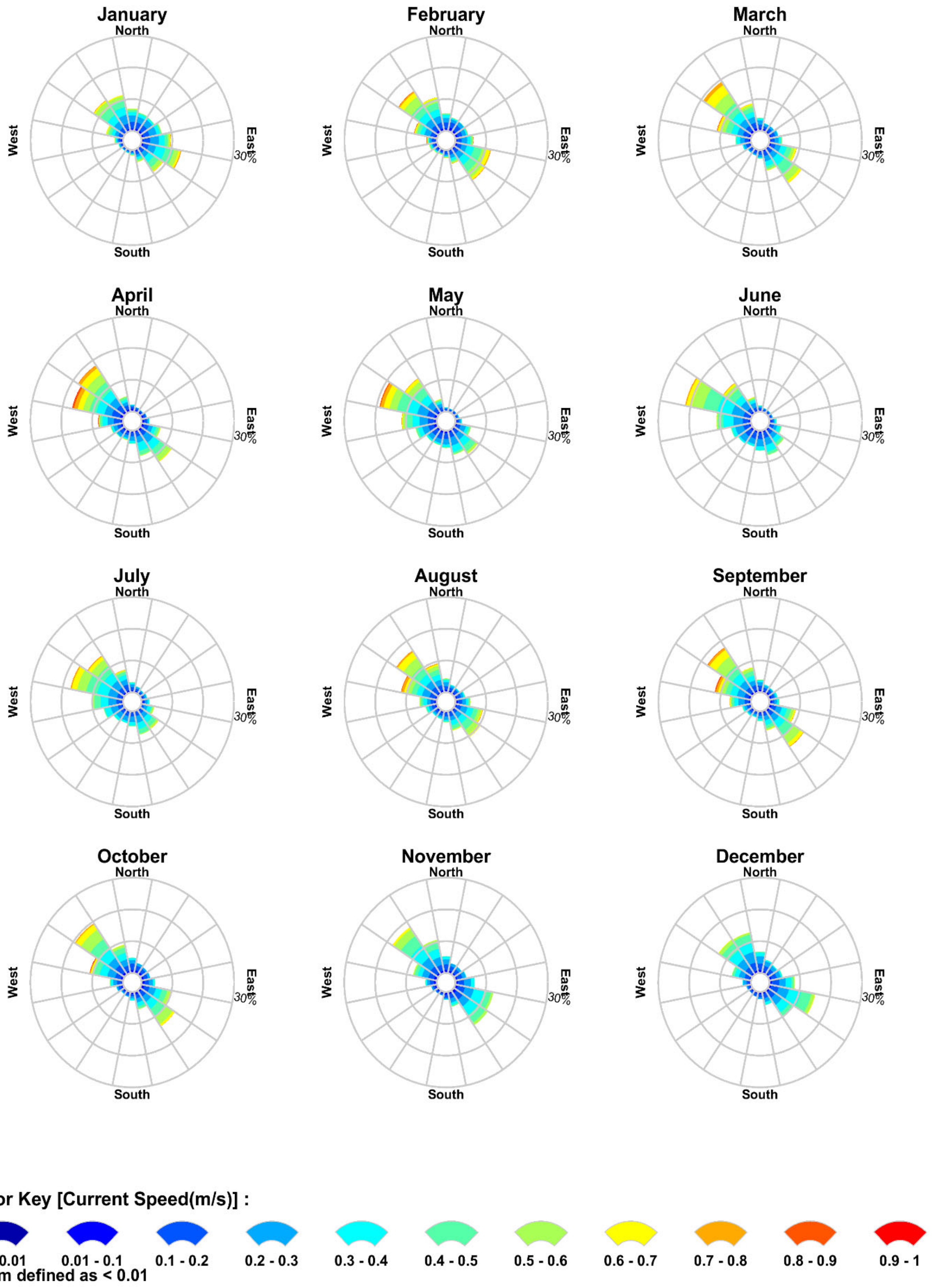


Figure 3.10 Monthly current distribution (2009-2018, inclusive) derived from the HYCOM database near the Dorado Project area. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

Figure 3.11 Seasonal (top) and total (bottom) current distribution (2009-2018, inclusive) derived from the HYCOM database near the Dorado Project area. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

4 WIND DATA

To account for the influence of the wind on surface-bound hydrocarbons, representation of the wind conditions was provided by spatial wind fields sourced from the National Center for Environmental Prediction (NCEP), National Oceanic and Atmospheric Administration (NOAA) Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Diagnostics Center in Boulder, Colorado, United States of America (USA). The NCEP Climate Forecast System Reanalysis (CFSR; Saha et al., 2010) is a fully-coupled, data-assimilative hindcast model representing the interaction between the Earth's oceans, land and atmosphere. The gridded data output, including surface winds, is available at 0.25° resolution and 1-hourly time intervals.

Time series of wind speed and direction were extracted from the CFSR database for all nodes in the model domain for the same temporal coverage as the current data (2009-2018, inclusive). The data was assumed to be a suitably representative sample of the wind conditions over the study area for future years.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node located near the release locations. This region typically experiences moderate winds all year round with monthly average wind speeds ranging from 5.1 m/s (April) to 7.6 m/s (June) while the maximum wind speeds can reach 28.7 m/s (December).

Figure 4.1 shows the monthly wind roses while Figure 4.2 shows the seasonal and total wind roses near the release locations. The data shows that wind speeds and directions vary between seasons. During summer (October to March), the winds blow predominantly from the west, in winter (May to August) the winds blow predominantly from the east and during transitional conditions, wind directionality is more variable.

The extracted wind data near the release location suggests that, in the absence of any current effects, the wind acting on hydrocarbons on the sea surface will tend to result in initial trajectories that will most frequently be towards the east during summer months and towards the west during winter period. Note that the actual trajectories of the hydrocarbons on the sea surface will be the net result of a combination of the prevailing wind and current vectors acting at a given time and location. For long duration spills which may span multiple "periods" of the year (like the well blowout scenarios), the net outcomes may be a blend between the seasons.

Table 4.1 Predicted average and maximum wind speeds for the closest data point to the release locations.

Season	Month	Average wind (m/s)	Maximum wind (m/s)	General direction (from)
Summer	January	6.0	19.7	West
	February	5.7	22.8	West
Transitional	March	4.9	27.0	West-southwest (variable)
Winter	April	5.1	16.2	East-southeast
	May	6.5	17.4	East-southeast
	June	7.6	17.8	East-southeast
	July	6.7	14.8	East-southeast
	August	5.7	15.8	East-southeast
Transitional	September	5.5	16.1	Southwest
Summer	October	5.6	15.1	West-southwest
	November	5.8	13.9	West-southwest
	December	5.8	28.7	West
	Minimum	**5.1**	**13.9**	
	Maximum	**7.6**	**28.7**	

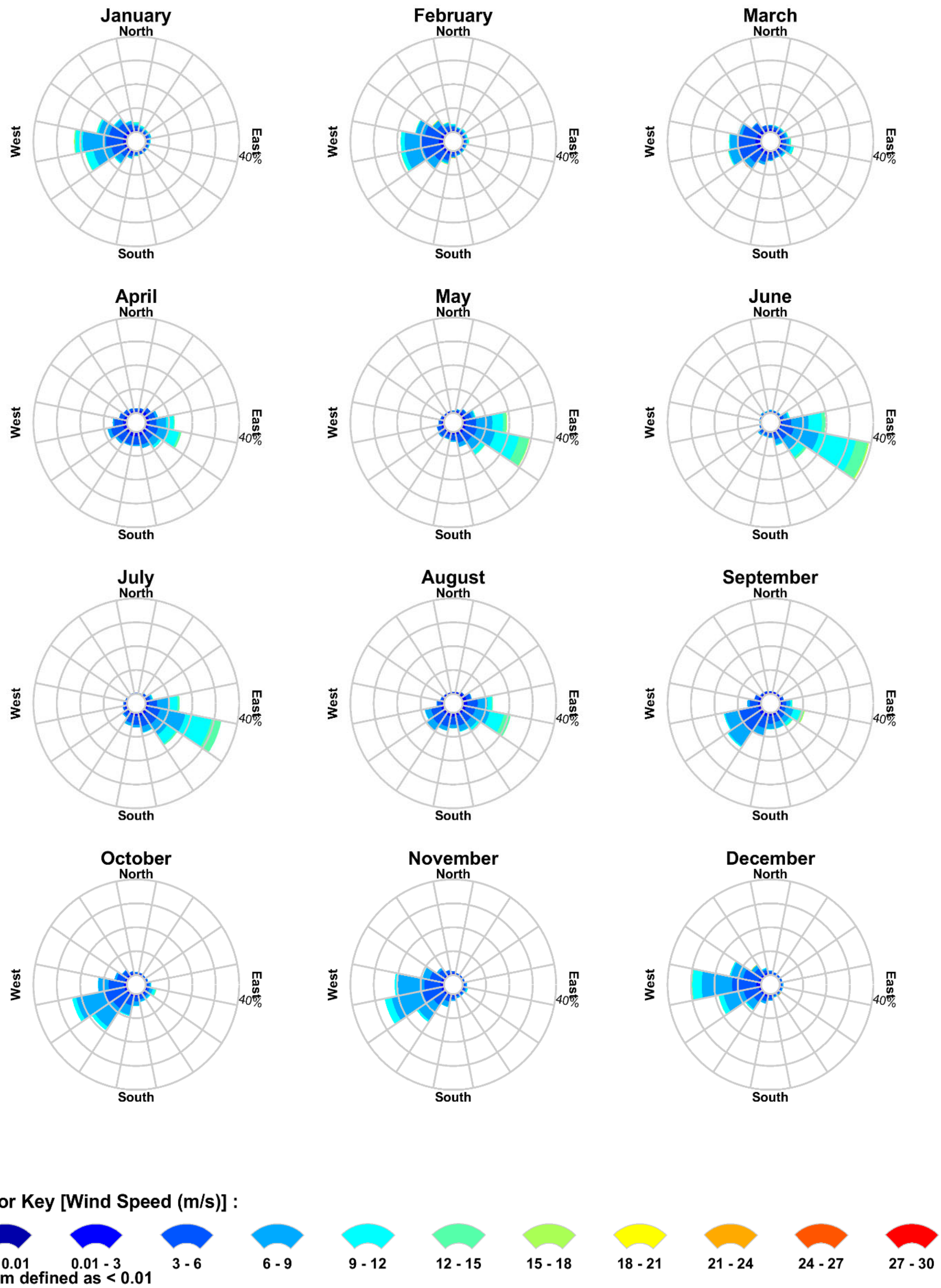


Figure 4.1 Monthly wind distribution (2009-2018, inclusive) derived from the CFSR closest data point to the release locations. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

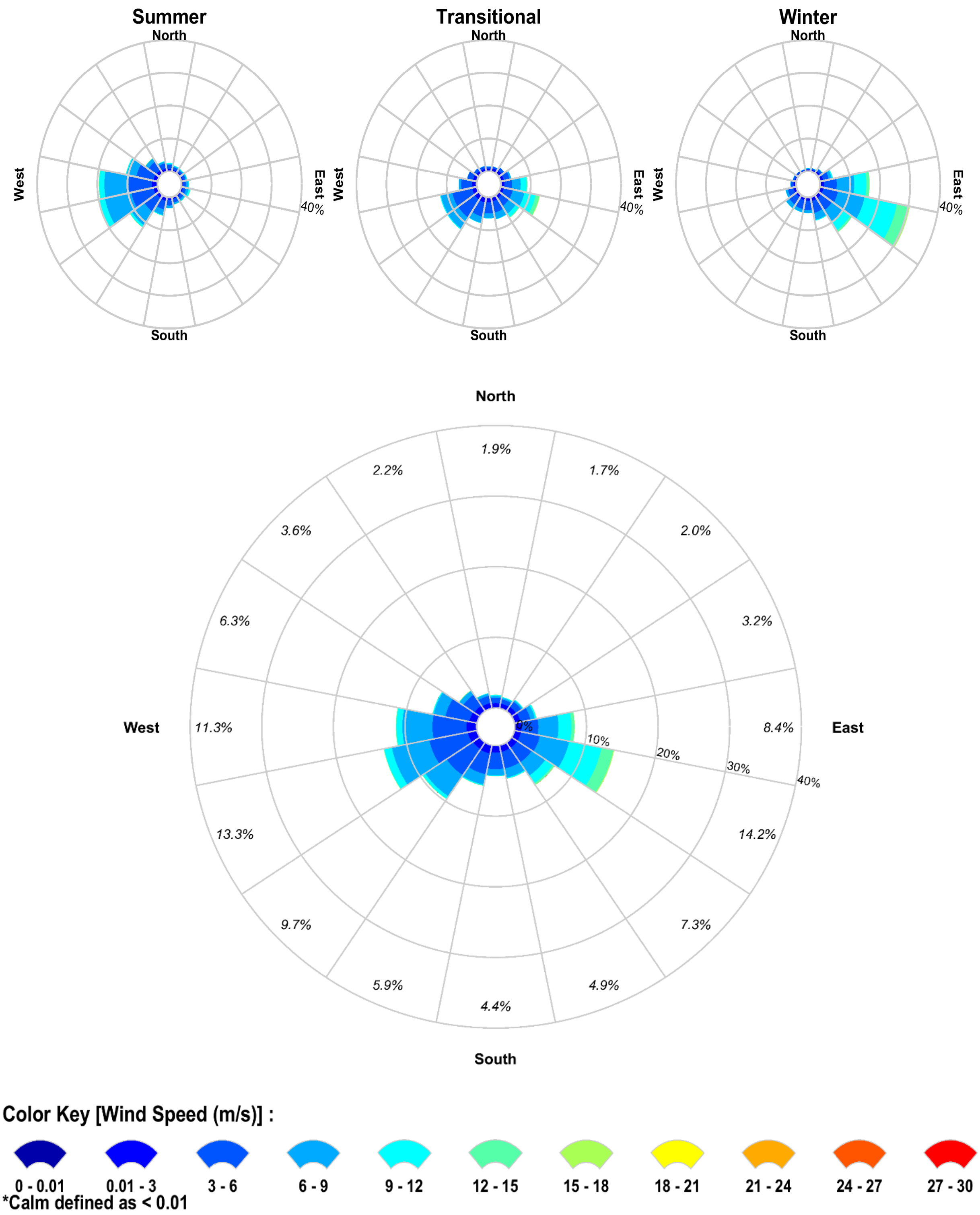


Figure 4.2 Seasonal (top) and total (bottom) wind distribution (2009-2018, inclusive) derived from the CFSR closest data point to the release locations. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

5 WATER TEMPERATURE AND SALINITY DATA

To accurately represent the water column temperature and salinity, monthly data was obtained from the World Ocean Atlas 2013 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus et al. 2013). The data is used to inform the weathering, movement and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

The World Ocean Atlas 2013 is a set of objectively analysed (1°grid) fields of in situ parameters (e.g. temperature, salinity and dissolved oxygen) at standard depth levels for annual, seasonal, and monthly periods for the global oceans. The dataset represents the largest collection of restriction-free ocean profile data available internationally. Locarnini et al. (2013) and Zweng et al. (2013) provide discussion regarding the temperature and salinity data as part of the World Ocean Atlas 2013 database.

The monthly mean sea surface temperature and salinity values in the 0-5 m depth layer derived from the World Ocean Atlas 2013 database are detailed in Table 5.1. Monthly temperatures were shown to range from 24.8°C (August) to 30.9°C (March). Salinity remained consistent throughout the year oscillating between 34.4 ppt and 35.2 ppt.

Figure 5.1 shows the temperature and salinity profiles at 5 m intervals through the water column near exploration well.

It is important to note that the WOA13 data was found to compare very well to measurements carried out at the Dorado development area.

Table 5.1 Monthly sea surface temperature and salinity per month in the 0-5 m depth layer for the closest data point to the release locations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	29.1	29.5	30.9	29.3	26.6	26.9	24.9	24.8	25.0	26.2	28.1	28.5
Salinity (ppt)	34.8	34.7	34.6	34.8	34.4	35.0	34.6	34.7	34.7	34.9	35.0	35.2

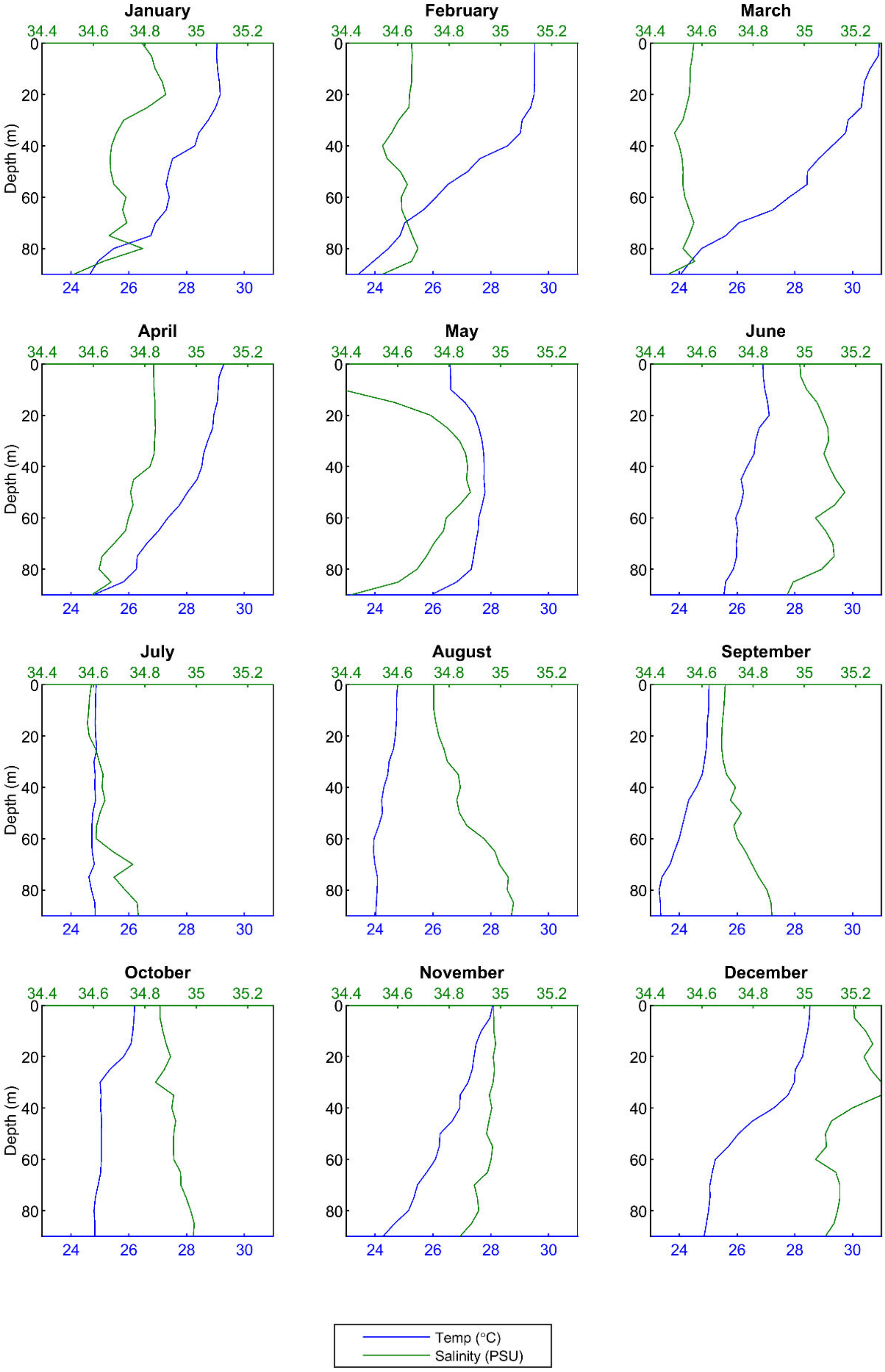


Figure 5.1 Monthly temperature and salinity profiles throughout the water column adjacent to the release locations.

6 SUBSEA PLUME MODEL – OILMAPDeep

In the event of an uncontrolled subsea blowout, the oil and associated gas released from the seabed is driven upward into the water column due to the momentum of the high-pressure release. It will initially behave like a jet, which dissipates in the water column over a short distance (<10 m). The escaping oil shears into small droplets due to turbulence generated by passing through the exit hole and subsequent turbulence generated in the plume jet. The size-distribution of the oil droplets will vary with the exit velocity and viscosity of the oil. Following this phase, the density and buoyancy difference of the gas, water and oil mixture relative to the surrounding waters, forces the plume upward. As the plume rises, the volume of gas will increase due to reduction of water pressure, with gas bubbles dividing into an increasing number of bubbles due to the shearing effect exerted by the water column.

In shallow water (<200 m) the rising plume of gas, oil and water will tend to reach the sea surface before deflecting as a radial, surface flow zone which will spread the oil droplets rapidly away from the centre of the plume (Spaulding et al., 2000). The velocity and oil concentrations in this surface flow zone decrease while the depth of the zone increases. Figure 6.1 conceptually illustrates the various stages of a subsea release of oil and gas.

OILMAPDeep model (Spaulding et al. 2015) was used to simulate the near-field behaviour of the gas-oil subsea release in two phases – the initial jet phase and the buoyant plume phase. The initial jet phase is predominately driven by the exit velocity. During this phase, the oil droplet-size-distribution is calculated for a range of classes or bins. Next, the plume model predicts the rise dynamics of the oil and gas plumes to calculate at which point gas lift will be lost (i.e. the trapping height).

Outputs from OILMAPDeep (plume trapping height, plume diameter and droplet size distribution) are used as input to the SIMAP model to simulate the rise and dispersion of the oil droplets from this point onwards.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al 2013, 2014; Belore 2014; Spaulding et al. 2015; Li et al. 2017).

The droplet size distribution was calculated using a modified form of the OILMAP Deep droplet size algorithm (Li et al., 2017). For releases in shallow water (<300 m) or with high gas to oil ratios, the modified algorithm improves the accuracy of the droplet prediction with a scaled pressure term that represents a balance between ambient hydrostatic pressure and the reservoir pressure. The typical effect of the inclusion of reservoir pressure in the droplet size algorithm is to increase predicted droplet sizes relative to those that would have been predicted if ambient hydrostatic pressure alone were used.

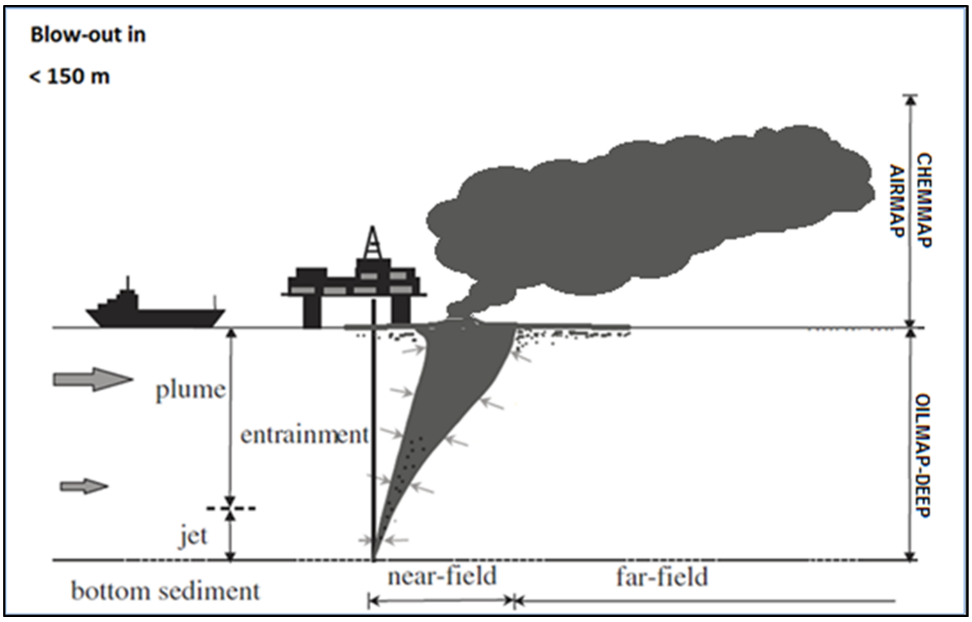


Figure 6.1 Example of a blowout plume illustrating the various stages of the plume in the water column (Source: Applied Science Associates, 2011).

Near-field modelling was carried out to better understand the plume dynamics due to the amalgamation of crude and gas at the seabed for Scenario 1 uncontrolled subsea blowout of crude. Near-field plume modelling was not necessary for the subsea pipeline release scenario (scenario 3) due to the smaller volume, short-term nature of the release and lower pressures.

Table 6.1 presents the input parameters for the subsea plume model and key results related to the near-field plume dynamics. Note a depleting release rate was used as input into the model, starting with 181,712 bbl/day on day 1 and decreasing to 105,923 bbl/day at week 14.

The near-field modelling showed that in the event of a blowout from a well, the amalgamated gas and crude would propel rapidly upward from the seabed and rupture the sea surface. Due to the velocity of the plume, the model predicted droplet sizes would be relatively small, ranging from 146 µm to 631 µm at day 1 to 182 µm to 787 µm by week 14. There were 10 oil droplet-size classes defined, which were evenly distributed (10%), to simulate the rise and dispersion of the oil droplets more accurately.

Table 6.1 Physical characteristics of the subsea releases and key results for the near-field model OILMAP-DEEP.

Input Variable	Value
Scenario	Scenario 1
Well name	WHP
Water depth (m)	90
Tubing diameter (inch)	12.25
Oil rate (stb/day)	181,712 (day 1) depleting to 105,923 (week 14)
Gas rate (MMscf/day)	594 (day 1) depleting to 285 (week 14)
Gas to oil ratio (scf/stb)	3,269 (day 1) depleting to 2,691 (week 14)
Flowing bottom hole pressure (psia)	4,1429 (day 1) depleting to 2,220 (week 14)
Key findings	
Plume execution depth (m BMSL)	Breach the surface
Droplet sizes (µm)	146 to 631 (day 1) to 182 to 787 (week 14)

7 OIL SPILL MODEL - SIMAP

The spill modelling was carried out using a purpose-developed oil spill trajectory and fates model, SIMAP (Spill Impact Mapping and Assessment Program). This model is designed to simulate the transport and weathering processes that affect the outcomes of hydrocarbon spills to the sea, accounting for the specific oil type, spill scenario, and prevailing wind and current patterns.

SIMAP is the evolution of the United States Environmental Protection Agency (US EPA) Natural Resource Damage Assessment model (French & Rines, 1997; French, 1998; French *et al.*, 1999) and is designed to simulate the fate and effects of spilled oils and fuels for both the surface slick and the three-dimensional plume that is generated in the water column. SIMAP includes algorithms to account for both physical transport and weathering processes. The latter are important for accounting for the partitioning of the spilled mass over time between the water surface (surface slick), water column (entrained oil and dissolved compounds), atmosphere (evaporated compounds) and land (stranded oil). The model also accounts for the interaction between weathering and transport processes.

The physical algorithms calculate transport and spreading by physical forces, including surface tension, gravity and wind and current forces for both surface slicks and oil within the water column. The fates algorithms calculate all the weathering processes known to be important for oil spilled to marine waters. These include droplet and slick formation, entrainment by wave action, emulsification, dissolution of soluble components, sedimentation, evaporation, bacterial and photo-chemical decay and shoreline interactions. These algorithms account for the specific oil type being considered.

Entrainment is the physical process where globules of oil are transported from the sea surface into the water column by wind and wave-induced turbulence or be generated subsea by a pressurised discharge at depth. It has been observed that entrained oil is broken into droplets of varying sizes. Small droplets spread and diffuse into the water column, while larger ones rise rapidly back to the surface (Delvigne & Sweeney, 1988; Delvigne, 1991).

Dissolution is the process by which soluble hydrocarbons enter the water from a surface slick or from entrained droplets. The lower molecular weight hydrocarbons tend to be both more volatile and more soluble than those of higher molecular weight.

The formation of water-in-oil emulsions, or mousse, which is termed 'emulsification', depends on oil composition and sea state. Emulsified oil can contain as much as 80% water in the form of micrometre-sized droplets dispersed within a continuous phase of oil (Wheeler, 1978; Daling & Brandvik, 1991; Bobra, 1991; Daling et al., 1997; Fingas, 1995; Fingas, 1997).

Evaporation can result in the transfer of large proportions of spilled oil from the sea surface to the atmosphere, depending on the type of oil (Gundlach & Boehm, 1981).

Evaporation rates vary over space and time dependent on the prevailing sea temperatures, wind and current speeds, the surface area of the slick and entrained droplets that are exposed to the atmosphere as well as the state of weathering of the oil. Evaporation rates will decrease over time, depending on the calculated rate of loss of the more volatile compounds. By this process, the model can differentiate between the fates of different oil types.

Decay (degradation) of hydrocarbons may occur as the result of photolysis, which is a chemical process energised by ultraviolet light form the sun, and by biological breakdown, termed biodegradation. Many types of marine organisms ingest, metabolise and utilise oil as a carbon source, producing carbon dioxide and water as by-products. The biodegradable portion of various crude oils range from 11 to 90% (NRC, 1985, 1989).

Entrainment, dissolution and emulsification rates are correlated to wave energy, which is accounted for by estimating wave heights from the sustained wind speed, direction and fetch (i.e. distance downwind from land barriers) at different locations in the domain. Dissolution rates are dependent upon the proportion of soluble, short-chained hydrocarbon compounds, and the surface area at the oil/water interface of slicks. Dissolution rates are also strongly affected by the level of turbulence. For example, dissolution rates will be relatively high at the site of the release for a deep-sea discharge at high pressure.

In contrast, the release of hydrocarbons onto the water surface will not generate high concentrations of soluble compounds. However, subsequent exposure of the surface slick to breaking waves will enhance entrainment of oil into the upper water column as oil droplets, which will enhance dissolution of the soluble components. Because the compounds that have high solubility also have high volatility, the processes of evaporation and dissolution will be in dynamic competition with the balance dictated by the nature of the release and the weather conditions that affect the oil after release. The SIMAP weathering algorithms include terms to represent these dynamic processes. Technical descriptions of the algorithms used in SIMAP and validations against real spill events are provided in French (1998), French et al. (1999) and French-McCay (2004).

Input specifications for oil types include the density, viscosity, pour-point, distillation curve (volume of oil distilled off versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges. The model calculates a distribution of the oil by mass into the following components:

- Surface-bound or floating oil.
- Entrained oil (non-dissolved oil droplets that are physically entrained by wave action).
- Dissolved hydrocarbons (principally the aromatic and short-chained aliphatic compounds).
- Evaporated hydrocarbons.
- Sedimented hydrocarbons.
- Decayed hydrocarbons.

7.1 Hydrocarbon Properties

Two different hydrocarbons were modelled as part of the study: Caley crude and Heavy Fuel Oil (HFO). Table 7.1 and Table 7.2 outlines the physical characteristics and boiling point ranges for the two oil types, respectively, which will determine the way it behaves in the marine environment.

Table 7.1 Physical properties of oil types used in this study.

Characteristic	Caley Crude	Heavy Fuel Oil
Density (kg/m^3)	773 (at 15 °C)	975 (at 25ºC)
API	51.4	12.3
Dynamic viscosity (cP)	1.45 (at 20ºC)	3,180 (at 25ºC)
Wax content (%)	9.2	2
Pour point (°C)	-15	7
Hydrocarbon property category	Group II	Group 4
Hydrocarbon property classification	Light persistent	Persistent

Table 7.2 Boiling point ranges of the oil types used in this study.

Characteristics	Non-Persistent			Persistent
	Volatile (%)	*Semi-volatile (%)*	*Low-volatility (%)*	*Residual (%)*
Boiling point (°C)	*<180*	*180-265*	*265-380*	*>380*
Caley crude	48	19	18	15
Heavy Fuel Oil	1	5	11	83

The boiling points are dictated by the length of the carbon chains, with the longer and more complex compounds having a higher boiling point, and therefore lower volatility and evaporation rate.

Atmospheric weathering will commence when oil droplets float to the water surface. Typical evaporation times once the hydrocarbons reach the surface and is exposed to the atmosphere are around:

- Up to 12 hours for the C4 to C10 compounds (or less than 180 °C BP);
- Up to 24 hours for the C11 to C15 compounds (180 – 265 °C BP);
- Several days for the C16 to C20 compounds (265 – 380 °C BP); and
- N/A for the residual compounds (BP>380 °C), which will resist evaporation, persist in the marine environment for longer periods, and be subject to relatively slow degradation.

7.1.1.1 Caley Crude

The physical-chemical properties of Caley crude were based on a detailed assay provided by Santos. The assay is considered to be representative of the reservoir characteristics of the Dorado field and the composition used to determine the weathering characteristics.

The crude is characterised by a low viscosity and is considered a Group II light persistent oil, as per the grouping classification presented by AMSA (2015). If spilt on the sea surface, the crude would rapidly spread and thin out resulting in a large surface area of hydrocarbon available for evaporation. The volatile component of Group I oils tend to dissipate through evaporation within a few hours (ITOPF 2014). Based upon the Caley crude assay (boiling point range, Table 7.2), up to 48% of the hydrocarbon would evaporate over the first few hours or day, with up to 67% evaporated after a few days when on the sea surface. Fifteen percent of the crude is considered persistent, which would eventually breakdown due to the decay. When on the surface Caley crude may also become entrained into the water column in the presence of moderate winds (above 10 knots) and in turn breaking waves, however, it would re-surface under calm conditions (less than 10 knots).

7.1.1.2 Heavy Fuel Oil

HFO is characterised by a very high density at 974.9 (API Gravity of 12.3) and a high dynamic viscosity (3,180 cP (@ 25ºC). It is comprised of a high percentage of persistent components (82.8%), which will not evaporate. When spilt at sea the HFO will initially remain as a liquid as sea surface temperatures are above its pour point during all seasons. The volatile components (1%) are immediately lost via evaporation and the physical properties will change quickly as the lighter more fluid components evaporate and disperse by the action of wind and waves. The residual component (approximately 83%) is expected to become semi-solid to solid at ambient temperatures and is susceptible to decay overtime. Previous weathering tests with HFO used as bunker fuels have shown that both the pour point and the viscosity of the oil increased with time (by an average of two orders of magnitude within 96 hours of weathering). Once the pour point of oil exceeded the seawater temperature (within 9-12 hours during all seasons) the oil weathered to a point where mostly solid non-spreading oil remained (up to 70% of bunker fuel remained as a solid residue even after the most extreme weathering tests).

Laboratory tests with Bunker C Crude oil (Fingas et al. 2002, Fingas and Fieldhouse 2004) which has similar physical properties to the HFO modelled in this study have shown that HFO does not form stable emulsions. Rather, when HFO is spilt at sea it takes up water very rapidly over a short energy range and the stability of the water-oil mixture remains the same in that it does not stabilise with increasing energy. This behaviour is consistent with entrained water in oil, where spilt oil will first appear as a black viscous liquid with large water droplets and within one week will become separated into oil and water as water energies abate.

The toxic potential of weathered HFO is low in comparison to other crudes, MDO and condensates as weathered oil is insoluble and the bioavailable portion of the oil is soon lost through evaporation. Solid residues can persist in the marine environment for extended periods and its longevity is dependent on its unique physio-chemical properties. The heaviest fractions (>C20) often break into discrete patches and may float or sink depending on density relationships and become incorporated into soils or sediments (American Petroleum Institute 2012). Selective biodegradation can also deplete hydrocarbons on sediments and on the sea surface overtime (Lee et al. 2003). Direct consumption of the residual tar patties or contaminated sediment poses the greatest risk to macrofauna and would present a greater threat for shallow coastal embayment's with concentrated populations and coastal vegetation.

7.2 Floating Oil, Shoreline and In-Water Thresholds

The thresholds described below for surface, shoreline, and in-water (entrained and dissolved) oil have been adopted according to low, moderate and high thresholds, based on increasing concentrations:

Low thresholds are unlikely to affect species but would be visible and detectable by instrumentation and may trigger socioeconomic impacts, such as temporary closures of areas such as fishing grounds as a precautionary measure.

Moderate thresholds represent moderate concentrations of oil exposure/accumulation which are anticipated to result in behavioural changes and sub-lethal effects to biota (effects that may result in changes in reproduction or growth) and are unlikely to result in lethal effects (representing potential death of individuals) although lethality may occur if ingestion occurs.

High thresholds represent high concentrations of oil that are expected to result in sub-lethal and lethal effects to at least some species (representing potential death of individuals).

Reporting threshold values (based on the scientific literature) represent potential effects ranging from possible social and economic effects, degradation of water quality as well as possible effects on the behaviour, survival and recruitment success on biota. The changes in the state of the oil over time, in addition to a wide range of sensitivities and in turn potential effects on marine life, does not make it possible to strictly assign single specific effect thresholds. Instead, the analysis presented herein is presented for ranges of low, moderate and high threshold levels, with separate analysis for oil floating at the sea surface, stranded on shoreline, dissolved in the water column and suspended in the water column.

Moderate levels were defined based on available evidence that indicated the potential for low-level sub-lethal effects on some biota, or else evidence of reduced survival rates of sensitive species. This level can be considered a lower ecological threshold. The higher threshold was defined on the assumption that there would be more potential for reduced survivorship of less sensitive species.

It is important to note that the thresholds used herein are consistent with NOPSEMA spill modelling bulletin (NOPSEMA 2019).

7.2.1 Sea-surface Exposure Thresholds

As a conservative approach, the same reporting thresholds for fresh and weathered oil exposure on the sea surface were applied in this study, which were 1 g/m^2 (low), 10 g/m^2 (moderate) and above 50 g/m^2 (high; Table 7.3). As the effects of fresh oil are better understood than for weathered oil, appropriate effects thresholds for fresh oil are more readily identifiable. Exposure pathways of species to weathered oil (i.e. smothering and potential ingestion for some species) are less likely to result in adverse effects.

Table 7.3 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA 2019).

Exposure level	Floating oil threshold (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50	Approximates surface oil slick and informs response planning

The lowest threshold to assess the potential for sea surface exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) (see Table 7.4). This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.4 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of sea surface exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009).

Scholten et al. (1996) and Koops et al. (2004) indicated that oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study, the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019) and because it is an appropriate threshold for spill response planning, as it is more suitable for targeted spill response strategies such as dispersant application and containment and recovery.

Figure 7.1 shows examples of the differences between oil colour and corresponding thickness on the sea surface. Hydrocarbons in the marine environment may appear differently due the ambient environmental conditions (wind and wave action).

Table 7.4 The Bonn Agreement Oil Appearance Code.

Code	Description/Appearance	Layer Thickness Interval (g/m^2 or μm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

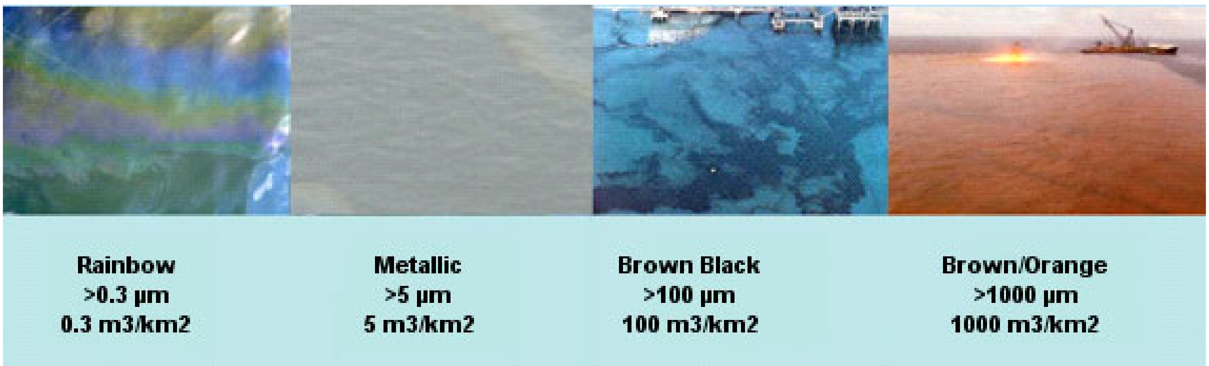


Figure 7.1 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions.org, 2015).

7.2.2 Shoreline Accumulation Thresholds

The thresholds for accumulation of oil after it reaches shoreline were 10 g/m^2 (low), 100 g/m^2 (moderate) and above 1000 g/m^2 (high). Table 7.5 shows the number of weathered oil patches per square meter on the shoreline for corresponding thresholds, if each patch was a sphere that was 1 inch in diameter.

The lower threshold (10 g/m^2) was applied as the reporting limit for oil on shore. This threshold may trigger socio-economic impact, such as triggering temporary closures of beaches to recreation or fishing, or closure of commercial fisheries and might trigger attempts for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2, equating to approximately two teaspoons of oil per square meter of shoreline, as a low impact threshold when assessing the potential for shoreline accumulation.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline. The appearance is described as a thin oil coat.

The higher threshold of 1,000 g/m^2, and above, was adopted to inform locations that might receive oil accumulation levels that could have a higher potential for ecological effect. Observations by Lin & Mendelssohn (1996), demonstrated that loadings of more than 1,000 g/m^2 of oil during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (Grant et al., 1993; Suprayogi & Murray, 1999). This concentration equates to approximately 1 litre or 4 ¼ cups of fresh oil per square meter of shoreline accumulation. The appearance is described as an oil cover.

Table 7.5 Thresholds for oil accumulation on shorelines.

Exposure level	Shoreline oil threshold (g/m^2)	Description
Low	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 Dissolved and Entrained Hydrocarbon Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath et al., 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50%

population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.6) were applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), in alignment with the commonly used exposure values for oil spill modelling presented in NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10-ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC (2000) water quality guidelines. Due to the requirement for relatively long exposure times (≥ 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

Exposure to entrained oil at 10 ppb is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.6), to cover the range of thresholds outlined in the ANZECC/ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.6 Dissolved and entrained hydrocarbon instantaneous exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

	Exposure level	In-water threshold (ppb)	Description
Disolved hydrocarbons	Low	10	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers
	Moderate	50	Approximates potential toxic effects, particularly sublethal effects to sensitive species
	High	400	Approximates toxic effects including lethal effects to sensitive species
Entrained hydrocarbons	Low	10	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers
	Moderate	100	As appropriate given oil characteristics for informing risk evaluation

7.3 Sensitive Receptors

A range of environmentally sensitive receptors and biological receptors and shorelines were assessed for sea surface exposure, shoreline accumulation and water column exposure as part of the study (see Figure 7.2 to Figure 7.13). Receptor categories (see Table 7.7) include sections of shorelines, which are defined by local government areas (LGAs) and offshore islands, along with submerged reefs, shoals and banks (RSB). All other sensitive receptors were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor and have been tabulated. Note, AMPs are assumed to extend from sea surface to seabed. While the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface and therefore, assumed not be impacted by floating oil if they occur >0-10m water depth.

Note that the Australian Exclusive Economic Zone (EEZ) and the Northwest Shelf Integrated Marine and Coastal Regionalisation of Australia (IMCRA) were excluded from tabulated results as the release locations reside within the receptor boundaries and therefore will always record a 100% probability of exposure.

Note that Indonesian shorelines presented in Figure 7.10 were grouped with the highest probability and lowest minimum time presented as ‘Indonesia’ in tabulated results.

Table 7.7 Summary of receptors used to assess surface, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Sea Surface	Shoreline
Australian Marine Park	AMP	✓	✓	×
Marine Nature Reserve	MNR	✓	✓	×
National/Marine Park	NP & MP	✓	✓	×
Nature Reserve	NR	✓	✓	×
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Key Ecological Feature	KEF	✓	×	×
Ramsar	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

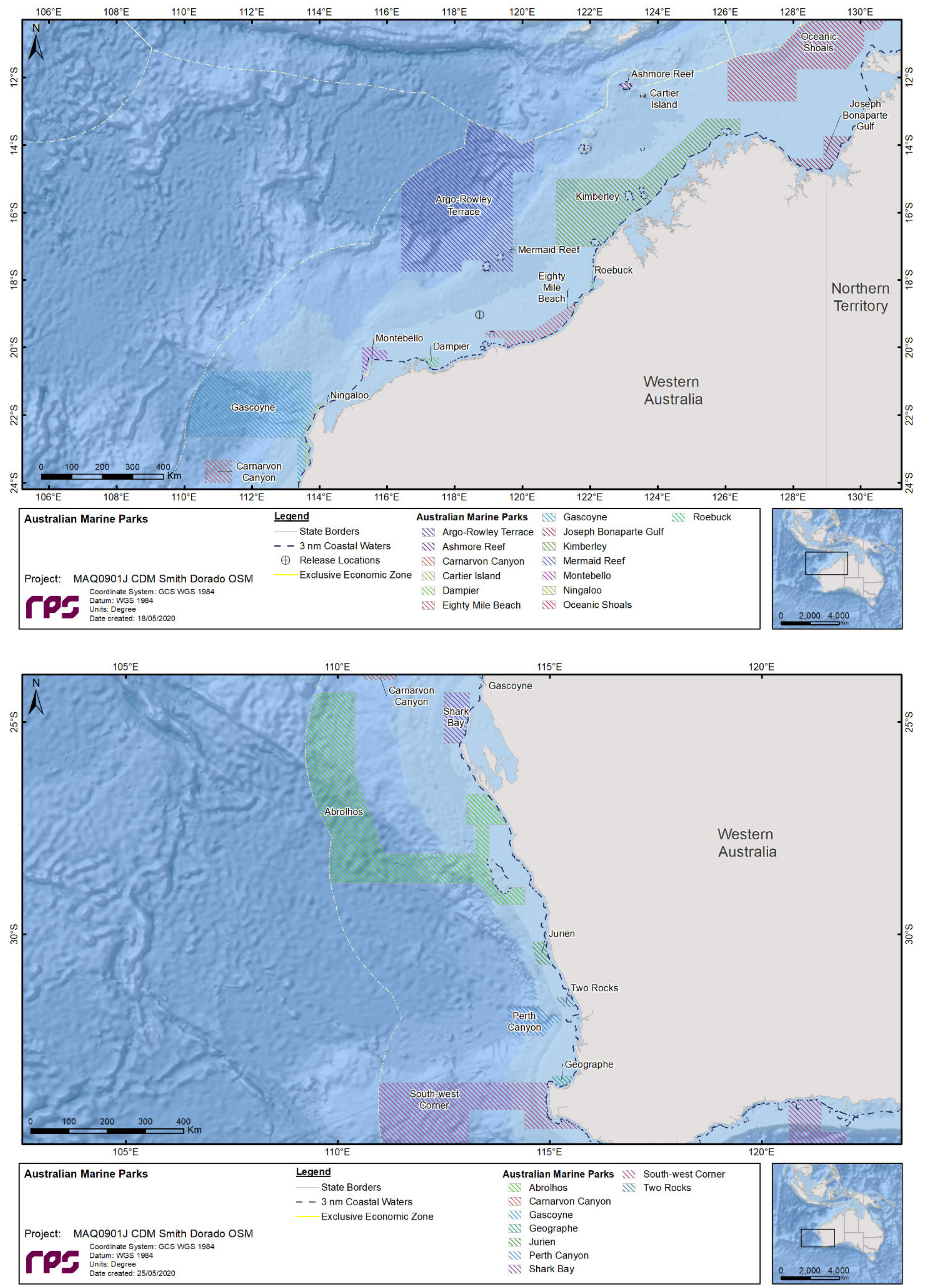


Figure 7.2 Receptor maps for Australian Marine Parks (AMP).

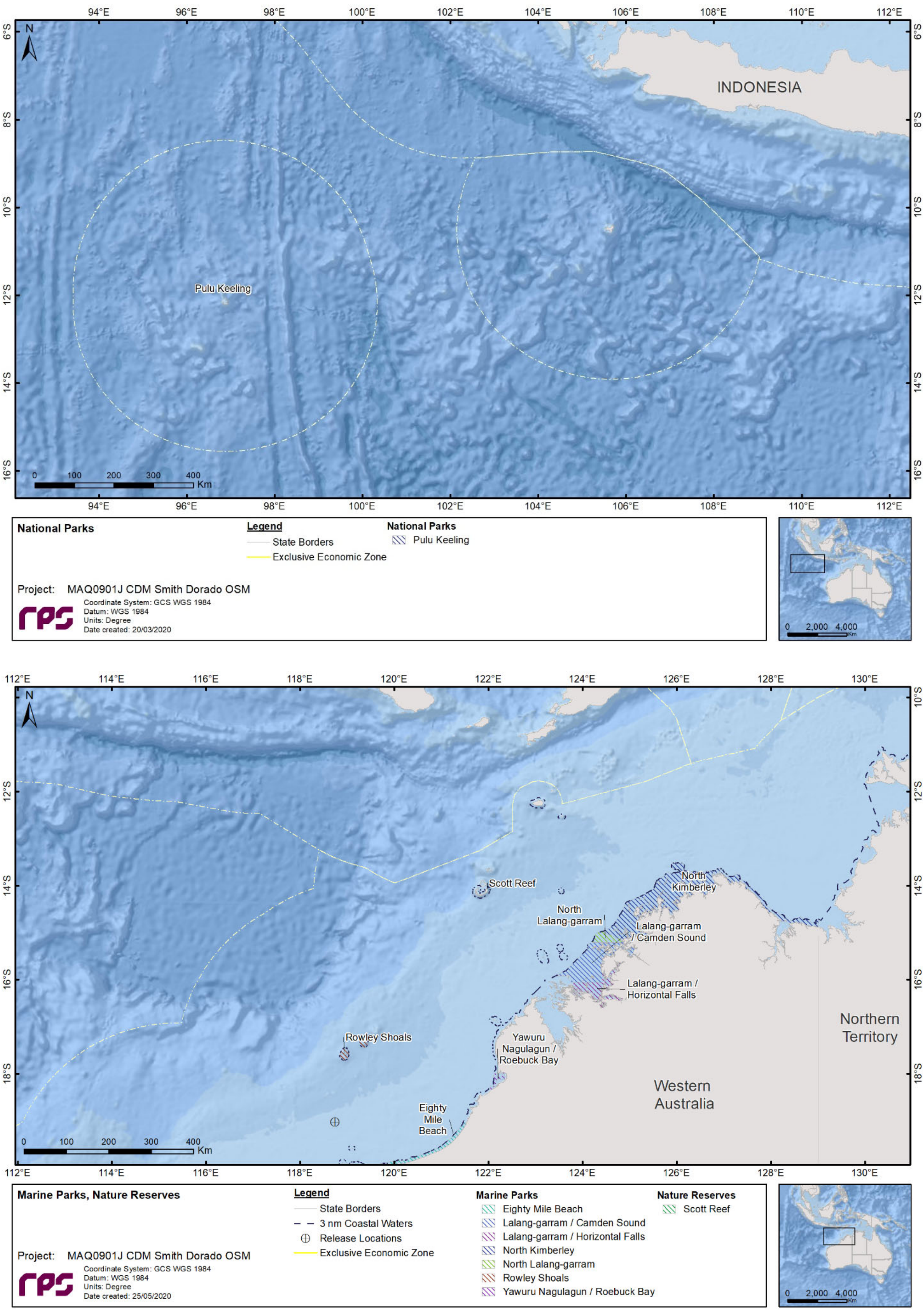


Figure 7.3 Receptor maps for Marine Parks (MP), National Parks (NP) and Nature Reserves (NR).

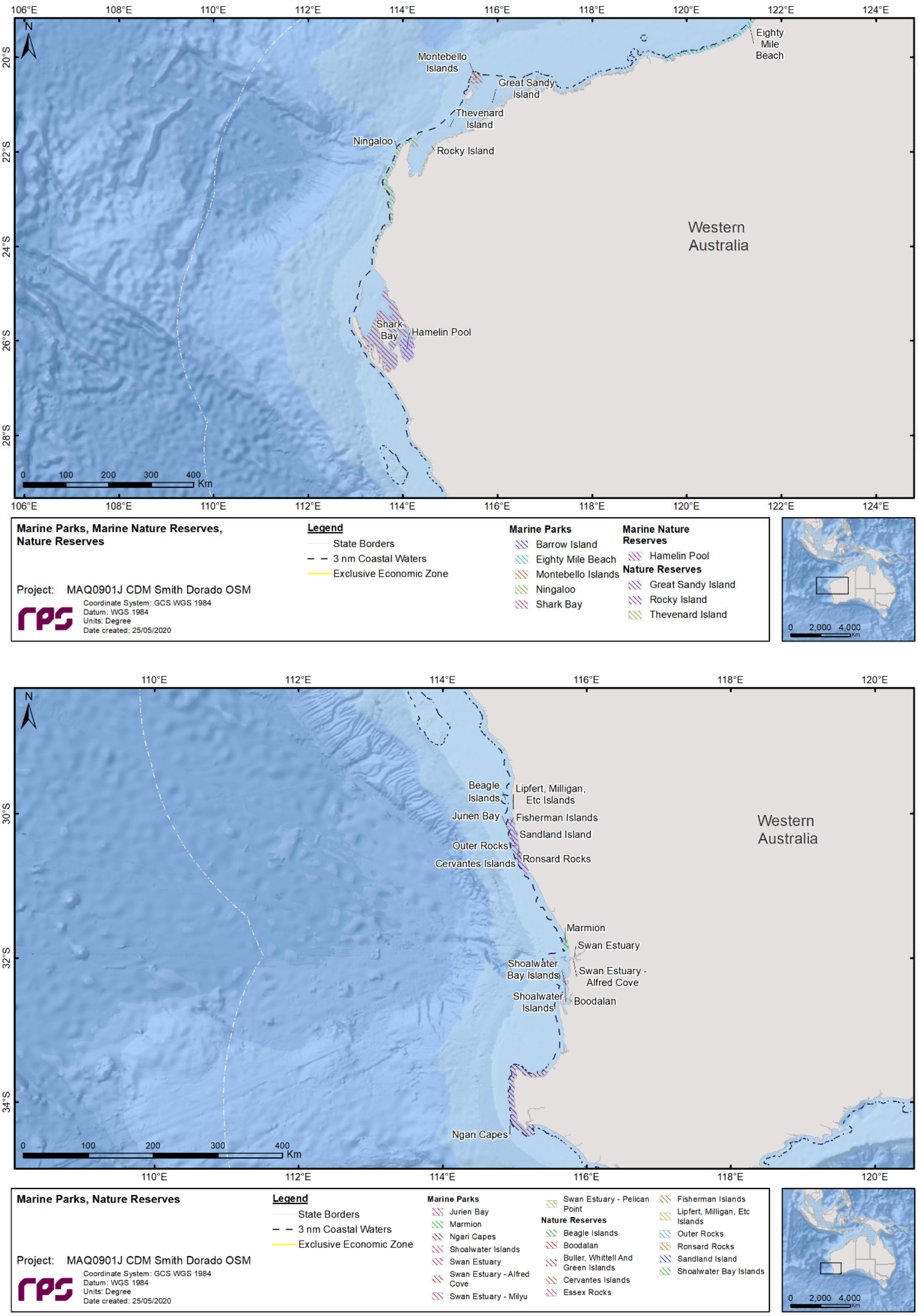


Figure 7.4 Receptor maps for Marine Parks (MP), Marine Nature Reserves (MNR) and Nature Reserves (NR).

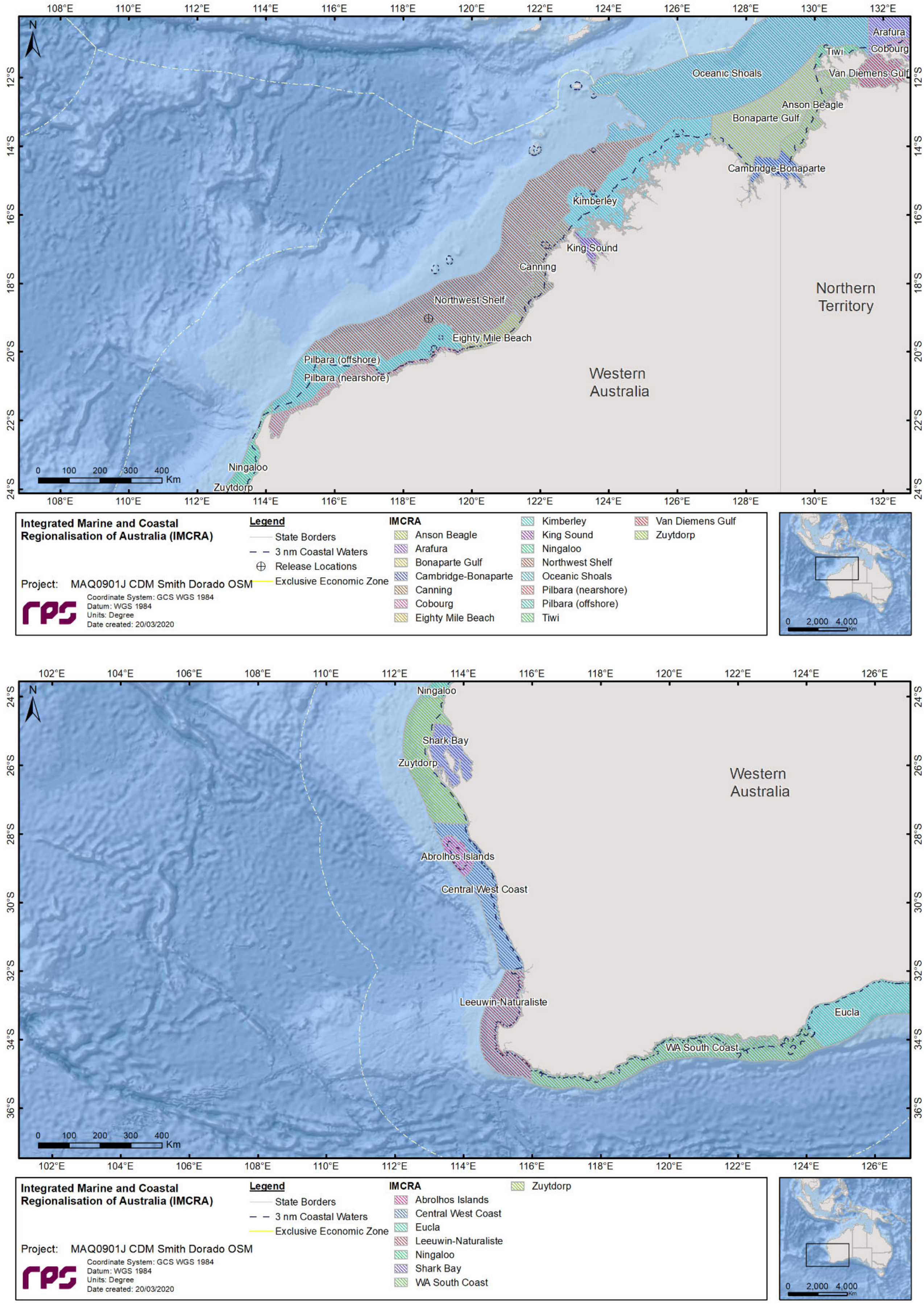


Figure 7.5 Receptor maps for Integrated Marine and Coastal Regionalisation of Australia (IMCRA).

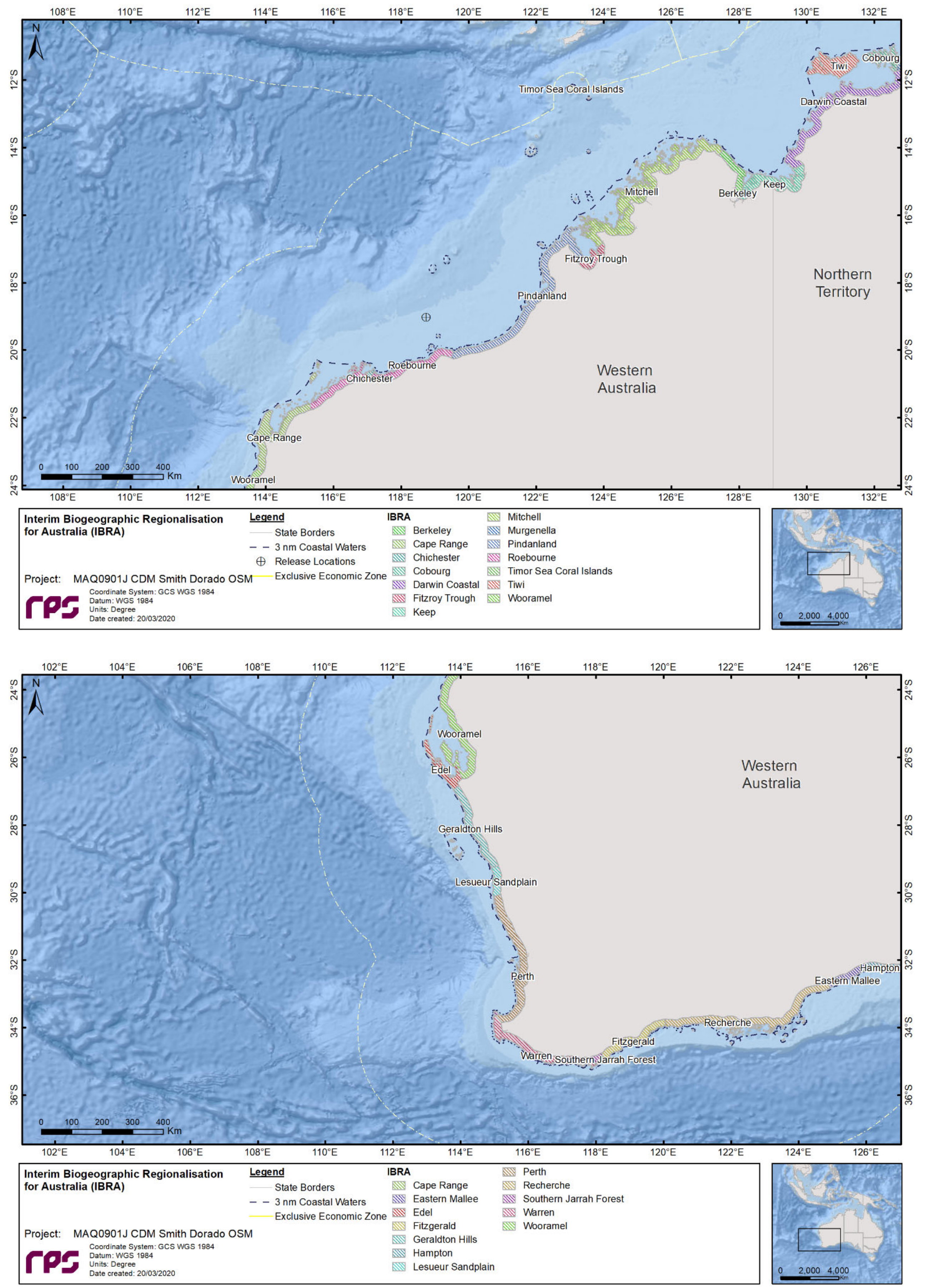


Figure 7.6 Receptor maps for Interim Biogeographic Regionalisation for Australia (IBRA).

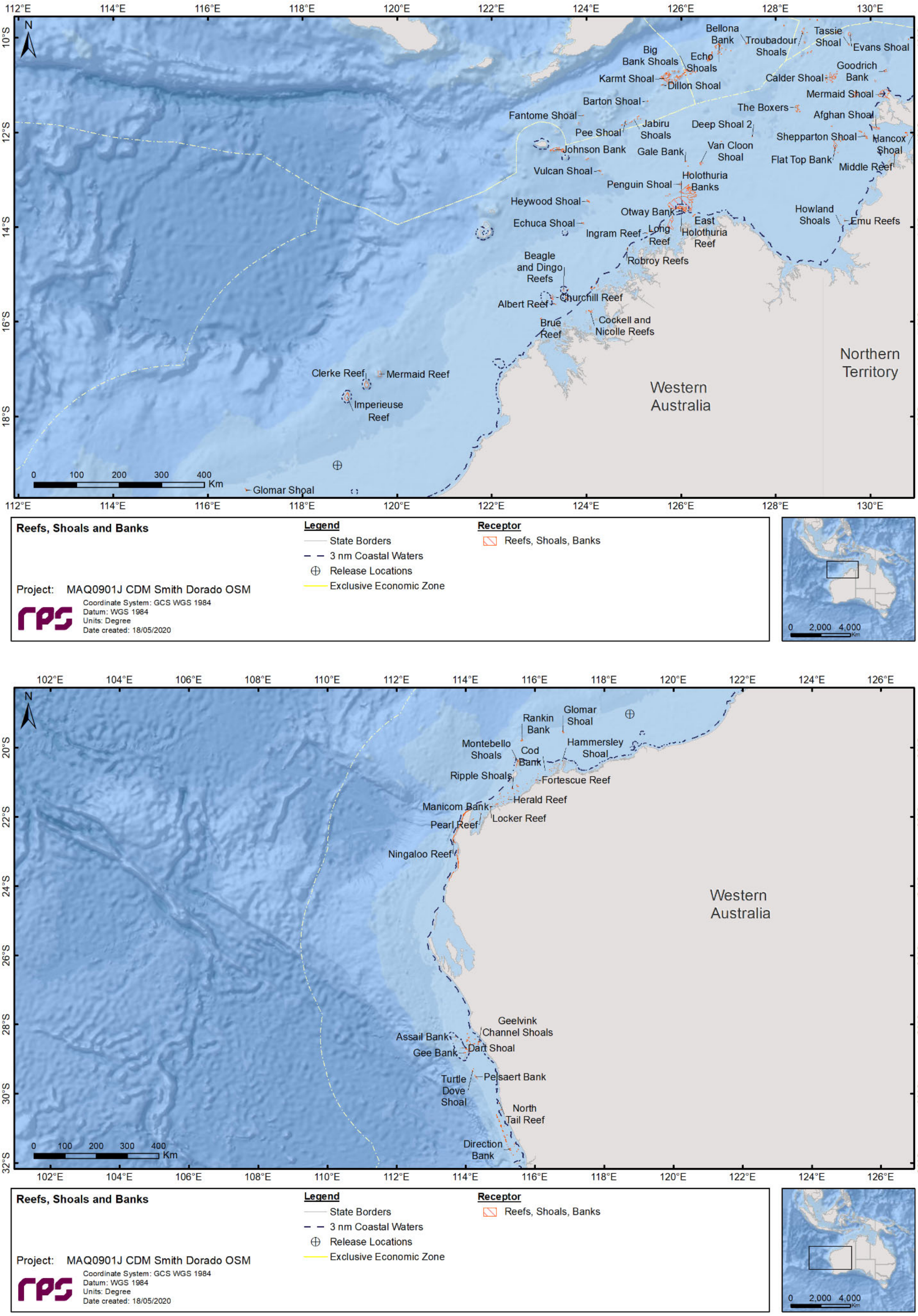


Figure 7.7 Receptor maps for Reefs, Shoals and Banks (RSB).

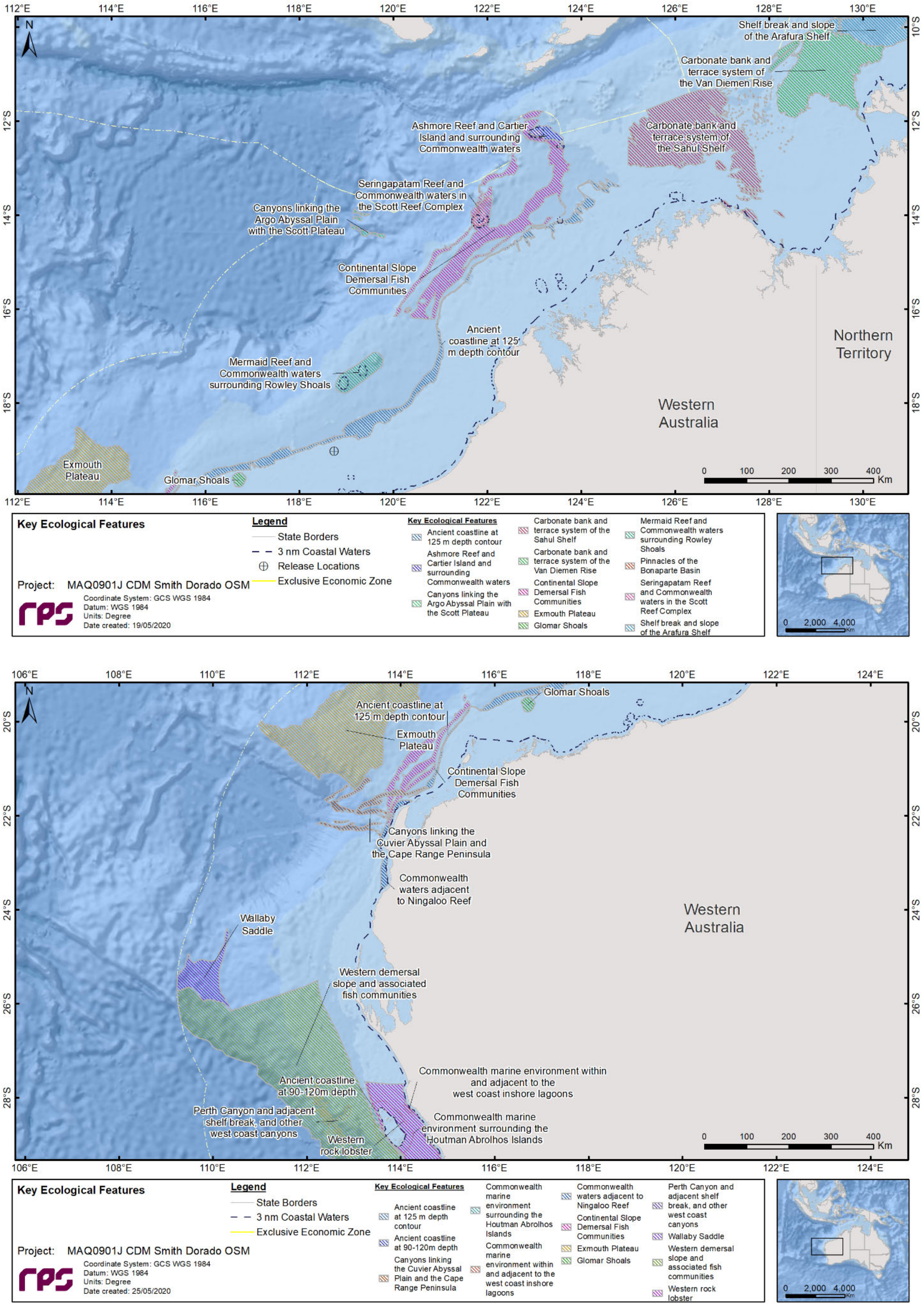


Figure 7.8 Receptor maps for Key Ecological Features (KEF).

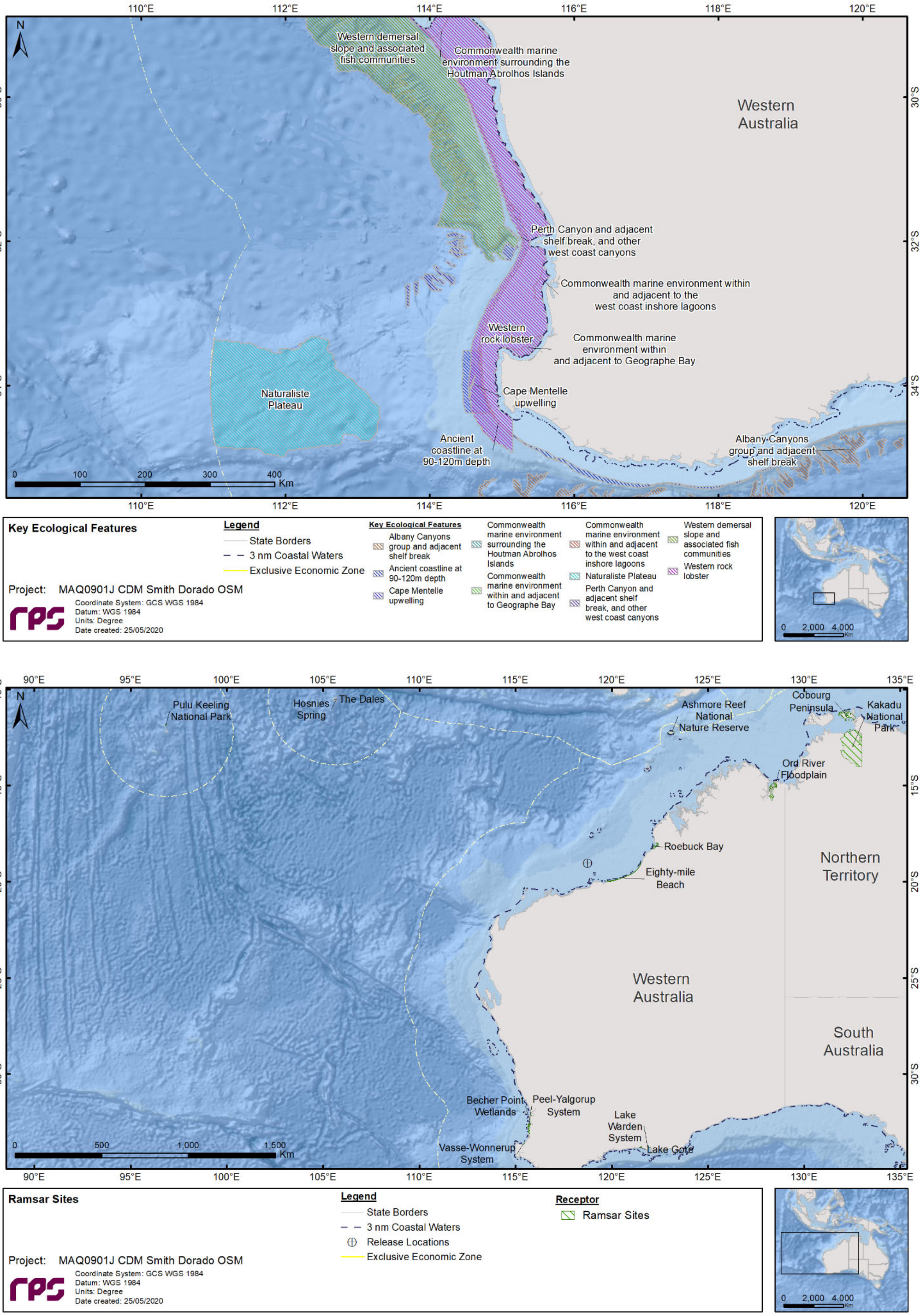
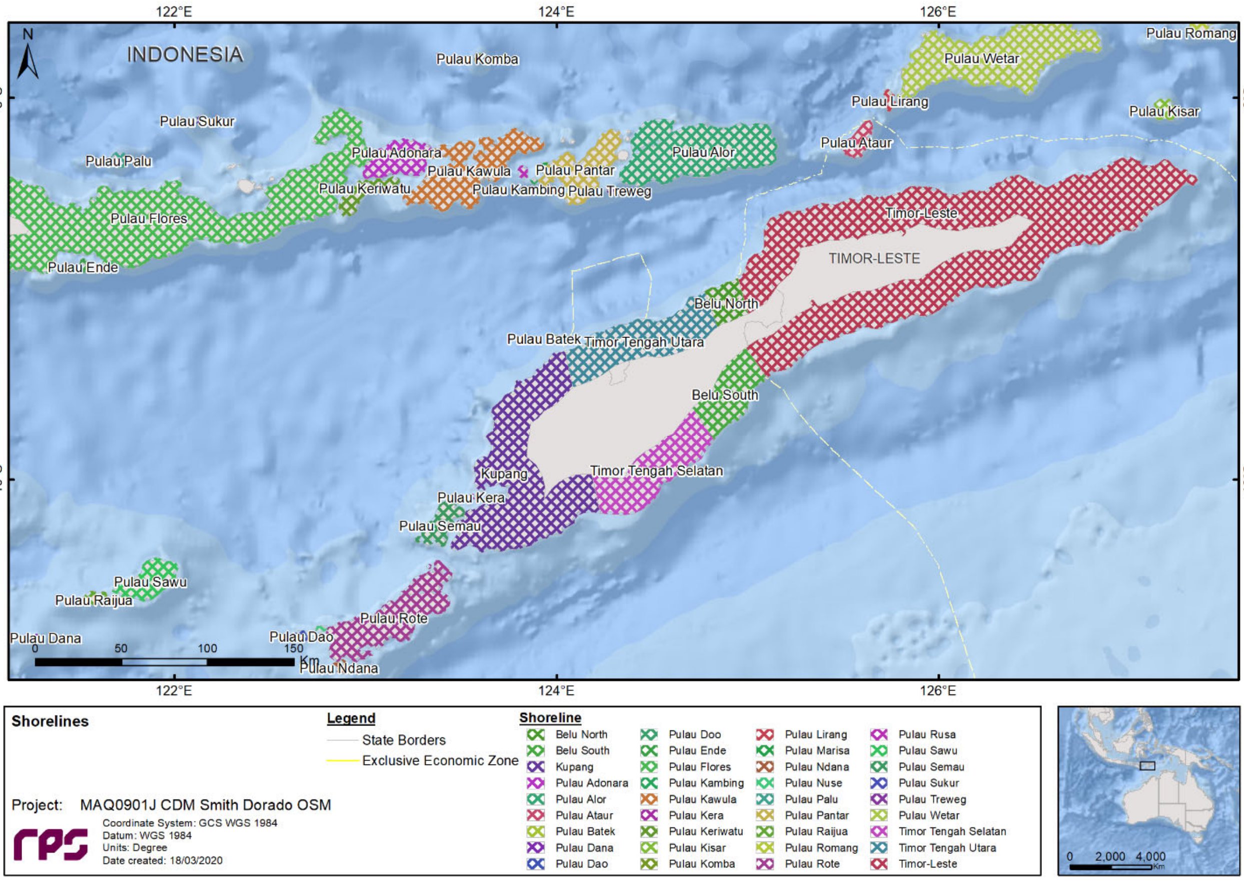


Figure 7.9 Receptor maps for Key Ecological Features (KEF; above) and Ramsar sites (below).



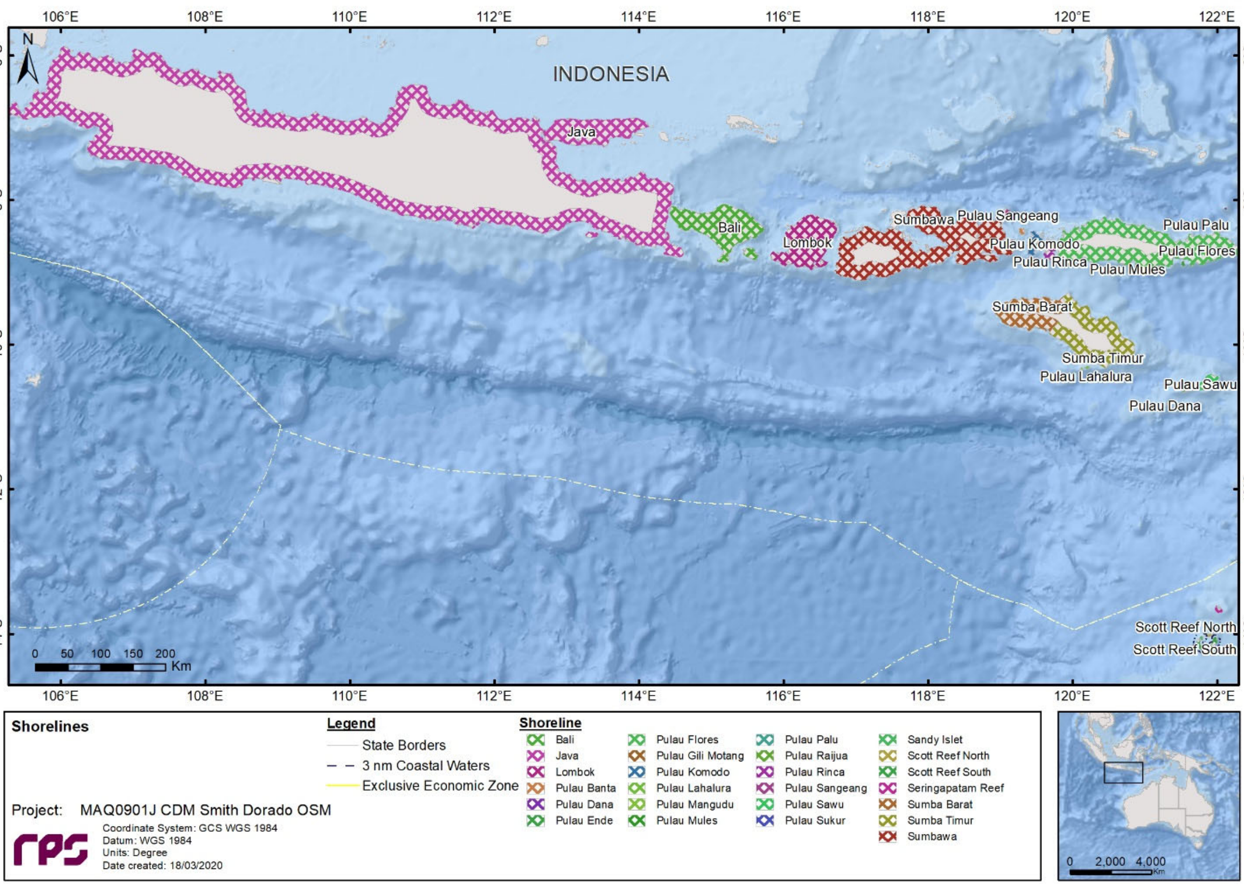
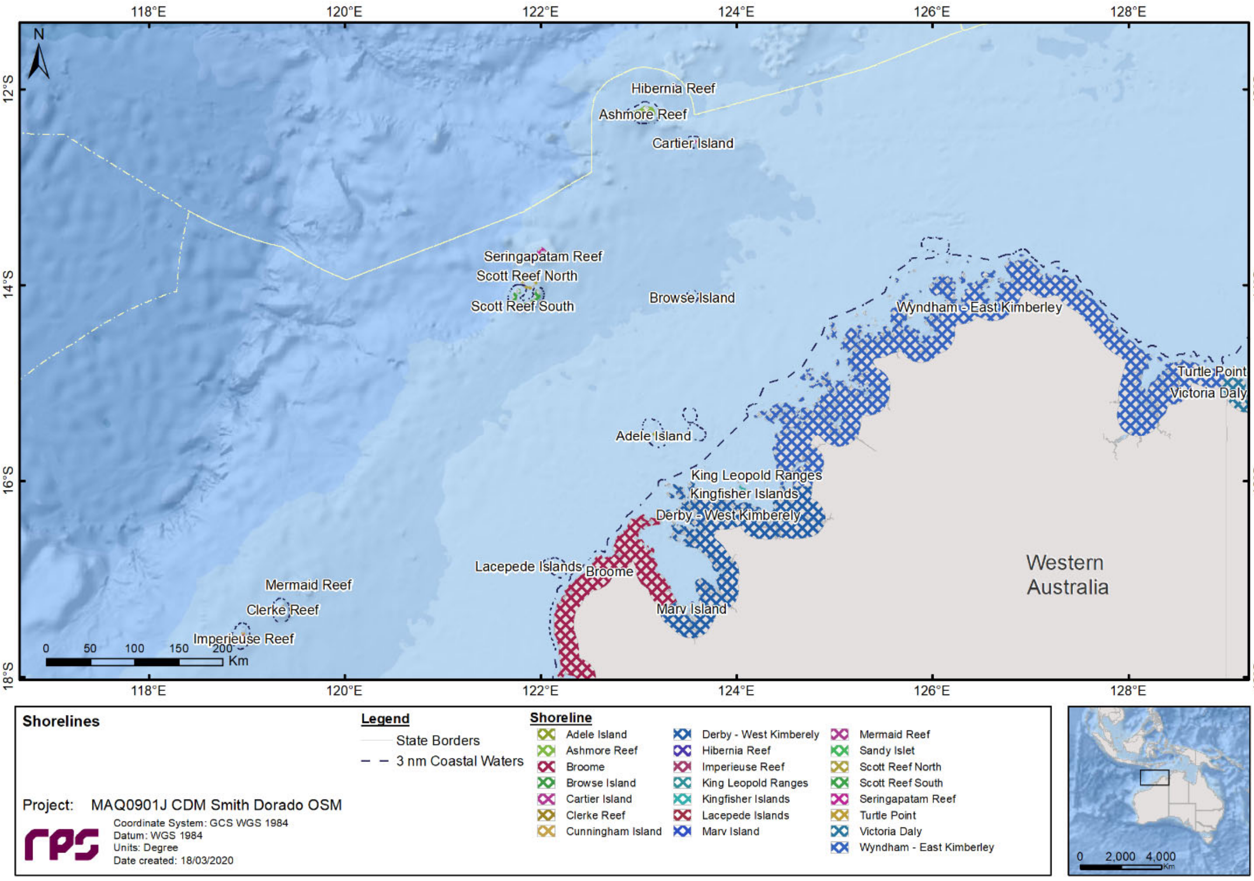


Figure 7.10 Receptor maps for Shorelines (Indonesia and Timor Leste).



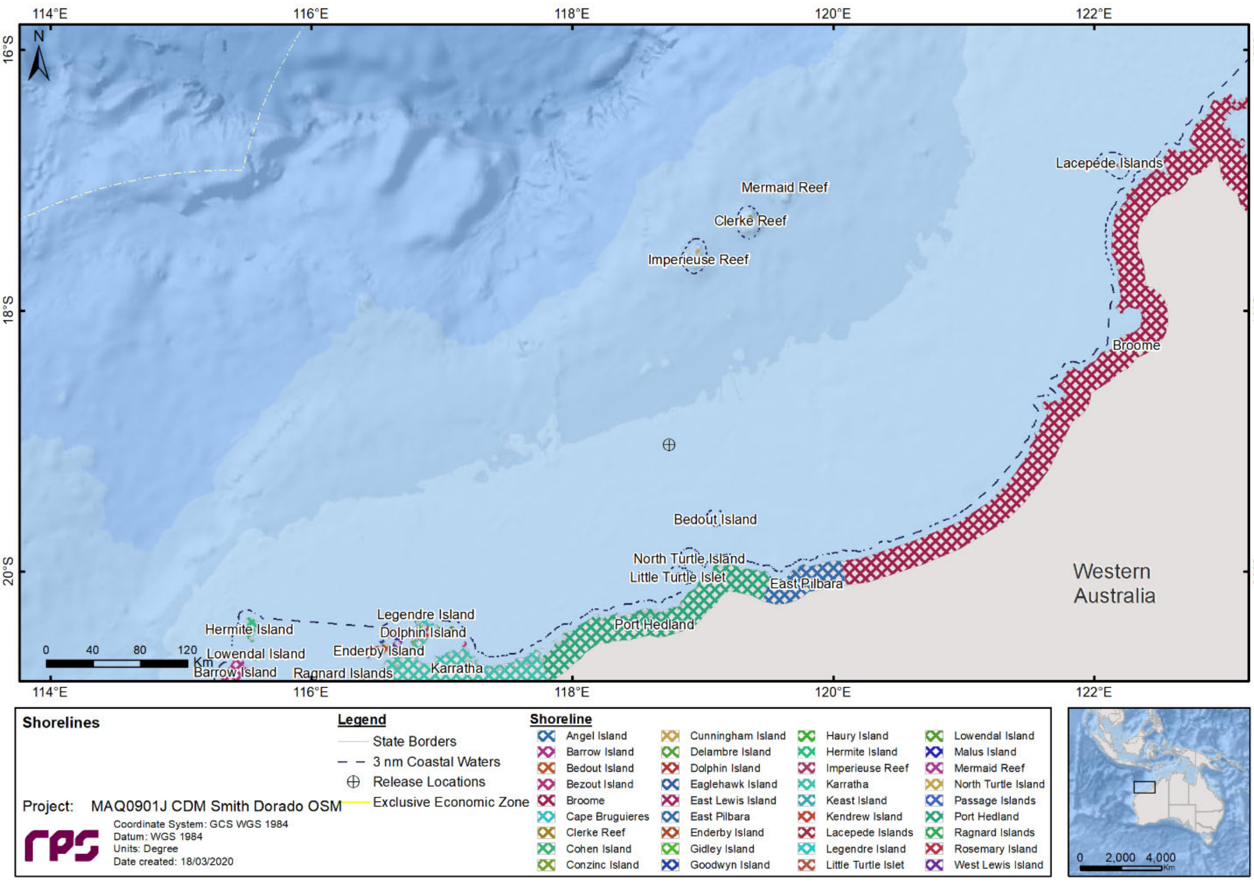


Figure 7.11 Receptor maps for Shorelines (Northeast Western Australia).

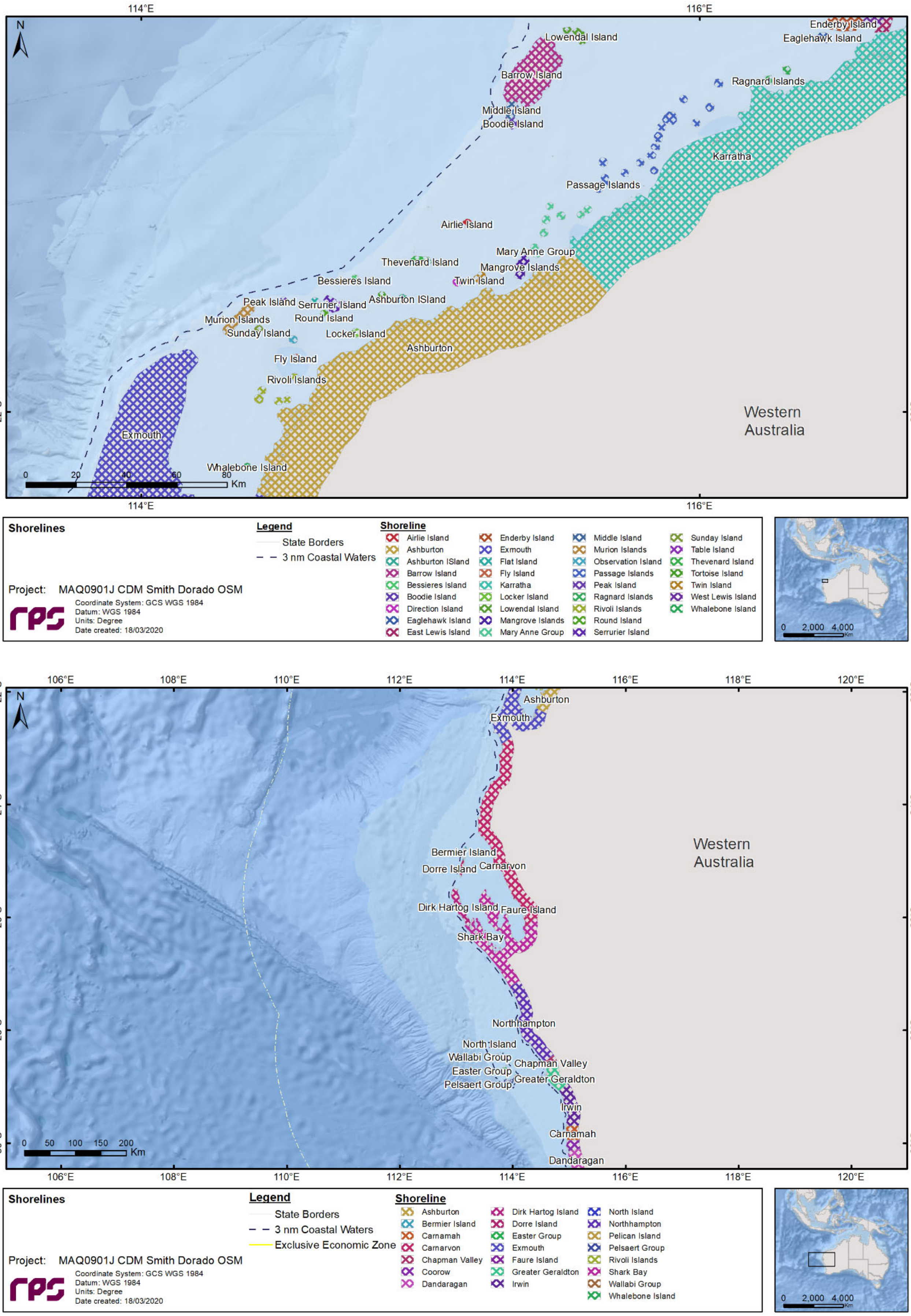


Figure 7.12 Receptor maps for Shorelines (East Western Australia).

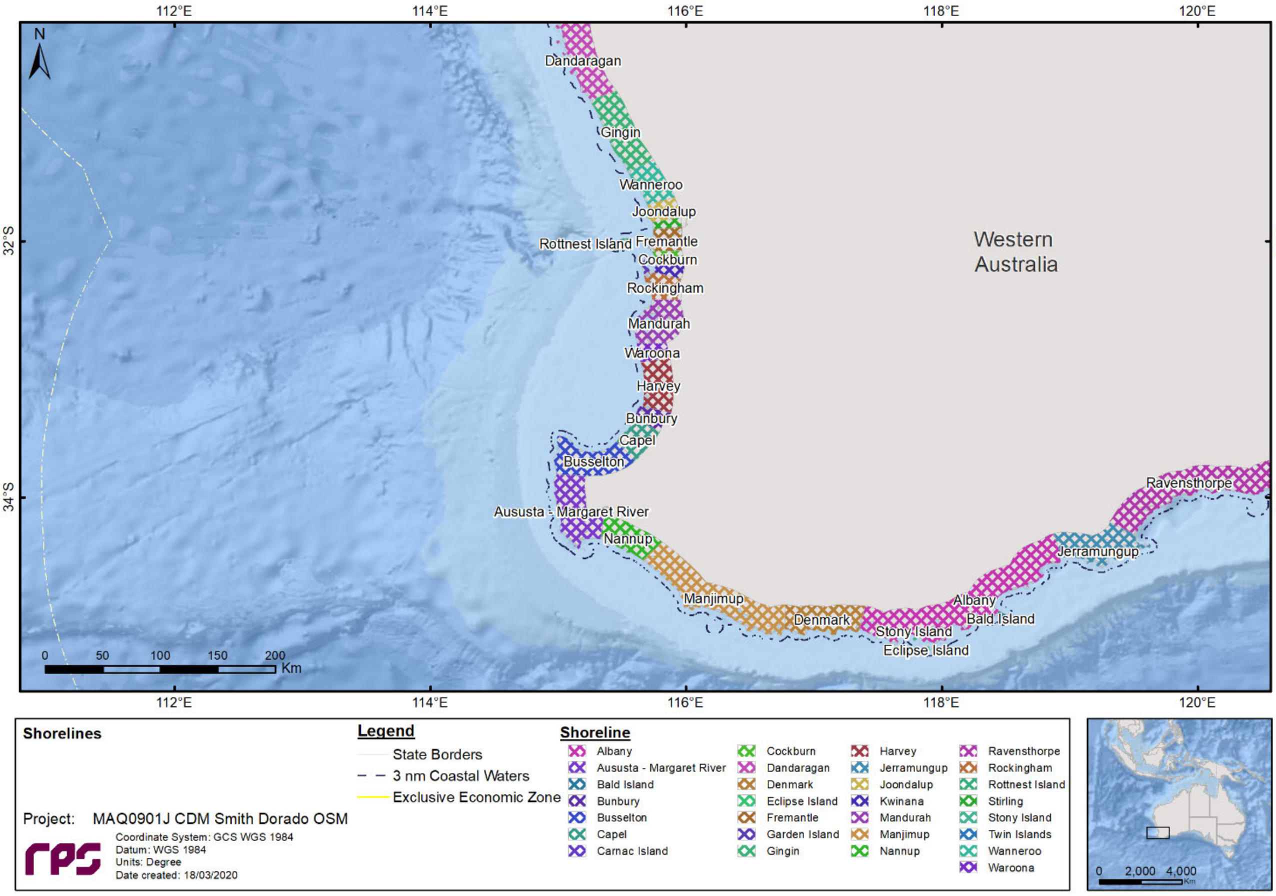


Figure 7.13 Receptor map for Shorelines (South Western Australia).

8 MODEL SETTINGS

Table 8.1 provides a summary of the oil spill model settings for each scenario. The table also shows the thresholds that were used.

The potential risk of exposure to the surrounding waters and accumulation on shorelines was assessed for three distinct seasons; summer (October to March), winter (May to August) and transitional (April and September). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The simulation lengths for each scenario was carefully selected based on extensive sensitivity testing. During the sensitivity testing process, sample spill simulations were run for longer than intended durations. Upon completion of the spill simulations, the results were carefully assessed to examine the persistence of the hydrocarbon (i.e. whether the maximum evaporative loss has been achieved for the period of time modelled; and whether a substantial volume of hydrocarbons remain in the water column (if any)) in conjunction with the extent of sea surface exposure based on reporting thresholds. Once there was agreement between the two factors (i.e. the final fate of hydrocarbon is accounted for and the full exposure area is identified) the simulation length was deemed appropriate.

Table 8.1 Summary of the oil spill model settings used in this assessment.

Input Parameters	Scenario 1 (Section 9.1)	Scenario 2 (Section 9.2)	Scenario 3 (Section 9.3)	Scenario 4 (Section 9.4)	Scenario 5 (Section 9.5)	Scenario 6 (Section 9.6)
Scenario Description	Uncontrolled subsea blowout	Uncontrolled surface blowout	Subsea release from export pipeline	Surface spill from offtake incident	Surface spill from tanker collision	Surface spill from loss of contents
Location Name	WHP	WHP	Between WHP and FPSO	FPSO	FPSO	FPSO
Number of randomly selected spill start times per season	100 (300 total)	100 (300 total)	100 (300 total)	100 (300 total)	100 (300 total)	100 (300 total)
Oil type	Caley crude	Caley crude	Caley crude	Caley crude	Marine Gas Oil	Caley crude
Daily flow rate	~20,733 m^3/day	~20,733 m^3/day	N/A	N/A	N/A	N/A
Total volume released	2,031,794 m^3	2,031,794 m^3	1,080 m^3	225 m^3	1,800 m^3	10,108 m^3
Release duration	98 days	98 days	1 hour	Instantaneous	Instantaneous	Instantaneous
Release depth	91 m	surface	91 m	surface	surface	surface
Simulation length	118 days	118 days	35 days	21 days	56 days	42 days
Seasons assessed	Summer (September to the following March)					
	Transitional period (April and August)					
	Winter (May to July)					
Surface thresholds (g/m^2)	1 (low exposure)					
	10 (moderate exposure)					
	50 (high exposure)					
Shoreline accumulation thresholds (g/m^2)	10 (low potential exposure)					
	100 (moderate potential exposure)					
	1,000 (high potential exposure)					
Dissolved hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure)					
	50 (50 ppb x 1 hr, potential moderate exposure)					
	400 (400 ppb x 1 hr, potential high exposure)					
Entrained hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure)					
	100 (100 ppb x 1 hr, potential moderate exposure)					

9 MODELLING RESULTS

9.1 Scenario 1: Simulation of a 14-week subsea blowout of crude at the WHP

This scenario examined a 12,779,600 bbl (2,031,794 m^3) subsea release of crude with a decreasing discharge rate over 14 weeks. A total of 300 simulations were run (i.e. 100 spills per season) and each was tracked for 118 days. These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Sections 9.1.1 presents an overview of the EMBA based on combining the 300 spill simulations and Section 9.1.3 shows the seasonal (or stochastic) analysis, while Section 9.1.2 presents the deterministic analysis results (i.e. a single spill simulation), based on largest volume ashore and longest length of oiled shoreline.

9.1.1 Overview

Figure 9.1 and Figure 9.2 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.3 and Figure 9.4 show the annualised extent of floating oil and in-water (entrained and dissolved) exposure as well as shoreline accumulation based on the low and moderate exposure thresholds, respectively, derived from combining the results from all 300 spill simulations.

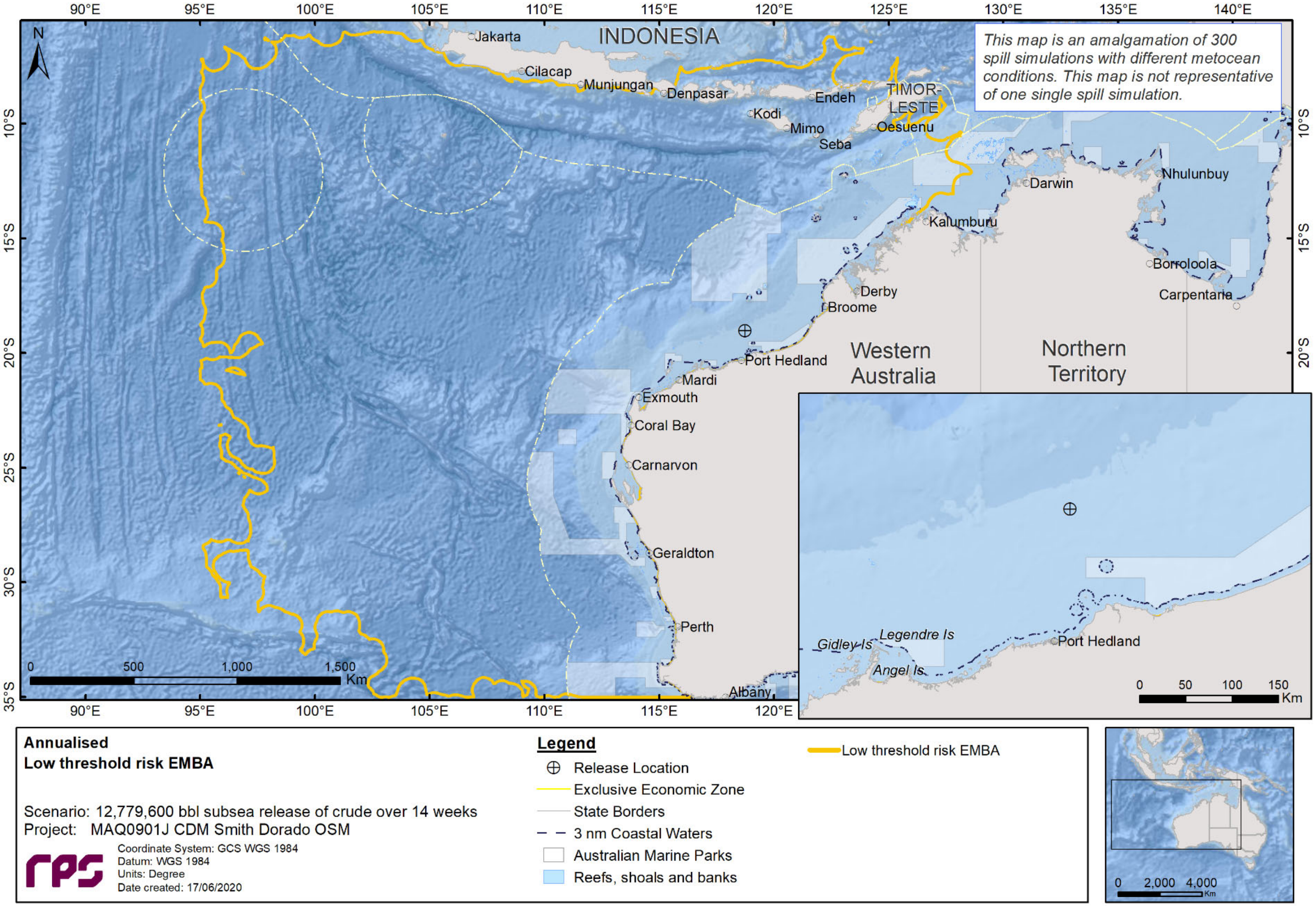


Figure 9.1 Predicted low threshold risk EMBA resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations and each was tracked for 118 days.

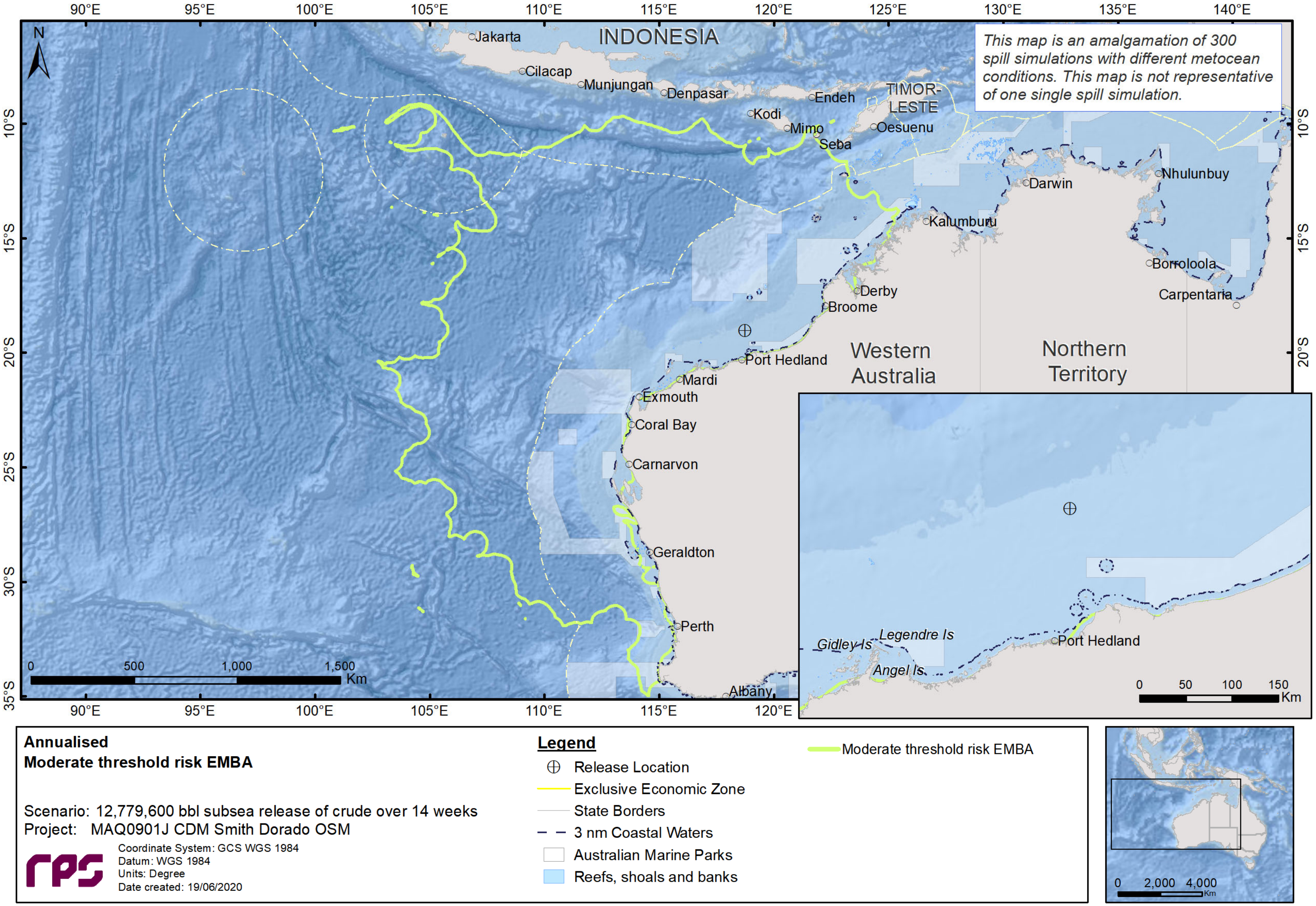


Figure 9.2 Predicted moderate threshold risk EMBA resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations and each was tracked for 118 days.

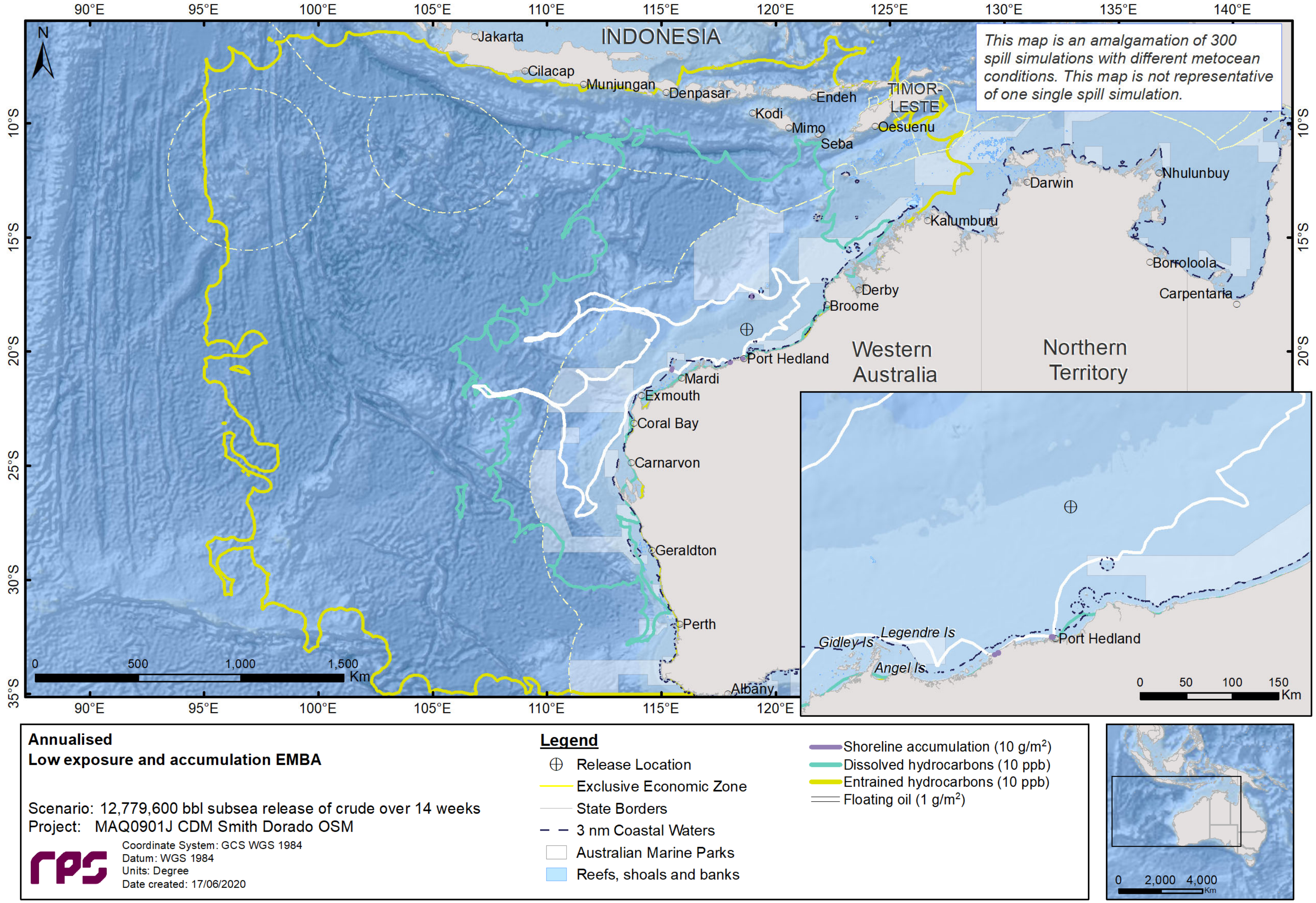


Figure 9.3 Annualised low threshold oil exposure and shoreline accumulation resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations and each was tracked for 118 days.

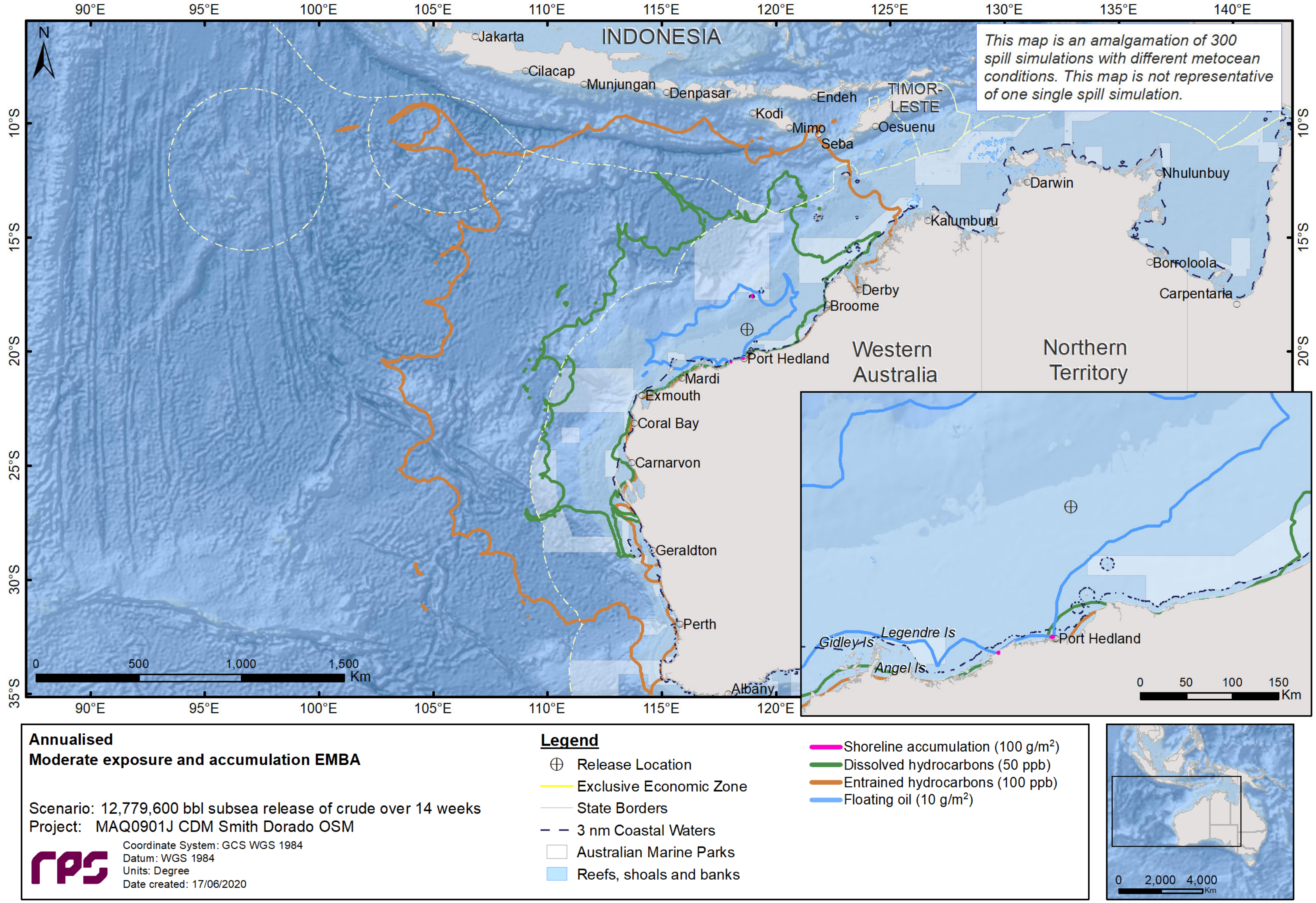


Figure 9.4 **Annualised moderate threshold oil exposure and shoreline accumulation resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP. The annualised results were calculated from 300 spill simulations and each was tracked for 118 days.**

9.1.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest volume of oil ashore; and

b. Longest length of oiled shoreline.

9.1.2.1 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that recorded the largest volume of oil ashore was identified during transitional conditions as run number 9, which commenced at 7 pm on the 4th of April 2018. The maximum volume ashore was 64.7 m^3, which occurred 3 days after the initial release.

Exposure from floating oil (swept area) and potential oil accumulation over the entire 118 day simulation are presented in Figure 9.5 and Figure 9.6, respectively. Floating oil exposure was predicted to occur northeast and west/southwest from the release location, while oil accumulation occurred at the sensitive receptor (refer Section 7.3) of Port Hedland.

Figure 9.7 displays the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and moderate shoreline oil (≥100 g/m^2) over the 118-day simulation.

Figure 9.8 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9.9 presents the fates and weathering graph for the corresponding simulation. At the conclusion of the simulation period, approximately 1,245,004 m^3 (61%) spilled oil was lost to the atmosphere through evaporation. Approximately 625,213 m^3 (31%) of the crude was predicted to have decayed, while 159,119 m^3 (8%) remained within the water column and 22 m^3 (<0.1%) was predicted to remain on the shoreline.

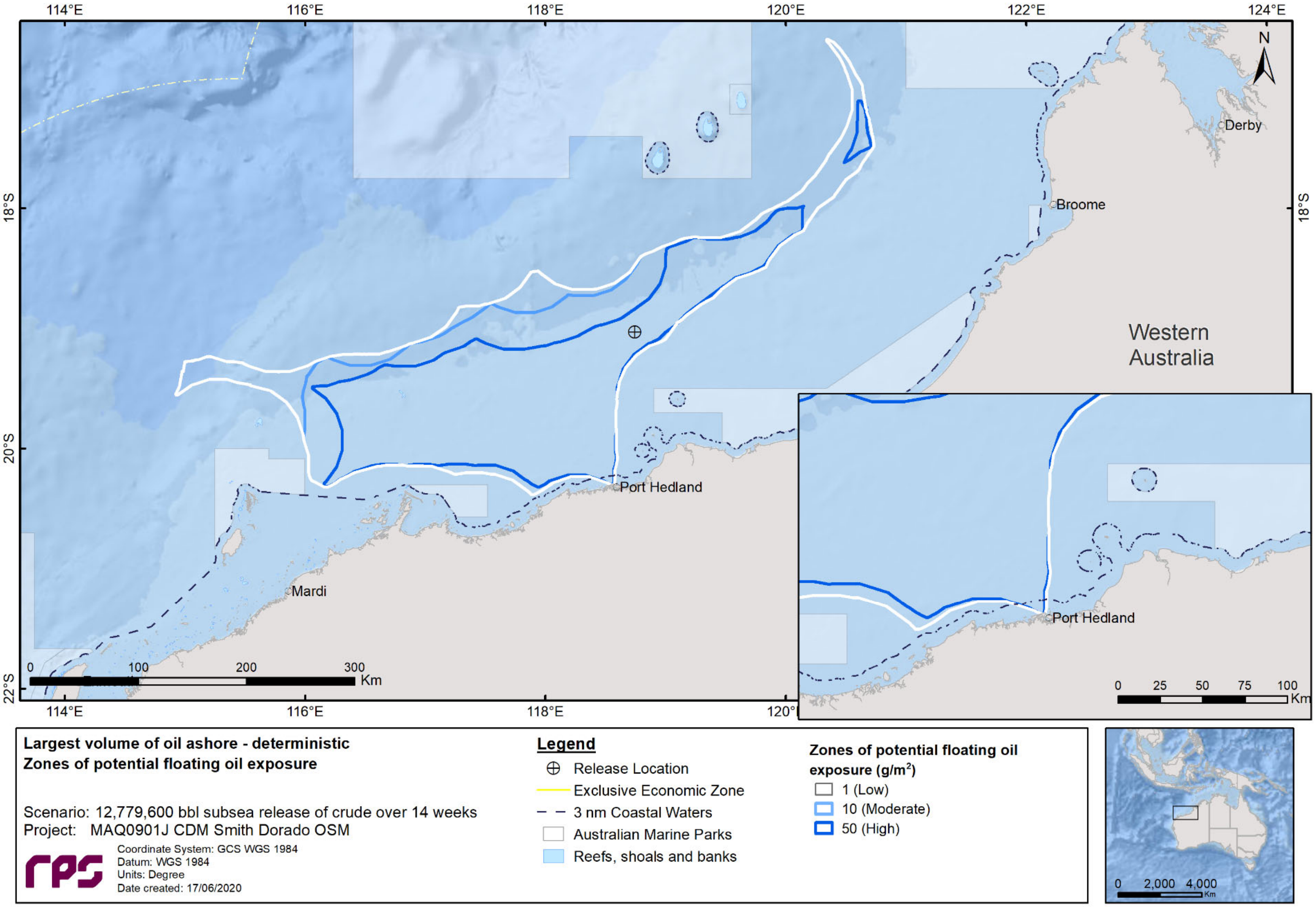


Figure 9.5 Exposure from floating oil (over the 118 day simulation) for the simulation with the largest volume of oil ashore. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 7 pm on the 4th of April 2018.

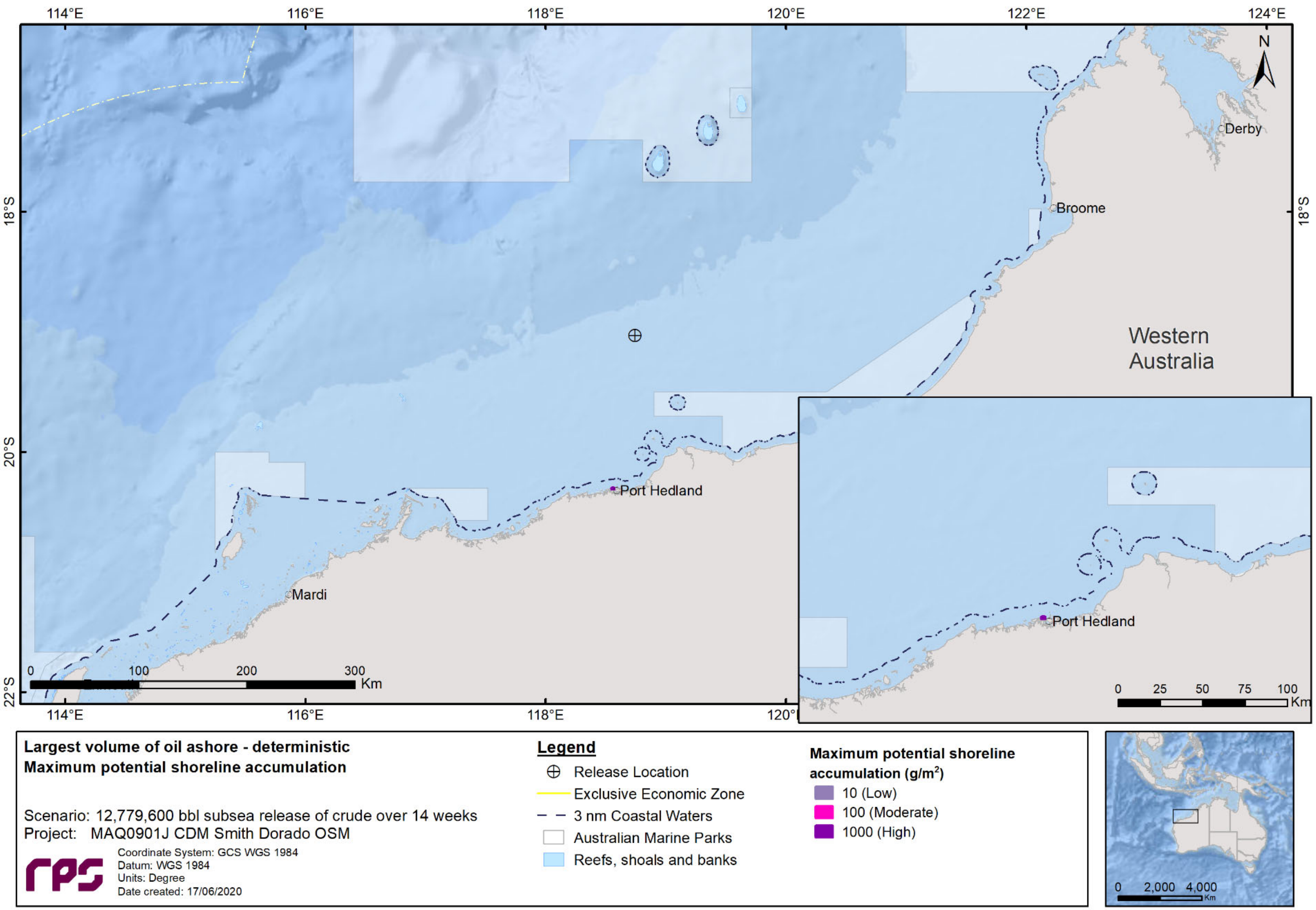


Figure 9.6 Potential shoreline accumulation (over the 118 day simulation) for the simulation with the largest volume of oil ashore. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 7 pm on the 4th of April 2018.

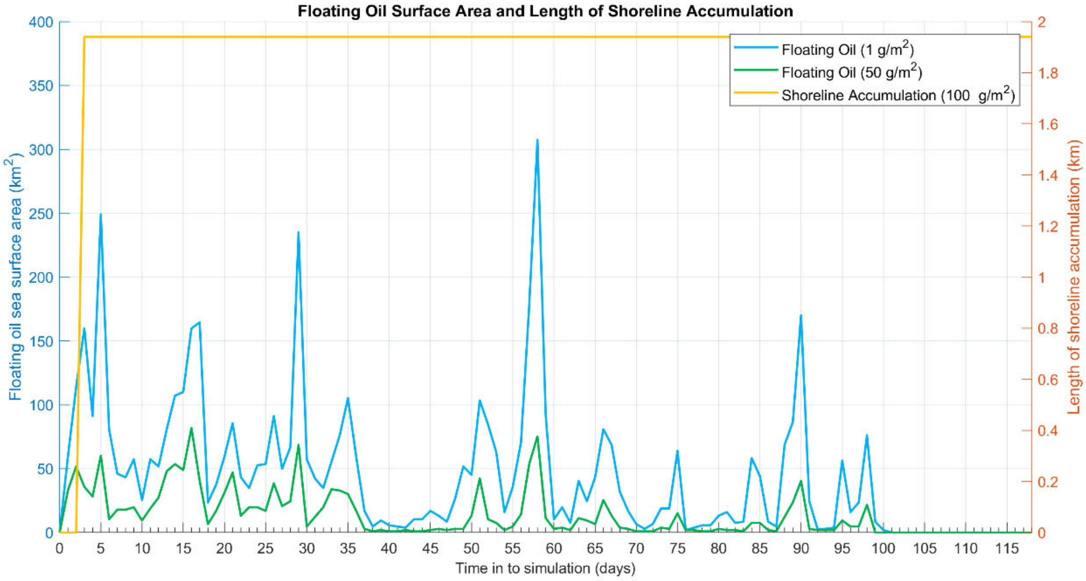


Figure 9.7 **Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface and length of actionable shoreline oil (≥100 g/m²) for the simulation with the largest volume of oil ashore. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days.**

Figure 9.8 **Time series of volume on shore at the low (10-100 g/m²), moderate (100-1,000 g/m²) and high (≥ 1,000 g/m²) thresholds for the simulation with the largest volume of oil ashore. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days.**

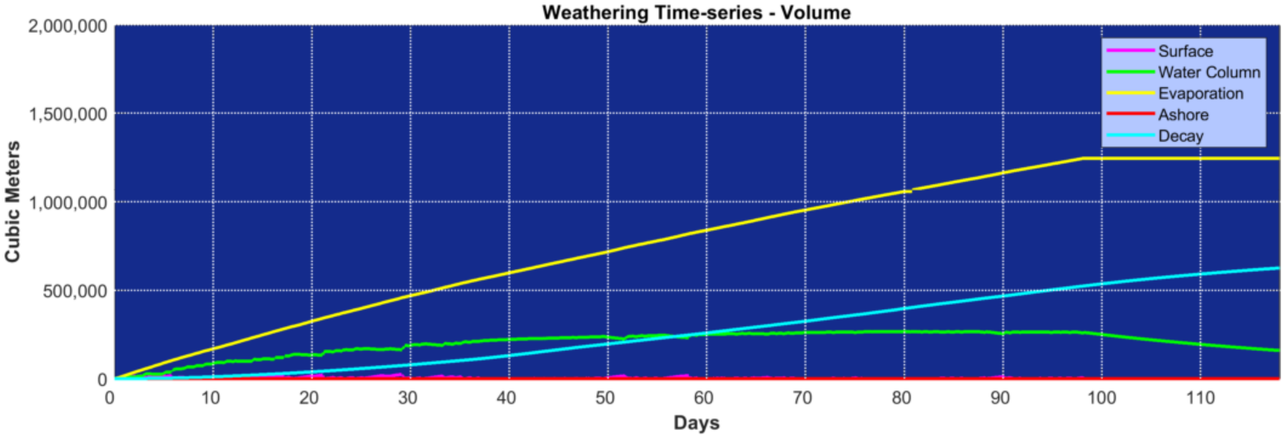


Figure 9.9 Predicted weathering and fates graph for the single spill simulation with the largest volume of oil ashore. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, tracked for 118 days.

9.1.2.2 Deterministic Case: Longest length of oiled shoreline

The deterministic simulation that resulted in the longest length of oiled shoreline above 100 g/m^2 was identified during summer conditions as run number 60, which commenced at 11 pm on the 17th of January 2018.

Exposure from floating oil (swept area) and potential oil accumulation over the entire 118-day simulation are presented in Figure 9.10 and Figure 9.11, respectively. Floating oil exposure was predicted to occur northeast and west/southwest from the release location with oil accumulation occurring at the sensitive shoreline receptors (refer Section 7.3) of Port Hedland, Cunningham Island and Imperieuse Reef.

Figure 9.12 displays the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and actionable shoreline oil (≥100 g/m^2) over the 118-day simulation. The maximum area of coverage of visible oil on the sea surface was predicted to occur 46 days after the spill started and covered approximately 559 km^2. While the maximum length of actionable shoreline oiled (above 100 g/m^2) at any given time was 2 km, approximately 80 days into the simulation.

Figure 9.13 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9.14 presents the fates and weathering graph for the corresponding simulation. At the conclusion of the simulation period, approximately 1,267,855 m^3 (62%) spilled oil was lost to the atmosphere through evaporation. Approximately 597,580 m^3 (29%) of the crude was predicted to have decayed, while 162,903 m^3 (8%) remained within the water column and 15 m^3 (<0.1%) was predicted to remain on the shoreline.

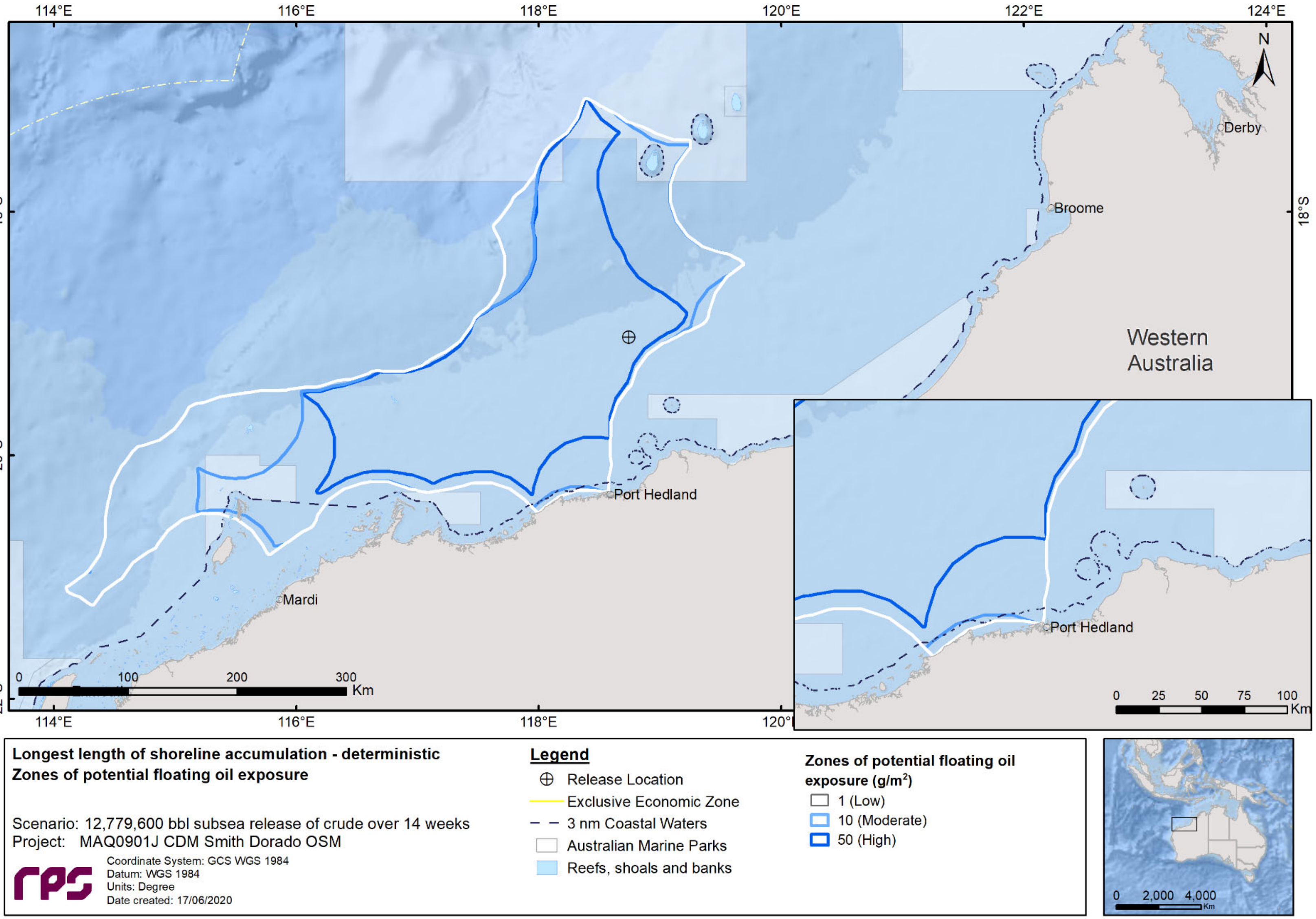


Figure 9.10 Exposure from floating oil (over the 118 day simulation) for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, starting 11 pm on the 17th of January 2018.

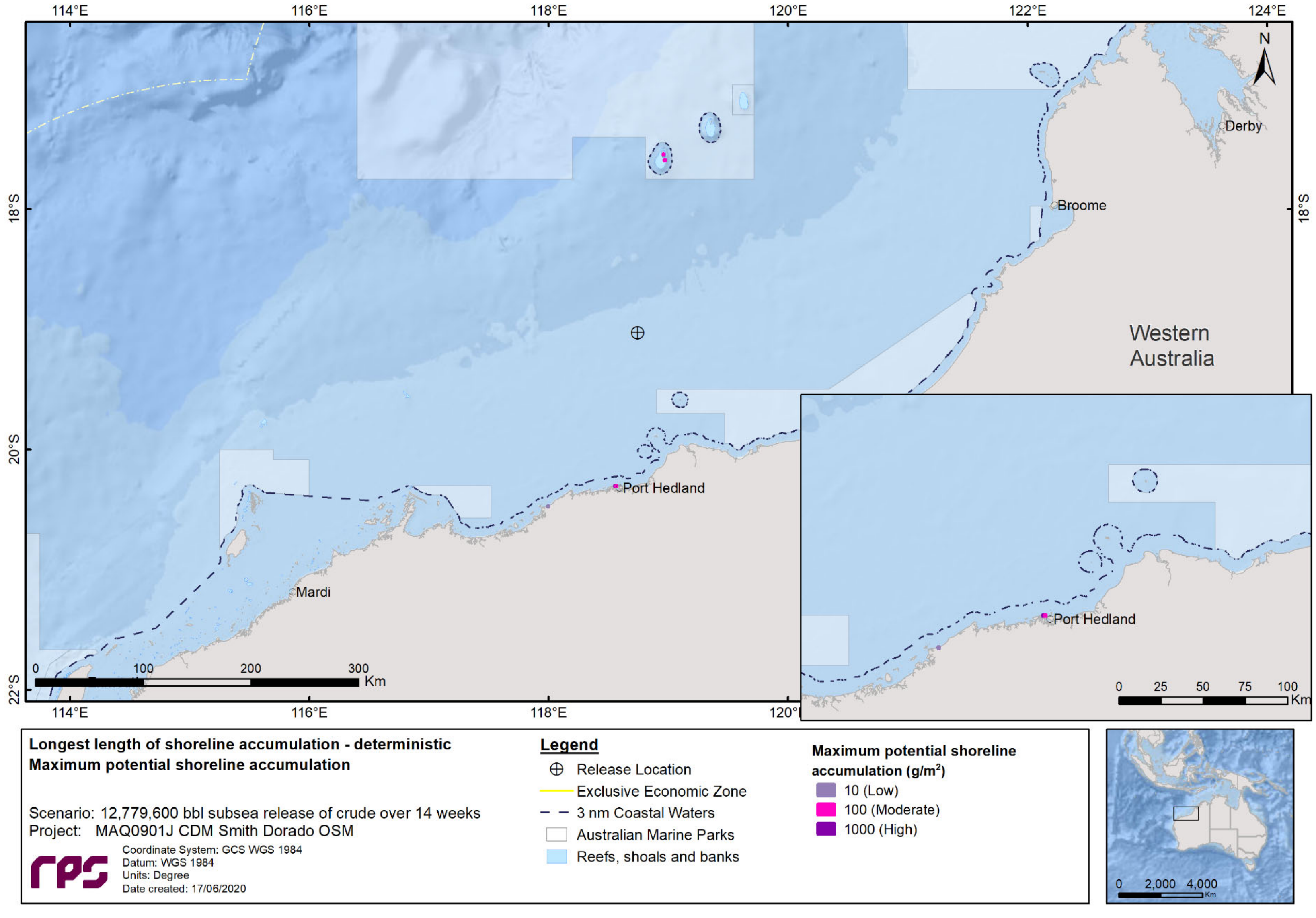


Figure 9.11 **Potential shoreline accumulation (over the 118 day simulation) for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, starting 11 pm on the 17th of January 2018.**

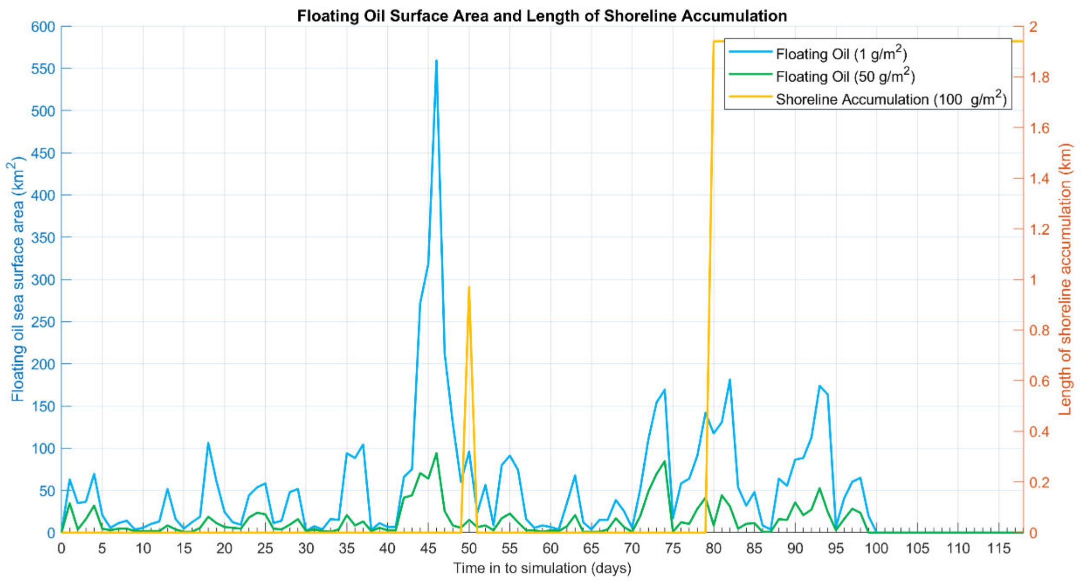


Figure 9.12 Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface and length of actionable shoreline oil (≥100 g/m²) for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days.

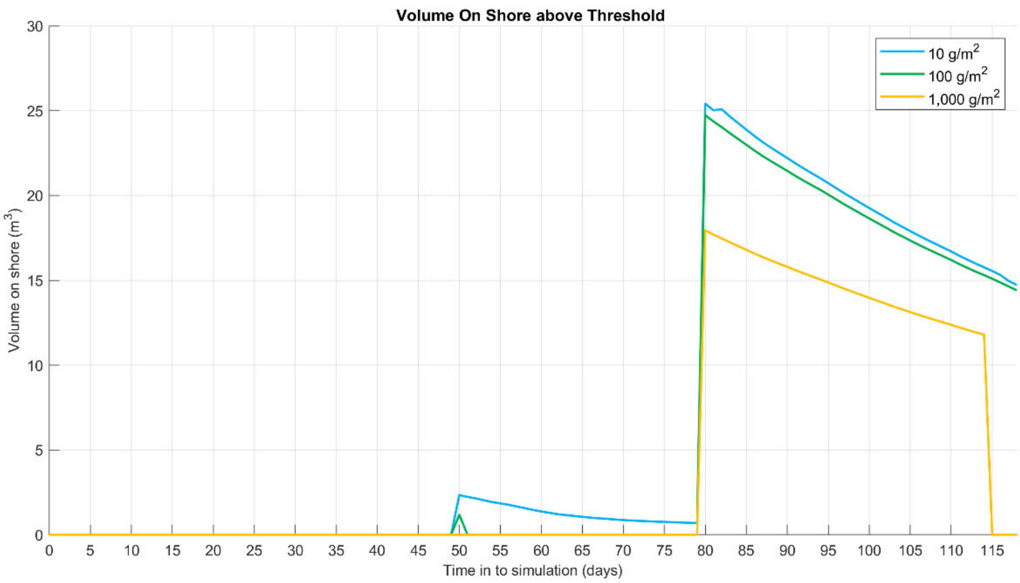


Figure 9.13 Time series of the volume on shore at the low (10-100 g/m²), moderate (100-1,000 g/m²) and high (≥ 1,000 g/m²) thresholds for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days.

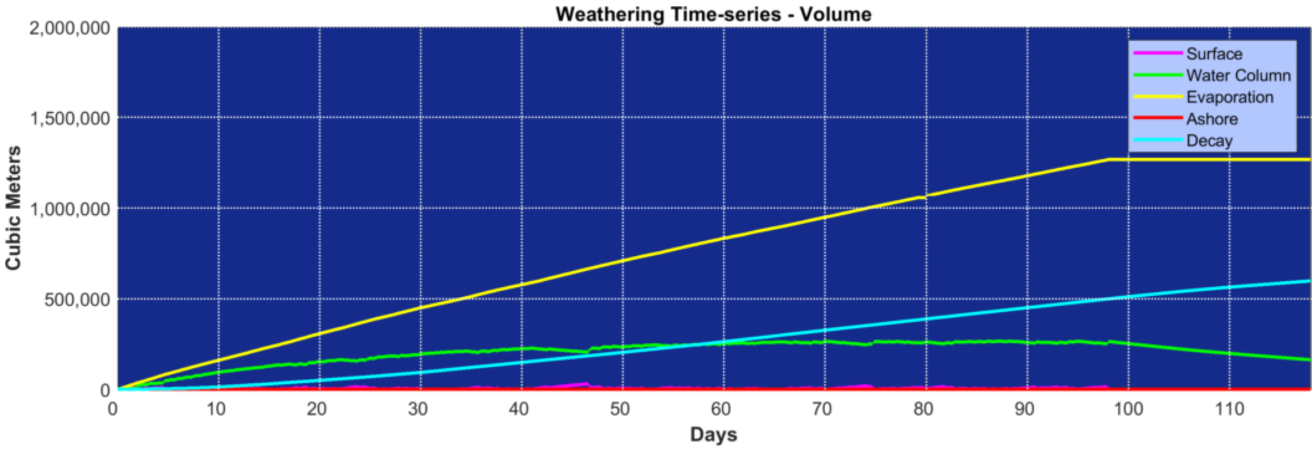


Figure 9.14 Predicted weathering and fates graph for the single spill simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, tracked for 118 days, 11 pm on the 17th of January 2018.

9.1.3 Seasonal analysis

9.1.3.1 Floating Oil Exposure

Table 9.1 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 1,278.2 km west-southwest, 528.3 km west-southwest and 304.5 km west-southwest, respectively, all predicted during summer conditions.

Images of floating oil exposure zones are depicted in Figure 9.15, Figure 9.16 and Figure 9.17 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively.

Table 9.2 to

Table 9.4 summarises the potential for floating oil exposure to individual receptors for each season, based on combining the results of the 100 simulations. Within the predicted exposure zone from the combined season simulations, there are 8 AMPs, 7 during summer and 2 each during transitional and winter conditions. The Montebello AMP recorded the highest probability of exposure to floating oil at 18% during summer conditions. The shortest time for floating oil to reach an AMP was recorded at Argo-Rowley Terrace (7.54 days) during summer conditions.

There are 3 RSBs within the predicted zone of floating oil exposure (at the low threshold), with the highest probability of exposure predicted at Imperieuse Reef during summer conditions (7%). The shortest time before floating oil contacted a RSB receptor was predicted at Tryal Rocks, taking 14.04 days during summer conditions.

Exposure (at the low threshold) was predicted to cross into WA State Waters during every season with probabilities ranging from 1-12%. The minimum time before oil crossed the WA State Waters boundary was 2.83 days recorded for a spill commencing during transitional conditions.

Table 9.1 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	1,278.2	528.3	304.5
	Max distance from release site (km) (99th percentile)	1,050.2	308.1	219.1
	Direction	West-Southwest	West-Southwest	West-Southwest
Transitional	Max. distance from release site (km)	498.8	498.8	305.0
	Max distance from release site (km) (99th percentile)	386.5	326.6	261.3
	Direction	West-Southwest	West-Southwest	West-Southwest
Winter	Max. distance from release site (km)	413.5	413.5	221.7
	Max distance from release site (km) (99th percentile)	298.4	269.5	153.2
	Direction	West	West	Northeast

Table 9.2 Summary of the potential floating oil exposure to individual receptors. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)	Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
AMP	Argo-Rowley Terrace	11	11	11	7.5	7.5	7.5
	Carnarvon Canyon	3	-	-	62.9	-	-
	Dampier	5	5	-	16.5	16.5	-
	Eighty Mile Beach	1	-	-	38.8	-	-
	Gascoyne	12	-	-	40.7	-	-
	Kimberley	-	-	-	-	-	-
	Montebello	18	11	-	12.2	12.9	-
	Shark Bay	2	-	-	101.8	-	-
IBRA	Cape Range	3	1	-	38.8	40.8	-
	Roebourne	7	7	-	11.6	11.6	-
IMCRA	Ningaloo	4	-	-	70.0	-	-
	Pilbara (nearshore)	10	8	-	11.5	11.5	-
	Pilbara (offshore)	51	44	15	3.0	3.0	7.8
	Zuytdorp	2	-	-	100.9	-	-
MP	Montebello Islands	6	2	-	12.2	58.3	-
	Rowley Shoals	11	10	-	10.0	10.0	-
RSB	Imperieuse Reef	7	1	-	36.0	56.0	-
	Rankin Bank	5	-	-	51.3	-	-
	Tryal Rocks	3	3	-	14.0	14.0	-
Nearshore	Barrow Island	2	1	-	40.8	40.8	-
	Cunningham Island	4	2	-	11.9	11.9	-
	Hermite Island	2	-	-	38.8	-	-
	Imperieuse Reef	4	-	-	36.0	-	-
	Port Hedland	7	7	-	11.6	11.6	-
State Waters	Western Australia State Waters	12	12	-	10.0	10.0	-

Table 9.3 Summary of the potential floating oil exposure to individual receptors. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	-	-	-	-	-	-
	Carnarvon Canyon	-	-	-	-	-	-
	Dampier	-	-	-	-	-	-
	Eighty Mile Beach	1	-	-	102.8	-	-
	Gascoyne	-	-	-	-	-	-
	Kimberley	-	-	-	-	-	-
	Montebello	7	4	-	19.4	19.4	-
	Shark Bay	-	-	-	-	-	-
IBRA	Cape Range	-	-	-	-	-	-
	Roebourne	1	1	1	2.8	2.8	2.8
IMCRA	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	1	1	1	2.8	2.8	2.8
	Pilbara (offshore)	44	39	9	2.6	2.6	2.6
	Zuytdorp	-	-	-	-	-	-
MP	Montebello Islands	-	-	-	-	-	-
	Rowley Shoals	-	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-	-
	Rankin Bank	1	1	-	34.8	34.8	-
	Tryal Rocks	-	-	-	-	-	-
Nearshore	Barrow Island	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-
	Port Hedland	1	1	1	2.8	2.8	2.8
State Waters	Western Australia State Waters	1	1	1	2.8	2.8	2.8

Table 9.4 Summary of the potential floating oil exposure to individual receptors. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	-	-	-	-	-	-
	Carnarvon Canyon	-	-	-	-	-	-
	Dampier	-	-	-	-	-	-
	Eighty Mile Beach	-	-	-	-	-	-
	Gascoyne	-	-	-	-	-	-
	Kimberley	2	-	-	82.7	-	-
	Montebello	5	3	-	61.8	61.8	-
	Shark Bay	-	-	-	-	-	-
IBRA	Cape Range	-	-	-	-	-	-
	Roebourne	-	-	-	-	-	-
IMCRA	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	-	-	-	-	-	-
	Pilbara (offshore)	31	24	8	9.5	9.5	9.6
	Zuytdorp	-	-	-	-	-	-
MP	Montebello Islands	-	-	-	-	-	-
	Rowley Shoals	-	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-	-
	Rankin Bank	-	-	-	-	-	-
	Tryal Rocks	-	-	-	-	-	-
Nearshore	Barrow Island	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-
	Port Hedland	-	-	-	-	-	-
State Waters	Western Australia State Waters	1	-	-	61.8	-	-

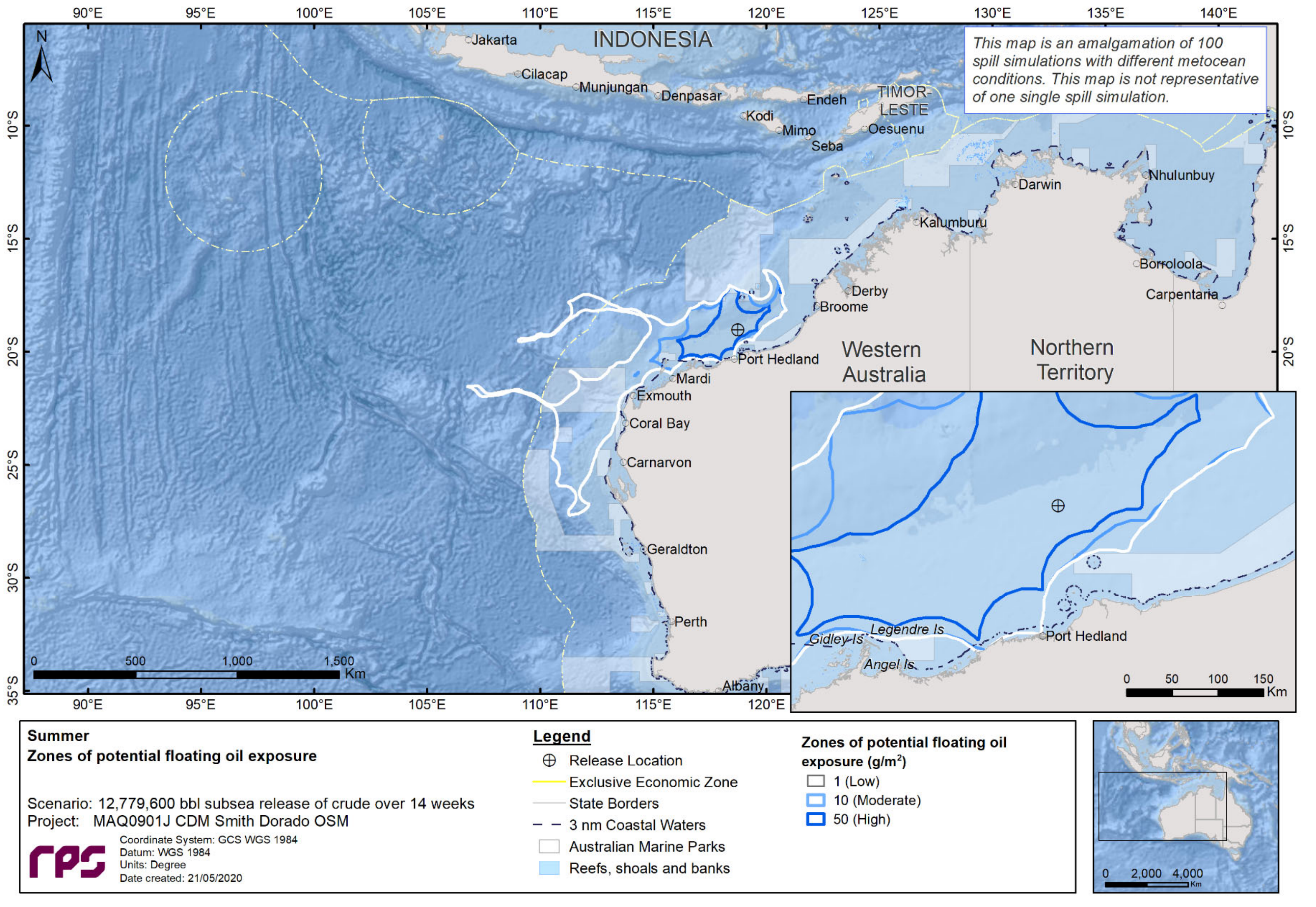


Figure 9.15 Predicted floating oil exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

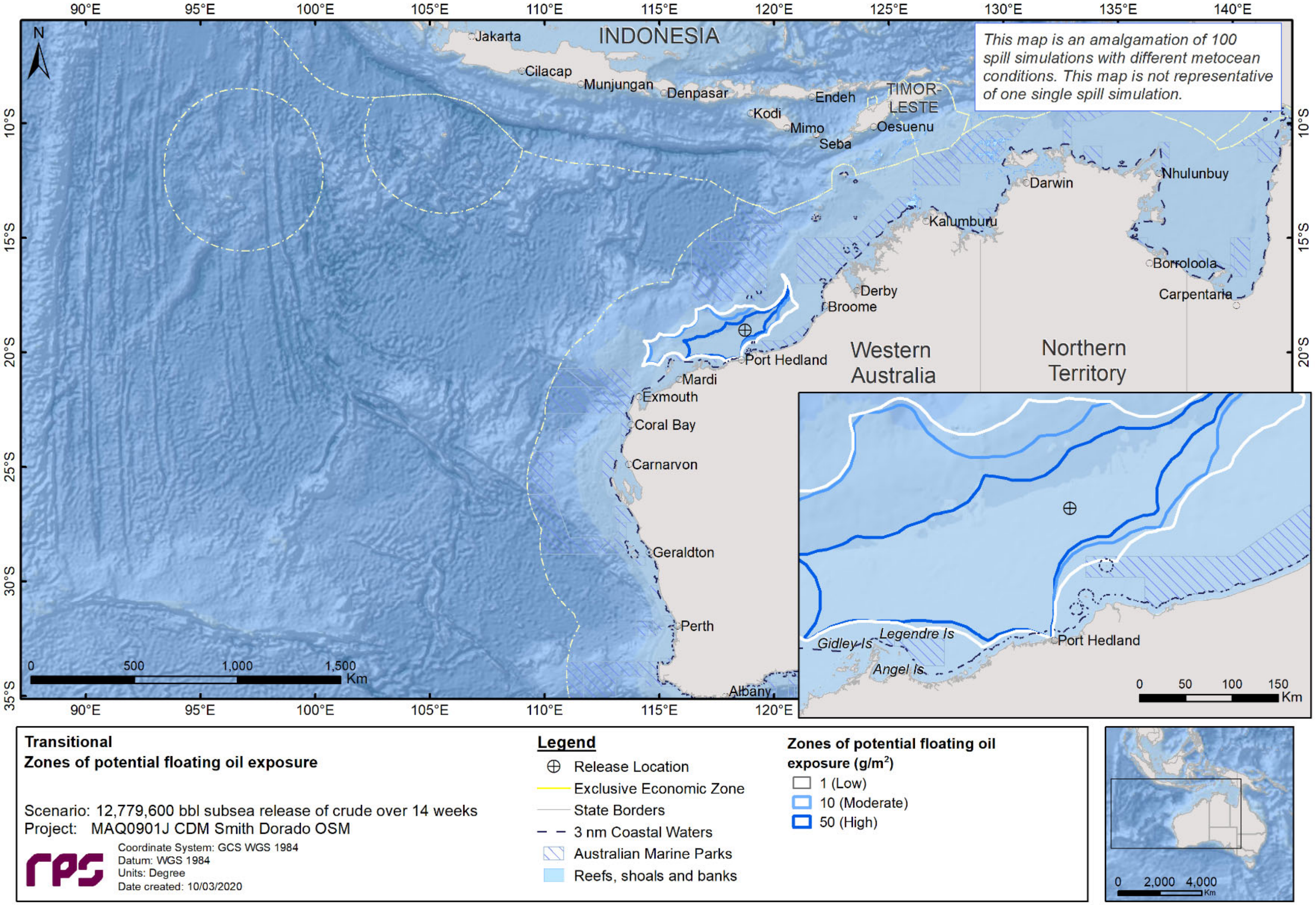


Figure 9.16 Predicted floating oil exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

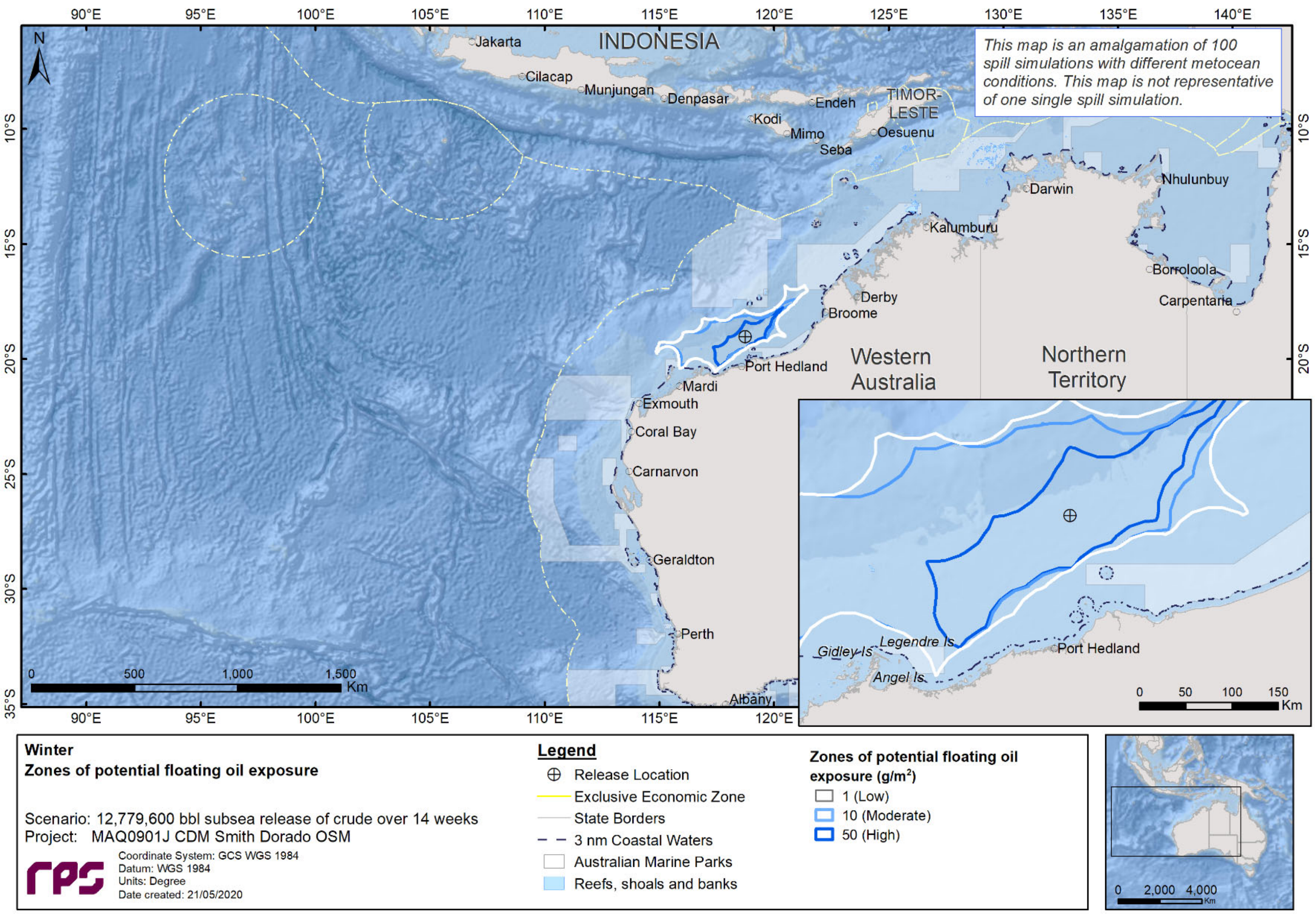


Figure 9.17 Predicted floating oil exposure zones exposure resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.1.3.2 Shoreline Accumulation

Table 9.5 presents a summary of the predicted oil accumulation on any shoreline for all three seasons assessed. The probability of oil accumulation at, or above, the low threshold (10-100 g/m^2) during the summer and transitional seasons was 10% and 1%, respectively. The minimum time before oil accumulation above the low threshold was approximately 11.63 days and 2.88 days, respectively. The greatest volume of oil ashore was 35.8 m^3 and 64.7 m^3 during summer and transitional conditions, respectively. There was no oil accumulation on any shoreline above the low impact threshold predicted for spills commencing during winter conditions.

Table 9.6 and Table 9.7 summarise the oil accumulation to individual sensitive shoreline receptors (as described in Section 7.3) assessed for summer and transitional conditions. Based on combining 100 simulations per season, oil was predicted to accumulate on 4 sensitive shoreline receptors at, or above, the low threshold (10-100 g/m^2) during summer and only 1 receptor (Port Hedland) during transitional conditions. Port Hedland recorded the highest probability of oil accumulation at the low threshold (10-100 g/m^2) during summer conditions (7%) and the quickest time before shoreline accumulation was predicted during transitional conditions at 2.88 days. The greatest volume of oil ashore was 64.7 m^3 and the maximum length of shoreline predicted to have accumulation at the low threshold was 3 km, both occurring at Port Hedland during transitional and summer conditions, respectively.

The maximum potential shoreline loading at low, moderate and high accumulation thresholds are depicted in Figure 9.18 and Figure 9.19 based on the 100 spill simulations commencing during summer and transitional conditions, respectively.

Table 9.5 Summary of oil accumulation on any shoreline. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during all seasonal conditions. The results were calculated from 100 spill simulations per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of shoreline accumulation at, or above **10 g/m^2** (%)	10	1	-
Minimum time before shoreline accumulation at, or above **10 g/m^2** (days)	11.6	2.9	-
Maximum volume of oil ashore (m^3) from a single simulation	35.8	64.7	-
Average volume of oil ashore (m^3) for all simulations predicted to reach the shorelines	16.0	64.7	-
Maximum length of shoreline accumulation at or above **10 g/m^2** (km) from a single simulation	6.0	2.0	-
Average length of shoreline accumulation at or above **10 g/m^2** (km) for all simulations predicted to reach the shorelines	2.5	2.0	-
Maximum length of shoreline accumulation at or above **100 g/m^2** (km) from a single simulation	2.0	2.0	-
Average length of shoreline accumulation at or above **100 g/m^2** (km) for all simulations predicted to reach the shorelines	2.0	2.0	-
Maximum length of shoreline accumulation at or above **1,000 g/m^2** (km) from a single simulation	1.0	2.0	-
Average length of shoreline accumulation at or above **1,000 g/m^2** (km) for all simulations predicted to reach the shorelines	1.0	2.0	-

Table 9.6 Summary of oil accumulation on individual shorelines. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Barrow Island	2	-	-	40.8	-	-	11.4	22.4	<0.1	0.3	1.0	-	-	1.0	-	-
Cunningham Island	3	2	-	36.0	36.2	-	58.8	108.8	<0.1	2.1	1.7	1.0	-	2.0	1.0	-
Imperieuse Reef	4	2	-	36.0	49.4	-	101.6	260.0	0.1	3.7	1.5	1.0	-	2.0	1.0	-
Port Hedland	7	7	7	11.6	11.6	11.7	1,271.0	2,718.1	1.6	34.3	1.7	1.6	1.0	3.0	3.0	1.0

Table 9.7 Summary of oil accumulation on individual shorelines. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Port Hedland	1	1	1	2.9	2.9	2.9	3,061.5	3,061.5	64.7	64.7	2.0	2.0	2.0	2.0	2.0	2.0

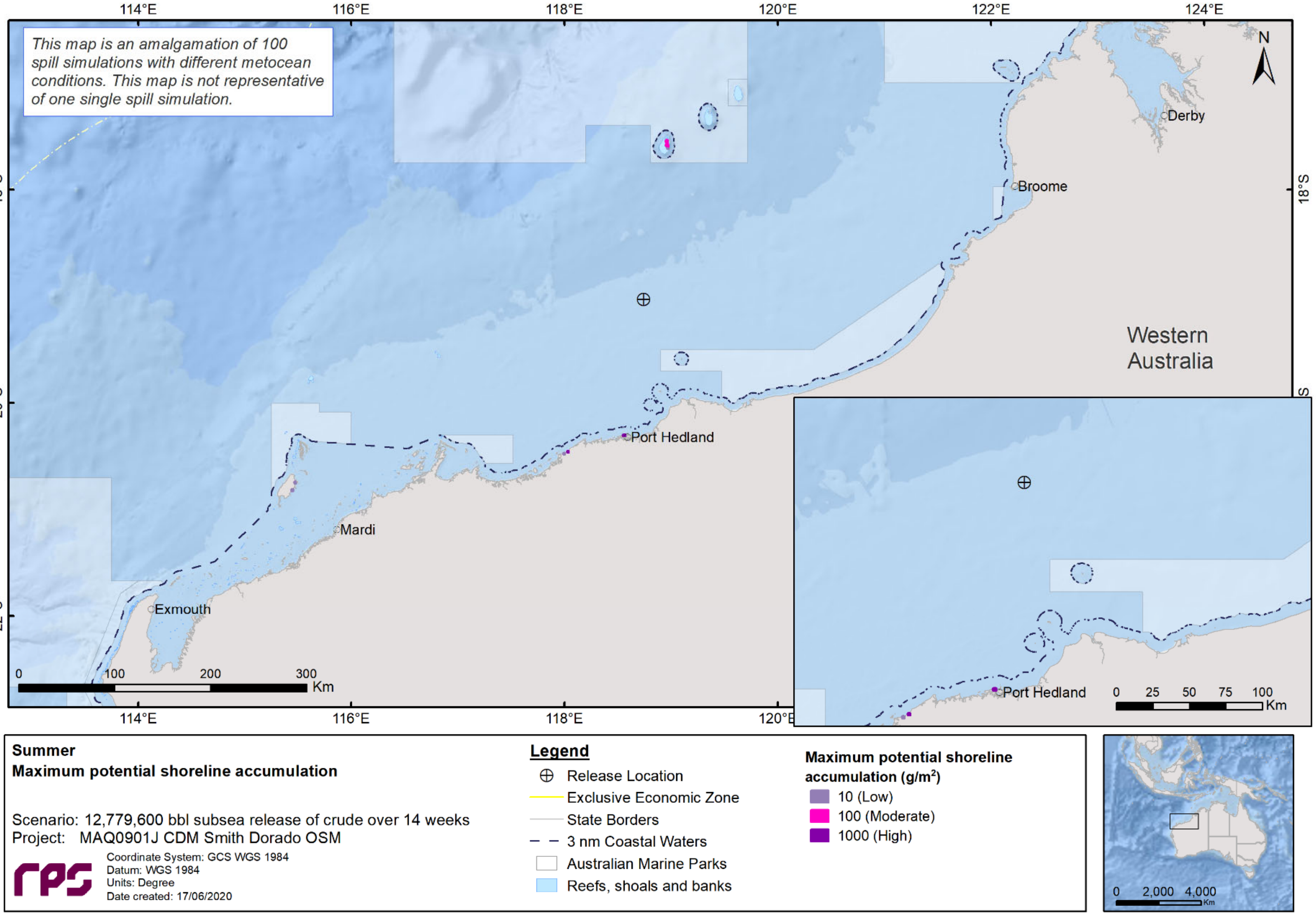


Figure 9.18 Predicted maximum shoreline loading resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

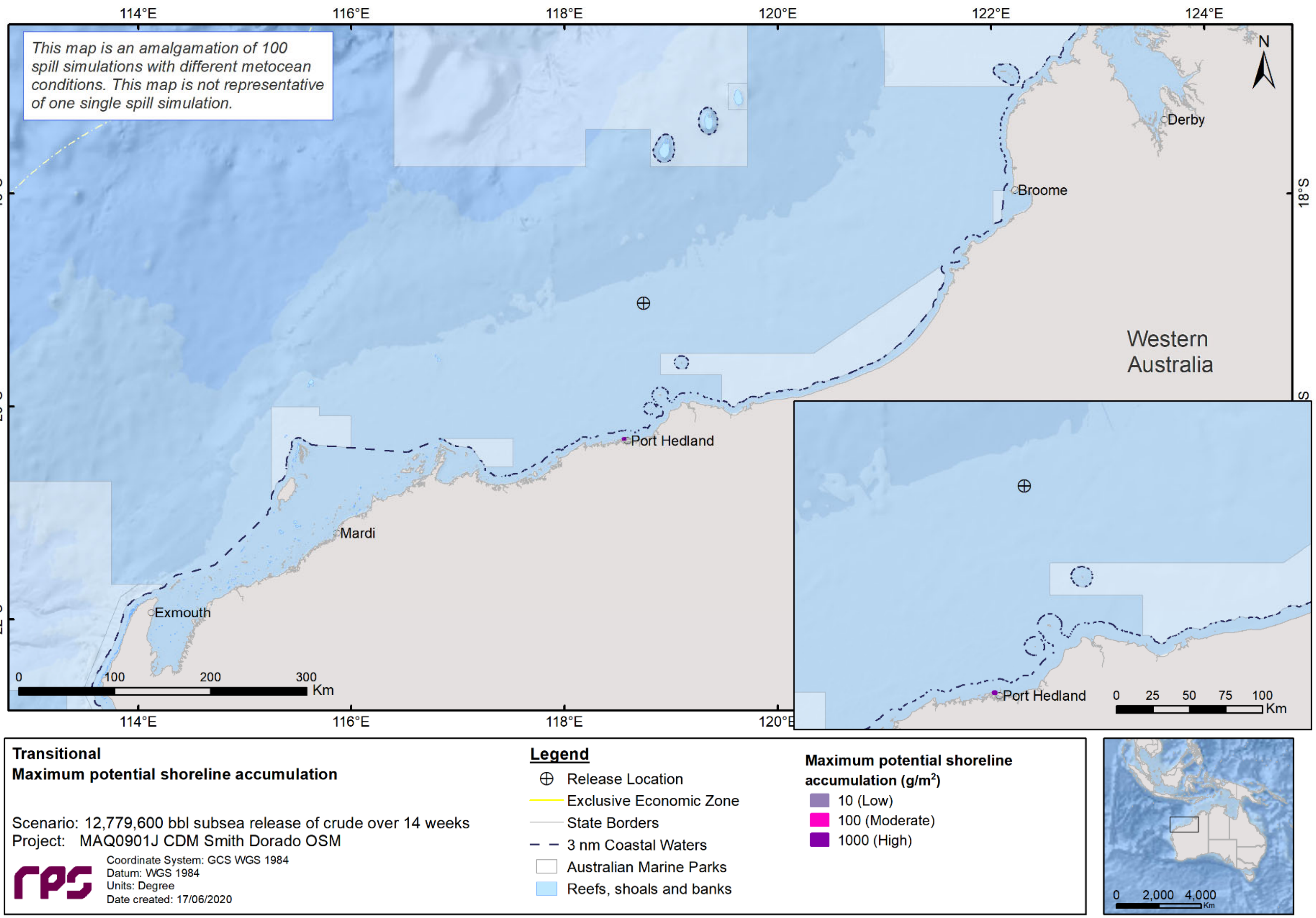


Figure 9.19 Predicted maximum shoreline loading resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

9.1.3.3 Entrained Hydrocarbons

Images of entrained hydrocarbon exposure zones in the 0-10 m depth layer are depicted in Figure 9.20 Figure 9.21 and Figure 9.22 for the combined 100 spill simulations each commencing during summer, transitional and winter conditions, respectively. The results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 2,878 km (west-northwest) from the spill site during winter conditions. This distance reduced to 2,158 km (west-northwest) based on the moderate threshold in winter conditions. The maximum distances for summer and transitional conditions at the low threshold were 2,635 km and 2,498 m, respectively. The maximum distances at the moderate threshold were reduced for summer (1,964 km) and transitional (1,739 km).

Table 9.8 to Table 9.10 summarise the probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at the shallowest depth from the sea surface for each KEF (representing the maximum concentrations).

There are a total of 20 AMPs within the low exposure zone across the three seasons (cumulative envelope of all the oil spill simulations), with Montebello AMP recording the highest probability of exposure during summer (95%), while Argo Rowley AMP had the highest probabilities for transitional (97%) and winter (100%) seasons. The shortest time for entrained hydrocarbons at the low threshold (10-100 ppb) to reach an AMP was recorded at Dampier during transitional conditions (2.67 days). Eighteen AMPs were within the moderate exposure zone (cumulative of 100 simulations) during summer reducing to 12 AMPs for cumulative spills moderate exposure zone commencing in winter conditions.

RSB receptors within the low exposure zone was predicted to vary between seasons (103 summer, 83 transitional and 74 winter). The highest probability of exposure was predicted at Rankin Bank during winter conditions (99%). The quickest time for entrained hydrocarbons at the low threshold to reach an RSB receptor was predicted at Madeleine Shoals (4 days during transitional conditions).

Entrained hydrocarbons at the low threshold were predicted to cross into WA State Waters during every season with probabilities ranging from 81-94%. The minimum time before oil crossed the WA State Waters boundary was 2.71 days, for a spill commencing during transitional conditions.

Table 9.8 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer unless specified otherwise. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	65	23	29.0	29.2	928.0
	Argo-Rowley Terrace	83	66	7.5	7.5	15871.0
	Ashmore Reef	10	3	64.2	74.9	234.0
	Carnarvon Canyon	78	38	21.6	22.5	2662.0
	Cartier Island	7	-	77.1	-	45.0
	Dampier	22	18	11.4	11.4	7944.0
	Eighty Mile Beach	48	37	7.4	7.4	5279.0
	Gascoyne	93	81	13.9	14.0	7247.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Geographe	11	1	64.3	65.6	120.0
	Jurien	16	3	42.0	42.0	174.0
	Kimberley	44	30	17.0	17.1	5693.0
	Mermaid Reef	50	36	13.4	13.4	3557.0
	Montebello	95	85	12.1	12.1	10823.0
	Ningaloo	89	50	13.7	14.9	5215.0
	Oceanic Shoals	3	-	90.5	-	59.0
	Perth Canyon	21	8	51.8	52.6	478.0
	Roebuck	28	14	43.4	43.5	1340.0
	Shark Bay	70	28	20.6	20.8	1020.0
	South-west Corner	16	3	57.7	62.3	158.0
	Two Rocks	13	1	57.0	90.1	104.0
EEZ	Christmas Island Exclusive Economic Zone	8	-	69.1	-	66.0
EEZ	Cocos Islands Exclusive Economic Zone	4	-	101.2	-	30.0
EEZ	Indonesian Exclusive Economic Zone	30	9	21.8	22.0	1705.0
EEZ	East Timorian Exclusive Economic Zone	2	-	100.0	-	29.0
EEZ	Oecussi Ambeno Exclusive Economic Zone	2	-	95.8	-	28.0
IBRA	Cape Range	73	31	12.2	12.4	8469.0
IBRA	Chichester	15	12	11.5	11.6	1782.0
IBRA	Christmas Island	-	-	-	-	3.0
IBRA	Cocos Islands	-	-	-	-	-
IBRA	Edel	17	11	28.5	30.1	378.0
IBRA	Fitzroy Trough	10	3	64.6	79.2	134.0
IBRA	Geraldton Hills	15	2	39.6	41.8	155.0
IBRA	Lesueur Sandplain	12	-	42.1	-	51.0
IBRA	Mitchell	19	11	47.1	51.7	534.0
IBRA	Perth	13	6	42.0	42.9	182.0
IBRA	Pindanland	29	16	13.1	13.4	4037.0
IBRA	Roebourne	42	32	11.5	11.5	9339.0
IBRA	Southern Jarrah Forest	10	1	65.3	68.8	117.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Timor Sea Coral Islands	12	3	64.2	74.9	289.0
	Warren	10	1	65.9	66.8	122.0
	Wooramel	11	-	42.0	-	53.0
IMCRA	Abrolhos Islands	18	5	32.8	38.6	253.0
	Bonaparte Gulf	1	-	97.5	-	15.0
	Canning	37	22	14.2	25.7	2551.0
	Central West Coast	31	6	29.9	30.3	389.0
	Eighty Mile Beach	34	22	7.4	7.4	4716.0
	Kimberley	22	12	41.8	44.5	959.0
	King Sound	13	6	57.2	59.4	208.0
	Leeuwin-Naturaliste	16	8	55.6	56.0	308.0
	Ningaloo	92	55	13.7	14.1	7750.0
	Oceanic Shoals	12	2	70.1	87.0	235.0
	Pilbara (nearshore)	53	15	11.4	11.5	9339.0
	Pilbara (offshore)	96	89	2.8	2.8	25125.0
	Shark Bay	14	11	28.7	29.1	363.0
	WA South Coast	10	-	72.0	-	56.0
	Zuytdorp	73	29	19.5	19.7	1475.0
KEF	Ancient coastline at 125 m depth contour (115-135m)	5	-	0.6	-	31.0
	Carbonate bank and terrace system of the Sahul Shelf (10-200m)	1	-	85.8	-	17.0
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands and surrounding reefs (0- 20m)	89	50	32.0	32.7	5215.0
	Commonwealth marine environment within and adjacent to Geographe Bay (15-45m)	3	-	64.8	-	30.0
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons (0-40m)	14	6	42.2	66.0	228.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Commonwealth waters adjacent to Ningaloo Reef (30-700m)	78	30	13.7	14.9	1738.0
	Glomar Shoals (35-80m)	12	3	7.6	11.3	226.0
	Western rock lobster (0-230m)	23	8	33.1	41.1	363.0
MNR	Hamelin Pool	-	-	-	-	-
MP	Barrow Island	59	24	15.9	23.1	781.0
	Eighty Mile Beach	24	16	13.0	13.1	5045.0
	Jurien Bay	15	6	42.0	42.1	186.0
	Lalang-garram / Camden Sound	18	8	57.7	62.6	605.0
	Lalang-garram / Horizontal Falls	13	2	64.8	74.2	196.0
	Marmion	7	-	66.5	-	42.0
	Montebello Islands	66	25	12.2	12.3	3591.0
	Ngari Capes	11	1	64.8	66.7	137.0
	Ningaloo	81	38	13.8	15.5	2073.0
	North Kimberley	7	2	65.1	77.8	172.0
	North Lalang-garram	9	3	59.7	73.3	203.0
	Rowley Shoals	68	57	8.9	9.8	10088.0
	Shark Bay	12	1	29.6	79.1	103.0
	Shoalwater Islands	8	-	66.0	-	88.0
	Yawuru Nagulagun / Roebuck Bay	28	10	43.5	43.8	695.0
NP	Pulu Keeling	-	-	-	-	-
NR	Beagle Islands	10	-	68.3	-	23.0
	Great Sandy Island	20	13	15.6	15.7	860.0
	Scott Reef	16	1	55.6	112.3	105.0
	Thevenard Island	30	12	15.6	15.6	793.0
Ramsar	Ashmore Reef National Nature Reserve	10	3	64.2	74.9	234.0
	Eighty-mile Beach	23	16	14.2	14.3	3157.0
	Peel-Yalgorup System	8	6	66.0	67.5	149.0
	Pulu Keeling National Park	-	-	-	-	-
	Roebuck Bay	26	7	43.5	58.8	631.0
	The Dales	-	-	-	-	0.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
RSB	Albert Reef	16	10	47.0	68.8	449.0
	Ashworth Shoal	12	-	23.5	-	71.0
	Assail Bank	9	1	41.9	113.9	103.0
	Baldwin Bank	2	-	88.0	-	25.0
	Barcoo Shoal	17	11	45.1	49.0	381.0
	Barracouta Shoal	3	-	98.6	-	23.0
	Barrow Island Reefs and Shoals	21	12	15.5	15.7	1039.0
	Barton Shoal	1	-	95.0	-	15.0
	Bassett-Smith Shoal	3	-	82.0	-	37.0
	Baylis Patches	16	-	17.8	-	98.0
	Beagle and Dingo Reefs	13	6	50.6	53.7	224.0
	Bennett Shoal	7	-	66.1	-	30.0
	Big Bank Shoals	1	-	113.5	-	21.0
	Branch Banks	2	-	93.3	-	19.0
	Brewis Reef	32	11	17.4	42.3	308.0
	Brue Reef	18	10	44.4	49.6	528.0
	Campbell Shoal	8	-	67.1	-	28.0
	Churchill Reef	16	9	48.1	52.1	278.0
	Clerke Reef	57	45	12.0	21.9	4303.0
	Clio Bank	15	-	44.7	-	46.0
	Cockell and Nicolle Reefs	13	4	63.0	71.2	403.0
	Courtenay Shoal	16	13	11.7	35.4	473.0
	Dailey Shoal	54	11	16.7	41.2	192.0
	Dart Shoal	10	-	42.2	-	92.0
	Dillon Shoal	1	-	97.9	-	21.0
	Direction Bank	15	1	42.4	92.2	103.0
	East Holothuria Reef	3	-	87.3	-	38.0
	Echuca Shoal	13	2	70.1	87.3	165.0
	Eliassen Rocks	14	1	21.5	49.2	100.0
	Eugene McDermott Shoal	2	-	92.3	-	56.0
	Exmouth Reef	21	-	42.3	-	86.0
	Fairway Reef	26	1	29.7	76.0	109.0
	Fantome Shoal	3	-	89.2	-	29.0

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Fantome Shoal	12	-	42.3	-	70.0
Fortescue Reef	15	6	22.0	48.9	141.0
Gale Bank	1	-	98.2	-	13.0
Gee Bank	12	1	41.9	83.5	108.0
Geelvink Channel Shoals	11	1	41.9	66.7	104.0
Glomar Shoal	7	-	11.3	-	77.0
Goeree Shoal	4	-	92.6	-	52.0
Hammersley Shoal	16	13	11.8	14.3	408.0
Hayman Rock	19	1	17.0	94.1	106.0
Hayward Rock	10	-	42.8	-	52.0
Herald Reef	14	8	18.8	42.0	815.0
Heritage Reef	4	-	79.6	-	38.0
Heywood Shoal	5	1	81.6	91.0	226.0
Holothuria Banks	4	-	79.1	-	84.0
Hood Reef	42	9	16.2	40.0	176.0
Imperieuse Reef	67	55	9.9	10.9	10088.0
Ingram Reef	5	-	79.0	-	60.0
Jabiru Shoals	2	-	95.9	-	20.0
Jamieson Reef	5	-	78.1	-	74.0
Johnson Bank	9	-	66.9	-	96.0
Karmt Shoal	2	-	98.6	-	32.0
Lightfoot Reef	18	9	15.6	49.1	230.0
Little Shoals	16	11	15.6	41.9	487.0
Locker Reef	20	3	16.8	91.8	132.0
Long Reef	4	-	90.8	-	32.0
Madeleine Shoals	20	15	12.7	15.5	1160.0
Mangola Shoal	2	-	96.2	-	14.0
Manicom Bank	16	5	42.2	69.2	142.0
Mavis Reef	16	8	50.3	69.3	255.0
McLennan Bank	18	13	14.3	15.5	671.0
Meda Reef	14	12	16.0	31.6	354.0
Mermaid Reef	47	36	13.5	20.8	3078.0
Mid Reef	11	-	42.0	-	80.0
Montebello Shoals	56	19	12.3	12.4	2114.0
Moresby Shoals	17	8	19.9	42.0	582.0

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Ningaloo Reef	74	29	15.5	17.9	763.0
North Tail Reef	13	1	42.0	67.9	109.0
O'Grady Shoal	15	11	14.3	19.8	519.0
Oliver Rock	3	-	82.7	-	33.0
Otway Bank	3	-	92.9	-	35.0
Pee Shoal	2	-	94.2	-	19.0
Pelsaert Bank	15	-	54.5	-	76.0
Penguin Shoal	2	-	85.0	-	40.0
Poivre Reef	41	19	15.5	15.6	1608.0
Rainbow Shoals	9	2	65.8	73.7	195.0
Rankin Bank	97	90	12.8	12.9	10233.0
Ripple Shoals	23	12	15.5	15.5	1070.0
Robroy Reefs	5	-	68.7	-	92.0
Rosily Shoals	50	16	15.7	15.8	604.0
Rothery Reef	2	-	92.8	-	30.0
Sand Knoll Ledge	13	4	42.0	43.6	167.0
Snapper Bank	11	-	42.0	-	79.0
Southwest Patch	15	8	42.3	43.3	246.0
Spider Reef	23	-	37.7	-	73.0
Stewart Shoal	6	-	66.3	-	37.0
Taunton Reef	19	12	15.6	16.3	528.0
Tongue Shoals	17	8	42.2	43.5	195.0
Trap Reef	31	12	15.6	16.3	547.0
Tryal Rocks	79	30	13.9	13.9	6144.0
Turtle Dove Shoal	16	-	42.2	-	82.0
Van Cloon Shoal	2	-	97.1	-	27.0
Vee Shoal	2	-	88.0	-	62.0
Vulcan Shoal	3	-	92.6	-	49.0
Wapet Shoal	5	-	66.4	-	39.0
Ward Reef	16	8	25.9	42.1	563.0
Web Reef	18	-	43.0	-	93.0
West Holothuria Reef	4	-	79.2	-	45.0
West Reef	16	9	16.7	42.0	214.0
Wildcat Reefs	10	3	63.5	72.6	344.0
Woodbine Bank	7	-	76.3	-	55.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Nearshore	Adele Island	15	11	47.1	51.1	276.0
	Airlie Island	27	12	15.6	15.6	847.0
	Angel Island	14	13	11.8	18.9	337.0
	Ashburton	16	8	26.3	42.0	679.0
	Ashburton Island	17	8	26.3	42.3	428.0
	Ashmore Reef	10	3	64.2	74.9	205.0
	Aususta - Margaret River	10	1	66.0	108.5	112.0
	Barrow Island	52	24	15.5	15.5	8469.0
	Bedout Island	37	33	17.7	20.2	2008.0
	Bermier Island	15	-	30.8	-	69.0
	Bessieres Island	53	13	15.7	15.7	230.0
	Bezout Island	15	12	11.5	11.7	625.0
	Boodie Island	39	17	15.5	15.5	3115.0
	Broome	27	16	14.3	31.0	2074.0
	Browse Island	11	2	68.3	84.3	289.0
	Bunbury	7	-	70.9	-	43.0
	Busselton	10	1	65.3	66.8	122.0
	Cape Bruguieres	16	13	11.6	14.0	338.0
	Capel	8	-	71.0	-	59.0
	Carnac Island	8	-	70.1	-	47.0
	Carnamah	10	-	42.2	-	32.0
	Carnarvon	10	-	53.4	-	46.0
	Cartier Island	7	-	80.1	-	38.0
	Chapman Valley	1	-	110.9	-	18.0
	Clerke Reef	57	45	21.4	22.0	4326.0
	Cockburn	4	-	85.4	-	31.0
	Cohen Island	16	13	11.6	14.3	408.0
	Conzinc Island	13	5	20.0	36.1	147.0
	Coorow	12	-	42.1	-	51.0
	Cunningham Island	67	52	11.0	11.8	8819.0
	Dandaragan	14	6	42.0	42.9	145.0
	Delambre Island	15	12	11.5	11.5	623.0
	Derby - West Kimberely	19	7	47.6	57.3	534.0
	Direction Island	18	12	15.6	25.0	1465.0

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Dirk Hartog Island	17	11	28.4	30.6	339.0
Dolphin Island	15	10	11.6	12.8	395.0
Dorre Island	15	11	28.8	30.1	378.0
Eaglehawk Island	14	8	32.3	42.5	208.0
East Lewis Island	13	-	40.2	-	83.0
East Pilbara	17	14	13.1	13.4	4037.0
Easter Group	13	2	39.9	68.5	137.0
Enderby Island	15	8	30.4	44.0	149.0
Exmouth	73	26	15.5	17.8	545.0
Faure Island	-	-	-	-	-
Flat Island	60	15	15.7	15.8	417.0
Fly Island	17	-	42.1	-	79.0
Fremantle	5	-	84.6	-	26.0
Garden Island	8	-	66.0	-	62.0
Gidley Island	15	13	11.6	15.2	426.0
Gingin	12	1	43.4	44.6	112.0
Goodwyn Island	15	1	30.2	62.5	114.0
Greater Geraldton	3	-	77.2	-	28.0
Harvey	7	-	73.5	-	39.0
Haury Island	15	9	11.5	11.5	852.0
Hermite Island	58	20	12.2	12.4	2533.0
Hibernia Reef	5	-	75.8	-	52.0
Imperieuse Reef	67	53	11.0	11.9	8903.0
Irwin	3	-	69.5	-	28.0
Joondalup	6	-	67.3	-	33.0
Karratha	15	12	11.5	11.6	1782.0
Keast Island	16	15	11.6	12.7	530.0
Kendrew Island	17	12	18.3	35.4	200.0
King Leopold Ranges	8	2	70.0	85.1	258.0
Kingfisher Islands	10	1	68.0	99.6	134.0
Kwinana	7	-	66.9	-	44.0
Lacepede Islands	29	14	44.8	45.2	1152.0
Legendre Island	18	15	11.5	11.5	852.0
Little Turtle Islet	16	1	31.5	38.9	149.0
Locker Island	16	1	20.5	103.5	109.0

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Lowendal Island	32	15	15.5	15.5	930.0
Malus Island	16	9	16.6	35.4	359.0
Mandurah	8	6	66.0	66.2	182.0
Mangrove Islands	13	6	24.4	66.1	176.0
Manjimup	9	-	67.6	-	55.0
Marv Island	10	2	72.5	79.2	134.0
Mary Anne Group	17	12	15.6	17.0	265.0
Mermaid Reef	44	34	20.7	21.3	1691.0
Middle Island	42	17	15.5	15.5	2915.0
Murion Islands	73	31	14.1	16.8	734.0
Nannup	6	-	67.6	-	45.0
North Island	11	2	40.3	75.1	155.0
North Turtle Island	22	13	15.7	30.4	4420.0
Northhampton	7	-	42.3	-	52.0
Observation Island	29	1	28.6	96.3	101.0
Passage Islands	16	13	14.1	14.5	796.0
Peak Island	71	26	15.8	16.0	488.0
Pelican Island	-	-	-	-	-
Pelsaert Group	15	1	40.3	96.9	114.0
Port Hedland	17	15	11.6	11.6	9339.0
Ragnard Islands	15	3	21.8	39.0	146.0
Rivoli Islands	16	3	42.2	43.5	119.0
Rockingham	8	-	66.0	-	80.0
Rosemary Island	17	12	14.1	26.0	574.0
Rottnest Island	12	-	59.7	-	92.0
Round Island	43	11	15.8	16.4	214.0
Sandy Islet	19	6	49.9	66.3	196.0
Scott Reef North	21	4	49.5	75.2	170.0
Scott Reef South	19	8	47.8	57.8	215.0
Seringapatam Reef	16	-	51.1	-	73.0
Serrurier Island	55	13	15.7	15.7	291.0
Shark Bay	14	-	42.0	-	53.0
Stirling	3	-	91.0	-	37.0
Sunday Island	60	13	16.9	17.8	379.0
Table Island	40	10	15.8	16.0	235.0

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Thevenard Island	30	12	15.6	15.6	838.0
	Tortoise Island	21	8	25.0	42.2	300.0
	Twin Island	16	9	19.0	42.0	1005.0
	Wallabi Group	12	2	39.6	42.0	146.0
	Wanneroo	6	-	72.3	-	44.0
	Waroona	8	-	66.2	-	90.0
	West Lewis Island	15	7	35.5	36.1	159.0
	Whalebone Island	4	-	66.0	-	18.0
	Wyndham - East Kimberley	10	2	64.1	72.7	380.0
	Indonesia	5	-	63.4	-	90.0
	Timor-Leste	1	-	116.7	-	10.0
State Waters	Western Australia State Waters	81	57	8.9	9.8	10088.0

Table 9.9 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	48	11	26.5	27.1	551
	Argo-Rowley Terrace	97	88	8.5	9.2	9,076
	Ashmore Reef	6	-	95.8	-	32
	Carnarvon Canyon	55	25	26.3	26.4	808
	Cartier Island	6	-	97.5	-	34
	Dampier	32	14	2.7	2.7	505
	Eighty Mile Beach	14	8	12.0	12.5	1,674
	Gascoyne	90	67	15.1	15.6	4,483
	Geographe	13	-	79.6	-	50
	Jurien	16	-	61.8	-	95
	Kimberley	42	39	3.7	3.9	4,091
	Mermaid Reef	59	48	8.7	9.5	6,204
	Montebello	94	75	4.1	4.1	5,592
	Ningaloo	79	37	14.9	23.4	776
	Oceanic Shoals	1	-	116.8	-	12
	Perth Canyon	18	-	62.2	-	96
	Roebuck	4	1	99.4	117.9	101
	Shark Bay	53	8	35.8	38.1	1,067
	South-west Corner	16	1	70.0	85.6	114
	Two Rocks	14	-	57.5	-	83
EEZ	Christmas Island Exclusive Economic Zone	9	-	71.5	-	72
	Cocos Islands Exclusive Economic Zone	1	-	103.0	-	20
	Indonesian Exclusive Economic Zone	38	16	31.9	33.5	644
	East Timorian Exclusive Economic Zone	1	-	114.0	-	17
	Oecussi Ambeno Exclusive Economic Zone	1	-	109.9	-	13
IBRA	Cape Range	71	21	7.6	8.9	745

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Chichester	5	2	2.9	2.9	1,683
	Christmas Island	-	-	-	-	3
	Cocos Islands	-	-	-	-	-
	Edel	7	-	57.8	-	53
	Fitzroy Trough	6	-	96.7	-	50
	Geraldton Hills	15	2	56.8	63.6	161
	Lesueur Sandplain	7	-	66.3	-	58
	Mitchell	15	10	81.0	87.8	657
	Perth	14	-	63.8	-	73
	Pindanland	25	15	58.3	60.2	960
	Roebourne	39	12	2.8	2.8	1,313
	Southern Jarrah Forest	12	-	73.6	-	43
	Timor Sea Coral Islands	10	-	73.7	-	32
	Warren	14	-	73.3	-	91
	Wooramel	-	-	94.0	-	5
IMCRA	Abrolhos Islands	18	3	55.3	56.8	280
	Bonaparte Gulf	-	-	-	-	-
	Canning	31	24	50.3	51.9	2,153
	Central West Coast	19	4	49.8	52.8	423
	Eighty Mile Beach	13	2	79.0	93.0	575
	Kimberley	22	12	71.7	83.5	1,209
	King Sound	12	3	83.1	92.5	187
	Leeuwin-Naturaliste	16	1	62.3	88.4	110
	Ningaloo	85	53	14.2	14.5	1,317
	Oceanic Shoals	9	-	94.2	-	45
	Pilbara (nearshore)	43	10	2.7	2.8	3,154
	Pilbara (offshore)	95	89	2.5	2.5	15,306
	Shark Bay	3	-	62.0	-	45
	WA South Coast	14	-	75.0	-	56
	Zuytdorp	53	15	26.5	37.6	1,067
KEF	Ancient coastline at 125 m depth contour	8	-	1.0	-	29
	Carbonate bank and terrace system of the Sahul Shelf	-	-	-	-	-

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	79	37	55.6	56.8	776
	Commonwealth marine environment within and adjacent to Geographe Bay	3	-	79.6	-	19
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons	14	-	64.7	-	98
	Commonwealth waters adjacent to Ningaloo Reef	70	8	14.9	23.4	259
	Glomar Shoals	22	4	3.8	3.8	216
	Western rock lobster	18	4	50.0	53.3	423
MNR	Hamelin Pool	-	-	-	-	-
MP	Barrow Island	60	17	13.8	15.4	582
	Eighty Mile Beach	1	-	114.6	-	11
	Jurien Bay	14	-	65.4	-	89
	Lalang-garram / Camden Sound	13	6	86.7	89.3	522
	Lalang-garram / Horizontal Falls	6	1	92.4	108.6	137
	Marmion	12	-	78.3	-	41
	Montebello Islands	71	31	6.8	7.5	1,710
	Ngari Capes	14	1	72.0	90.1	100
	Ningaloo	71	13	24.8	25.8	360
	North Kimberley	6	5	96.8	98.5	329
	North Lalang-garram	6	6	93.5	96.3	452
	Rowley Shoals	81	55	11.0	11.3	7,567
	Shark Bay	2	-	102.2	-	15
	Shoalwater Islands	13	-	75.0	-	92
	Yawuru Nagulagun / Roebuck Bay	2	1	108.5	117.9	107
NP	Pulu Keeling	-	-	-	-	-
NR	Beagle Islands	10	-	66.9	-	30
	Great Sandy Island	13	2	23.8	24.3	182

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Scott Reef	20	-	76.8	-	31
	Thevenard Island	34	-	36.5	-	97
Ramsar	Ashmore Reef National Nature Reserve	6	-	95.8	-	32
	Eighty-mile Beach	-	-	-	-	2
	Peel-Yalgorup System	11	-	67.5	-	65
	Pulu Keeling National Park	-	-	-	-	-
	Roebuck Bay	2	-	110.0	-	39
	The Dales	-	-	-	-	-
RSB	Albert Reef	11	7	86.7	88.7	898
	Ashworth Shoal	3	-	24.2	-	37
	Assail Bank	6	2	57.7	64.4	113
	Baldwin Bank	-	-	-	-	3
	Barcoo Shoal	18	8	86.9	87.4	682
	Barracouta Shoal	2	-	104.1	-	23
	Barrow Island Reefs and Shoals	13	1	24.0	32.6	179
	Barton Shoal	-	-	-	-	6
	Bassett-Smith Shoal	-	-	-	-	6
	Baylis Patches	6	-	60.4	-	43
	Beagle and Dingo Reefs	9	6	89.0	90.1	701
	Bennett Shoal	-	-	-	-	8
	Big Bank Shoals	-	-	-	-	-
	Branch Banks	-	-	-	-	-
	Brewis Reef	28	-	37.3	-	40
	Brue Reef	18	9	82.3	86.8	1,091
	Campbell Shoal	-	-	-	-	6
	Churchill Reef	10	7	88.1	88.9	650
	Clerke Reef	62	41	11.3	11.9	6,845
	Clio Bank	11	-	61.0	-	56
	Cockell and Nicolle Reefs	6	6	93.3	102.2	368
	Courtenay Shoal	8	2	17.7	23.6	698
	Dailey Shoal	45	-	26.7	-	65
	Dart Shoal	12	-	61.9	-	84

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Dillon Shoal	-	-	-	-	1
Direction Bank	14	-	57.9	-	85
East Holothuria Reef	-	-	-	-	3
Echuca Shoal	8	-	102.8	-	21
Eliassen Rocks	2	-	24.3	-	49
Eugene McDermott Shoal	4	-	106.2	-	24
Exmouth Reef	10	-	58.1	-	36
Fairway Reef	18	-	59.1	-	44
Fantome Shoal	1	-	117.2	-	12
Fantome Shoal	14	-	62.4	-	67
Fortescue Reef	3	-	24.0	-	95
Gale Bank	-	-	-	-	5
Gee Bank	14	1	61.5	72.1	104
Geelvink Channel Shoals	9	-	65.5	-	68
Glomar Shoal	22	2	3.8	3.8	185
Goeree Shoal	1	-	101.8	-	14
Hammersley Shoal	15	5	5.3	8.5	285
Hayman Rock	6	-	60.6	-	41
Hayward Rock	-	-	-	-	6
Herald Reef	6	-	38.1	-	38
Heritage Reef	3	2	105.5	115.8	109
Heywood Shoal	8	-	95.5	-	30
Holothuria Banks	1	-	116.0	-	14
Hood Reef	30	-	41.5	-	48
Imperieuse Reef	81	53	13.8	14.0	6,406
Ingram Reef	2	-	108.4	-	71
Jabiru Shoals	1	-	115.8	-	10
Jamieson Reef	2	-	108.8	-	76
Johnson Bank	5	-	101.1	-	23
Karmt Shoal	-	-	-	-	1
Lightfoot Reef	7	-	33.6	-	56
Little Shoals	7	-	37.5	-	39
Locker Reef	9	-	59.8	-	61
Long Reef	2	-	114.8	-	35

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Madeleine Shoals	18	5	4.0	8.0	296
Mangola Shoal	-	-	-	-	9
Manicom Bank	4	-	80.1	-	45
Mavis Reef	9	6	88.1	89.7	814
McLennan Bank	5	-	25.1	-	56
Meda Reef	3	-	27.0	-	55
Mermaid Reef	56	46	9.5	9.8	4,740
Mid Reef	9	-	65.5	-	44
Montebello Shoals	63	20	9.5	9.9	536
Moresby Shoals	6	-	38.5	-	26
Ningaloo Reef	58	7	26.1	27.9	227
North Tail Reef	11	-	66.6	-	49
O'Grady Shoal	2	-	24.1	-	98
Oliver Rock	2	-	112.0	-	46
Otway Bank	-	-	-	-	1
Pee Shoal	-	-	-	-	9
Pelsaert Bank	16	1	59.3	67.7	101
Penguin Shoal	-	-	-	-	7
Poivre Reef	45	13	25.0	47.6	326
Rainbow Shoals	6	6	95.3	101.3	183
Rankin Bank	94	84	6.4	6.8	5,576
Ripple Shoals	18	-	31.2	-	93
Robroy Reefs	6	3	100.0	104.9	276
Rosily Shoals	55	4	34.8	58.9	246
Rothery Reef	1	-	117.5	-	14
Sand Knoll Ledge	13	-	65.8	-	49
Snapper Bank	11	-	64.9	-	72
Southwest Patch	5	-	60.1	-	46
Spider Reef	14	-	58.8	-	43
Stewart Shoal	-	-	-	-	4
Taunton Reef	17	-	34.7	-	66
Tongue Shoals	5	-	60.4	-	45
Trap Reef	36	-	34.8	-	84
Tryal Rocks	79	35	10.1	10.5	1,235
Turtle Dove Shoal	16	-	59.1	-	92

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Van Cloon Shoal	-	-	-	-	4
	Vee Shoal	2	-	114.8	-	14
	Vulcan Shoal	2	-	101.9	-	16
	Wapet Shoal	-	-	-	-	3
	Ward Reef	5	-	46.4	-	28
	Web Reef	9	-	60.5	-	39
	West Holothuria Reef	-	-	-	-	4
	West Reef	6	-	36.1	-	33
	Wildcat Reefs	6	6	92.8	94.9	303
	Woodbine Bank	5	-	102.3	-	28
Nearshore	Adele Island	11	7	87.9	88.5	625
	Airlie Island	26	1	34.4	37.5	149
	Angel Island	9	2	10.4	23.7	409
	Ashburton	5	-	44.5	-	55
	Ashburton Island	6	-	49.0	-	58
	Ashmore Reef	6	-	95.8	-	32
	Aususta - Margaret River	13	-	73.8	-	91
	Barrow Island	46	15	14.8	17.4	504
	Bedout Island	6	3	17.9	23.8	199
	Bermier Island	3	-	58.5	-	40
	Bessieres Island	56	2	37.5	59.9	147
	Bezout Island	5	1	2.9	2.9	611
	Boodie Island	36	10	24.8	48.1	383
	Broome	17	11	77.3	84.8	461
	Browse Island	9	-	73.7	-	27
	Bunbury	10	-	80.4	-	33
	Busselton	14	-	73.3	-	50
	Cape Bruguieres	13	4	4.0	13.4	345
	Capel	10	-	86.0	-	39
	Carnac Island	12	-	73.9	-	48
	Carnamah	6	-	67.7	-	26
	Carnarvon	5	-	71.7	-	28
	Cartier Island	5	-	98.3	-	26
	Chapman Valley	7	-	83.9	-	33

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Clerke Reef	62	42	11.2	11.8	5,851
Cockburn	11	-	82.0	-	37
Cohen Island	15	6	4.0	7.3	309
Conzinc Island	3	2	12.9	24.3	163
Coorow	7	-	66.3	-	51
Cunningham Island	73	47	13.8	14.0	2,656
Dandaragan	13	-	65.7	-	62
Delambre Island	15	2	2.8	2.8	469
Derby - West Kimberely	15	10	81.0	87.8	511
Direction Island	5	-	38.6	-	49
Dirk Hartog Island	7	-	57.8	-	27
Dolphin Island	11	4	3.5	4.4	347
Dorre Island	3	-	61.0	-	53
Eaglehawk Island	2	-	27.2	-	25
East Lewis Island	2	-	31.4	-	65
East Pilbara	-	-	-	-	2
Easter Group	15	2	58.7	69.9	143
Enderby Island	5	-	27.2	-	42
Exmouth	58	6	25.9	26.8	263
Faure Island	-	-	-	-	-
Flat Island	60	-	26.7	-	68
Fly Island	8	-	60.7	-	51
Fremantle	11	-	81.9	-	37
Garden Island	13	-	74.3	-	63
Gidley Island	10	4	4.0	23.7	495
Gingin	13	-	75.0	-	70
Goodwyn Island	9	-	23.8	-	93
Greater Geraldton	7	-	82.6	-	37
Harvey	10	-	80.7	-	42
Haury Island	13	3	3.0	3.1	468
Hermite Island	64	21	7.6	8.9	745
Hibernia Reef	4	-	106.5	-	27
Imperieuse Reef	79	50	13.9	14.0	3,776
Irwin	7	-	87.8	-	58
Joondalup	12	-	81.6	-	35

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Karratha	4	2	2.9	2.9	1,683
Keast Island	15	7	4.0	4.0	255
Kendrew Island	14	2	20.6	23.7	254
King Leopold Ranges	6	-	99.1	-	53
Kingfisher Islands	6	-	101.3	-	71
Kwinana	12	-	80.9	-	47
Lacepede Islands	25	15	58.3	60.2	960
Legendre Island	16	8	3.9	3.9	468
Little Turtle Islet	1	-	26.7	-	82
Locker Island	5	-	61.5	-	86
Lowendal Island	28	7	13.9	17.1	197
Malus Island	7	2	21.2	23.6	370
Mandurah	12	-	67.1	-	73
Mangrove Islands	5	-	58.7	-	30
Manjimup	13	-	74.6	-	71
Marv Island	4	-	107.0	-	50
Mary Anne Group	8	-	33.7	-	51
Mermaid Reef	55	46	9.6	10.5	4,740
Middle Island	39	12	17.3	32.2	388
Murion Islands	71	6	26.6	26.6	171
Nannup	11	-	81.2	-	50
North Island	7	2	56.8	63.6	161
North Turtle Island	4	-	23.7	-	63
Northhampton	5	-	87.9	-	24
Observation Island	18	-	53.0	-	52
Passage Islands	7	2	23.7	24.5	213
Peak Island	63	2	26.6	48.0	125
Pelican Island	-	-	-	-	-
Pelsaert Group	15	1	59.8	74.0	104
Port Hedland	2	1	2.8	2.8	1,313
Ragnard Islands	1	-	59.4	-	11
Rivoli Islands	6	-	63.4	-	62
Rockingham	13	-	75.0	-	67
Rosemary Island	14	3	12.3	23.5	729
Rottnest Island	14	-	63.8	-	71

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Round Island	39	-	40.7	-	71
	Sandy Islet	23	6	73.2	75.5	218
	Scott Reef North	22	6	72.3	76.3	202
	Scott Reef South	24	6	68.5	74.9	231
	Seringapatam Reef	17	-	75.6	-	80
	Serrurier Island	56	-	38.2	-	77
	Shark Bay	5	-	80.5	-	21
	Stirling	10	-	82.0	-	32
	Sunday Island	51	-	26.6	-	66
	Table Island	36	-	38.8	-	72
	Thevenard Island	34	-	36.5	-	97
	Tortoise Island	11	-	56.3	-	58
	Twin Island	6	-	38.0	-	36
	Wallabi Group	12	2	57.5	65.0	144
	Wanneroo	13	-	81.2	-	55
	Waroona	12	-	81.9	-	41
	West Lewis Island	5	2	23.7	24.3	230
	Whalebone Island	-	-	-	-	3
	Wyndham - East Kimberley	6	6	93.8	98.4	256
	Indonesia	8	-	85.1	-	60
	Timor-Leste	-	-	-	-	9
State Waters	Western Australia State Waters	81	55	2.7	2.8	7,253

Table 9.10 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	47	7	47.9	53.0	585
	Argo-Rowley Terrace	100	97	11.0	12.1	8,867
	Ashmore Reef	10	-	86.3	-	32
	Carnarvon Canyon	57	14	43.2	47.1	852
	Cartier Island	7	-	83.3	-	29
	Dampier	50	19	15.4	21.5	1,535
	Eighty Mile Beach	48	14	6.2	6.7	3,697
	Gascoyne	95	64	20.0	20.4	6,878
	Geographe	1	-	105.3	-	10
	Jurien	4	-	72.0	-	39
	Kimberley	68	26	33.7	34.5	7,378
	Mermaid Reef	90	67	26.8	29.5	4,924
	Montebello	98	88	16.8	17.0	8,439
	Ningaloo	73	11	30.3	32.8	882
	Oceanic Shoals	-	-	-	-	-
	Perth Canyon	5	-	88.7	-	34
	Roebuck	5	2	81.0	82.4	298
	Shark Bay	39	5	53.8	81.0	3,831
	South-west Corner	3	-	94.6	-	26
	Two Rocks	4	-	79.1	-	37
EEZ	Christmas Island Exclusive Economic Zone	29	6	62.4	81.1	249
	Cocos Islands Exclusive Economic Zone	8	-	88.8	-	80
	Indonesian Exclusive Economic Zone	70	18	42.4	43.7	1,501
	East Timorian Exclusive Economic Zone	1	-	111.5	-	16
	Oecussi Ambeno Exclusive Economic Zone	-	-	-	-	-
IBRA	Cape Range	80	30	20.2	21.1	551

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Chichester	13	2	36.0	61.5	186
	Christmas Island	14	1	77.5	95.0	110
	Cocos Islands	2	-	108.0	-	26
	Edel	6	5	75.2	81.1	2,701
	Fitzroy Trough	2	-	108.6	-	63
	Geraldton Hills	5	-	69.5	-	72
	Lesueur Sandplain	3	-	81.8	-	45
	Mitchell	5	2	92.1	106.4	277
	Perth	2	-	79.9	-	36
	Pindanland	14	5	79.3	81.3	785
	Roebourne	38	13	10.3	11.8	542
	Southern Jarrah Forest	-	-	-	-	6
	Timor Sea Coral Islands	9	-	86.3	-	35
	Warren	-	-	-	-	9
	Wooramel	5	5	82.6	82.7	4,163
IMCRA	Abrolhos Islands	8	-	68.9	-	66
	Bonaparte Gulf	-	-	-	-	-
	Canning	29	10	60.4	81.0	1,721
	Central West Coast	12	-	69.0	-	86
	Eighty Mile Beach	9	-	44.1	-	68
	Kimberley	8	4	83.5	84.6	335
	King Sound	4	-	94.1	-	89
	Leeuwin-Naturaliste	3	-	94.1	-	26
	Ningaloo	83	43	26.0	28.0	525
	Oceanic Shoals	6	-	83.0	-	35
	Pilbara (nearshore)	45	16	19.9	21.9	1,124
	Pilbara (offshore)	98	89	2.2	2.7	22,658
	Shark Bay	5	5	75.2	81.1	4,219
	WA South Coast	1	-	104.9	-	15
	Zuytdorp	43	6	51.5	55.6	4,414
KEF	Ancient coastline at 125 m depth contour	5	-	0.6	-	27
	Carbonate bank and terrace system of the Van Diemen Rise	-	-	-	-	-

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	73	-	68.6	-	882
	Commonwealth marine environment within and adjacent to Geographe Bay	-	-	-	-	-
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons	4	-	79.0	-	86
	Commonwealth waters adjacent to Ningaloo Reef	61	6	30.3	32.8	297
	Glomar Shoals	23	4	8.5	8.8	264
	Western rock lobster	7	-	69.0	-	86
MNR	Hamelin Pool	1	-	117.3	-	23
MP	Barrow Island	66	16	20.0	21.3	511
	Eighty Mile Beach	4	-	69.9	-	36
	Jurien Bay	2	-	79.7	-	17
	Lalang-garram / Camden Sound	2	2	98.5	108.3	285
	Lalang-garram / Horizontal Falls	2	-	109.0	-	96
	Marmion	1	-	80.6	-	27
	Montebello Islands	87	44	22.3	23.0	1,146
	Ngari Capes	1	-	99.9	-	14
	Ningaloo	67	6	32.9	53.6	358
	North Kimberley	2	1	109.0	116.4	125
	North Lalang-garram	2	2	108.5	108.6	235
	Rowley Shoals	94	81	12.0	16.5	7,130
	Shark Bay	5	5	75.2	81.1	4,163
	Shoalwater Islands	-	-	-	-	1
	Yawuru Nagulagun / Roebuck Bay	4	2	82.2	83.6	504
NP	Pulu Keeling	2	-	108.0	-	24
NR	Beagle Islands	2	-	83.0	-	12
	Great Sandy Island	11	6	47.0	61.7	445

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Scott Reef	41	-	60.0	-	84
	Thevenard Island	19	-	37.2	-	87
Ramsar	Ashmore Reef National Nature Reserve	10	-	86.3	-	32
	Eighty-mile Beach	1	-	96.8	-	13
	Peel-Yalgorup System	-	-	-	-	<1
	Pulu Keeling National Park	2	-	108.0	-	24
	Roebuck Bay	4	2	82.2	108.2	645
	The Dales	9	-	88.6	-	35
RSB	Albert Reef	3	-	92.4	-	75
	Ashworth Shoal	4	-	73.2	-	23
	Assail Bank	2	-	85.1	-	15
	Baldwin Bank	-	-	-	-	-
	Barcoo Shoal	4	2	89.4	109.8	131
	Barracouta Shoal	1	-	115.0	-	13
	Barrow Island Reefs and Shoals	11	6	46.6	61.7	445
	Barton Shoal	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	<1
	Baylis Patches	6	-	45.0	-	53
	Beagle and Dingo Reefs	2	2	108.1	108.3	134
	Bennett Shoal	-	-	-	-	8
	Big Bank Shoals	-	-	-	-	-
	Branch Banks	-	-	-	-	-
	Brewis Reef	17	-	41.3	-	41
	Brue Reef	2	-	99.0	-	45
	Campbell Shoal	-	-	-	-	5
	Churchill Reef	4	2	92.6	108.3	309
	Clerke Reef	86	66	25.0	25.5	4,844
	Clio Bank	4	-	75.5	-	30
	Cockell and Nicolle Reefs	2	-	109.0	-	30
	Courtenay Shoal	14	2	25.7	86.4	153
	Dailey Shoal	47	-	38.9	-	64
	Dart Shoal	2	-	73.6	-	12

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Dillon Shoal	-	-	-	-	9
Direction Bank	4	-	77.0	-	18
East Holothuria Reef	-	-	-	-	-
Echuca Shoal	5	-	93.7	-	24
Eliassen Rocks	4	-	69.6	-	65
Eugene McDermott Shoal	1	-	112.4	-	10
Exmouth Reef	6	-	49.3	-	21
Fairway Reef	17	-	40.8	-	50
Fantome Shoal	-	-	-	-	9
Fantome Shoal	3	-	70.5	-	22
Fortescue Reef	5	-	62.1	-	32
Gale Bank	-	-	-	-	-
Gee Bank	3	-	70.7	-	33
Geelvink Channel Shoals	3	-	72.7	-	41
Glomar Shoal	20	2	8.8	8.9	192
Goeree Shoal	1	-	114.8	-	16
Hammersley Shoal	25	9	24.8	25.4	181
Hayman Rock	9	-	44.6	-	32
Hayward Rock	-	-	-	-	9
Herald Reef	2	-	93.3	-	19
Heritage Reef	-	-	-	-	-
Heywood Shoal	4	-	93.7	-	31
Holothuria Banks	-	-	-	-	-
Hood Reef	30	-	39.4	-	63
Imperieuse Reef	94	80	16.8	17.3	5,281
Ingram Reef	-	-	-	-	-
Jabiru Shoals	-	-	-	-	-
Jamieson Reef	-	-	-	-	-
Johnson Bank	6	-	83.0	-	23
Karmt Shoal	1	-	103.5	-	16
Lightfoot Reef	8	-	55.2	-	34
Little Shoals	10	-	45.5	-	92
Locker Reef	13	-	45.0	-	34
Long Reef	-	-	-	-	-

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Madeleine Shoals	33	9	21.8	22.7	719
Mangola Shoal	-	-	-	-	-
Manicom Bank	1	-	109.2	-	46
Mavis Reef	3	1	100.8	113.8	111
McLennan Bank	10	2	49.0	68.2	232
Meda Reef	5	-	61.6	-	52
Mermaid Reef	87	65	29.1	30.3	3,512
Mid Reef	2	-	74.2	-	20
Montebello Shoals	77	31	22.5	24.2	431
Moresby Shoals	3	-	85.4	-	14
Ningaloo Reef	59	4	38.0	54.2	194
North Tail Reef	-	-	-	-	7
O'Grady Shoal	6	-	61.7	-	74
Oliver Rock	-	-	-	-	-
Otway Bank	-	-	-	-	-
Pee Shoal	-	-	-	-	-
Pelsaert Bank	5	-	74.3	-	58
Penguin Shoal	-	-	-	-	-
Poivre Reef	42	8	21.2	22.4	320
Rainbow Shoals	2	1	108.5	115.8	118
Rankin Bank	99	92	15.5	15.7	10,815
Ripple Shoals	13	6	44.5	61.7	401
Robroy Reefs	2	-	110.8	-	26
Rosily Shoals	42	3	29.9	62.1	133
Rothery Reef	-	-	-	-	-
Sand Knoll Ledge	-	-	-	-	9
Snapper Bank	3	-	74.1	-	20
Southwest Patch	1	-	109.8	-	35
Spider Reef	13	-	41.3	-	49
Stewart Shoal	1	-	97.1	-	14
Taunton Reef	16	6	43.0	61.9	292
Tongue Shoals	4	-	47.9	-	35
Trap Reef	28	1	30.6	68.7	113
Tryal Rocks	90	62	22.7	23.3	955
Turtle Dove Shoal	5	-	74.0	-	58

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Van Cloon Shoal	-	-	-	-	-
	Vee Shoal	-	-	-	-	9
	Vulcan Shoal	1	-	114.1	-	13
	Wapet Shoal	1	-	101.0	-	11
	Ward Reef	1	-	112.3	-	19
	Web Reef	10	-	43.0	-	32
	West Holothuria Reef	-	-	-	-	-
	West Reef	8	-	46.6	-	74
	Wildcat Reefs	2	-	108.5	-	69
	Woodbine Bank	2	-	83.0	-	18
Nearshore	Adele Island	4	2	91.8	108.3	193
	Airlie Island	23	7	41.0	53.3	311
	Angel Island	14	1	25.3	31.3	106
	Ashburton	2	-	46.1	-	53
	Ashburton Island	6	-	48.6	-	58
	Ashmore Reef	9	-	86.3	-	32
	Aususta - Margaret River	-	-	-	-	6
	Barrow Island	55	16	20.2	21.1	551
	Bedout Island	18	6	10.3	11.8	541
	Bermier Island	5	4	82.6	82.7	300
	Bessieres Island	58	2	36.3	85.0	153
	Bezout Island	13	2	36.0	61.5	186
	Boodie Island	38	13	21.3	22.1	369
	Broome	11	4	79.5	81.3	744
	Browse Island	8	-	94.5	-	35
	Bunbury	-	-	-	-	-
	Busselton	-	-	-	-	6
	Cape Bruguieres	21	8	23.1	25.6	190
	Capel	-	-	-	-	-
	Carnac Island	-	-	-	-	4
	Carnamah	2	-	84.8	-	20
	Carnarvon	4	3	87.1	88.7	635
	Cartier Island	3	-	92.5	-	17
	Chapman Valley	3	-	85.7	-	22

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Clerke Reef	85	66	25.4	26.0	4,570
Cockburn	-	-	-	-	5
Cohen Island	27	11	22.8	25.4	255
Conzinc Island	12	-	27.0	-	72
Coorow	-	-	-	-	9
Cunningham Island	91	77	18.3	18.9	2,482
Dandaragan	1	-	112.7	-	11
Delambre Island	27	10	22.0	24.5	455
Derby - West Kimberely	5	2	93.1	106.4	136
Direction Island	5	-	63.1	-	28
Dirk Hartog Island	6	5	75.2	81.1	2,701
Dolphin Island	20	4	22.9	26.0	191
Dorre Island	5	5	82.6	82.6	407
Eaglehawk Island	6	-	61.5	-	68
East Lewis Island	9	-	40.4	-	83
East Pilbara	2	-	77.2	-	32
Easter Group	4	-	69.5	-	38
Enderby Island	10	6	30.0	61.5	200
Exmouth	56	5	37.5	54.1	221
Faure Island	2	-	97.6	-	33
Flat Island	58	2	35.0	84.9	168
Fly Island	8	-	43.5	-	42
Fremantle	-	-	-	-	4
Garden Island	-	-	-	-	6
Gidley Island	19	4	23.8	25.8	173
Gingin	1	-	84.8	-	14
Goodwyn Island	16	6	27.1	61.5	264
Greater Geraldton	3	-	82.0	-	34
Harvey	-	-	-	-	-
Haury Island	24	3	22.8	35.4	142
Hermite Island	80	30	23.0	24.4	467
Hibernia Reef	2	-	96.5	-	13
Imperieuse Reef	93	79	17.3	18.3	3,327
Irwin	3	-	81.8	-	45
Joondalup	1	-	80.9	-	23

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Karratha	12	2	26.9	61.3	198
Keast Island	27	10	22.4	24.9	361
Kendrew Island	19	7	26.2	30.0	439
King Leopold Ranges	1	-	116.0	-	36
Kingfisher Islands	1	-	116.0	-	67
Kwinana	-	-	-	-	1
Lacepede Islands	14	5	79.3	82.7	785
Legendre Island	30	11	22.0	23.8	542
Little Turtle Islet	3	-	79.2	-	21
Locker Island	5	-	45.6	-	52
Lowendal Island	32	3	24.5	30.8	175
Malus Island	14	4	26.5	62.4	118
Mandurah	-	-	-	-	1
Mangrove Islands	1	-	111.4	-	15
Manjimup	-	-	-	-	9
Marv Island	1	-	113.8	-	49
Mary Anne Group	10	-	47.0	-	65
Mermaid Reef	86	65	30.7	31.2	3,360
Middle Island	38	13	20.7	22.1	435
Murion Islands	67	1	33.6	42.5	133
Nannup	-	-	-	-	5
North Island	3	-	83.8	-	16
North Turtle Island	7	-	64.3	-	25
Northhampton	5	-	82.6	-	67
Observation Island	18	-	41.5	-	66
Passage Islands	7	2	61.5	65.6	161
Peak Island	68	2	33.7	85.0	155
Pelican Island	2	-	98.6	-	32
Pelsaert Group	4	-	70.1	-	37
Port Hedland	5	2	65.1	75.8	185
Ragnard Islands	6	-	61.5	-	56
Rivoli Islands	3	-	56.0	-	35
Rockingham	-	-	-	-	1
Rosemary Island	18	8	25.7	28.1	324
Rottnest Island	-	-	-	-	9

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before entrained hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Round Island	31	-	37.5	-	70
	Sandy Islet	43	11	54.2	81.3	207
	Scott Reef North	43	10	57.0	81.3	200
	Scott Reef South	48	13	53.5	81.1	210
	Seringapatam Reef	43	-	60.8	-	90
	Serrurier Island	51	1	36.4	85.2	113
	Shark Bay	5	5	81.1	81.1	4,163
	Stirling	-	-	-	-	8
	Sunday Island	52	-	39.5	-	70
	Table Island	35	-	37.4	-	67
	Thevenard Island	20	-	37.2	-	87
	Tortoise Island	9	-	37.3	-	55
	Twin Island	3	-	63.9	-	15
	Wallabi Group	4	-	82.1	-	25
	Wanneroo	2	-	79.9	-	36
	Waroona	-	-	-	-	-
	West Lewis Island	12	2	26.6	62.3	125
	Whalebone Island	-	-	-	-	4
	Wyndham - East Kimberley	2	2	108.4	108.5	277
	Indonesia	4	-	104.2	-	53
	Timor-Leste	-	-	-	-	-
State Waters	Western Australia State Waters	94	81	9.3	10.2	6,609

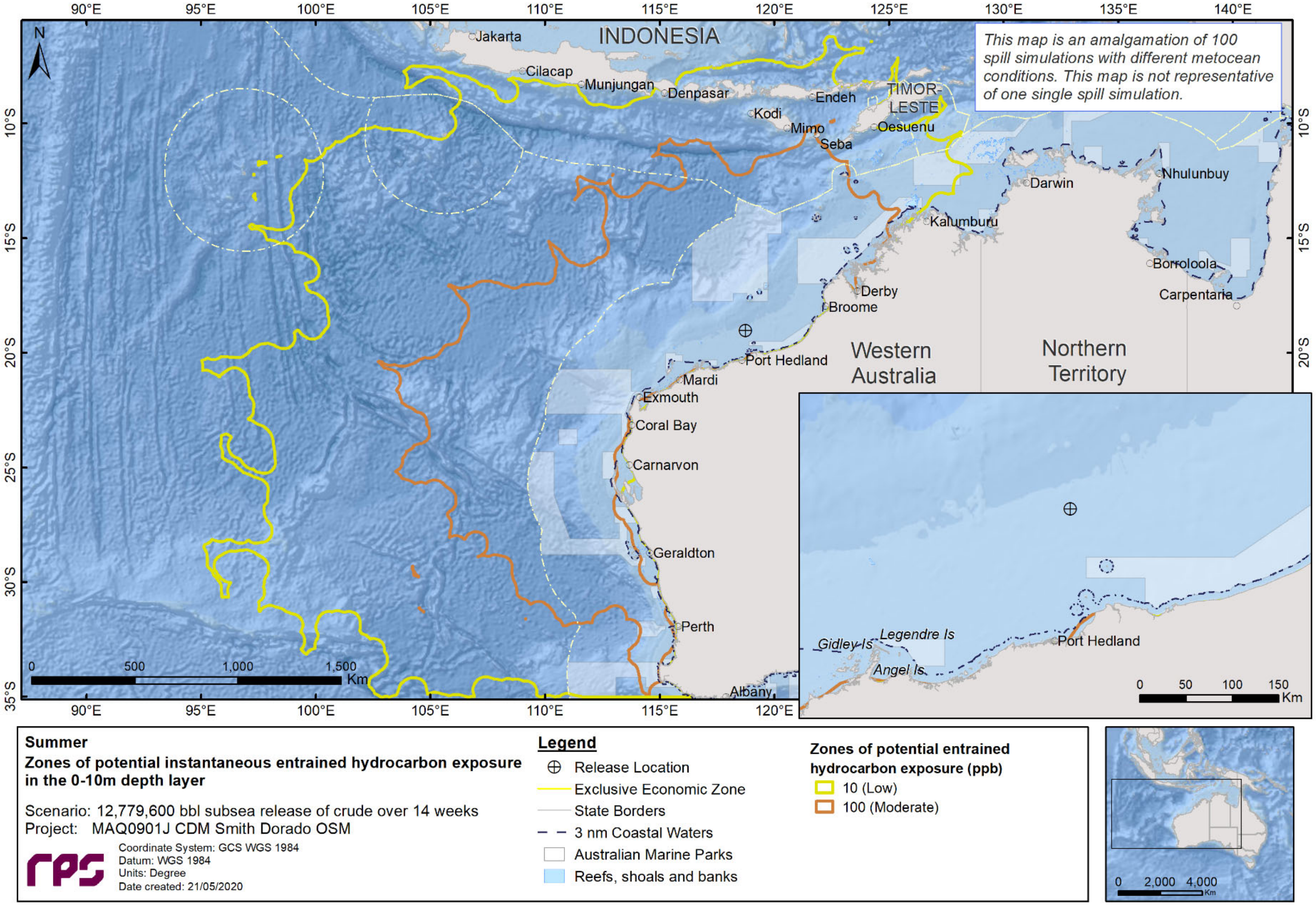


Figure 9.20 Predicted entrained hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

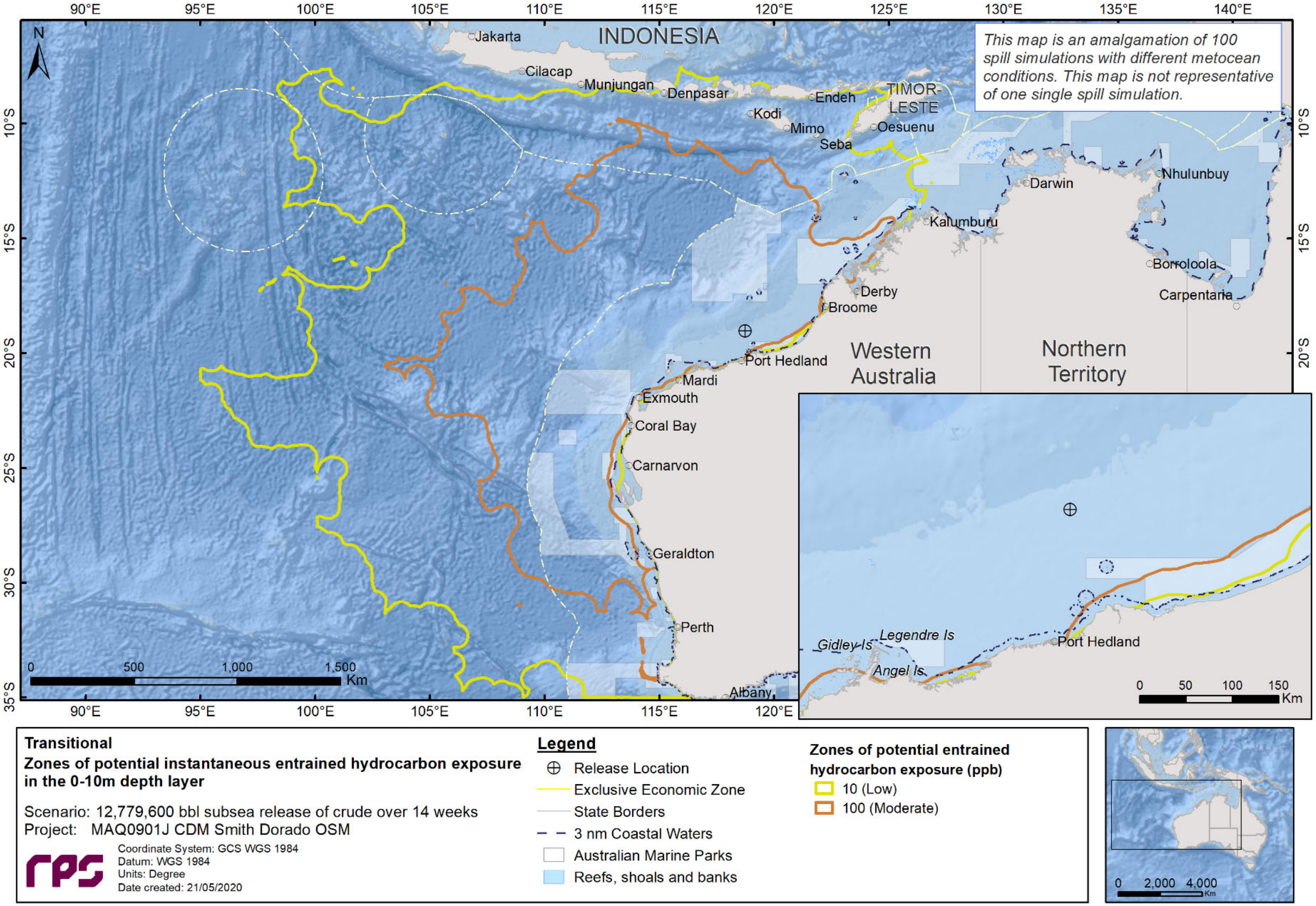


Figure 9.21 Predicted entrained hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

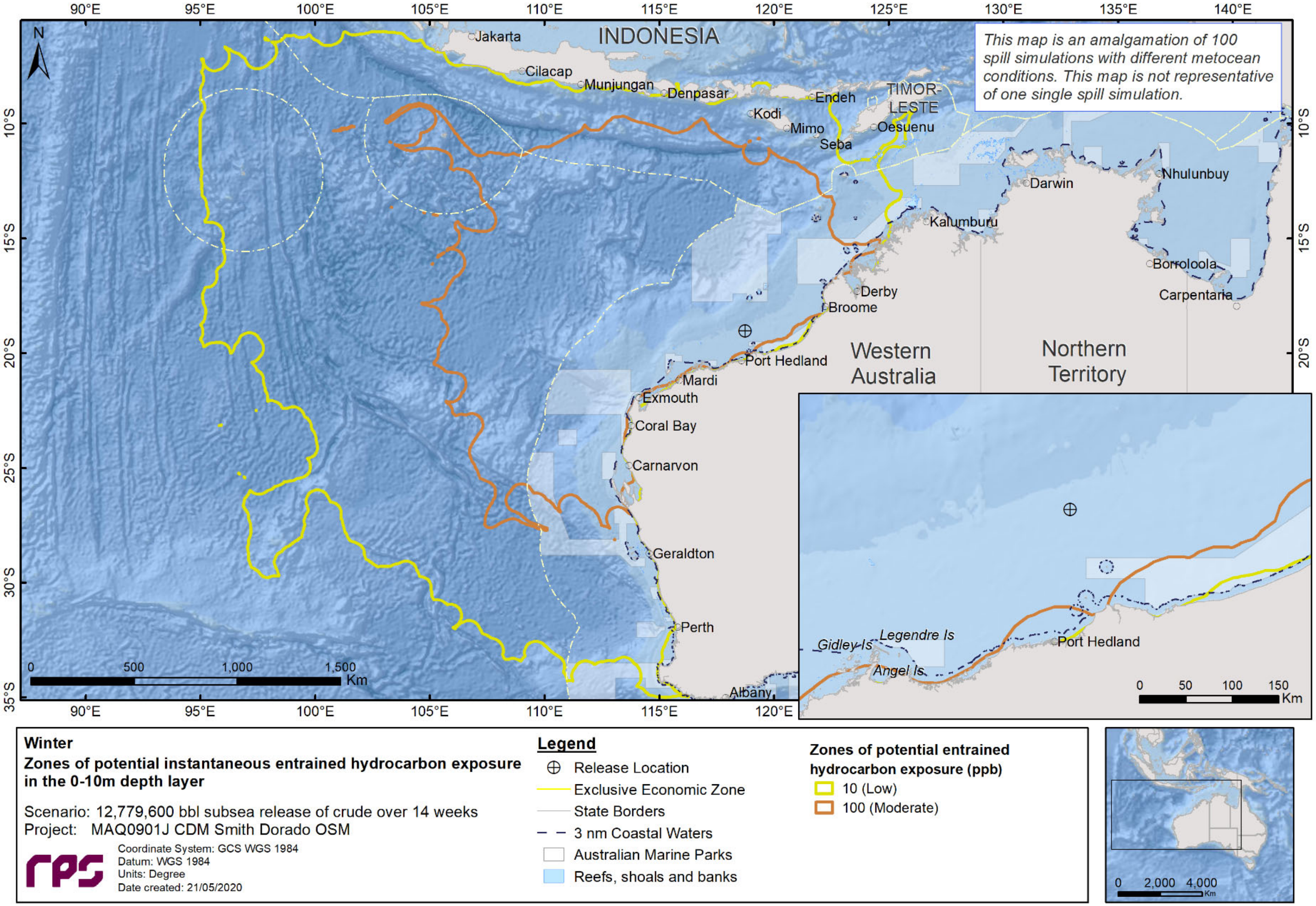


Figure 9.22 Predicted entrained hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.1.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones (0-10 m depth layer) are depicted in Figure 9.23, Figure 9.24 and Figure 9.25 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The maximum distance from the spill site to the low exposure threshold (10-50 ppb) for summer, transitional and winter results were 1,581 km (west-southwest), 1,321 km (south southwest) and 1,339 km (west), respectively. This distance reduced to 1,342 km (southwest; summer), 1,124 km (southwest; transitional) and 1,171 km (southwest; winter) as the threshold increased to moderate (50 – 400 ppb). Based on the high threshold (≥400 ppb) the distance reduced further to 930 km (west southwest; summer), 582 km (west southwest; transitional) and 843 km (southwest; winter).

Table 9.11 to Table 9.13 summarise the probability of exposure to receptors from instantaneous dissolved hydrocarbon thresholds in the 0-10 m depth layer. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

Eleven AMPs during transitional conditions and 12 AMPs during summer and winter are within the low exposure zone. The Argo-Rowley Terrace AMP recorded the greatest probability of exposure of 74% during winter conditions. The shortest time for dissolved hydrocarbon exposure at the low threshold to an AMP was recorded at Dampier during transitional conditions (2.67 days).

A total of 45 RSB receptors are within the dissolved hydrocarbon low exposure zone across the 3 seasons. The highest probability of exposure predicted at Rankin Bank during winter conditions (72%). The quickest time before low exposure at a RSB receptor was 7 days at Rankin Bank during transitional conditions.

Dissolved hydrocarbons at the low threshold were predicted to cross into WA State Waters during every season with probabilities ranging from 38-64%. The minimum time before dissolved hydrocarbons at the low threshold crossed the WA State Waters boundary was 2.83 days, for a spill commencing during transitional conditions.

Table 9.11 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	5	2	-	29.0	62.4	-	140
	Argo-Rowley Terrace	41	24	7	7.5	7.5	7.5	2,449
	Carnarvon Canyon	13	7	-	23.4	23.6	-	358
	Dampier	15	11	2	11.4	11.4	11.5	2,436
	Eighty Mile Beach	19	10	2	12.3	12.5	12.6	951
	Gascoyne	44	16	3	15.5	15.5	15.6	1,418
	Kimberley	22	9	1	17.8	18.0	25.4	483
	Mermaid Reef	23	6	-	13.4	22.7	-	165
	Montebello	61	34	4	12.2	12.8	12.8	1,330

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Ningaloo	28	12	1	15.5	15.7	18.9	492
	Roebuck	3	-	-	56.4	-	-	21
	Shark Bay	16	6	1	20.7	20.9	65.1	506
EEZ	Indonesian Exclusive Economic Zone	3	1	-	22.4	47.6	-	152
IBRA	Cape Range	13	11	2	14.7	15.5	15.6	902
	Chichester	11	10	3	11.9	12.1	67.3	961
	Edel	3	-	-	31.2	-	-	32
	Geraldton Hills	-	-	-	81.2	-	-	4
	Mitchell	1	-	-	65.4	-	-	11
	Pindanland	12	5	-	31.0	33.6	-	342
	Roebourne	12	9	3	11.7	12.3	15.7	2,257
	Wooramel	-	-	-	-	-	-	4
IMCRA	Abrolhos Islands	1	-	-	32.8	-	-	20
	Canning	7	2	-	28.1	42.0	-	84
	Central West Coast	1	-	-	35.7	-	-	14
	Eighty Mile Beach	12	10	2	12.3	13.3	36.7	737
	Kimberley	3	1	-	59.8	103.5	-	52
	King Sound	-	-	-	77.2	-	-	9
	Ningaloo	29	13	2	15.5	15.6	17.8	1,458
	Pilbara (nearshore)	14	10	3	11.5	11.5	11.5	2,436
	Pilbara (offshore)	71	46	11	2.8	3.8	5.2	3,165
	Shark Bay	1	-	-	31.3	-	-	48
	Zuytdorp	18	7	1	19.6	19.7	63.8	534
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	-
	Ancient coastline at 90-120m depth	-	-	-	-	-	-	-
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	-	-	-	-	-	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	-	-	-	-	-	-	-

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	28	12	-	32.1	88.7	-	492
	Commonwealth waters adjacent to Ningaloo Reef	24	6	-	15.5	15.7	-	200
	Continental Slope Demersal Fish Communities	-	-	-	-	-	-	-
	Exmouth Plateau	-	-	-	-	-	-	-
	Glomar Shoals	11	2	-	11.3	11.3	-	196
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	-	-	-	-	-	-	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	-	-	-	-	-	-	-
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	-	-	-	-	-	-	-
	Wallaby Saddle	-	-	-	-	-	-	-
	Western demersal slope and associated fish communities	-	-	-	-	-	-	-
	Western rock lobster	1	-	-	33.0	-	-	18
MP	Barrow Island	6	-	-	39.8	66.0	-	33
	Eighty Mile Beach	12	8	1	30.5	30.6	44.6	687
	Lalang-garram / Camden Sound	-	-	-	-	-	-	-
	Montebello Islands	14	10	3	13.8	14.5	39.5	1,122
	Ningaloo	18	6	-	16.8	17.5	-	187
	North Kimberley	-	-	-	-	-	-	-
	North Lalang-garram	-	-	-	-	-	-	-
	Rowley Shoals	38	18	3	8.9	9.4	11.9	922
	Shark Bay	1	-	-	68.8	-	-	12

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Yawuru Nagulagun / Roebuck Bay	1	-	-	56.6	-	-	12
NR	Great Sandy Island	11	5	-	14.1	23.6	-	110
	Thevenard Island	5	1	-	48.9	49.1	-	79
Ramsar	Eighty-mile Beach	12	6	-	31.0	31.8	-	323
	Roebuck Bay	-	-	-	-	-	-	-
RSB	Albert Reef	-	-	-	-	-	-	-
	Barcoo Shoal	-	-	-	-	-	-	-
	Barrow Island Reefs and Shoals	11	5	-	14.1	19.6	-	264
	Baylis Patches	1	-	-	96.0	-	-	41
	Beagle and Dingo Reefs	-	-	-	-	-	-	-
	Brewis Reef	1	-	-	99.1	-	-	21
	Brue Reef	1	-	-	78.7	-	-	13
	Churchill Reef	-	-	-	-	-	-	-
	Clerke Reef	25	9	1	22.1	26.4	28.8	450
	Courtenay Shoal	2	1	-	92.7	116.1	-	81
	Dailey Shoal	3	-	-	74.7	-	-	23
	Fairway Reef	1	-	-	98.8	-	-	22
	Fortescue Reef	1	-	-	78.2	-	-	18
	Glomar Shoal	11	1	-	11.3	11.3	11.3	109
	Hammersley Shoal	9	2	-	31.9	48.0	-	124
	Hayman Rock	1	-	-	100.7	-	-	11
	Herald Reef	5	1	-	69.2	88.2	-	56
	Hood Reef	1	1	-	96.1	96.1	-	84
	Imperieuse Reef	35	14	3	9.9	11.8	11.9	888
	Lightfoot Reef	2	-	-	49.2	-	-	32
	Little Shoals	2	-	-	86.2	-	-	46
	Locker Reef	1	-	-	95.9	-	-	39
	Madeleine Shoals	11	1	-	19.3	21.3	-	117
	Manicom Bank	1	-	-	99.8	-	-	11
	Mavis Reef	-	-	-	-	-	-	8
	McLennan Bank	10	2	-	15.5	71.5	-	167

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Meda Reef	7	-	-	42.9	-	-	39
	Mermaid Reef	21	4	-	21.9	22.7	-	135
	Montebello Shoals	13	8	-	14.5	17.8	-	212
	Moresby Shoals	3	-	-	81.4	-	-	23
	Ningaloo Reef	11	1	-	17.5	44.0	-	90
	O'Grady Shoal	6	-	-	43.3	-	-	42
	Poivre Reef	11	8	-	15.7	15.7	-	232
	Rainbow Shoals	-	-	-	-	-	-	<1
	Rankin Bank	72	44	3	12.9	12.9	36.5	1,048
	Ripple Shoals	12	5	1	15.8	15.9	100.1	416
	Robroy Reefs	-	-	-	-	-	-	<1
	Rosily Shoals	7	-	-	25.6	-	-	45
	Southwest Patch	1	-	-	100.2	-	-	15
	Taunton Reef	8	1	-	16.2	101.5	-	91
	Tongue Shoals	1	-	-	101.2	-	-	14
	Trap Reef	7	1	-	25.1	95.8	-	111
	Tryal Rocks	15	8	-	14.0	14.0	-	259
	Ward Reef	4	-	-	69.9	-	-	19
	Wildcat Reefs	-	-	-	-	-	-	1
	Adele Island	-	-	-	-	-	-	5
	Airlie Island	11	3	-	17.0	60.7	-	169
	Angel Island	5	1	-	41.9	115.9	-	72
	Ashburton	6	-	-	68.7	-	-	39
	Ashburton Island	2	-	-	79.5	-	-	38
	Barrow Island	12	11	2	15.5	15.5	15.6	902
Nearshore	Bedout Island	12	4	-	27.1	27.3	-	209
	Bermier Island	-	-	-	-	-	-	3
	Bessieres Island	2	1	-	67.8	95.8	-	99
	Bezout Island	11	7	-	12.2	12.2	-	243
	Boodie Island	11	9	2	15.6	15.6	15.7	1,047
	Broome	12	5	-	31.0	33.6	-	225
	Cape Bruguieres	10	3	-	17.9	39.3	-	75

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Carnarvon	-	-	-	-	-	-	4
Clerke Reef	22	9	-	25.2	26.4	-	354
Cohen Island	10	3	-	19.7	44.8	-	124
Conzinc Island	1	-	-	116.0	-	-	39
Cunningham Island	33	10	1	11.8	11.8	45.3	509
Delambre Island	11	8	1	11.7	12.3	86.6	485
Derby - West Kimberely	1	-	-	65.4	-	-	11
Direction Island	8	2	-	15.5	39.8	-	72
Dirk Hartog Island	3	-	-	53.6	-	-	32
Dolphin Island	10	5	1	15.9	42.5	42.5	464
Dorre Island	1	-	-	31.2	-	-	29
Eaglehawk Island	1	-	-	67.7	-	-	39
East Pilbara	10	4	-	31.0	33.1	-	342
Enderby Island	1	-	-	67.4	68.8	-	43
Exmouth	11	1	-	19.2	43.6	-	80
Flat Island	4	1	-	70.0	95.9	-	183
Gidley Island	8	3	-	21.9	43.9	-	75
Goodwyn Island	1	-	-	67.4	-	-	13
Haury Island	10	6	2	12.2	16.6	42.5	1,080
Hermite Island	13	9	1	14.7	15.7	51.1	529
Imperieuse Reef	35	11	2	11.8	11.8	11.9	649
Karratha	11	10	3	11.9	12.1	67.3	961
Keast Island	11	5	-	17.3	43.5	-	192
Kendrew Island	1	1	-	66.7	66.9	-	62
Lacepede Islands	4	-	-	46.9	-	-	27
Legendre Island	11	6	3	12.1	12.7	42.5	2,257
Lowendal Island	11	8	1	19.1	21.1	52.4	548
Malus Island	2	1	-	66.5	115.9	-	54
Mary Anne Group	5	1	-	39.5	39.5	-	102
Mermaid Reef	16	3	-	22.5	43.2	-	63
Middle Island	11	9	1	15.6	15.6	52.9	802
Murion Islands	6	1	-	36.0	49.1	-	128

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	North Turtle Island	7	2	-	30.5	30.5	-	157
	Observation Island	1	-	-	96.3	-	-	14
	Passage Islands	10	2	-	16.4	42.5	-	99
	Peak Island	4	-	-	54.3	-	-	35
	Port Hedland	12	9	1	12.0	30.6	32.1	784
	Ragnard Islands	2	1	-	46.8	61.4	-	62
	Rivoli Islands	1	-	-	80.3	-	-	10
	Rosemary Island	4	1	-	66.4	66.4	-	109
	Round Island	3	1	-	70.0	96.0	-	184
	Sandy Islet	1	-	-	110.8	-	-	11
	Scott Reef North	1	-	-	69.5	-	-	11
	Scott Reef South	1	-	-	69.2	-	-	27
	Seringapatam Reef	1	-	-	70.4	-	-	16
	Serrurier Island	4	1	-	69.5	95.9	-	173
	Shark Bay	-	-	-	-	-	-	3
	Sunday Island	1	-	-	108.1	-	-	17
	Table Island	2	1	-	69.9	95.9	-	122
	Thevenard Island	7	1	-	40.6	49.0	-	79
	Tortoise Island	2	-	-	79.6	-	-	37
	Twin Island	8	1	-	18.3	87.8	-	53
	West Lewis Island	1	-	-	115.9	-	-	27
	Wyndham - East Kimberley	-	-	-	-	-	-	2
State Waters	Western Australia State Waters	38	18	6	8.9	9.4	11.7	2,947

Table 9.12 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	5	1	-	40.4	99.8	-	89
	Argo-Rowley Terrace	48	26	2	10.5	11.0	13.8	1,007
	Carnarvon Canyon	9	2	-	28.8	94.3	-	113
	Dampier	7	2	-	2.7	2.7	-	245
	Eighty Mile Beach	5	1	-	15.7	17.8	-	138
	Gascoyne	36	11	1	23.0	23.6	92.2	474
	Kimberley	29	13	1	4.0	5.9	11.4	591
	Mermaid Reef	35	7	-	10.5	13.7	33.1	397
	Montebello	55	26	1	4.1	4.2	28.3	429
	Ningaloo	10	-	-	25.1	39.1	-	35
	Roebuck	-	-	-	-	-	-	<1
	Shark Bay	2	1	-	35.3	43.0	-	56
EEZ	Indonesian Exclusive Economic Zone	2	-	-	44.0	-	-	19
IBRA	Cape Range	4	-	-	9.1	14.0	-	48
	Chichester	1	-	-	3.1	-	-	47
	Edel	-	-	-	-	-	-	<1
	Geraldton Hills	-	-	-	-	-	-	3
	Mitchell	5	1	-	89.7	91.5	-	83
	Pindanland	3	-	-	74.0	-	-	40
	Roebourne	4	2	-	3.1	3.8	-	282
	Wooramel	-	-	-	-	-	-	<1
IMCRA	Abrolhos Islands	-	-	-	64.8	-	-	9
	Canning	11	5	1	18.0	56.5	74.1	526
	Central West Coast	1	-	-	59.5	-	-	12
	Eighty Mile Beach	1	-	-	17.9	-	-	17
	Kimberley	8	5	-	85.8	88.1	-	267
	King Sound	1	-	-	97.8	-	-	12

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Ningaloo	16	1	-	23.3	37.2	-	63
	Pilbara (nearshore)	4	2	-	2.8	2.9	-	282
	Pilbara (offshore)	82	59	16	2.6	2.6	5.4	3,686
	Shark Bay	-	-	-	-	-	-	<1
	Zuytdorp	3	1	-	34.8	42.5	-	65
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	-
	Ancient coastline at 90-120m depth	-	-	-	-	-	-	-
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	-	-	-	-	-	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	-	-	-	-	-	-	-
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	10	-	-	61.0	-	-	35
	Commonwealth waters adjacent to Ningaloo Reef	3	-	-	25.1	-	-	28
	Continental Slope Demersal Fish Communities	-	-	-	-	-	-	-
	Exmouth Plateau	-	-	-	-	-	-	-
	Glomar Shoals	14	3	1	4.0	4.0	11.1	549
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	-	-	-	-	-	-	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	-	-	-	-	-	-	-
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	-	-	-	-	-	-	-
	Wallaby Saddle	-	-	-	-	-	-	-

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Western demersal slope and associated fish communities	-	-	-	-	-	-	-
	Western rock lobster	1	-	-	65.1	-	-	12
MP	Barrow Island	4	-	-	17.8	-	-	16
	Eighty Mile Beach	-	-	-	-	-	-	<1
	Lalang-garram / Camden Sound	5	2	-	89.8	97.9	-	69
	Montebello Islands	5	1	-	8.2	9.3	-	85
	Ningaloo	2	-	-	26.5	-	-	23
	North Kimberley	3	-	-	100.3	-	-	32
	North Lalang-garram	5	1	-	98.0	104.6	-	53
	Rowley Shoals	43	14	2	14.2	16.7	19.3	1,100
	Shark Bay	-	-	-	-	-	-	<1
	Yawuru Nagulagun / Roebuck Bay	-	-	-	-	-	-	1
NR	Great Sandy Island	-	-	-	-	-	-	3
	Thevenard Island	-	-	-	-	-	-	2
Ramsar	Eighty-mile Beach	-	-	-	-	-	-	<1
	Roebuck Bay	-	-	-	-	-	-	<1
RSB	Albert Reef	5	3	-	89.9	91.3	-	156
	Barcoo Shoal	2	-	-	90.6	-	-	45
	Barrow Island Reefs and Shoals	-	-	-	-	-	-	1
	Baylis Patches	-	-	-	-	-	-	<1
	Beagle and Dingo Reefs	5	1	-	91.5	96.1	-	89
	Brewis Reef	-	-	-	-	-	-	3
	Brue Reef	5	3	-	88.2	89.4	-	92
	Churchill Reef	5	1	-	90.2	91.6	-	146
	Clerke Reef	27	14	1	16.7	17.1	25.8	618
	Courtenay Shoal	-	-	-	-	-	-	8
	Dailey Shoal	1	-	-	45.2	-	-	12
	Fairway Reef	-	-	-	-	-	-	<1

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Fortescue Reef	-	-	-	-	-	-	2
Glomar Shoal	80	56	5	4.0	5.5	11.8	834
Hammersley Shoal	1	-	-	12.0	-	-	11
Hayman Rock	-	-	-	-	-	-	<1
Herald Reef	-	-	-	-	-	-	<1
Hood Reef	-	-	-	-	-	-	4
Imperieuse Reef	41	9	-	17.0	21.9	-	260
Lightfoot Reef	-	-	-	-	-	-	<1
Little Shoals	-	-	-	-	-	-	<1
Locker Reef	-	-	-	-	-	-	<1
Madeleine Shoals	3	-	-	11.5	-	-	37
Manicom Bank	-	-	-	-	-	-	<1
Mavis Reef	5	3	-	91.4	92.8	-	82
McLennan Bank	-	-	-	-	-	-	1
Meda Reef	-	-	-	-	-	-	1
Mermaid Reef	35	7	-	10.9	14.2	-	345
Montebello Shoals	3	-	-	10.5	-	-	28
Moresby Shoals	-	-	-	-	-	-	<1
Ningaloo Reef	-	-	-	76.1	-	-	9
O'Grady Shoal	-	-	-	-	-	-	1
Poivre Reef	-	-	-	-	-	-	6
Rainbow Shoals	1	-	-	118.0	-	-	11
Rankin Bank	61	35	1	7.1	8.2	18.3	414
Ripple Shoals	-	-	-	-	-	-	1
Robroy Reefs	1	-	-	113.4	-	-	18
Rosily Shoals	-	-	-	-	-	-	5
Southwest Patch	-	-	-	-	-	-	<1
Taunton Reef	-	-	-	-	-	-	<1
Tongue Shoals	-	-	-	-	-	-	<1
Trap Reef	-	-	-	-	-	-	2
Tryal Rocks	6	-	-	11.4	94.9	-	39
Ward Reef	-	-	-	-	-	-	<1

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Wildcat Reefs	3	-	-	98.0	-	-	20
Nearshore	Adele Island	5	1	-	89.7	91.5	-	83
	Airlie Island	-	-	-	-	-	-	2
	Angel Island	-	-	-	-	-	-	4
	Ashburton	-	-	-	-	-	-	<1
	Ashburton Island	-	-	-	-	-	-	1
	Barrow Island	2	-	-	50.7	-	-	16
	Bedout Island	1	-	-	17.9	19.4	-	26
	Bermier Island	-	-	-	-	-	-	<1
	Bessieres Island	1	-	-	42.4	-	-	10
	Bezout Island	1	-	-	7.4	-	-	22
	Boodie Island	1	-	-	50.4	-	-	11
	Broome	2	-	-	89.9	-	-	40
	Cape Bruguieres	2	-	-	11.1	-	-	21
	Carnarvon	-	-	-	-	-	-	1
	Clerke Reef	27	12	1	16.5	17.7	31.0	444
	Cohen Island	4	-	-	11.4	-	-	20
	Conzinc Island	-	-	-	-	-	-	4
	Cunningham Island	37	8	-	17.0	32.5	-	160
	Delambre Island	2	1	-	3.8	3.8	-	282
	Derby - West Kimberely	5	-	-	89.8	-	-	44
	Direction Island	-	-	-	-	-	-	<1
	Dirk Hartog Island	-	-	-	-	-	-	<1
	Dolphin Island	2	-	-	10.9	-	-	32
	Dorre Island	-	-	-	-	-	-	<1
	Eaglehawk Island	-	-	-	-	-	-	1
	East Pilbara	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	4
	Exmouth	-	-	-	28.2	-	-	8
	Flat Island	1	-	-	43.0	-	-	13
	Gidley Island	2	-	-	11.1	-	-	21
	Goodwyn Island	-	-	-	-	-	-	3

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Haury Island	3	-	-	9.5	-	-	40
Hermite Island	4	-	-	9.1	14.0	-	48
Imperieuse Reef	36	7	-	17.2	32.5	-	170
Karratha	1	-	-	3.1	-	-	47
Keast Island	4	-	-	11.0	-	-	32
Kendrew Island	-	-	-	90.6	-	-	7
Lacepede Islands	3	-	-	74.0	-	-	17
Legendre Island	4	2	-	4.0	11.1	-	69
Lowendal Island	1	-	-	17.0	-	-	15
Malus Island	-	-	-	-	-	-	6
Mary Anne Group	-	-	-	-	-	-	<1
Mermaid Reef	32	4	-	13.9	24.3	-	345
Middle Island	1	-	-	51.0	-	-	16
Murion Islands	2	-	-	45.4	-	-	13
North Turtle Island	-	-	-	-	-	-	<1
Observation Island	-	-	-	-	-	-	2
Passage Islands	-	-	-	-	-	-	7
Peak Island	1	-	-	43.4	-	-	13
Port Hedland	1	-	-	4.0	-	-	14
Ragnard Islands	-	-	-	-	-	-	<1
Rivoli Islands	-	-	-	-	-	-	<1
Rosemary Island	1	-	-	28.3	-	-	13
Round Island	-	-	-	-	-	-	8
Sandy Islet	-	-	-	-	-	-	1
Scott Reef North	-	-	-	-	-	-	1
Scott Reef South	-	-	-	-	-	-	2
Seringapatam Reef	-	-	-	-	-	-	<1
Serrurier Island	1	-	-	42.8	-	-	12
Shark Bay	-	-	-	-	-	-	<1
Sunday Island	-	-	-	-	-	-	7
Table Island	-	-	-	-	-	-	9
Thevenard Island	-	-	-	-	-	-	3

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before dissolved hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Tortoise Island	-	-	-	-	-	-	1
	Twin Island	-	-	-	-	-	-	<1
	West Lewis Island	-	-	-	-	-	-	3
	Wyndham - East Kimberley	1	-	-	99.5	-	-	15
State Waters	Western Australia State Waters	43	14	2	2.8	2.9	19.3	1,100

Table 9.13 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	4	1	-	61.1	68.8	-	118
	Argo-Rowley Terrace	74	35	2	13.7	16.8	18.3	1,562
	Carnarvon Canyon	4	2	-	53.6	63.3	-	192
	Dampier	12	7	2	22.3	22.8	35.5	1,019
	Eighty Mile Beach	14	8	2	6.7	7.2	9.3	613
	Gascoyne	20	8	2	24.8	25.1	66.7	1,947
	Kimberley	11	4	2	70.8	82.5	83.1	591
	Mermaid Reef	38	8	-	29.1	31.1	-	322
	Montebello	53	17	2	18.5	19.7	61.7	1,486
	Ningaloo	3	1	-	30.5	54.0	-	59
	Roebuck	1	-	-	82.2	-	-	20
	Shark Bay	3	2	-	81.7	82.4	-	230
EEZ	Indonesian Exclusive Economic Zone	3	1	-	56.0	84.5	-	143
IBRA	Cape Range	6	2	1	27.7	65.0	100.5	485
	Chichester	4	2	-	41.2	78.4	-	294
	Edel	4	1	-	82.6	82.8	-	113
	Geraldton Hills	1	-	-	112.7	113.1	-	18
	Mitchell	-	-	-	-	-	-	1
	Pindanland	3	1	-	82.4	83.4	-	94
	Roebourne	6	3	-	11.7	11.8	-	329
	Wooramel	5	2	-	82.8	83.9	-	125
IMCRA	Abrolhos Islands	-	-	-	-	-	-	1
	Canning	6	3	-	81.1	81.9	-	215
	Central West Coast	-	-	-	-	-	-	1
	Eighty Mile Beach	2	1	-	87.4	99.9	-	107
	Kimberley	-	-	-	-	-	-	4
	King Sound	-	-	-	-	-	-	1

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Ningaloo	9	2	-	28.2	46.8	-	110
	Pilbara (nearshore)	9	5	1	22.2	22.6	87.0	474
	Pilbara (offshore)	82	64	20	2.7	3.2	4.1	2,540
	Shark Bay	5	2	-	82.6	82.6	-	247
	Zuytdorp	5	3	-	74.9	81.2	-	230
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	-
	Ancient coastline at 90-120m depth	-	-	-	-	-	-	-
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	-	-	-	-	-	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	-	-	-	-	-	-	-
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	-	-	-	-	-	-	-
	Commonwealth waters adjacent to Ningaloo Reef	3	-	-	30.5	-	-	22
	Continental Slope Demersal Fish Communities	-	-	-	-	-	-	-
	Exmouth Plateau	-	-	-	-	-	-	-
	Glomar Shoals	11	2	1	9.1	9.8	17.9	425
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	-	-	-	-	-	-	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	-	-	-	-	-	-	-
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	-	-	-	-	-	-	-
	Wallaby Saddle	-	-	-	-	-	-	-

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Western demersal slope and associated fish communities	2	1	-	82.6	111.0	-	70
	Western rock lobster	-	-	-	-	-	-	-
MP	Barrow Island	4	-	-	30.0	-	-	17
	Eighty Mile Beach	-	-	-	-	-	-	<1
	Lalang-garram / Camden Sound	-	-	-	-	-	-	1
	Montebello Islands	8	3	1	27.5	57.0	86.0	711
	Ningaloo	1	-	-	31.6	54.9	-	35
	North Kimberley	-	-	-	-	-	-	<1
	North Lalang-garram	-	-	-	-	-	-	1
	Rowley Shoals	64	30	1	16.2	18.3	80.5	408
	Shark Bay	5	2	-	82.6	82.9	-	247
	Yawuru Nagulagun / Roebuck Bay	1	-	-	82.7	-	-	20
NR	Great Sandy Island	2	-	-	69.2	-	-	23
	Thevenard Island	-	-	-	-	-	-	6
Ramsar	Eighty-mile Beach	-	-	-	-	-	-	<1
	Roebuck Bay	1	-	-	114.9	-	-	14
RSB	Albert Reef	-	-	-	-	-	-	<1
	Barcoo Shoal	-	-	-	-	-	-	1
	Barrow Island Reefs and Shoals	2	-	-	68.0	-	-	31
	Baylis Patches	-	-	-	-	-	-	<1
	Beagle and Dingo Reefs	-	-	-	-	-	-	<1
	Brewis Reef	-	-	-	-	-	-	1
	Brue Reef	-	-	-	-	-	-	<1
	Churchill Reef	-	-	-	-	-	-	1
	Clerke Reef	42	11	1	26.0	27.5	80.5	408
	Courtenay Shoal	3	1	-	28.1	109.5	-	66
	Dailey Shoal	-	-	-	-	-	-	3
	Fairway Reef	-	-	-	-	-	-	1

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Fortescue Reef	-	-	-	-	-	-	<1
Glomar Shoal	95	57	1	9.8	10.0	23.2	518
Hammersley Shoal	2	-	-	27.0	109.4	-	35
Hayman Rock	-	-	-	-	-	-	<1
Herald Reef	-	-	-	-	-	-	<1
Hood Reef	-	-	-	-	-	-	1
Imperieuse Reef	62	22	-	17.4	21.2	-	360
Lightfoot Reef	-	-	-	-	-	-	3
Little Shoals	-	-	-	-	-	-	<1
Locker Reef	-	-	-	-	-	-	<1
Madeleine Shoals	5	1	-	22.5	34.2	-	92
Manicom Bank	-	-	-	-	-	-	<1
Mavis Reef	-	-	-	-	-	-	<1
McLennan Bank	3	1	-	72.6	82.9	-	52
Meda Reef	-	-	-	-	-	-	1
Mermaid Reef	38	7	-	29.6	31.7	-	244
Montebello Shoals	4	1	-	27.7	96.4	-	73
Moresby Shoals	-	-	-	-	-	-	<1
Ningaloo Reef	-	-	-	52.2	-	-	9
O'Grady Shoal	-	-	-	-	-	-	1
Poivre Reef	1	-	-	30.5	-	-	11
Rainbow Shoals	-	-	-	-	-	-	<1
Rankin Bank	64	26	3	16.5	18.2	71.2	1,004
Ripple Shoals	-	-	-	-	-	-	7
Robroy Reefs	-	-	-	-	-	-	<1
Rosily Shoals	1	-	-	69.3	-	-	11
Southwest Patch	-	-	-	-	-	-	<1
Taunton Reef	-	-	-	-	-	-	2
Tongue Shoals	-	-	-	-	-	-	<1
Trap Reef	1	-	-	70.8	-	-	10
Tryal Rocks	4	1	-	33.4	83.0	-	90
Ward Reef	-	-	-	-	-	-	<1

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Wildcat Reefs	-	-	-	-	-	-	<1
Nearshore	Adele Island	-	-	-	-	-	-	1
	Airlie Island	-	-	-	-	-	-	3
	Angel Island	2	1	-	27.0	114.6	-	54
	Ashburton	-	-	-	-	-	-	<1
	Ashburton Island	-	-	-	-	-	-	<1
	Barrow Island	2	1	-	30.8	71.8	-	93
	Bedout Island	3	-	-	10.8	11.2	-	49
	Bermier Island	3	1	-	82.7	82.8	-	113
	Bessieres Island	-	-	-	-	-	-	3
	Bezout Island	4	2	-	41.2	78.4	-	294
	Boodie Island	1	-	-	30.1	-	-	22
	Broome	3	1	-	82.4	83.4	-	94
	Cape Bruguieres	4	1	-	26.0	26.3	-	70
	Carnarvon	2	-	-	96.5	-	-	27
	Clerke Reef	38	10	-	26.5	27.5	-	147
	Cohen Island	6	1	-	26.1	108.3	-	90
	Conzinc Island	1	-	-	114.7	-	-	14
	Cunningham Island	49	17	-	21.4	24.0	-	221
	Delambre Island	6	3	-	24.4	36.0	-	349
	Derby - West Kimberely	-	-	-	-	-	-	1
	Direction Island	-	-	-	-	-	-	<1
	Dirk Hartog Island	2	1	-	82.6	82.8	-	97
	Dolphin Island	3	-	-	25.7	-	-	36
	Dorre Island	2	-	-	82.6	-	-	33
	Eaglehawk Island	2	-	-	87.5	-	-	21
	East Pilbara	-	-	-	-	-	-	<1
	Enderby Island	3	-	-	60.4	-	-	43
	Exmouth	-	-	-	52.0	-	-	9
	Flat Island	-	-	-	-	-	-	2
	Gidley Island	3	1	-	26.0	26.3	-	68
	Goodwyn Island	1	-	-	61.2	-	-	16

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Haury Island	3	-	-	23.8	-	-	49
Hermite Island	6	2	1	27.7	65.0	100.5	485
Imperieuse Reef	53	22	-	19.3	23.7	-	285
Karratha	2	2	-	82.1	82.6	-	201
Keast Island	5	2	-	23.7	26.6	-	95
Kendrew Island	2	-	-	29.6	-	-	18
Lacepede Islands	2	-	-	82.7	-	-	13
Legendre Island	5	2	-	22.8	25.8	-	135
Lowendal Island	3	2	-	66.6	67.9	-	172
Malus Island	2	-	-	109.1	-	-	45
Mary Anne Group	-	-	-	-	-	-	4
Mermaid Reef	31	6	-	31.8	40.1	-	244
Middle Island	1	-	-	30.3	-	-	30
Murion Islands	-	-	-	45.4	-	-	3
North Turtle Island	-	-	-	-	-	-	8
Observation Island	-	-	-	-	-	-	1
Passage Islands	1	1	-	72.5	72.5	-	72
Peak Island	-	-	-	54.3	-	-	3
Port Hedland	2	-	-	82.6	-	-	45
Ragnard Islands	1	-	-	116.1	-	-	18
Rivoli Islands	-	-	-	-	-	-	<1
Rosemary Island	4	1	-	28.5	108.6	-	117
Round Island	-	-	-	-	-	-	1
Sandy Islet	-	-	-	-	-	-	1
Scott Reef North	-	-	-	-	-	-	3
Scott Reef South	-	-	-	-	-	-	2
Seringapatam Reef	-	-	-	-	-	-	1
Serrurier Island	-	-	-	-	-	-	2
Shark Bay	5	2	-	82.8	83.9	-	125
Sunday Island	-	-	-	-	-	-	2
Table Island	-	-	-	-	-	-	1
Thevenard Island	-	-	-	-	-	-	6

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Tortoise Island	-	-	-	-	-	-	1
	Twin Island	-	-	-	-	-	-	<1
	West Lewis Island	-	-	-	-	-	-	9
	Wyndham - East Kimberley	-	-	-	-	-	-	1
State Waters	Western Australia State Waters	64	30	3	10.3	10.3	61.7	1,436

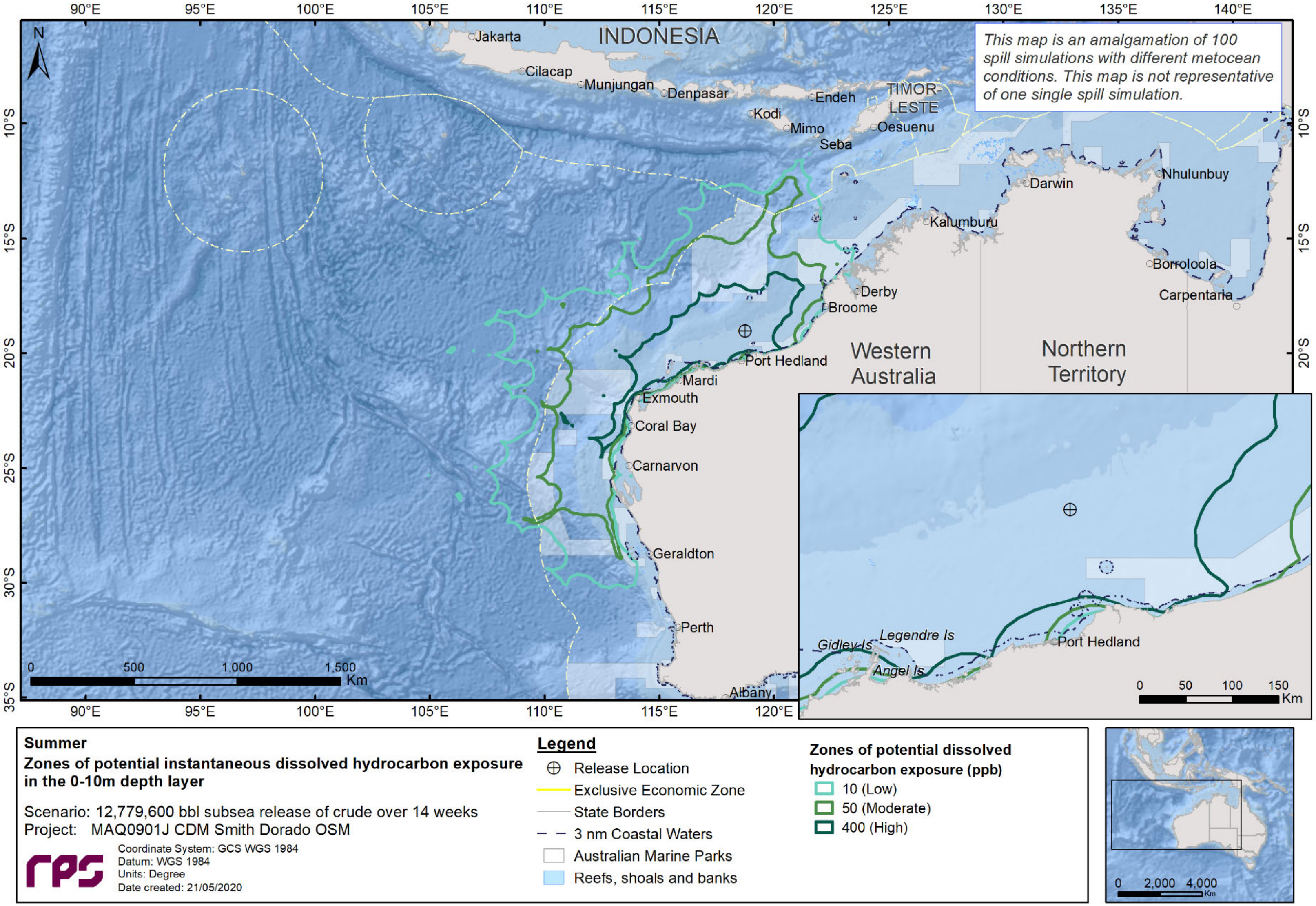


Figure 9.23 Predicted dissolved hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

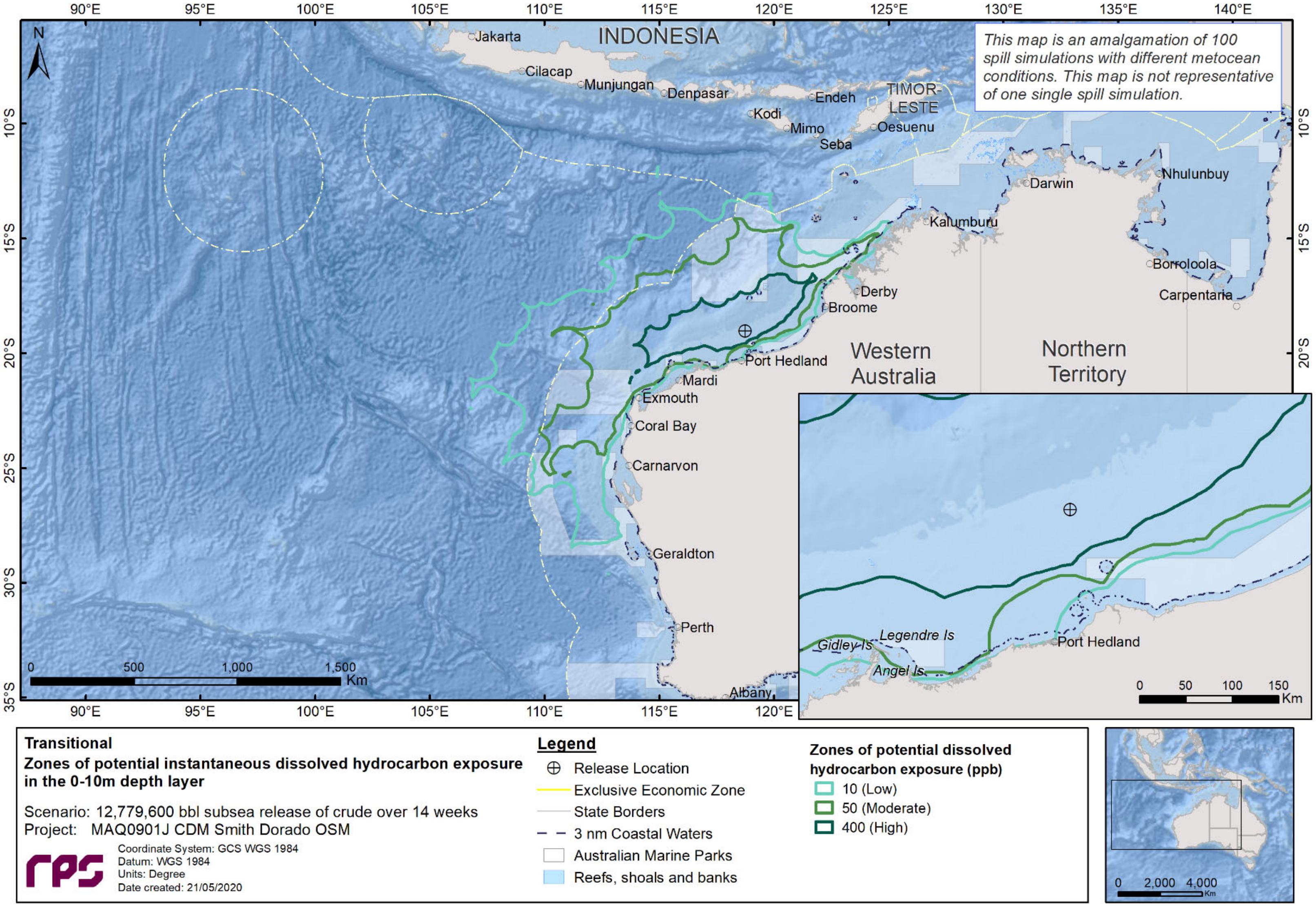


Figure 9.24 Predicted dissolved hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

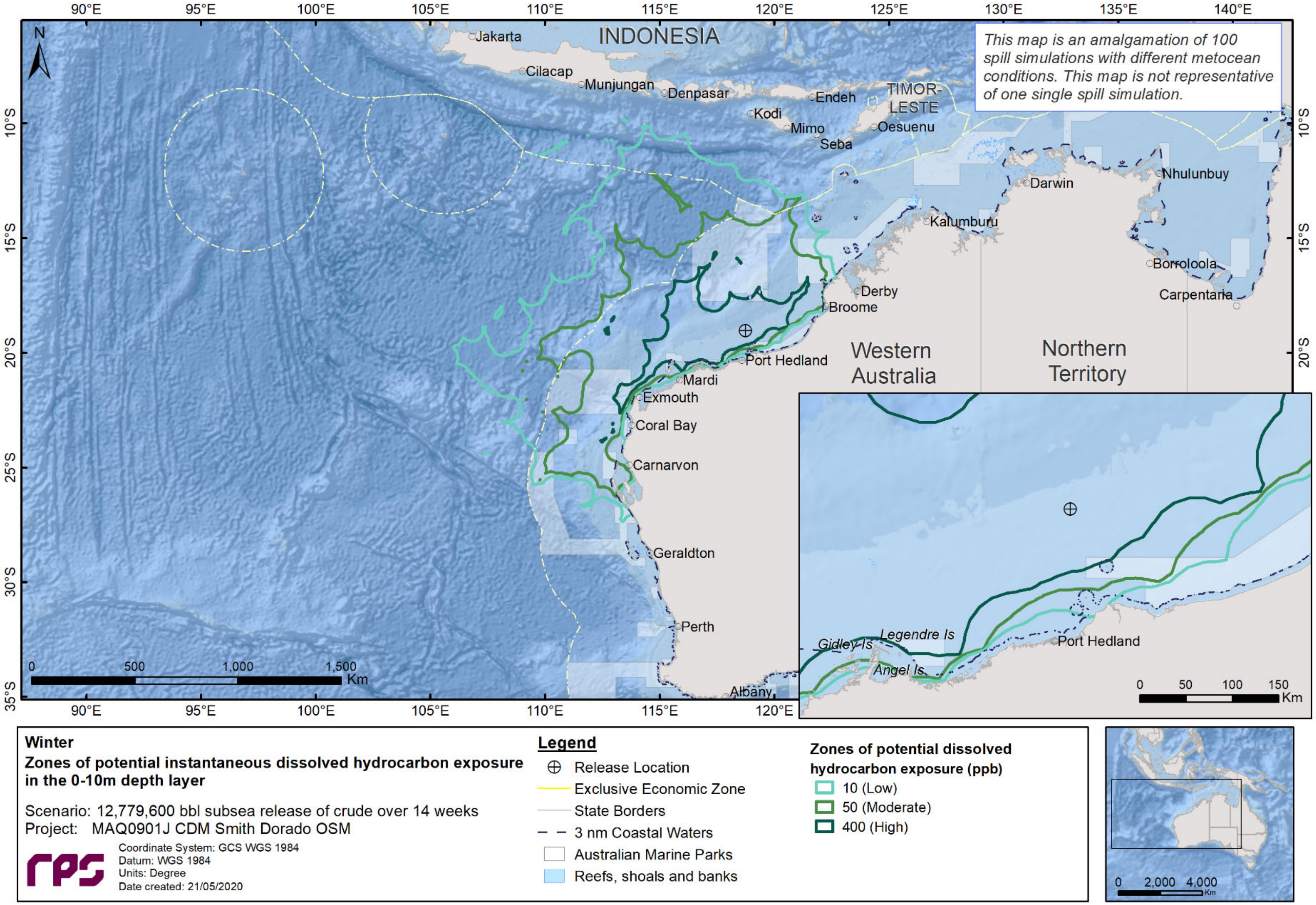


Figure 9.25 Predicted dissolved hydrocarbon exposure zones resulting from a subsea blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.2 Scenario 2: Simulation of a 14-week surface blowout of crude at the WHP

This scenario examined a 12,779,600 bbl (2,031,794 m^3) surface release of crude with a decreasing discharge rate over 14 weeks. A total of 300 simulations were run (i.e. 100 spills per season) and each was tracked for 118 days. These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Sections 9.2.1 presents the overview of the EMBA based on combining the 300 spill simulations and Section 9.2.3 shows the seasonal (or stochastic) analysis, while Section 9.2.2 presents the deterministic analysis results (i.e. a single spill simulation), based on largest volume ashore and longest length of oiled shoreline.

9.2.1 Overview

Figure 9.26 and Figure 9.27 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.28 and Figure 9.29 show the annualised extent of floating oil and in-water (entrained and dissolved) exposure as well as shoreline accumulation based on the low and moderate exposure thresholds, respectively, derived from combining the results from all 300 spill simulations.

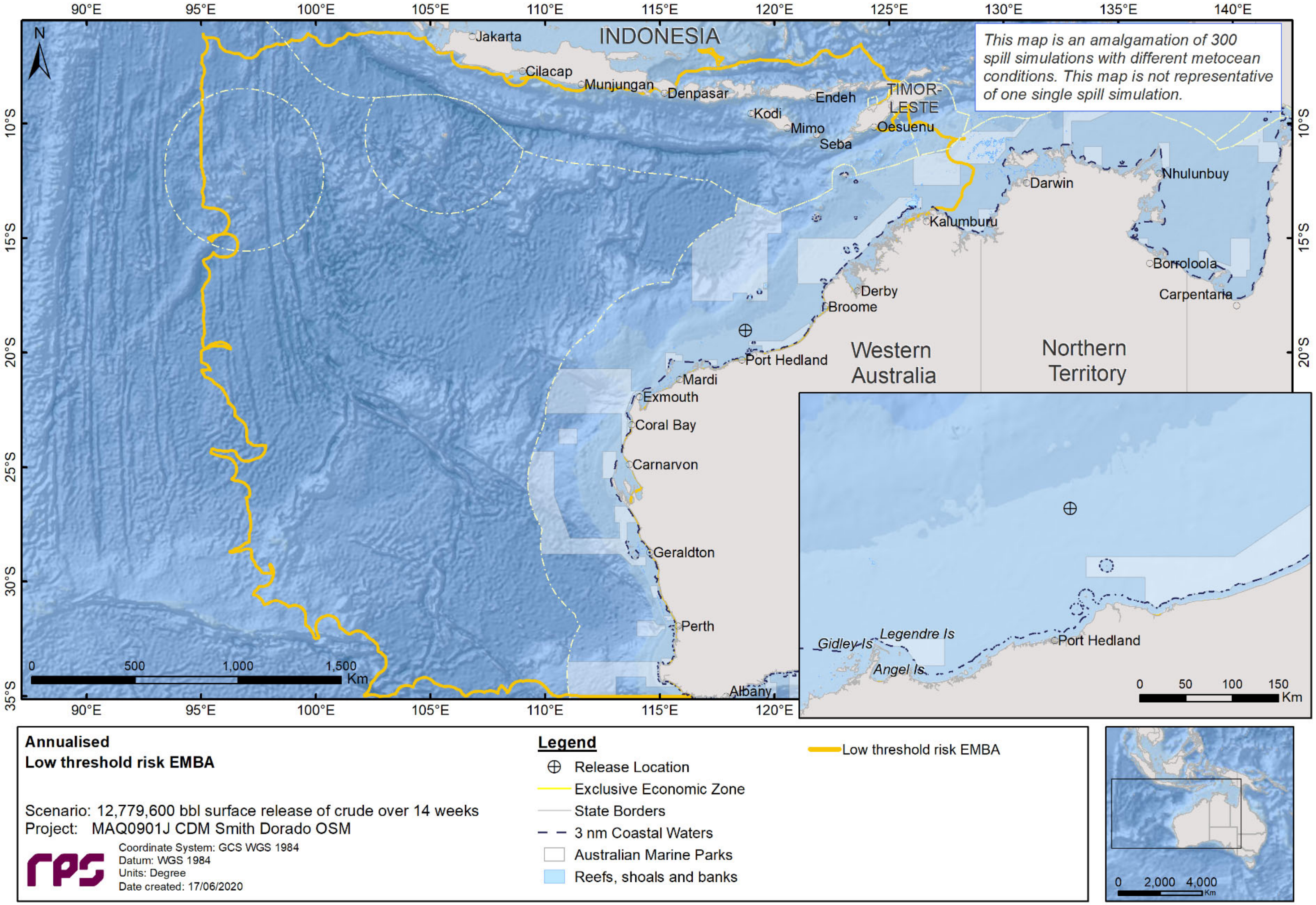


Figure 9.26 Predicted low threshold risk EMBA resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations, which were tracked for 118 days.

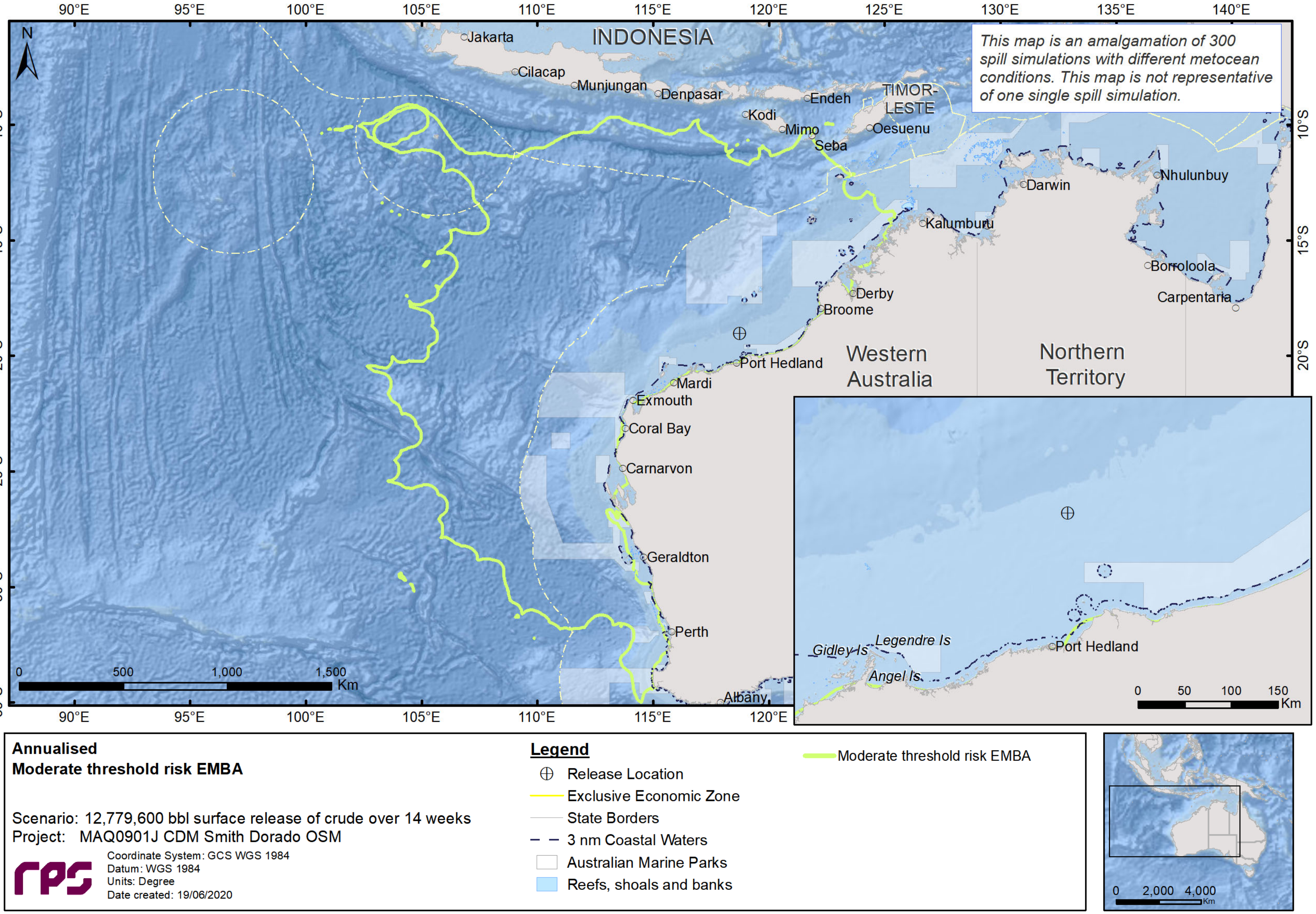


Figure 9.27 Predicted moderate threshold risk EMBA resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations, which were tracked for 118 days.

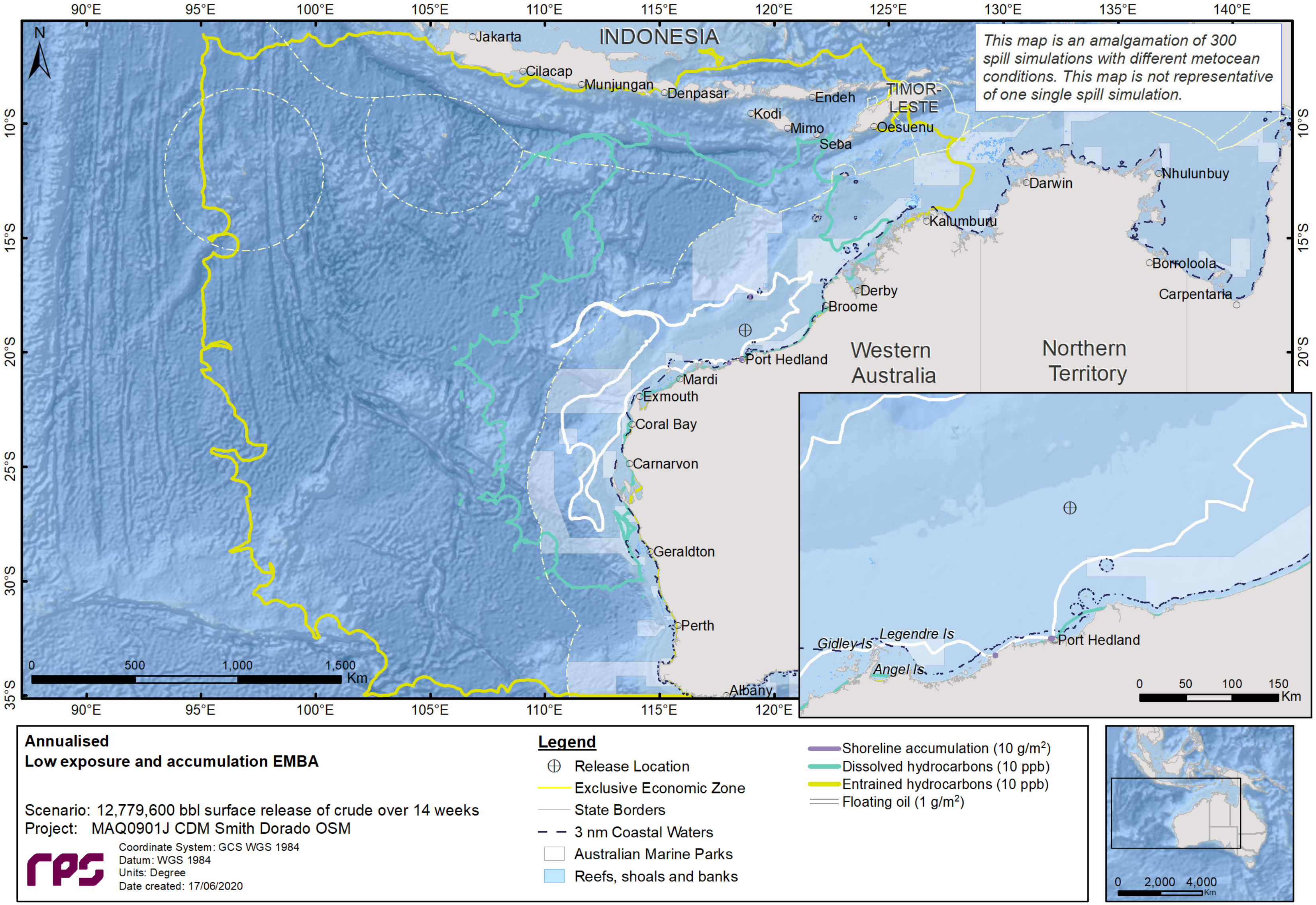


Figure 9.28 Annualised low threshold oil exposure and shoreline accumulation resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP. The annualised results were calculated from 300 spill simulations, which were tracked for 118 days.

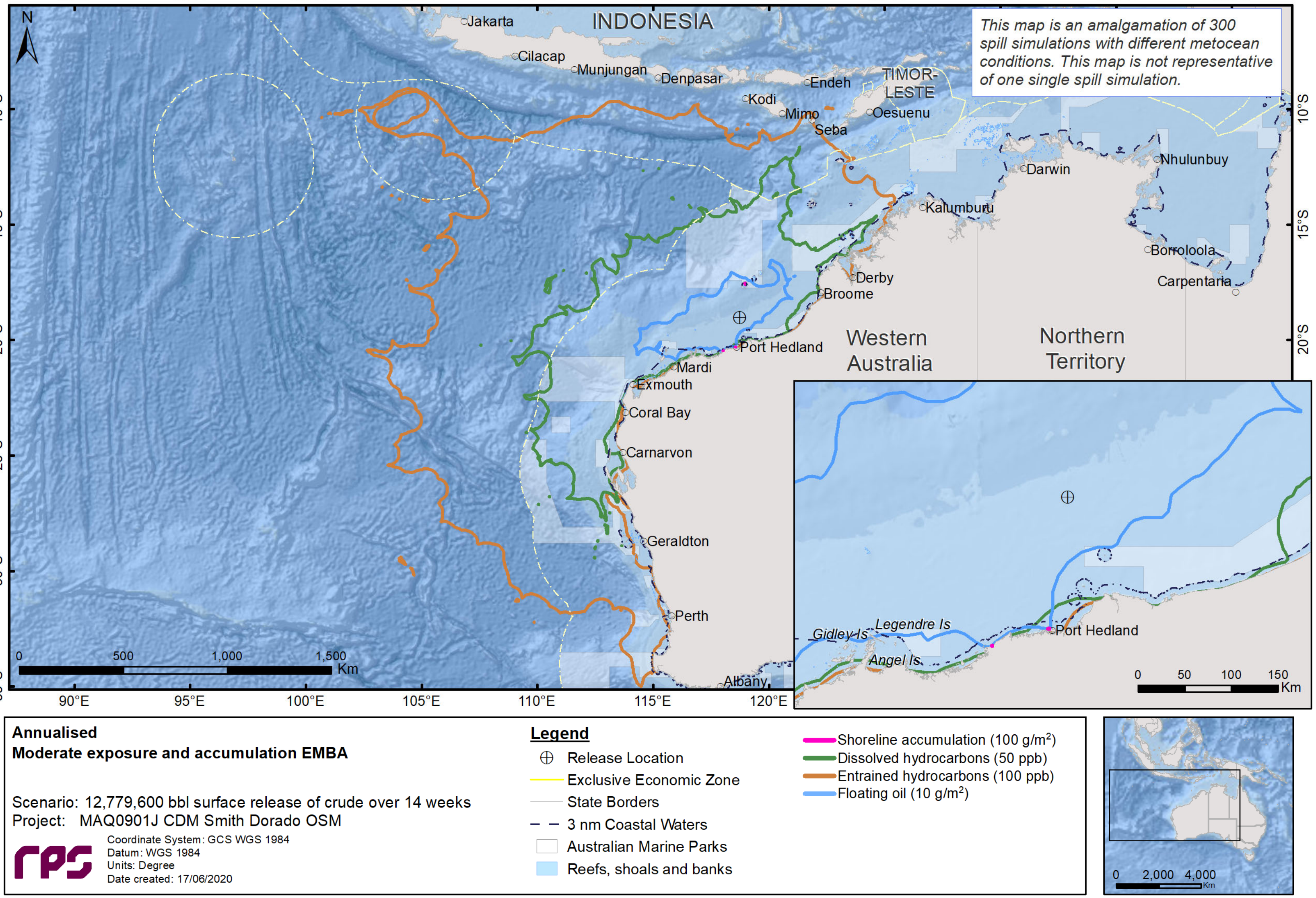


Figure 9.29 Annualised moderate threshold oil exposure and shoreline accumulation resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The annualised results were calculated from 300 spill simulations, which were tracked for 118 days.

9.2.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest volume of oil ashore; and

b. Longest length of oiled shoreline.

9.2.2.1 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that recorded the largest volume of oil ashore (38.1 m^3) was identified during summer conditions as run number 40, which commenced at 6 am on the 24th of February 2018. The maximum volume ashore was 38.1 m^3, which occurred 44 days after the initial release.

Exposure from floating oil (swept area) and potential oil accumulation over the entire 118 day simulation are presented in Figure 9.30 and Figure 9.31, respectively. Floating oil exposure was predicted north/northeast and west/southwest from the release location with oil accumulation occurring at Port Hedland.

Figure 9.32 displays the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and actionable shoreline oil (≥100 g/m^2) over the 118-day simulation.

Figure 9.33 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9.34 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 1,242,759 m^3 (61%) spilled oil was lost to the atmosphere through evaporation. Approximately 625,632 m^3 (31%) of the crude was predicted to have decayed, while 159,384 m^3 (8%) remained within the water column and 15 m^3 (<0.1%) was predicted to remain on the shoreline.

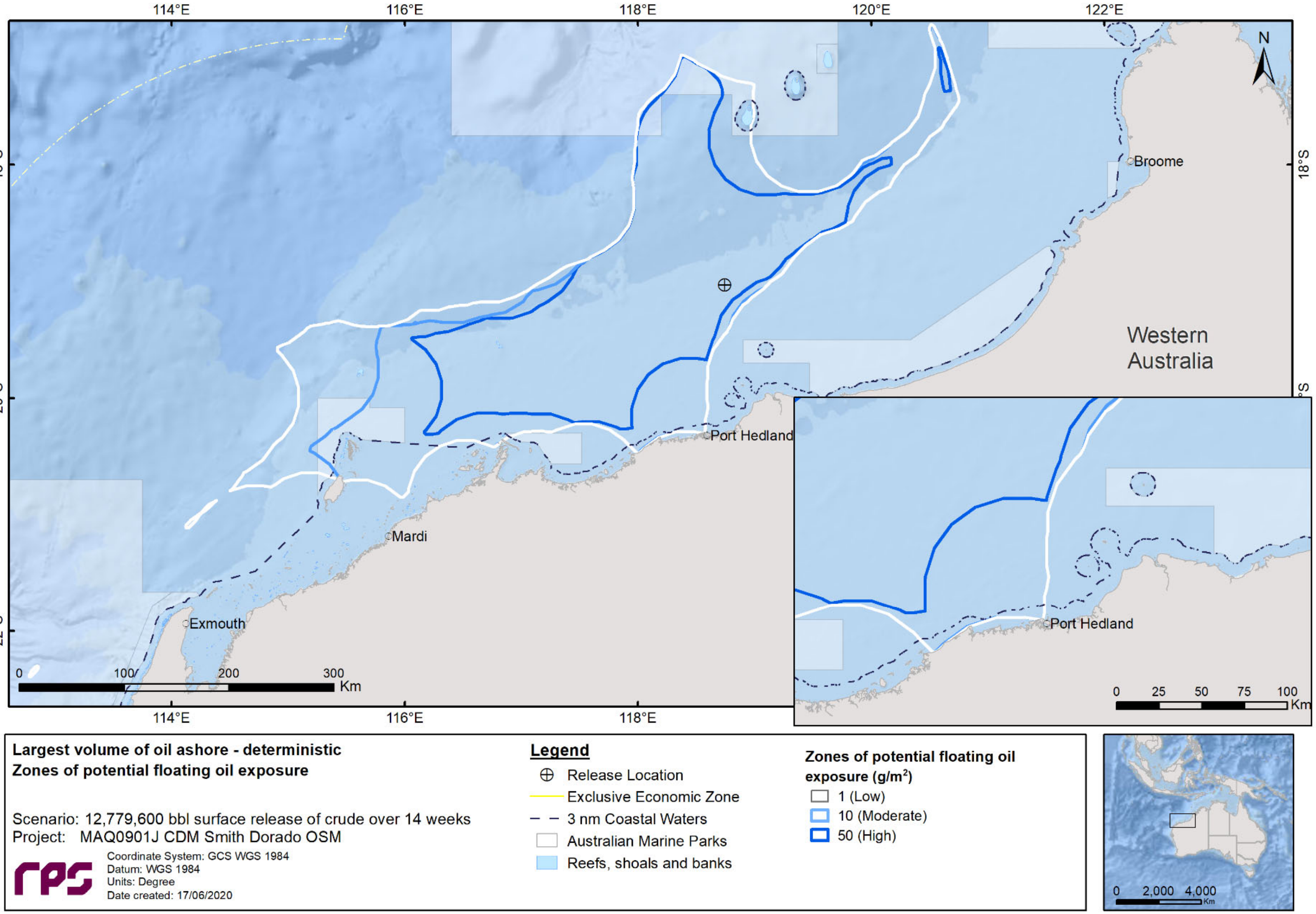


Figure 9.30 **Exposure from floating oil (over the 118 day simulation) for the simulation with the largest volume of oil ashore. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 6 am on the 24th of February 2018.**

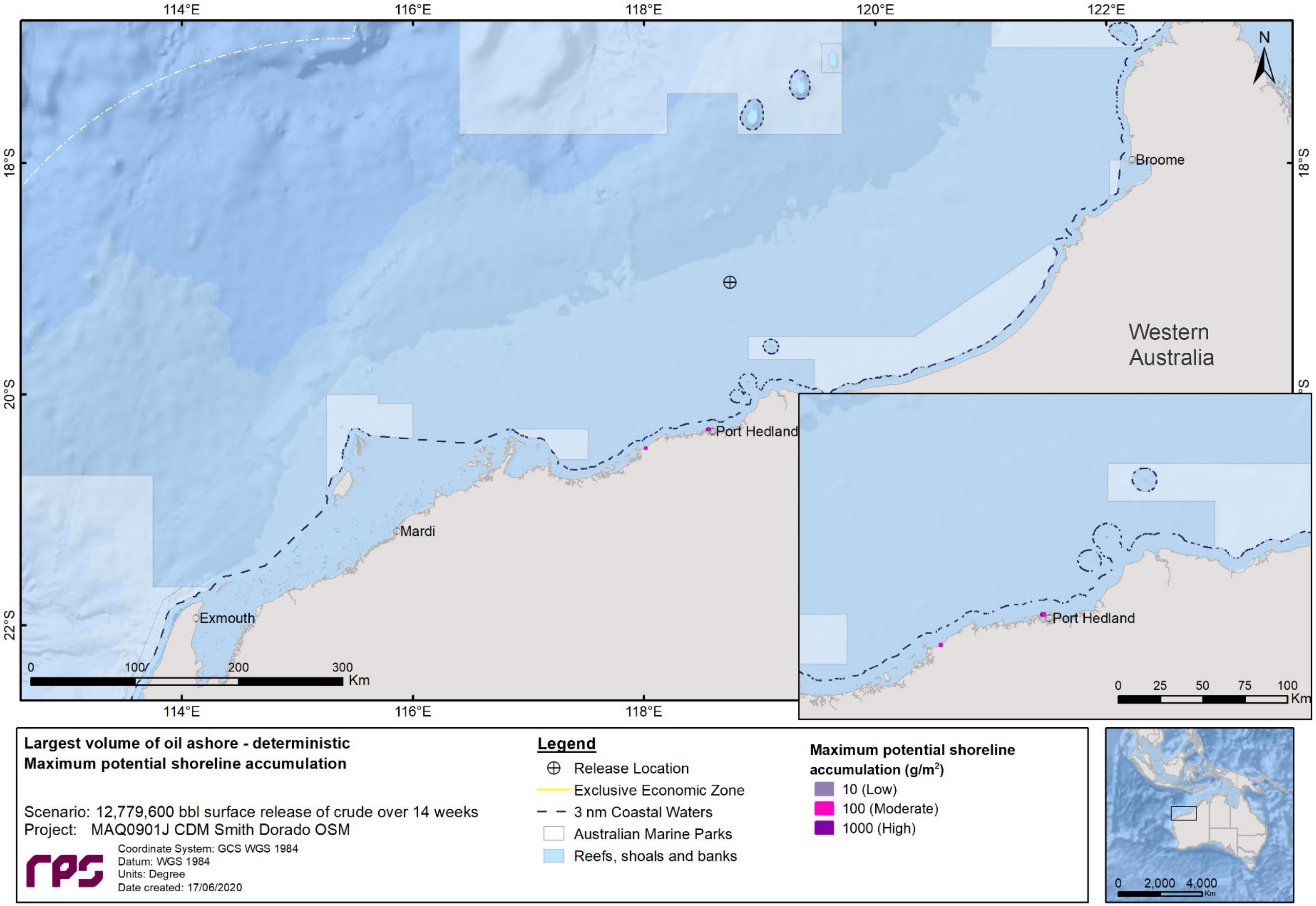


Figure 9.31 **Potential shoreline accumulation (over the 118 day simulation) for the simulation with the largest volume of oil ashore. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 6 am on the 24th of February 2018.**

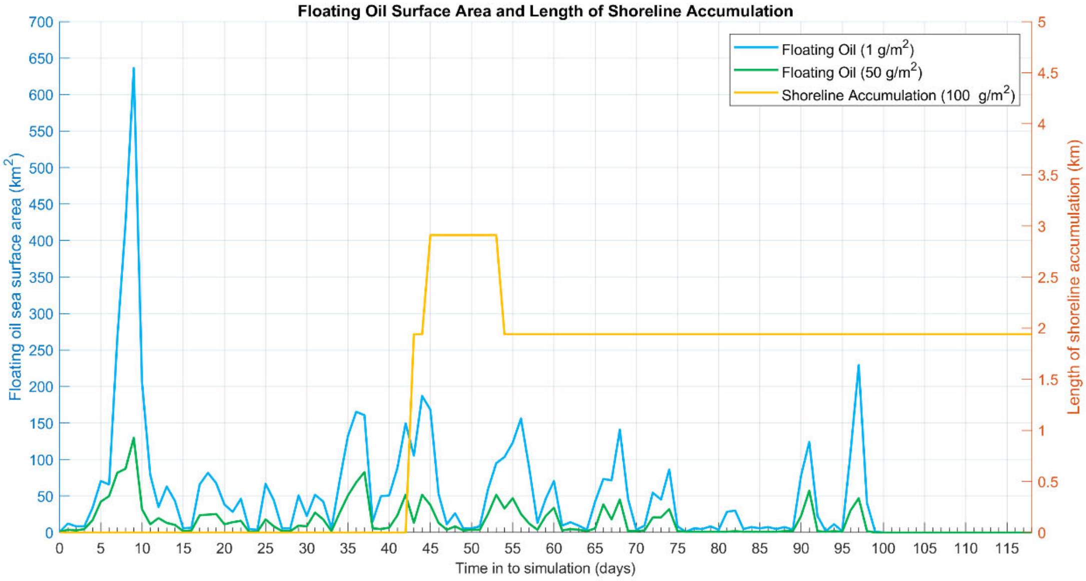


Figure 9.32 Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface and length of actionable shoreline oil (≥100 g/m²) for the simulation with the largest volume of oil ashore. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days, 6 am on the 24th of February 2018.

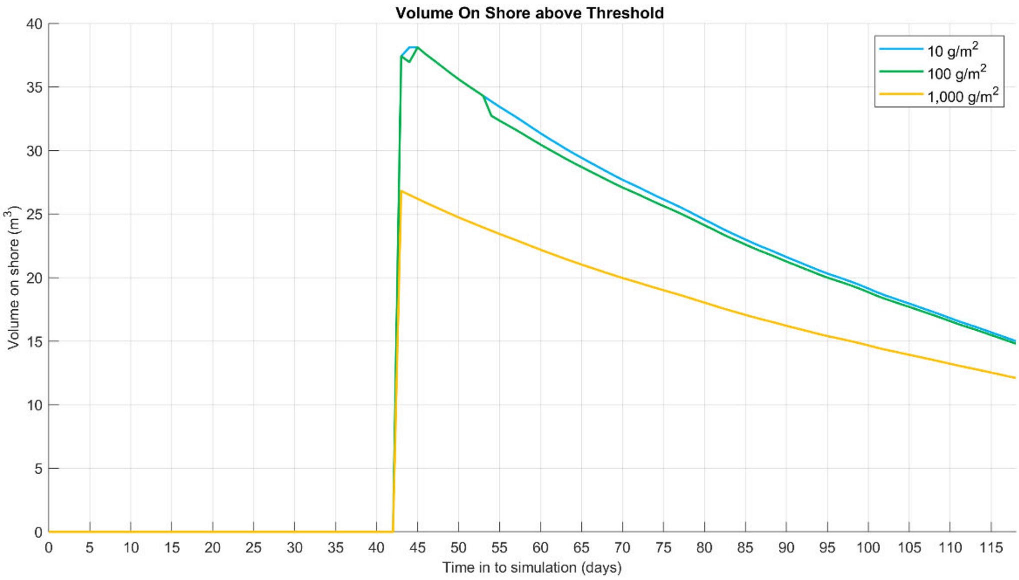


Figure 9.33 Time series of the volume on shore at the low (10-100 g/m²), moderate (100-1,000 g/m²) and high (≥ 1,000 g/m²) thresholds for the simulation with the largest volume of oil ashore. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days, 6 am on the 24th of February 2018.

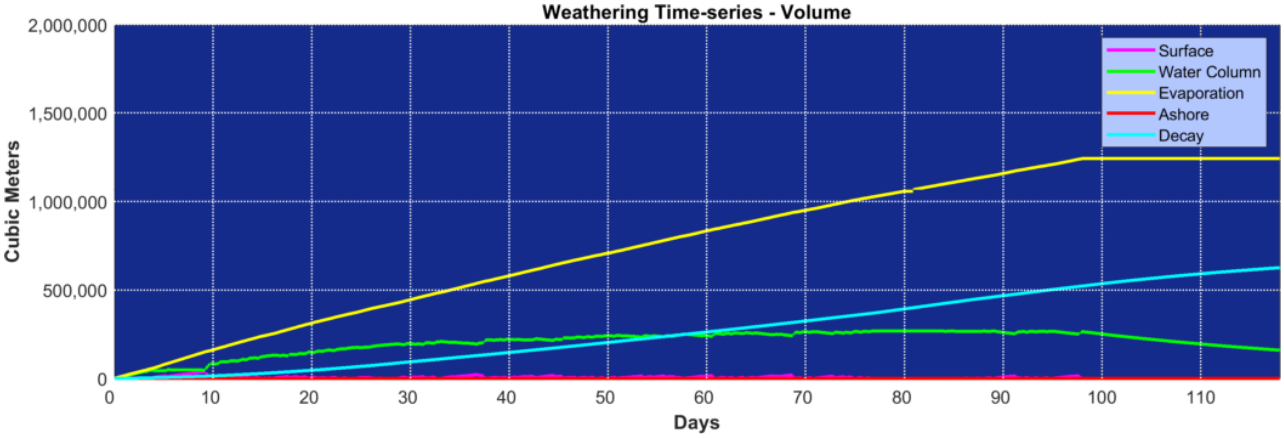


Figure 9.34 Predicted weathering and fates graph for the single spill simulation with the largest volume of oil ashore. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP, tracked for 118 days, 6 am on the 24th of February 2018.

9.2.2.2 Deterministic Case: Longest length of oiled shoreline

The deterministic simulation that resulted in the longest length of oiled shoreline 100 g/m^2 was identified during summer conditions as run number 21 which commenced at 9 pm on the 21st of January 2018.

Exposure from floating oil (swept area) and potential oil accumulation over the entire 118-day simulation are presented in Figure 9.35 and Figure 9.36, respectively. Floating oil exposure was predicted to occur northeast and west/southwest from the release location with shoreline accumulation occurring at the following sensitive shoreline receptors (refer Section 7.3) Port Hedland, Cunningham Island and Imperieuse Reef.

Figure 9.37 displays the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and actionable shoreline oil (≥100 g/m^2) over the 118-day simulation. The maximum area of coverage of visible oil on the sea surface was predicted to occur 42 days after the spill started and covered approximately 552 km^2. While the maximum length of actionable shoreline oiled (above 100 g/m^2) at any given time was 2 km, approximately 76 days into the simulation.

Figure 9.38 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9.39 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 1,228,951 m^3 (60%) spilled oil was lost to the atmosphere through evaporation. Approximately 637,450 m^3 (31%) of the crude was predicted to have decayed, while 161,393 m^3 (8%) remained within the water column and 5 m^3 (<0.1%) was predicted to remain on the shoreline.

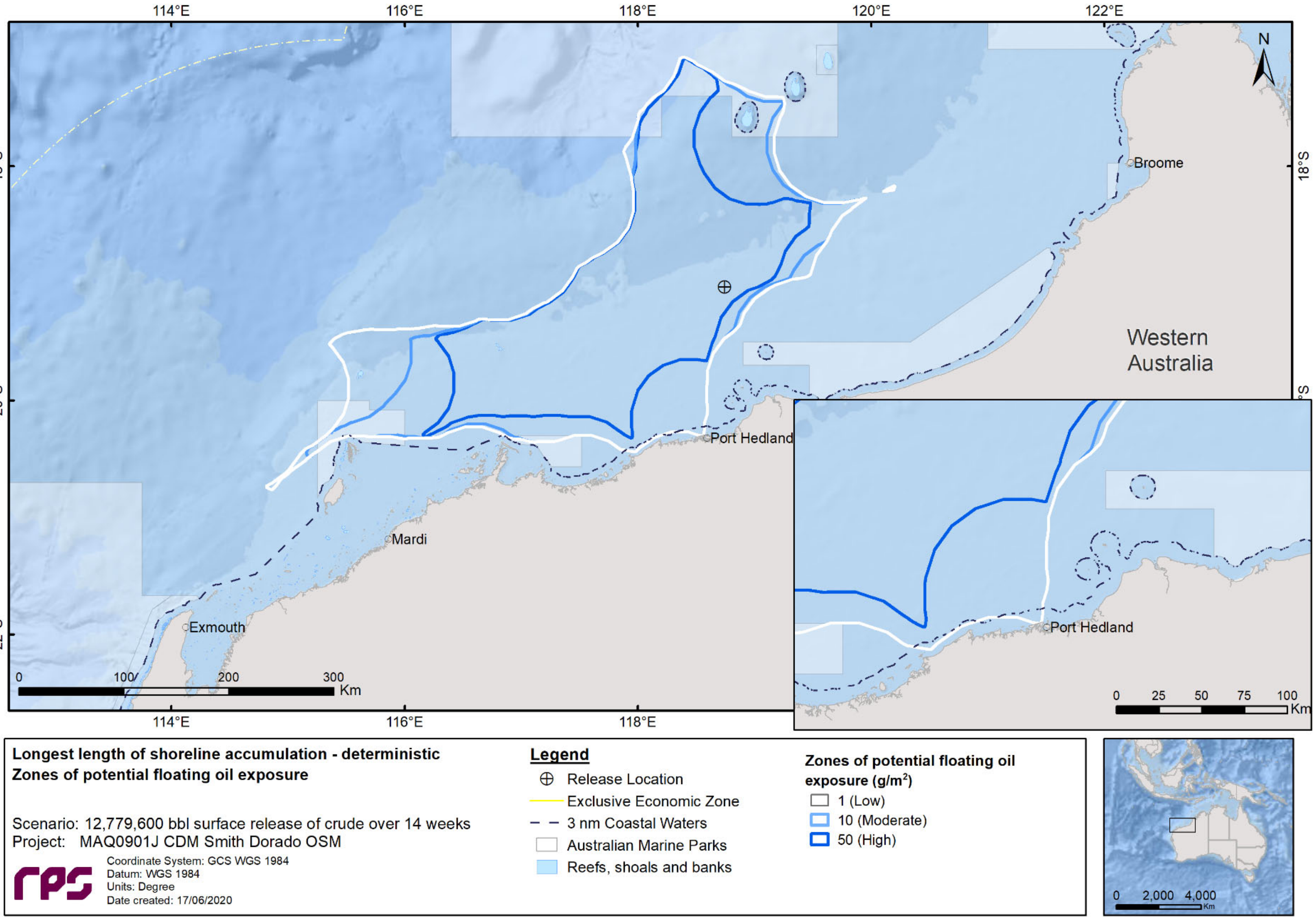


Figure 9.35 Exposure from floating oil (over the 118 day simulation) for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 9 pm on the 21st of January 2018.

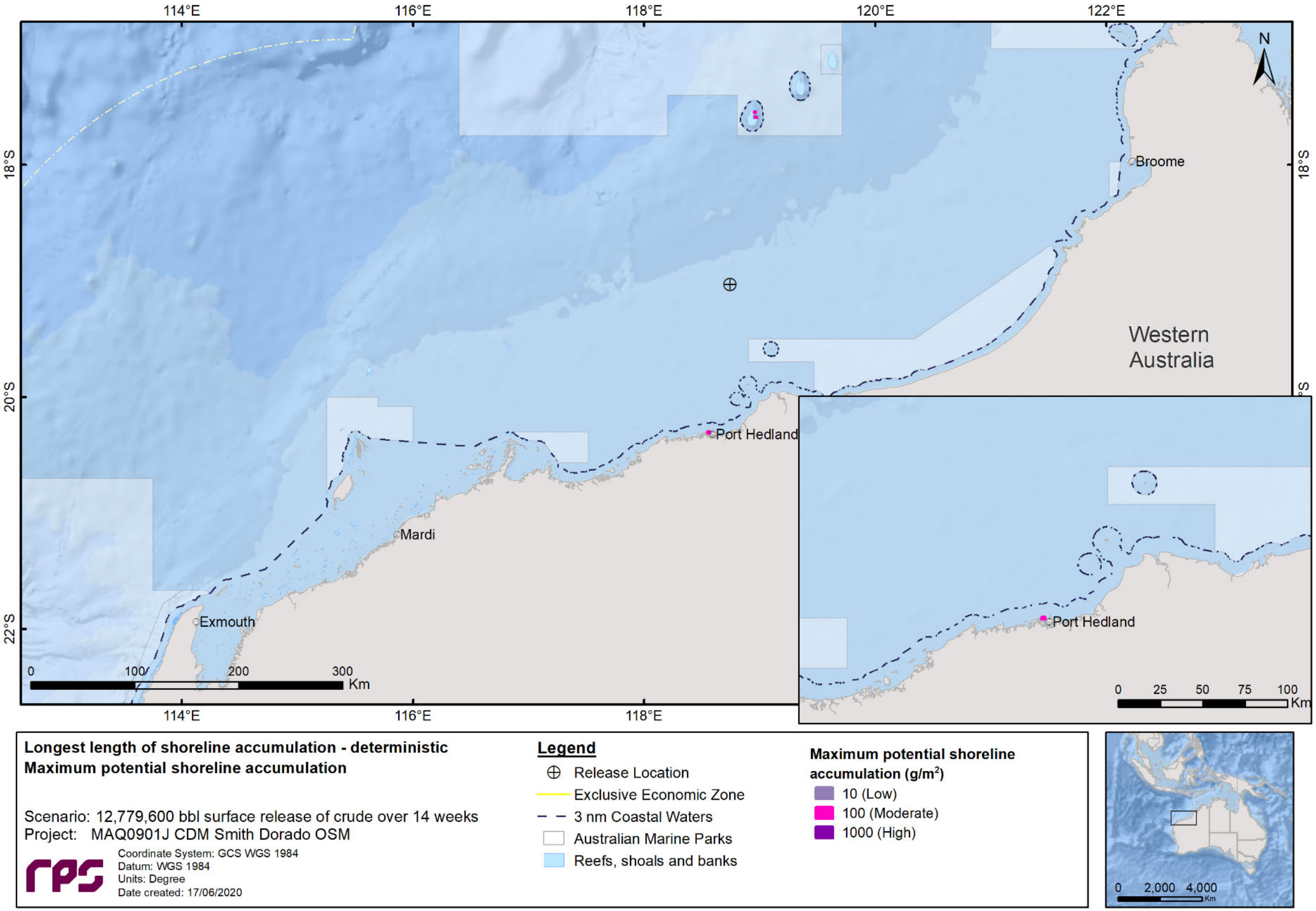


Figure 9.36 Potential shoreline accumulation (over the 118 day simulation) for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, starting 9 pm on the 21st of January 2018.

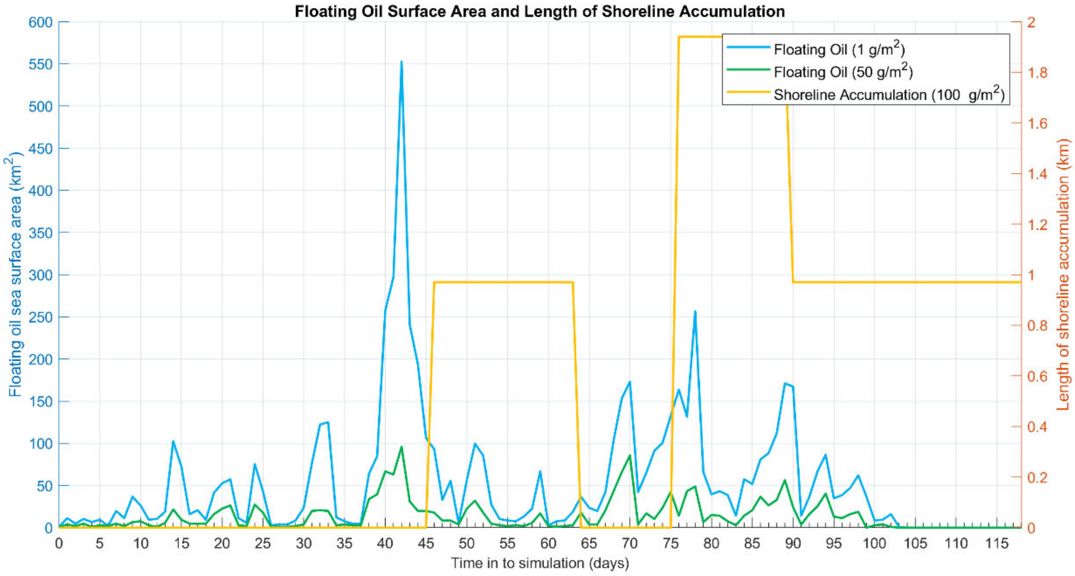


Figure 9.37 Time series of the area of visible (≥1 g/m^2) and actionable floating oil (≥50 g/m^2) on the sea surface and length of actionable shoreline oil (≥100 g/m^2) for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, tracked for 118 days, 9 pm on the 21st of January 2018.

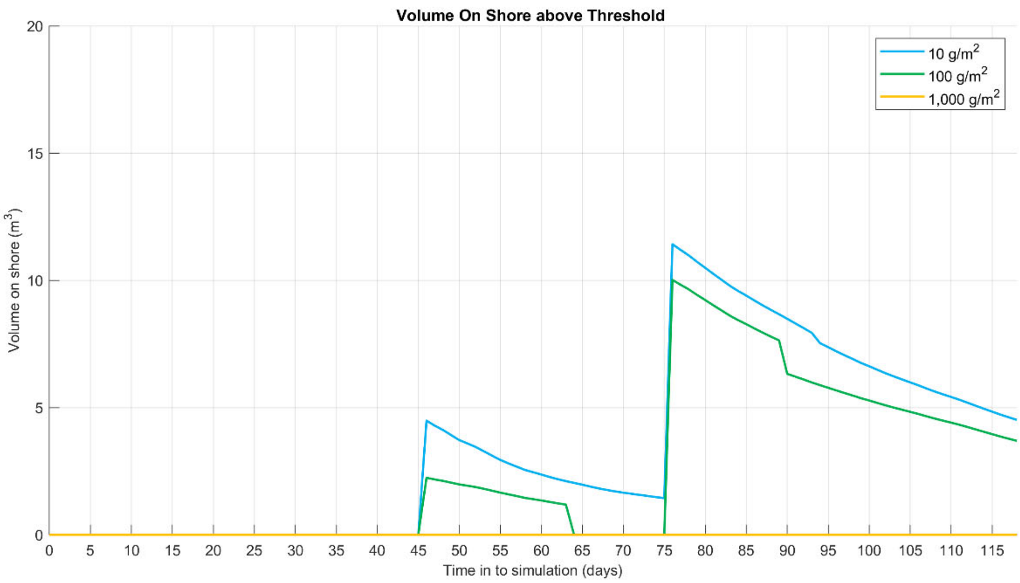


Figure 9.38 Time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, tracked for 118 days, 9 pm on the 21st of January 2018.

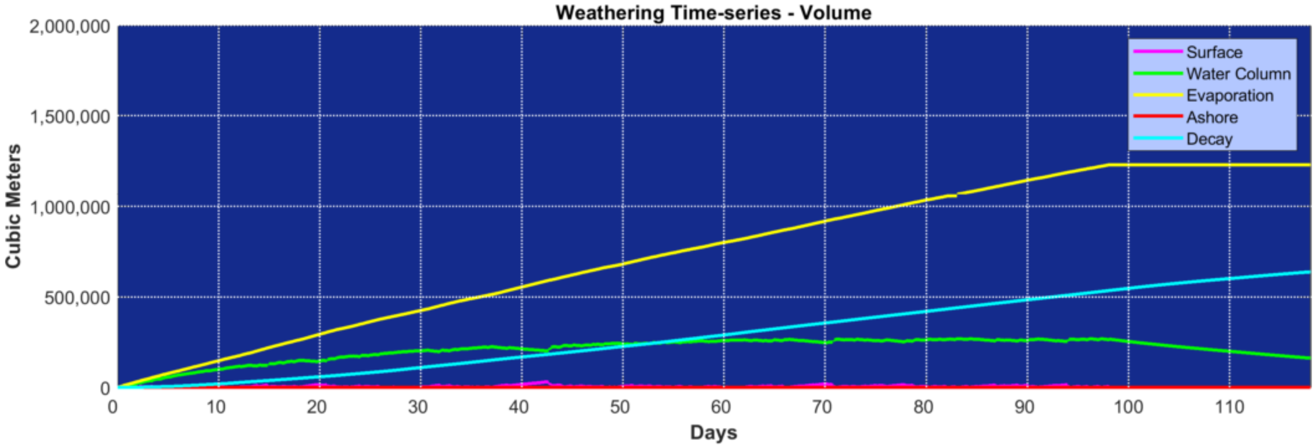


Figure 9.39 Predicted weathering and fates graph for the single spill simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP, tracked for 118 days, 9 pm on the 21st of January 2018.

9.2.3 Seasonal analysis

9.2.3.1 Floating Oil Exposure

Table 9.14 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 1,201.9 km southwest (summer), 497.3 km west-southwest (transitional) and 304.5 km west-southwest (summer and transitional), respectively.

Images of floating oil exposure zones are depicted in Figure 9.40, Figure 9.41 and Figure 9.42 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively.

Table 9.15 to Table 9.17 summarise the potential floating oil exposure to individual receptors for each season, based on combining the results of the 100 simulations. Within the predicted exposure zone from the combined season simulations, there are 7 AMPs, 6 during summer, 1 during transitional and 4 for winter conditions. Montebello AMP recorded the highest probability of exposure to floating oil at 18% during summer conditions. The shortest time for floating oil at the low threshold to reach an AMP was recorded at Argo-Rowley Terrace as 7.50 days during summer conditions.

There are 3 RSBs within the predicted zone of floating oil exposure (at the low threshold) and Imperieuse Reef recorded the highest probability at 9% during summer conditions and the quickest time before exposure of 12.88 days.

Low (1-10 g/m^2) floating oil was predicted to cross into WA State Waters during every season with probabilities ranging from 1-12%. The minimum time before oil crossed the WA State Waters boundary was 2.83 days recorded for a spill commencing during transitional conditions.

Table 9.14 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	1201.9	407.4	304.5
	Max distance from release site (km) (99th percentile)	1044.2	303.3	217.1
	Direction	Southwest	West-Southwest	West-Southwest
Transitional	Max. distance from release site (km)	508.2	497.3	304.5
	Max distance from release site (km) (99th percentile)	399.6	342.2	251.9
	Direction	West-Southwest	West-Southwest	West-Southwest
Winter	Max. distance from release site (km)	413.8	375.9	221.7
	Max distance from release site (km) (99th percentile)	304.4	257.8	152.5
	Direction	Northeast	Northeast	Northeast

Table 9.15 Summary of the potential floating oil exposure to individual receptors. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	11	11	11	7.50	7.50	7.54
	Carnarvon Canyon	3	-	-	94.71	-	-
	Dampier	6	6	-	39.88	39.88	-
	Gascoyne	12	-	-	15.83	-	-
	Kimberley	-	-	-	-	-	-
	Montebello	18	10	-	12.83	12.92	-
	Shark Bay	1	-	-	117.83	-	-
IBRA	Cape Range	1	1	-	16.08	16.08	-
	Roebourne	9	8	-	11.58	11.58	-
IMCRA	Ningaloo	1	-	-	112.96	-	-
	Pilbara (nearshore)	10	9	-	11.54	11.54	-
	Pilbara (offshore)	49	44	15	2.96	2.96	7.83
	Zuytdorp	1	-	-	117.29	-	-
MP	Montebello Islands	1	-	-	95.50	-	-
	Rowley Shoals	11	10	-	10.38	10.38	-
RSB	Imperieuse Reef	9	4	-	12.88	12.88	-
	Rankin Bank	4	-	-	62.33	-	-
	Tryal Rocks	4	2	-	14.04	14.04	-
Nearshore	Barrow Island	1	1	-	16.08	16.08	-
	Cunningham Island	5	-	-	35.96	-	-
	Imperieuse Reef	4	1	-	45.25	45.29	-
	Port Hedland	9	8	-	11.58	11.58	-
State Waters	Western Australia State Waters	12	12	-	10.38	10.38	-

Table 9.16 Summary of the potential floating oil exposure to individual receptors. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of

crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	-	-	-	-	-	-
	Carnarvon Canyon	-	-	-	-	-	-
	Dampier	-	-	-	-	-	-
	Gascoyne	-	-	-	-	-	-
	Kimberley	-	-	-	-	-	-
	Montebello	8	5	-	7.04	7.04	-
	Shark Bay	-	-	-	-	-	-
IBRA	Cape Range	-	-	-	-	-	-
	Roebourne	1	1	-	2.83	2.83	-
IMCRA	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	1	1	-	2.83	2.83	-
	Pilbara (offshore)	45	40	9	2.63	2.63	2.63
	Zuytdorp	-	-	-	-	-	-
MP	Montebello Islands	-	-	-	-	-	-
	Rowley Shoals	-	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-	-
	Rankin Bank	4	2	-	24.46	24.46	-
	Tryal Rocks	-	-	-	-	-	-
Nearshore	Barrow Island	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-
	Port Hedland	1	1	-	2.83	2.83	-
State Waters	Western Australia State Waters	1	1	-	2.83	2.83	-

Table 9.17 Summary of the potential floating oil exposure to individual receptors. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	2	-	-	44.38	-	-
	Carnarvon Canyon	-	-	-	-	-	-
	Dampier	2	1	-	60.38	60.38	-
	Gascoyne	-	-	-	-	-	-
	Kimberley	2	-	-	83.04	-	-
	Montebello	5	1	-	61.75	61.75	-
	Shark Bay	-	-	-	-	-	-
IBRA	Cape Range	-	-	-	-	-	-
	Roebourne	-	-	-	-	-	-
IMCRA	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	-	-	-	-	-	-
	Pilbara (offshore)	26	17	7	9.08	9.08	9.58
	Zuytdorp	-	-	-	-	-	-
MP	Montebello Islands	-	-	-	-	-	-
	Rowley Shoals	-	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-	-
	Rankin Bank	-	-	-	-	-	-
	Tryal Rocks	-	-	-	-	-	-
Nearshore	Barrow Island	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-
	Port Hedland	-	-	-	-	-	-
State Waters	Western Australia State Waters	1	1	-	62.17	62.17	-

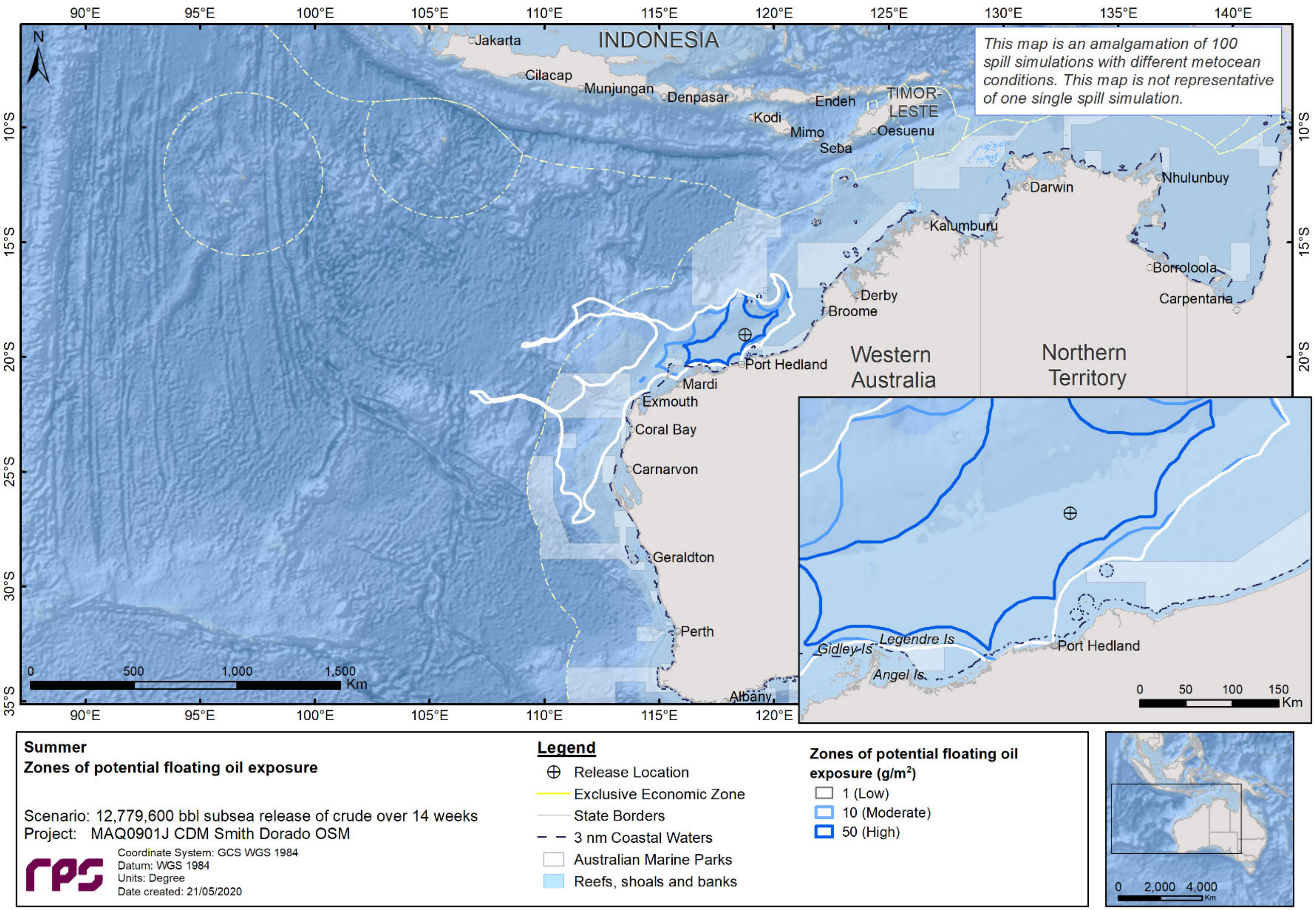


Figure 9.40 Predicted floating oil exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

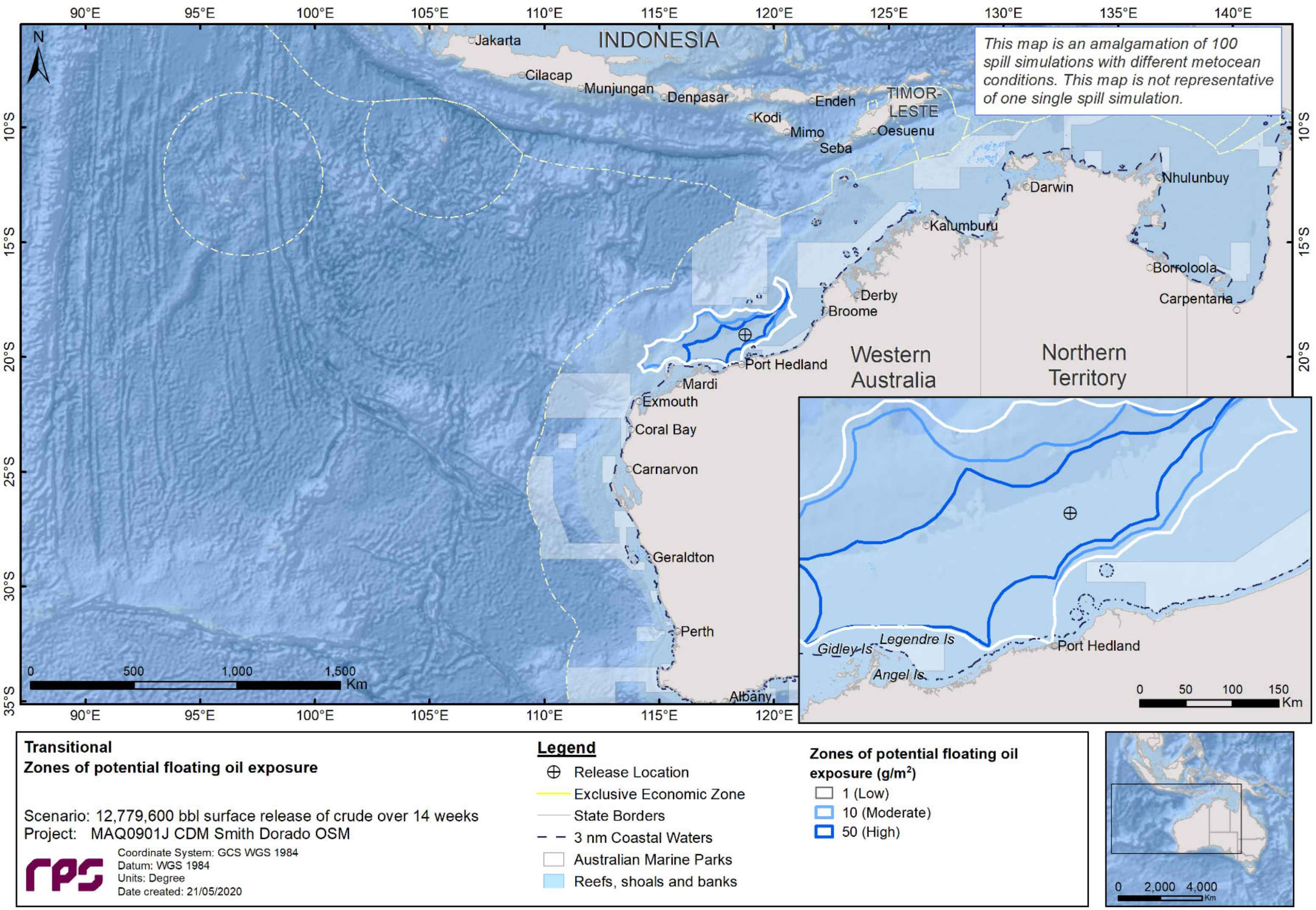


Figure 9.41 Predicted floating oil exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

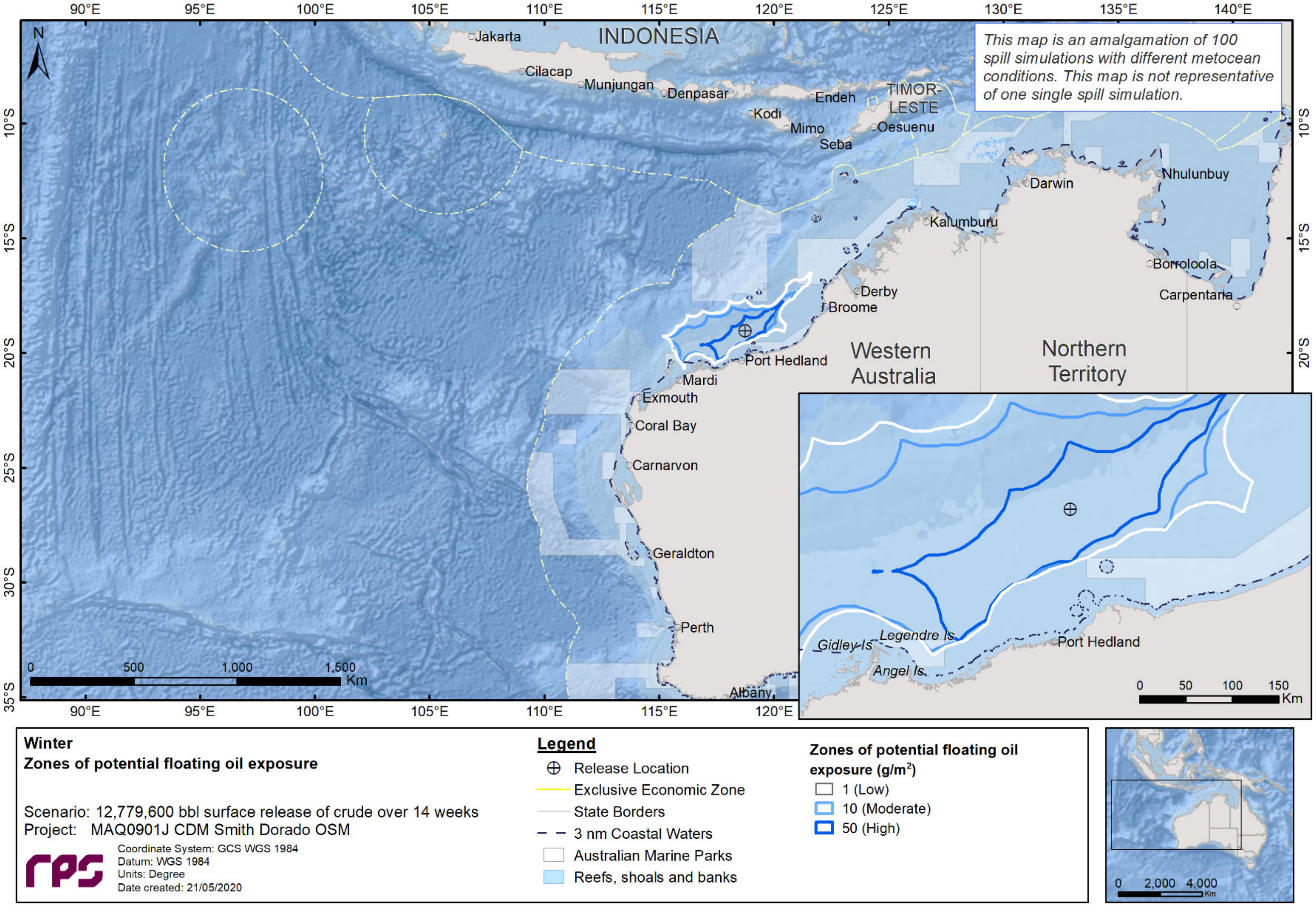


Figure 9.42 Predicted floating oil exposure zones exposure resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.2.3.2 Shoreline Accumulation

Table 9.18 presents a summary of the predicted oil accumulation on any shoreline for all three seasons assessed. The probability of oil accumulation at, or above, the low threshold (10-100 g/m^2) during the summer and transitional seasons was 11% and 1%, respectively. The minimum time before oil accumulation above the low threshold was approximately 11.63 days and 2.88 days, respectively. The greatest volume of oil ashore was 38.1 m^3 and 10 m^3 during summer and transitional conditions, respectively. There was no oil accumulation on any shoreline above the low threshold predicted for spills commencing during winter conditions.

Table 9.19 and Table 9.20 summarise the oil accumulation on individual sensitive shoreline receptors assessed for summer and transitional conditions. Based on combining 100 simulations per season, oil was predicted to accumulate on 3 shoreline receptors at, or above, the low threshold (10-100 g/m^2) during summer and only 1 receptor (Port Hedland) during transitional conditions. Port Hedland recorded the highest probability of oil accumulation at the low threshold (9%) during summer conditions, while the quickest time before soil accumulation was predicted during transitional conditions as 2.88 days. The greatest potential volume of oil ashore was 38.1 m^3 and the maximum length of shoreline predicted to have accumulation at the low threshold was 3 km, both occurring at Port Hedland during summer conditions.

The maximum potential shoreline loading at low, moderate and high accumulation thresholds are depicted in Figure 9.43 and Figure 9.44 based on the 100 spill simulations commencing during summer and transitional conditions, respectively.

Table 9.18 Summary of oil accumulation on any shoreline. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during all seasonal conditions. The results were calculated from 100 spill simulations per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of shoreline accumulation at, or above **10 g/m^2** (%)	11.0	1.0	-
Minimum time before shoreline accumulation at, or above **10 g/m^2** (days)	11.6	2.9	-
Maximum volume of oil ashore (m^3) from a single simulation	38.1	10.0	-
Average volume of oil ashore (m^3)	17.3	10.0	-
Maximum length of shoreline accumulation at or above **10 g/m^2** (km) from a single simulation	6.0	1.0	-
Average length of shoreline accumulation at or above **10 g/m^2** (km)	2.4	1.0	-
Maximum length of shoreline accumulation at or above **100 g/m^2** (km) from a single simulation	4.0	1.0	-
Average length of shoreline accumulation at or above **100 g/m^2** (km)	2.1	1.0	-
Maximum length of shoreline accumulation at or above **1,000 g/m^2** (km) from a single simulation	2.0	-	-
Average length of shoreline accumulation at or above **1,000 g/m^2** (km) for all simulations predicted to reach the shorelines	1.2	-	-

Table 9.19 Summary of oil accumulation on individual shorelines. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Cunningham Island	2	1	-	36.0	45.5	-	30.6	100.8	<0.1	1.2	1.0	1.0	-	1.0	1.0	-
Imperieuse Reef	4	1	-	45.3	45.4	-	75.4	193.4	0.1	3.3	1.8	1.0	-	3.0	1.0	-
Port Hedland	9	9	6	11.6	11.6	11.7	885.5	2,320.9	1.9	38.1	1.9	1.9	1.2	3.0	3.0	2.0

Table 9.20 Summary of oil accumulation on individual shorelines. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Port Hedland	1	1	-	2.9	2.9	-	854.1	854.1	0.1	10.0	1.0	1.0	-	1.0	1.0	-

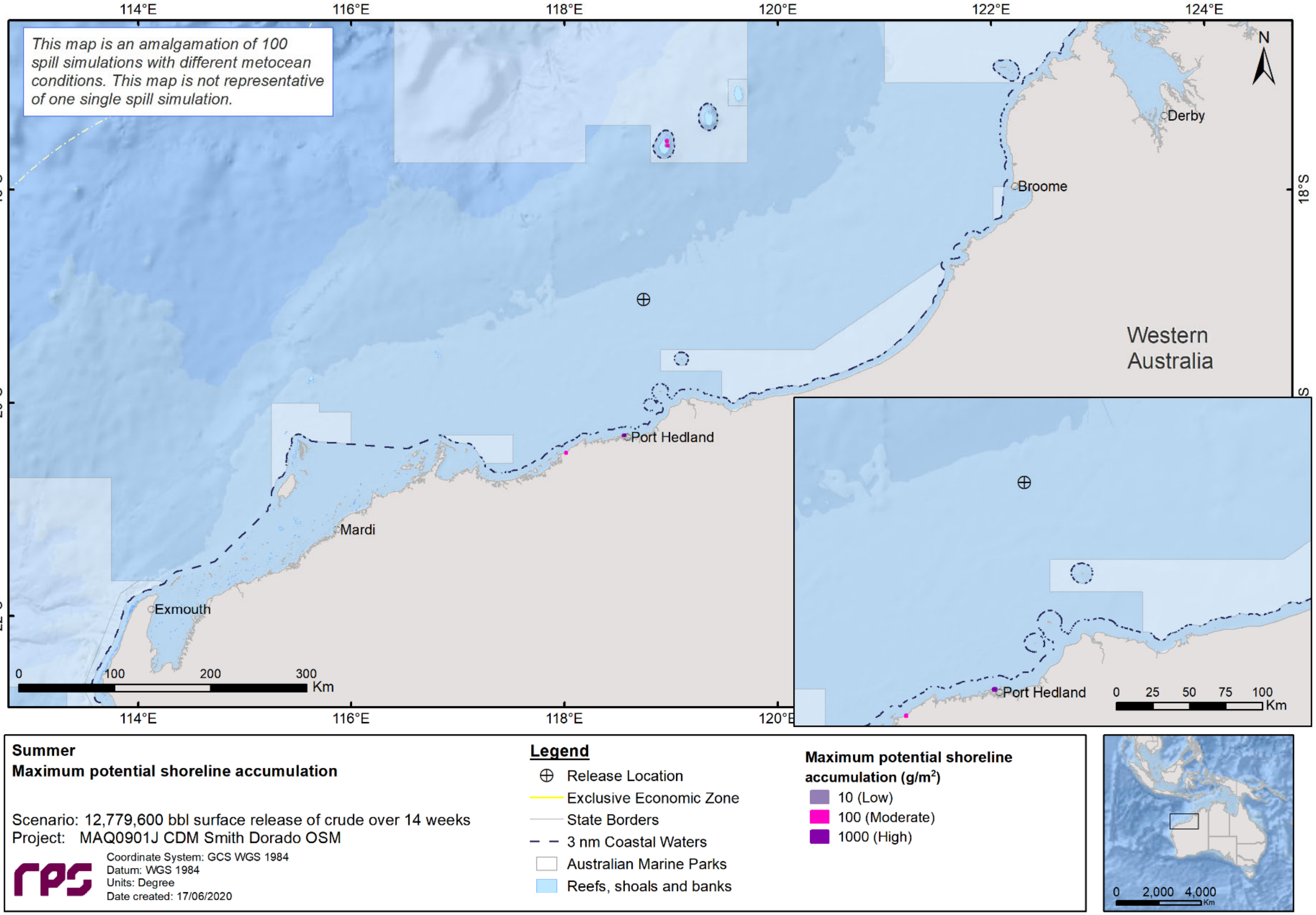


Figure 9.43 Predicted maximum shoreline accumulation resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

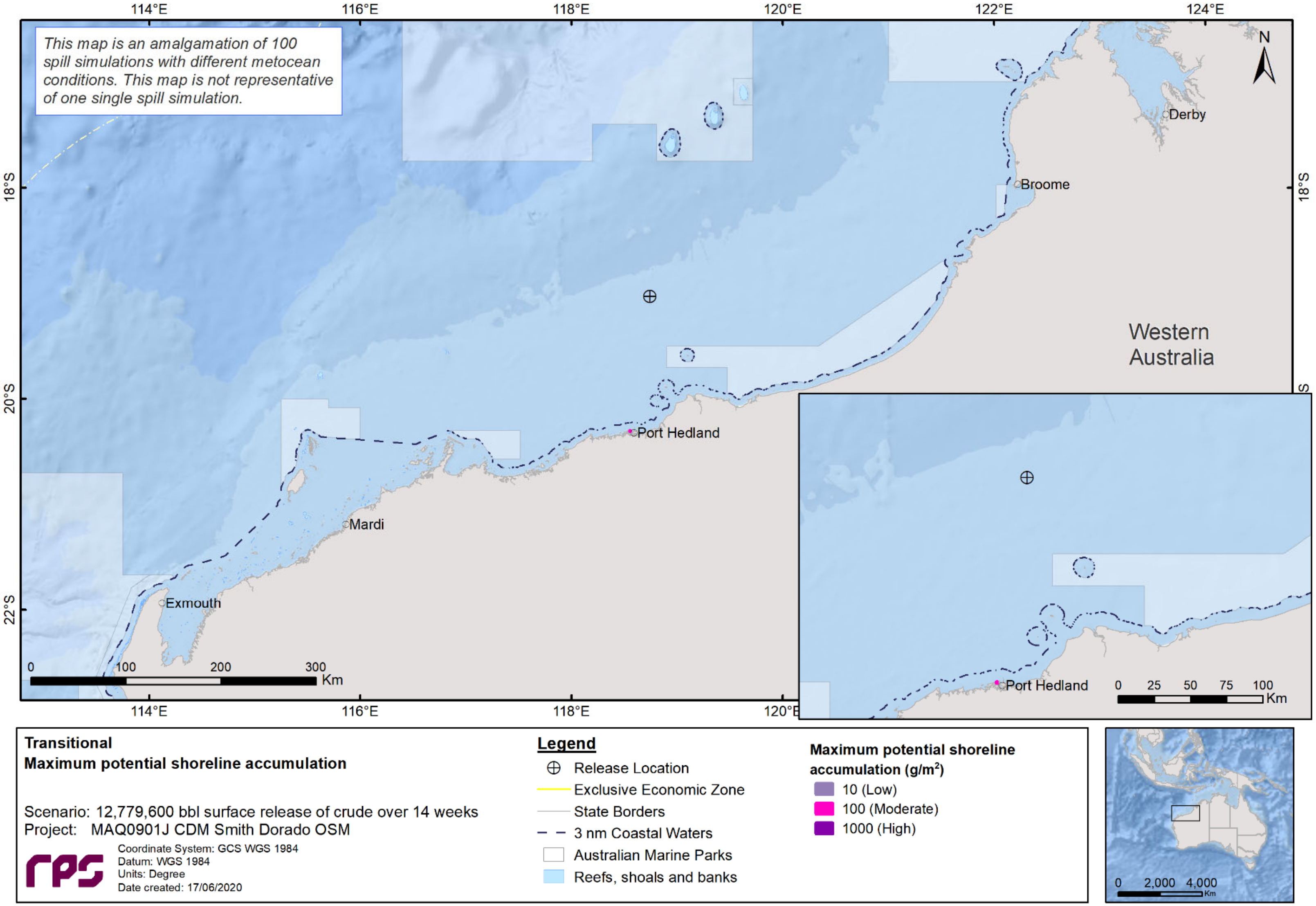


Figure 9.44 Predicted maximum shoreline accumulation resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

9.2.3.3 Entrained Hydrocarbons

Images of the entrained hydrocarbon exposure zones in the 0-10 m depth layer are depicted in Figure 9.45 , Figure 9.46 and Figure 9.47 for the combined 100 spill simulations each commencing during summer, transitional and winter conditions, respectively. The results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 2,932 km (west-northwest) from the spill site during winter conditions. This distance reduced to 2,169 km (west-northwest) as the threshold increased to moderate in winter conditions. The maximum distances for summer and transitional conditions at the low threshold were 2,600 km and 2,488 m, respectively. The maximum distances at the moderate threshold were reduced for summer (1,994 km) and transitional (1,753 km).

Table 9.21 to Table 9.23 summarise the probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at the shallowest depth from the sea surface for each KEF (representing the maximum concentrations).

There are 20 AMPs each within the low exposure zone for summer and transitional results and 19 AMPs within the zone based on winter conditions. Montebello AMP recorded the highest probability of exposure during summer (95%), while Argo Rowley AMP had the highest probabilities for transitional (96%) and winter (100%). The shortest time for entrained hydrocarbons at the low threshold (10-100 ppb) to contact an AMP was recorded at Dampier during transitional conditions as 2.63 days before exposure.

A total of 3 KEFs are within the low exposure zone across the cumulative envelope for the 3 seasons. The Houtman Abrolhos Islands and surrounding reefs KEF recorded the highest probability of exposure at the low threshold during all three seasons (12- 23%).

The number of RSB receptors within the low exposure zone varied from 75 in winter to 104 in summer conditions. The highest probability of exposure was predicted at Rankin Bank during all three seasons (summer 96%; transitional 94% and winter 97%). The quickest time for entrained hydrocarbons at the low threshold to reach an RSB receptor was predicted at Madeleine Shoals (4 days during transitional conditions).

Entrained hydrocarbons at the low threshold were predicted to cross into WA State Waters during every season with probabilities ranging from 81-93%. The minimum time before oil crossed the WA State Waters boundary was 2.71 days, for a spill commencing during transitional conditions.

Table 9.21 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	65	23	29.1	29.3	1,022
	Argo-Rowley Terrace	85	66	7.5	7.5	15,962
	Ashmore Reef	10	3	64.4	74.8	221
	Carnarvon Canyon	78	37	19.6	19.9	2,578
	Cartier Island	7	-	77.1	-	48
	Dampier	25	17	11.4	11.4	7,941

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Eighty Mile Beach	49	38	7.5	12.3	5,322
	Gascoyne	93	82	13.8	13.9	7,447
	Geographe	9	1	64.3	65.7	109
	Jurien	16	3	42.0	42.0	171
	Kimberley	45	31	17.0	17.1	5,520
	Mermaid Reef	51	36	20.3	20.5	3,630
	Montebello	95	85	12.1	12.2	10,713
	Ningaloo	90	50	13.7	13.7	5,079
	Oceanic Shoals	5	-	51.3	-	62
	Perth Canyon	20	8	52.1	52.6	473
	Roebuck	27	14	43.4	49.9	1,220
	Shark Bay	72	29	20.6	21.0	912
	South-west Corner	16	4	57.7	62.3	161
	Two Rocks	13	1	57.2	99.4	101
EEZ	Christmas Island Exclusive Economic Zone	8	-	69.3	-	76
	Cocos Islands Exclusive Economic Zone	4	-	101.3	-	28
	Indonesian Exclusive Economic Zone	29	9	21.8	22.0	1,646
	East Timorian Exclusive Economic Zone	2	-	107.0	-	30
	Oecussi Ambeno Exclusive Economic Zone	2	-	96.1	-	28
IBRA	Cape Range	76	30	12.3	12.3	8,190
	Chichester	15	12	11.5	11.5	1,443
	Christmas Island	-	-	-	-	3
	Cocos Islands	-	-	-	-	8
	Edel	18	11	28.4	29.8	310
	Fitzroy Trough	12	3	66.2	87.5	136
	Geraldton Hills	15	3	40.0	41.8	143
	Lesueur Sandplain	11	-	42.2	-	65
	Mitchell	20	11	46.1	51.1	540
	Perth	14	7	42.0	42.3	193
	Pindanland	29	16	12.6	13.5	4,107
	Roebourne	41	33	11.4	11.4	9,064

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Southern Jarrah Forest	9	1	65.0	104.3	101
	Timor Sea Coral Islands	11	2	62.8	74.8	301
	Warren	11	1	65.9	92.8	115
	Wooramel	12	-	29.7	-	47
IMCRA	Abrolhos Islands	19	6	33.4	34.4	277
	Bonaparte Gulf	2	-	79.3	-	31
	Canning	37	22	24.9	25.1	2,718
	Central West Coast	30	8	29.9	30.7	440
	Eighty Mile Beach	35	22	12.2	12.3	4,382
	Kimberley	23	13	42.3	44.5	935
	King Sound	15	6	54.4	59.8	229
	Leeuwin-Naturaliste	17	8	55.6	56.0	327
	Ningaloo	91	54	13.7	13.7	7,691
	Oceanic Shoals	11	2	51.3	86.8	291
	Pilbara (nearshore)	49	16	11.4	11.4	9,807
	Pilbara (offshore)	95	88	2.8	2.8	29,154
	Shark Bay	14	11	28.7	29.3	407
	WA South Coast	9	-	72.9	-	55
	Zuytdorp	73	29	19.5	19.7	1,529
KEF	Carbonate bank and terrace system of the Sahul Shelf	1	-	51.3	-	15
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	23	11	32.5	33.1	277
	Commonwealth marine environment within and adjacent to Geographe Bay	3	-	64.9	-	24
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons	13	6	42.2	44.1	223
	Commonwealth waters adjacent to Ningaloo Reef	79	30	13.7	13.7	1,707
	Glomar Shoals	3	1	7.6	7.6	109

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Western rock lobster	23	8	33.6	41.2	365
MNR	Hamelin Pool	-	-	-	-	-
MP	Barrow Island	59	24	16.3	22.7	751
	Eighty Mile Beach	24	15	12.5	12.5	5,229
	Jurien Bay	15	8	42.0	42.1	205
	Lalang-garram / Camden Sound	19	9	57.7	62.4	647
	Lalang-garram / Horizontal Falls	13	2	62.9	73.8	190
	Marmion	7	-	67.9	-	55
	Montebello Islands	66	25	12.2	12.3	3,577
	Ngari Capes	12	1	64.8	70.1	109
	Ningaloo	83	36	13.8	15.5	1,992
	North Kimberley	10	2	49.4	76.6	184
	North Lalang-garram	11	3	49.3	73.0	222
	Rowley Shoals	68	57	8.9	9.5	10,648
	Shark Bay	12	-	30.0	-	89
	Shoalwater Islands	8	-	66.0	-	98
	Yawuru Nagulagun / Roebuck Bay	26	10	43.4	44.8	769
NP	Pulu Keeling	-	-	-	-	8
NR	Beagle Islands	12	-	67.7	-	59
	Great Sandy Island	19	13	15.5	15.7	799
	Scott Reef	18	-	52.1	-	98
	Thevenard Island	33	12	15.6	15.6	871
RAMSAR	Ashmore Reef National Nature Reserve	10	3	64.4	74.8	221
	Eighty-mile Beach	23	15	12.5	19.1	2,912
	Peel-Yalgorup System	8	5	66.0	67.0	148
	Pulu Keeling National Park	-	-	-	-	8
	Roebuck Bay	26	7	43.5	55.3	673
	The Dales	-	-	-	-	-
RSB	Albert Reef	20	9	45.8	66.1	436
	Ashworth Shoal	14	-	24.5	-	79
	Assail Bank	9	1	41.8	83.3	111
	Baldwin Bank	2	-	69.8	-	25

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Barcoo Shoal	16	11	45.0	49.0	358
Barracouta Shoal	3	-	81.1	-	31
Barrow Island Reefs and Shoals	21	12	15.5	15.5	1,008
Barton Shoal	1	-	107.2	-	20
Bassett-Smith Shoal	3	-	72.8	-	34
Baylis Patches	18	-	17.0	-	81
Beagle and Dingo Reefs	13	6	49.2	54.1	194
Bennett Shoal	8	-	66.1	-	20
Big Bank Shoals	1	-	112.4	-	23
Branch Banks	2	-	113.7	-	14
Brewis Reef	32	11	15.6	25.5	357
Brue Reef	21	9	44.3	64.0	517
Campbell Shoal	8	-	53.5	-	27
Churchill Reef	20	10	47.0	52.4	239
Clerke Reef	59	45	11.9	21.9	4,456
Clio Bank	14	-	67.4	-	79
Cockell and Nicolle Reefs	13	4	63.0	71.1	398
Courtenay Shoal	15	13	12.2	23.5	567
Dailey Shoal	53	12	16.3	17.0	226
Dart Shoal	12	-	42.5	-	71
Deep Shoal 2	2	-	52.9	-	14
Dillon Shoal	1	-	109.0	-	17
Direction Bank	16	-	42.1	-	93
East Holothuria Reef	4	-	80.1	-	38
Echuca Shoal	10	2	58.0	86.8	171
Eliassen Rocks	16	-	22.0	-	97
Eugene McDermott Shoal	3	-	88.0	-	65
Exmouth Reef	18	-	42.3	-	93
Fairway Reef	28	2	17.2	42.3	104
Fantome Shoal	2	-	89.2	-	37
Fantome Shoal	14	-	42.1	-	75
Fortescue Reef	15	8	22.0	43.4	140
Gee Bank	13	-	42.0	-	91

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Geelvink Channel Shoals	11	-	42.0	-	92
Glomar Shoal	2	-	11.3		27
Goeree Shoal	3	-	92.8	-	58
Hammersley Shoal	15	13	11.9	13.2	287
Hayman Rock	21	-	16.8	-	100
Hayward Rock	9	-	42.4	-	57
Herald Reef	16	8	17.1	42.0	878
Heritage Reef	6	-	78.8	-	38
Heywood Shoal	4	2	81.8	90.9	185
Holothuria Banks	6	-	51.2	-	73
Hood Reef	42	8	15.8	42.5	159
Imperieuse Reef	67	54	9.8	10.9	10,648
Ingram Reef	5	-	79.3	-	62
Jabiru Shoals	3	-	91.0	-	19
Jamieson Reef	6	-	50.9	-	72
Johnson Bank	8	-	68.7	-	83
Karmt Shoal	1	-	109.1	-	26
Lightfoot Reef	16	9	16.0	17.3	284
Little Shoals	17	9	15.9	42.0	563
Locker Reef	22	5	15.8	57.1	150
Long Reef	4	-	91.4	-	33
Madeleine Shoals	20	15	12.7	16.8	1,370
Mangola Shoal	2	-	97.2	-	13
Manicom Bank	13	5	42.0	78.6	162
Mavis Reef	18	8	50.3	69.3	298
McLennan Bank	19	12	13.4	21.0	602
Meda Reef	14	12	15.6	40.9	364
Mermaid Reef	47	35	20.5	20.8	3,233
Mid Reef	11	-	42.0	-	82
Montebello Shoals	56	19	12.3	12.3	1,972
Moresby Shoals	15	8	16.3	42.0	617
Ningaloo Reef	76	29	15.5	17.7	668
North Tail Reef	12	2	42.1	42.1	128
O'Grady Shoal	16	11	13.6	22.3	414
Oliver Rock	4	-	92.6	-	50

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Otway Bank	3	-	100.9	-	21
	Pee Shoal	2	-	94.4	-	25
	Pelsaert Bank	14	-	41.9	-	79
	Penguin Shoal	4	-	67.9	-	46
	Poivre Reef	34	19	15.5	15.5	1,532
	Rainbow Shoals	9	2	65.2	73.3	192
	Rankin Bank	96	89	12.9	12.9	9,809
	Ripple Shoals	22	12	15.5	15.5	1,190
	Robroy Reefs	6	1	61.1	93.4	120
	Rosily Shoals	52	16	15.7	15.7	634
	Rothery Reef	3	-	94.1	-	30
	Sand Knoll Ledge	13	5	42.0	51.8	136
	Snapper Bank	12	1	42.0	87.2	110
	Southwest Patch	16	8	42.0	42.3	232
	Spider Reef	21	-	36.7	-	76
	Stewart Shoal	7	-	66.2	-	21
	Tait Bank	1	-	90.4	-	13
	Taunton Reef	21	12	15.6	15.6	524
	Tongue Shoals	17	8	42.2	44.1	222
	Trap Reef	35	12	15.6	15.8	586
	Tryal Rocks	79	32	13.6	13.9	5,953
	Turtle Dove Shoal	15	-	41.9	-	62
	Van Cloon Shoal	2	-	51.3	-	40
	Vee Shoal	3	-	88.3	-	61
	Vulcan Shoal	4	-	92.2	-	50
	Wapet Shoal	7	-	68.6	-	24
	Ward Reef	16	8	26.2	42.1	557
	Web Reef	19	-	42.3	-	88
	West Holothuria Reef	4	-	51.2	-	31
	West Reef	16	8	26.8	47.2	221
	Wildcat Reefs	10	3	63.3	71.9	291
	Woodbine Bank	7	-	76.8	-	53
Nearshore	Adele Island	19	11	46.1	51.6	298
	Airlie Island	28	12	15.5	15.6	949
	Angel Island	15	12	12.2	23.0	310

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Ashburton	17	8	24.9	42.0	679
Ashburton Island	19	8	24.3	42.3	538
Ashmore Reef	9	2	64.4	74.8	195
Aususta - Margaret River	11	1	66.0	110.0	102
Barrow Island	49	23	14.0	14.0	8,049
Bedout Island	38	33	14.3	14.7	1,743
Bermier Island	14	1	30.1	58.4	108
Bessieres Island	55	14	15.7	15.7	347
Bezout Island	15	12	11.5	11.5	739
Boodie Island	37	16	15.5	15.5	3,107
Broome	26	16	12.6	19.8	2,113
Browse Island	11	2	63.8	84.0	301
Bunbury	7	-	70.8	-	44
Busselton	9	1	65.0	92.8	115
Cape Bruguieres	15	13	11.8	12.1	470
Capel	7	-	70.8	-	46
Carnac Island	7	-	74.7	-	43
Carnamah	11	-	66.2	-	50
Carnarvon	12	-	29.8	-	61
Cartier Island	7	-	77.7	-	34
Chapman Valley	1	-	110.6	-	16
Clerke Reef	59	44	21.3	22.4	4,456
Cockburn	3	-	84.7	-	39
Cohen Island	16	13	11.7	13.2	313
Conzinc Island	14	6	20.6	25.0	147
Coorow	11	-	42.1	-	65
Cunningham Island	67	52	11.8	11.8	10,648
Dandaragan	14	7	42.0	42.3	195
Delambre Island	16	12	11.4	11.4	621
Derby - West Kimberely	20	7	47.2	57.3	540
Direction Island	17	11	15.8	26.5	1,303
Dirk Hartog Island	16	11	28.3	30.9	292
Dolphin Island	15	10	11.5	12.0	400
Dorre Island	15	11	28.7	29.8	310

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Eaglehawk Island	15	8	17.9	42.5	208
East Lewis Island	13	-	28.6	-	67
East Pilbara	17	14	13.0	13.5	4,107
Easter Group	14	2	40.7	82.0	138
Enderby Island	16	8	15.5	15.8	154
Exmouth	75	26	15.5	18.0	497
Faure Island	-	-	-	-	-
Flat Island	60	14	15.7	15.8	335
Fly Island	17	-	41.5	-	77
Fremantle	4	-	84.5	-	34
Garden Island	8	-	66.0	-	69
Gidley Island	15	13	11.8	12.7	346
Gingin	11	-	43.4	-	99
Goodwyn Island	16	4	15.5	42.7	134
Greater Geraldton	4	-	79.9	-	29
Harvey	7	-	67.7	-	49
Haury Island	15	10	11.5	11.5	807
Hermite Island	57	19	12.3	12.3	3,016
Hibernia Reef	5	-	76.0	-	57
Imperieuse Reef	67	53	11.0	11.8	9,411
Irwin	8	-	70.1	-	40
Joondalup	5	-	84.8	-	41
Karratha	15	12	11.6	11.6	1,443
Keast Island	16	15	11.7	12.8	440
Kendrew Island	17	10	18.7	35.5	198
King Leopold Ranges	8	2	69.0	85.5	229
Kingfisher Islands	8	1	66.0	103.8	108
Kwinana	7	-	66.1	-	44
Lacepede Islands	29	13	44.7	45.2	1,124
Legendre Island	19	15	11.5	11.5	814
Little Turtle Islet	13	-	30.4	-	96
Locker Island	17	-	16.3	-	96
Lowendal Island	31	14	15.5	15.5	1,046
Malus Island	15	9	18.7	35.4	382
Mandurah	8	6	65.9	66.0	182

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Mangrove Islands	14	7	15.7	42.0	170
Manjimup	9	-	68.0	-	53
Marv Island	12	2	72.0	87.5	117
Mary Anne Group	16	11	15.6	17.4	332
Mermaid Reef	44	33	20.7	21.2	1,672
Middle Island	41	18	15.5	15.5	2,907
Murion Islands	76	30	15.5	16.7	791
Nannup	6	-	67.5	-	55
North Island	12	2	40.7	75.2	143
North Turtle Island	22	14	14.3	25.2	4,700
Northhampton	4	-	66.5	-	40
Observation Island	27	-	36.7	-	88
Passage Islands	17	13	13.5	15.1	767
Peak Island	71	24	15.8	16.1	461
Pelican Island	-	-	-	-	-
Pelsaert Group	15	1	42.0	42.5	104
Port Hedland	17	15	11.6	11.6	9,064
Ragnard Islands	15	3	18.6	48.4	141
Rivoli Islands	16	2	42.2	43.2	119
Rockingham	8	-	66.0	-	78
Rosemary Island	17	12	15.9	16.8	597
Rottnest Island	10	1	59.4	117.0	124
Round Island	43	11	15.8	16.3	215
Sandy Islet	20	8	50.3	66.1	225
Scott Reef North	22	5	49.3	75.5	167
Scott Reef South	20	8	48.0	60.9	215
Seringapatam Reef	13	-	51.0	-	82
Serrurier Island	53	12	15.7	15.7	280
Shark Bay	14	-	30.3	-	66
Stirling	3	-	94.4	-	31
Sunday Island	59	13	16.4	16.8	396
Table Island	43	10	15.7	16.0	206
Thevenard Island	32	12	15.5	15.6	922
Tortoise Island	24	8	15.7	42.2	345
Twin Island	16	9	16.9	42.0	1,164

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Wallabi Group	11	2	40.0	41.8	135
	Wanneroo	5	-	92.4	-	54
	Waroona	8	-	66.0	-	68
	West Lewis Island	15	7	25.0	35.7	191
	Whalebone Island	5	-	67.7	-	27
	Wyndham - East Kimberley	10	2	64.0	72.6	430
	Indonesia	6	-	52.0	-	82
State Waters	Western Australia State Waters	83	57	8.9	9.5	10,648

Table 9.22 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	47	11	28.0	28.1	561
	Argo-Rowley Terrace	96	87	8.0	9.2	9,274
	Ashmore Reef	6	-	92.2	-	30
	Carnarvon Canyon	55	25	26.5	27.3	849
	Cartier Island	6	-	96.6	-	34
	Dampier	37	14	2.6	2.6	636
	Eighty Mile Beach	13	9	12.0	12.6	1,832
	Gascoyne	91	66	15.8	16.1	4,511
	Geographe	12	-	78.4	-	56
	Jurien	16	-	59.1	-	94
	Kimberley	42	38	5.3	5.4	4,203
	Mermaid Reef	59	48	9.0	9.2	6,146
	Montebello	94	75	4.1	4.1	5,428
	Ningaloo	79	37	22.8	23.3	733
	Oceanic Shoals	1	-	115.8	-	13
	Perth Canyon	18	1	65.6	86.9	110
	Roebuck	4	-	88.7	-	97
	Shark Bay	51	8	35.8	38.0	1,101
	South-west Corner	16	1	70.0	85.7	122
	Two Rocks	15	-	63.8	-	78
EEZ	Christmas Island Exclusive Economic Zone	10	-	70.5	-	81
	Cocos Islands Exclusive Economic Zone	2	-	107.8	-	21
	Indonesian Exclusive Economic Zone	37	16	32.7	33.1	639
	East Timorian Exclusive Economic Zone	1	-	117.4	-	11
	Oecussi Ambeno Exclusive Economic Zone	-	-	-	-	8
IBRA	Cape Range	69	21	8.0	9.2	728

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Chichester	5	1	2.8	2.9	1,240
	Christmas Island	-	-	-	-	3
	Cocos Islands	-	-	-	-	-
	Edel	8	-	57.6	-	39
	Fitzroy Trough	6	-	95.6	-	65
	Geraldton Hills	17	2	56.8	63.5	166
	Lesueur Sandplain	9	-	67.7	-	59
	Mitchell	15	9	80.5	87.7	650
	Perth	15	-	65.9	-	87
	Pindanland	23	15	58.7	59.8	883
	Roebourne	41	11	2.8	2.8	1,761
	Southern Jarrah Forest	11	-	81.2	-	46
	Timor Sea Coral Islands	10	-	93.7	-	31
	Warren	14	-	79.1	-	88
	Wooramel	-	-	-	-	8
IMCRA	Abrolhos Islands	18	4	54.6	56.9	295
	Bonaparte Gulf	-	-	-	-	-
	Canning	32	24	50.3	51.9	2,079
	Central West Coast	18	4	50.1	52.6	454
	Eighty Mile Beach	13	2	79.0	93.0	509
	Kimberley	23	12	70.7	83.5	1,202
	King Sound	13	3	82.5	90.5	159
	Leeuwin-Naturaliste	16	1	66.4	90.0	122
	Ningaloo	85	50	21.3	22.0	1,196
	Oceanic Shoals	9	-	90.0	-	41
	Pilbara (nearshore)	45	10	2.7	2.7	3,200
	Pilbara (offshore)	96	89	2.5	2.6	16,212
	Shark Bay	3	-	62.1	-	32
	WA South Coast	12	-	80.3	-	68
	Zuytdorp	53	15	26.5	37.5	1,101
KEF	Carbonate bank and terrace system of the Sahul Shelf	-	-	103.5	-	-
	Commonwealth marine environment surrounding the	19	4	55.1	56.9	295

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Houtman Abrolhos Islands					
	Commonwealth marine environment within and adjacent to Geographe Bay	3	-	81.5	-	20
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons	16	1	66.3	94.5	105
	Commonwealth waters adjacent to Ningaloo Reef	79	33	22.8	23.3	383
	Glomar Shoals	5	1	3.8	3.9	247
	Western rock lobster	18	4	52.5	52.8	454
MNR	Hamelin Pool	-	-	-	-	-
MP	Barrow Island	58	16	13.8	15.5	548
	Eighty Mile Beach	1	-	110.5	-	12
	Jurien Bay	14	-	65.4	-	82
	Lalang-garram / Camden Sound	13	6	86.2	89.3	517
	Lalang-garram / Horizontal Falls	6	1	92.8	109.1	131
	Marmion	13	-	76.3	-	52
	Montebello Islands	71	30	7.0	7.6	1,629
	Ngari Capes	15	-	78.7	-	96
	Ningaloo	72	14	23.8	26.1	347
	North Kimberley	6	5	96.9	98.5	397
	North Lalang-garram	6	6	93.6	96.7	399
	Rowley Shoals	81	56	10.8	11.4	7,374
	Shark Bay	2	-	93.3	-	15
	Shoalwater Islands	13	-	75.5	-	69
	Yawuru Nagulagun / Roebuck Bay	2	-	108.0	-	98
NP	Pulu Keeling	-	-	-	-	-
NR	Beagle Islands	9	-	68.7	-	23
	Great Sandy Island	10	2	23.8	24.5	214
	Scott Reef	18	-	76.5	-	32
	Thevenard Island	28	-	33.1	-	85

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
RAMSAR	Ashmore Reef National Nature Reserve	6	-	92.2	-	30
	Eighty-mile Beach	-	-	-	-	3
	Peel-Yalgorup System	11	-	79.3	-	70
	Pulu Keeling National Park	-	-	-	-	-
	Roebuck Bay	2	-	110.0	-	44
	The Dales	-	-	-	-	-
RSB	Albert Reef	12	7	86.9	88.6	812
	Ashworth Shoal	2	-	24.3	-	43
	Assail Bank	10	2	57.5	67.5	131
	Baldwin Bank	-	-	-	-	4
	Barcoo Shoal	18	8	86.9	87.5	694
	Barracouta Shoal	2	-	111.9	-	14
	Barrow Island Reefs and Shoals	10	-	24.5	-	80
	Barton Shoal	-	-	-	-	8
	Bassett-Smith Shoal	-	-	-	-	2
	Baylis Patches	8	-	42.8	-	48
	Beagle and Dingo Reefs	9	6	89.5	90.0	668
	Bennett Shoal	1	-	116.3	-	10
	Big Bank Shoals	-	-	-	-	3
	Branch Banks	-	-	-	-	3
	Brewis Reef	28	-	37.6	-	51
	Brue Reef	19	8	82.2	86.8	1,039
	Campbell Shoal	-	-	-	-	7
	Churchill Reef	10	7	88.0	88.9	684
	Clerke Reef	62	41	11.3	11.8	6,351
	Clio Bank	15	-	61.1	-	61
	Cockell and Nicolle Reefs	6	6	93.9	101.8	274
	Courtenay Shoal	8	2	21.8	23.5	572
	Dailey Shoal	46	-	26.7	-	56
	Dart Shoal	12	-	60.8	-	95
	Deep Shoal 2	-	-	-	-	-
	Dillon Shoal	-	-	-	-	8

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Direction Bank	15	-	64.3	-	67
East Holothuria Reef	-	-	-	-	4
Echuca Shoal	8	-	102.0	-	29
Eliassen Rocks	2	-	24.2	-	43
Eugene McDermott Shoal	4	-	100.3	-	19
Exmouth Reef	12	-	61.8	-	25
Fairway Reef	20	-	26.9	-	53
Fantome Shoal	2	-	115.4	-	15
Fantome Shoal	13	-	60.2	-	61
Fortescue Reef	2	-	23.9	-	60
Gee Bank	13	-	60.1	-	89
Geelvink Channel Shoals	11	-	65.0	-	67
Glomar Shoal	4	1	3.8	3.9	166
Goeree Shoal	2	-	100.9	-	17
Hammersley Shoal	14	3	4.0	13.9	317
Hayman Rock	11	-	33.4	-	42
Hayward Rock	1	-	97.2	-	11
Herald Reef	6	-	40.0	-	40
Heritage Reef	3	1	106.1	116.2	154
Heywood Shoal	9	-	102.6	-	24
Holothuria Banks	1	-	117.5	-	13
Hood Reef	31	-	26.8	-	86
Imperieuse Reef	81	53	13.5	14.0	6,498
Ingram Reef	2	-	107.5	-	78
Jabiru Shoals	2	-	107.5	-	13
Jamieson Reef	2	-	107.1	-	87
Johnson Bank	6	-	94.1	-	24
Karmt Shoal	1	-	115.7	-	17
Lightfoot Reef	6	-	27.0	-	46
Little Shoals	7	-	33.0	-	35
Locker Reef	12	-	38.4	-	45
Long Reef	2	-	114.3	-	44
Madeleine Shoals	20	6	4.0	8.6	192
Mangola Shoal	-	-	-	-	10

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Manicom Bank	4	-	80.5	-	46
Mavis Reef	10	6	88.0	89.8	825
McLennan Bank	5	-	23.8	-	33
Meda Reef	4	1	24.6	42.6	105
Mermaid Reef	57	46	9.3	9.6	4,825
Mid Reef	11	-	65.4	-	46
Montebello Shoals	61	20	9.5	9.6	559
Moresby Shoals	6	-	40.0	-	36
Ningaloo Reef	57	7	26.1	28.0	247
North Tail Reef	12	-	66.4	-	38
O'Grady Shoal	2	-	24.4	-	49
Oliver Rock	2	-	111.2	-	42
Otway Bank	-	-	-	-	7
Pee Shoal	1	-	113.0	-	18
Pelsaert Bank	16	-	57.2	-	86
Penguin Shoal	-	-	-	-	8
Poivre Reef	42	13	17.6	48.4	354
Rainbow Shoals	6	5	95.2	101.2	172
Rankin Bank	94	86	6.3	6.5	4,973
Ripple Shoals	14	-	26.6	-	77
Robroy Reefs	5	3	100.2	105.4	375
Rosily Shoals	51	4	32.3	58.8	250
Rothery Reef	1	-	117.3	-	14
Sand Knoll Ledge	12	-	65.7	-	64
Snapper Bank	10	-	64.2	-	93
Southwest Patch	4	-	80.7	-	49
Spider Reef	14	-	28.5	-	40
Stewart Shoal	1	-	115.3	-	17
Tait Bank	-	-	-	-	-
Taunton Reef	14	-	30.1	-	44
Tongue Shoals	7	-	41.8	-	52
Trap Reef	32	-	31.5	-	78
Tryal Rocks	78	36	10.0	10.5	1,101
Turtle Dove Shoal	15	-	60.8	-	91
Van Cloon Shoal	-	-	-	-	4

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Vee Shoal	3	-	112.8	-	16
	Vulcan Shoal	2	-	101.5	-	22
	Wapet Shoal	-	-	-	-	3
	Ward Reef	5	-	46.4	-	35
	Web Reef	9	-	44.6	-	41
	West Holothuria Reef	-	-	-	-	7
	West Reef	6	-	28.8	-	49
	Wildcat Reefs	6	6	92.8	95.3	307
	Woodbine Bank	6	-	95.1	-	28
Nearshore	Adele Island	12	7	87.9	88.4	650
	Airlie Island	21	-	28.3	-	65
	Angel Island	9	2	9.2	23.7	293
	Ashburton	5	-	43.8	-	65
	Ashburton Island	7	-	41.0	-	68
	Ashmore Reef	6	-	93.7	-	30
	Aususta - Margaret River	14	-	79.4	-	88
	Barrow Island	47	16	14.9	17.5	470
	Bedout Island	6	4	17.8	24.0	203
	Bermier Island	2	-	57.2	-	32
	Bessieres Island	53	2	34.7	59.6	133
	Bezout Island	5	1	2.8	2.9	707
	Boodie Island	37	11	23.6	48.1	328
	Broome	17	11	77.8	85.6	436
	Browse Island	10	-	102.0	-	26
	Bunbury	11	-	86.1	-	40
	Busselton	12	-	79.1	-	50
	Cape Bruguieres	14	4	7.4	13.5	322
	Capel	11	-	86.0	-	39
	Carnac Island	14	-	72.8	-	46
	Carnamah	7	-	69.2	-	28
	Carnarvon	5	-	61.9	-	31
	Cartier Island	5	-	97.7	-	31
	Chapman Valley	7	-	97.1	-	28
	Clerke Reef	62	41	11.3	11.8	5,829

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Cockburn	12	-	81.1	-	38
Cohen Island	14	5	4.0	9.7	317
Conzinc Island	5	2	13.0	25.3	195
Coorow	7	-	67.7	-	37
Cunningham Island	72	48	13.5	14.1	2,694
Dandaragan	14	-	65.9	-	65
Delambre Island	15	2	2.8	2.9	638
Derby - West Kimberely	15	9	80.5	87.7	499
Direction Island	6	-	39.3	-	45
Dirk Hartog Island	8	-	57.7	-	27
Dolphin Island	12	5	3.4	6.3	435
Dorre Island	5	-	60.3	-	39
Eaglehawk Island	3	-	27.1	-	22
East Lewis Island	5	-	27.4	-	48
East Pilbara	-	-	-	-	0
Easter Group	16	2	58.6	71.0	153
Enderby Island	4	-	27.0	-	46
Exmouth	60	7	25.9	26.8	288
Faure Island	-	-	-	-	-
Flat Island	58	-	26.8	-	79
Fly Island	9	-	43.6	-	69
Fremantle	12	-	82.0	-	39
Garden Island	13	-	72.3	-	66
Gidley Island	10	3	7.4	12.1	340
Gingin	14	-	74.8	-	63
Goodwyn Island	7	-	23.7	-	85
Greater Geraldton	7	-	83.2	-	39
Harvey	8	-	85.2	-	35
Haury Island	13	3	2.8	2.8	479
Hermite Island	61	21	8.0	9.2	728
Hibernia Reef	4	-	105.4	-	28
Imperieuse Reef	79	50	13.8	14.1	3,953
Irwin	9	-	83.7	-	59
Joondalup	12	-	81.4	-	39
Karratha	5	2	2.8	2.9	1,240

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Keast Island	15	7	4.0	7.8	347
Kendrew Island	12	2	21.1	23.7	194
King Leopold Ranges	6	-	99.6	-	49
Kingfisher Islands	5	-	98.4	-	60
Kwinana	11	-	81.0	-	42
Lacepede Islands	23	15	58.7	59.8	883
Legendre Island	16	8	2.8	2.8	479
Little Turtle Islet	1	-	26.7	-	68
Locker Island	8	-	42.6	-	44
Lowendal Island	29	6	13.8	16.0	202
Malus Island	7	2	23.5	23.6	358
Mandurah	12	-	78.5	-	87
Mangrove Islands	5	-	47.2	-	31
Manjimup	12	-	80.3	-	76
Marv Island	4	-	107.0	-	65
Mary Anne Group	8	-	25.0	-	48
Mermaid Reef	57	46	9.4	9.8	4,825
Middle Island	41	11	17.4	47.5	432
Murion Islands	69	6	26.6	26.8	172
Nannup	9	-	81.1	-	57
North Island	11	2	56.8	63.5	164
North Turtle Island	4	-	23.6	-	100
Northhampton	7	-	83.3	-	22
Observation Island	16	-	26.9	-	47
Passage Islands	6	2	23.8	24.5	326
Peak Island	61	2	26.6	26.7	130
Pelican Island	-	-	-	-	-
Pelsaert Group	17	1	59.7	74.1	111
Port Hedland	3	1	2.8	2.8	1,761
Ragnard Islands	1	-	59.0	-	12
Rivoli Islands	6	-	47.5	-	52
Rockingham	12	-	75.1	-	66
Rosemary Island	12	3	18.5	23.5	588
Rottnest Island	15	-	66.7	-	63
Round Island	37	-	26.9	-	70

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Sandy Islet	22	6	73.1	75.6	169
	Scott Reef North	22	5	73.5	76.3	149
	Scott Reef South	23	6	67.8	74.7	216
	Seringapatam Reef	16	-	75.7	-	92
	Serrurier Island	54	-	26.8	-	73
	Shark Bay	3	-	58.9	-	21
	Stirling	10	-	81.9	-	33
	Sunday Island	51	-	26.6	-	71
	Table Island	39	-	26.8	-	70
	Thevenard Island	28	-	33.1	-	85
	Tortoise Island	20	-	38.9	-	57
	Twin Island	5	-	40.5	-	25
	Wallabi Group	12	2	57.3	64.5	166
	Wanneroo	13	-	77.1	-	60
	Waroona	11	-	83.0	-	43
	West Lewis Island	5	2	23.7	25.8	180
	Whalebone Island	-	-	-	-	4
	Wyndham - East Kimberley	6	6	92.9	97.9	279
	Indonesia	8	-	79.0	-	47
State Waters	Western Australia State Waters	81	56	2.7	2.7	7,350

Table 9.23 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Abrolhos	46	7	47.6	53.0	636
	Argo-Rowley Terrace	100	98	13.2	14.0	9,426
	Ashmore Reef	11	-	75.3	-	30
	Carnarvon Canyon	58	15	43.6	45.0	837
	Cartier Island	5	-	82.8	-	25
	Dampier	60	19	18.0	20.9	1,480
	Eighty Mile Beach	48	16	6.2	6.7	5,340
	Gascoyne	96	65	20.1	20.4	6,594
	Geographe	1	-	104.8	-	15
	Jurien	4	-	79.4	-	27
	Kimberley	67	26	33.7	35.0	8,133
	Mermaid Reef	89	66	27.8	29.2	4,669
	Montebello	97	87	16.8	17.1	8,658
	Ningaloo	75	13	30.2	32.5	906
	Oceanic Shoals	-	-	-	-	-
	Perth Canyon	5	-	86.5	-	29
	Roebuck	5	2	81.0	82.3	310
	Shark Bay	37	5	53.5	81.0	3,722
	South-west Corner	3	-	94.3	-	24
	Two Rocks	3	-	76.9	-	25
EEZ	Christmas Island Exclusive Economic Zone	30	6	65.2	81.1	273
	Cocos Islands Exclusive Economic Zone	7	-	97.0	-	88
	Indonesian Exclusive Economic Zone	70	18	42.5	45.3	1,457
	East Timorian Exclusive Economic Zone	1	-	109.3	-	20
	Oecussi Ambeno Exclusive Economic Zone	-	-	-	-	-
IBRA	Cape Range	80	29	20.3	21.7	599

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Chichester	13	3	37.0	76.3	165
	Christmas Island	13	-	77.7	-	91
	Cocos Islands	3	-	107.1	-	29
	Edel	6	5	81.0	81.1	2,685
	Fitzroy Trough	2	-	108.6	-	48
	Geraldton Hills	5	1	72.5	84.5	100
	Lesueur Sandplain	3	-	80.3	-	56
	Mitchell	5	2	93.5	108.2	276
	Perth	2	-	78.5	-	35
	Pindanland	14	5	72.6	81.3	974
	Roebourne	42	14	10.7	12.8	609
	Southern Jarrah Forest	1	-	108.2	-	14
	Timor Sea Coral Islands	11	-	75.4	-	29
	Warren	1	-	99.7	-	17
	Wooramel	5	5	82.6	82.6	3,815
IMCRA	Abrolhos Islands	8	-	69.3	-	64
	Bonaparte Gulf	-	-	-	-	-
	Canning	30	10	66.5	81.0	1,794
	Central West Coast	11	-	69.6	-	73
	Eighty Mile Beach	9	-	49.7	-	95
	Kimberley	8	4	84.2	84.6	374
	King Sound	4	1	93.2	105.5	120
	Leeuwin-Naturaliste	2	-	78.4	-	35
	Ningaloo	81	42	26.3	27.9	521
	Oceanic Shoals	6	-	82.5	-	34
	Pilbara (nearshore)	50	14	20.0	22.0	1,206
	Pilbara (offshore)	97	89	2.2	2.7	27,788
	Shark Bay	5	5	81.1	81.1	3,952
	WA South Coast	1	-	116.9	-	20
	Zuytdorp	42	6	51.3	56.8	4,518
KEF	Carbonate bank and terrace system of the Sahul Shelf	-	-	115.5	-	-
	Commonwealth marine environment surrounding the	12	-	69.3	-	84

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Houtman Abrolhos Islands					
	Commonwealth marine environment within and adjacent to Geographe Bay	-	-	105.7	-	-
	Commonwealth marine environment within and adjacent to the west coast inshore lagoons	4	-	79.3	-	70
	Commonwealth waters adjacent to Ningaloo Reef	77	12	30.2	32.5	535
	Glomar Shoals	6	3	8.4	8.8	372
	Western rock lobster	8	-	69.8	-	73
MNR	Hamelin Pool	1	-	117.8	-	10
MP	Barrow Island	63	15	20.1	21.2	479
	Eighty Mile Beach	4	-	65.9	-	31
	Jurien Bay	2	-	107.5	-	18
	Lalang-garram / Camden Sound	2	2	98.5	108.3	276
	Lalang-garram / Horizontal Falls	2	-	108.9	-	93
	Marmion	-	-	-	-	10
	Montebello Islands	86	43	22.2	23.1	1,235
	Ngari Capes	1	-	96.4	-	17
	Ningaloo	65	6	32.8	42.3	409
	North Kimberley	2	1	109.1	111.3	116
	North Lalang-garram	2	2	108.5	108.6	204
	Rowley Shoals	93	82	13.9	16.8	6,812
	Shark Bay	5	5	81.1	81.1	3,952
	Shoalwater Islands	1	-	82.3	-	18
	Yawuru Nagulagun / Roebuck Bay	4	3	81.2	81.2	489
NP	Pulu Keeling	1	-	107.1	-	23
NR	Beagle Islands	1	-	90.1	-	12
	Great Sandy Island	13	6	46.9	61.7	352
	Scott Reef	40	1	63.2	97.0	113
	Thevenard Island	22	-	38.0	-	76

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
RAMSAR	Ashmore Reef National Nature Reserve	11	-	75.3	-	30
	Eighty-mile Beach	1	-	116.8	-	17
	Peel-Yalgorup System	-	-	-	-	5
	Pulu Keeling National Park	1	-	107.1	-	23
	Roebuck Bay	4	3	81.2	81.2	592
	The Dales	7	-	82.0	-	39
RSB	Albert Reef	3	-	108.1	-	81
	Ashworth Shoal	5	-	65.4	-	24
	Assail Bank	2	-	93.3	-	14
	Baldwin Bank	-	-	-	-	-
	Barcoo Shoal	4	2	97.2	110.2	117
	Barracouta Shoal	3	-	115.1	-	16
	Barrow Island Reefs and Shoals	13	6	43.1	61.7	352
	Barton Shoal	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-
	Baylis Patches	6	-	51.5	-	33
	Beagle and Dingo Reefs	3	1	108.2	108.3	106
	Bennett Shoal	-	-	-	-	7
	Big Bank Shoals	-	-	-	-	-
	Branch Banks	-	-	-	-	-
	Brewis Reef	15	-	38.3	-	48
	Brue Reef	2	-	100.3	-	46
	Campbell Shoal	2	-	83.2	-	33
	Churchill Reef	3	2	108.1	108.2	253
	Clerke Reef	84	64	25.0	25.5	5,115
	Clio Bank	3	-	74.3	-	27
	Cockell and Nicolle Reefs	2	-	108.3	-	26
	Courtenay Shoal	16	3	26.4	27.5	195
	Dailey Shoal	46	-	43.4	-	68
	Dart Shoal	2	-	90.8	-	12
	Deep Shoal 2	-	-	-	-	-
	Dillon Shoal	-	-	-	-	5

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Direction Bank	4	-	75.3	-	21
East Holothuria Reef	-	-	-	-	-
Echuca Shoal	5	-	95.8	-	25
Eliassen Rocks	5	-	62.9	-	48
Eugene McDermott Shoal	-	-	-	-	9
Exmouth Reef	8	-	57.0	-	25
Fairway Reef	21	-	42.5	-	42
Fantome Shoal	1	-	92.5	-	12
Fantome Shoal	2	-	78.2	-	23
Fortescue Reef	6	-	62.0	-	37
Gee Bank	2	-	78.0	-	23
Geelvink Channel Shoals	3	-	82.5	-	25
Glomar Shoal	4	1	8.8	9.0	115
Goeree Shoal	-	-	-	-	10
Hammersley Shoal	24	6	23.7	34.2	234
Hayman Rock	11	-	55.8	-	29
Hayward Rock	1	-	88.9	-	41
Herald Reef	4	-	52.2	-	15
Heritage Reef	-	-	-	-	-
Heywood Shoal	4	-	94.7	-	24
Holothuria Banks	-	-	-	-	-
Hood Reef	30	-	41.6	-	70
Imperieuse Reef	92	80	17.2	17.4	5,461
Ingram Reef	-	-	-	-	-
Jabiru Shoals	-	-	-	-	6
Jamieson Reef	-	-	-	-	-
Johnson Bank	4	-	81.0	-	29
Karmt Shoal	1	-	102.6	-	18
Lightfoot Reef	8	-	56.3	-	33
Little Shoals	10	1	45.8	61.9	119
Locker Reef	11	-	40.3	-	33
Long Reef	-	-	-	-	-
Madeleine Shoals	35	10	21.9	24.7	718
Mangola Shoal	-	-	-	-	-

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Manicom Bank	1	-	109.7	-	29
Mavis Reef	2	-	108.1	-	61
McLennan Bank	11	1	40.5	93.1	110
Meda Reef	6	-	61.6	-	50
Mermaid Reef	88	65	29.4	30.0	3,484
Mid Reef	2	-	83.0	-	18
Montebello Shoals	80	29	22.3	24.1	435
Moresby Shoals	5	-	52.7	-	20
Ningaloo Reef	58	3	38.3	54.1	222
North Tail Reef	1	-	111.9	-	13
O'Grady Shoal	7	1	45.7	95.8	116
Oliver Rock	-	-	-	-	-
Otway Bank	-	-	-	-	-
Pee Shoal	-	-	-	-	3
Pelsaert Bank	5	-	72.3	-	63
Penguin Shoal	-	-	-	-	-
Poivre Reef	45	9	21.2	22.3	321
Rainbow Shoals	2	-	108.5	-	80
Rankin Bank	97	92	15.5	15.8	10,764
Ripple Shoals	18	6	44.0	61.7	374
Robroy Reefs	2	-	109.8	-	46
Rosily Shoals	43	3	27.6	63.1	117
Rothery Reef	-	-	-	-	-
Sand Knoll Ledge	1	-	116.3	-	12
Snapper Bank	2	-	81.4	-	14
Southwest Patch	1	-	110.0	-	29
Spider Reef	14	-	45.8	-	34
Stewart Shoal	-	-	-	-	3
Tait Bank	-	-	-	-	-
Taunton Reef	16	6	42.4	61.8	289
Tongue Shoals	1	-	109.4	-	31
Trap Reef	30	1	37.4	83.5	111
Tryal Rocks	90	60	20.3	23.3	1,067
Turtle Dove Shoal	5	-	72.1	-	46
Van Cloon Shoal	-	-	-	-	-

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Vee Shoal	-	-	-	-	8
	Vulcan Shoal	1	-	113.3	-	12
	Wapet Shoal	-	-	-	-	2
	Ward Reef	3	-	68.0	-	18
	Web Reef	9	-	46.2	-	47
	West Holothuria Reef	-	-	-	-	-
	West Reef	10	-	47.0	-	66
	Wildcat Reefs	2	-	108.5	-	75
	Woodbine Bank	3	-	82.5	-	19
Nearshore	Adele Island	4	2	99.0	108.2	154
	Airlie Island	25	6	37.7	61.8	439
	Angel Island	14	-	25.7	-	97
	Ashburton	3	-	59.6	-	56
	Ashburton Island	4	-	45.4	-	62
	Ashmore Reef	11	-	75.4	-	29
	Aususta - Margaret River	1	-	99.7	-	17
	Barrow Island	56	17	20.3	21.7	500
	Bedout Island	18	6	10.3	12.2	1,029
	Bermier Island	5	4	82.6	82.7	339
	Bessieres Island	56	2	38.0	85.0	119
	Bezout Island	13	3	37.0	78.4	141
	Boodie Island	38	13	21.2	22.8	363
	Broome	9	3	76.5	81.3	974
	Browse Island	8	-	95.1	-	28
	Bunbury	-	-	-	-	0
	Busselton	1	-	108.2	-	14
	Cape Bruguieres	22	6	24.1	27.2	170
	Capel	-	-	-	-	0
	Carnac Island	1	-	80.2	-	17
	Carnamah	1	-	80.3	-	13
	Carnarvon	5	3	86.5	88.4	618
	Cartier Island	3	-	92.7	-	24
	Chapman Valley	3	-	85.8	-	25
	Clerke Reef	84	65	25.2	25.7	4,670

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Cockburn	1	-	91.7	-	11
Cohen Island	24	8	22.8	25.4	283
Conzinc Island	9	-	31.1	-	53
Coorow	-	-	-	-	9
Cunningham Island	92	77	18.4	19.3	2,652
Dandaragan	1	-	112.3	-	15
Delambre Island	27	10	21.0	24.5	425
Derby - West Kimberely	5	1	93.5	108.7	182
Direction Island	8	-	51.3	-	28
Dirk Hartog Island	6	5	81.0	81.1	2,685
Dolphin Island	22	4	23.2	25.4	159
Dorre Island	5	5	82.6	82.6	398
Eaglehawk Island	7	-	42.8	-	70
East Lewis Island	8	-	31.7	-	80
East Pilbara	3	-	71.4	-	14
Easter Group	4	-	72.5	-	30
Enderby Island	10	6	28.8	61.5	178
Exmouth	56	5	38.2	42.3	283
Faure Island	2	-	97.7	-	30
Flat Island	57	2	39.5	85.5	125
Fly Island	9	-	45.7	-	42
Fremantle	-	-	-	-	7
Garden Island	1	-	80.3	-	25
Gidley Island	21	4	24.4	27.2	170
Gingin	1	-	118.0	-	12
Goodwyn Island	15	6	28.1	61.5	259
Greater Geraldton	4	-	82.3	-	31
Harvey	-	-	-	-	2
Haury Island	24	4	23.2	25.5	200
Hermite Island	80	29	23.2	24.3	564
Hibernia Reef	2	-	95.6	-	20
Imperieuse Reef	92	79	17.5	18.3	3,460
Irwin	3	-	81.1	-	56
Joondalup	-	-	-	-	7
Karratha	10	3	31.2	76.3	165

Receptors	Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
	Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
Keast Island	26	9	22.5	25.3	303
Kendrew Island	19	6	26.5	61.0	402
King Leopold Ranges	1	-	109.3	-	59
Kingfisher Islands	1	-	108.9	-	45
Kwinana	1	-	88.4	-	15
Lacepede Islands	14	5	80.5	82.6	779
Legendre Island	33	9	22.1	24.3	527
Little Turtle Islet	1	-	80.7	-	42
Locker Island	2	-	43.9	-	44
Lowendal Island	33	3	23.9	34.9	163
Malus Island	15	2	27.0	31.5	125
Mandurah	-	-	-	-	7
Mangrove Islands	2	-	62.4	-	14
Manjimup	-	-	-	-	8
Marv Island	2	-	108.6	-	46
Mary Anne Group	10	-	46.5	-	81
Mermaid Reef	88	65	30.1	30.9	3,376
Middle Island	43	14	20.7	22.3	407
Murion Islands	68	1	33.1	81.2	137
Nannup	1	-	109.6	-	15
North Island	2	-	93.0	-	16
North Turtle Island	2	-	77.3	-	22
Northhampton	5	-	82.6	-	81
Observation Island	20	-	45.0	-	45
Passage Islands	8	2	45.4	62.0	146
Peak Island	69	1	39.0	85.5	121
Pelican Island	2	-	98.8	-	30
Pelsaert Group	3	-	73.3	-	35
Port Hedland	6	1	36.8	111.4	111
Ragnard Islands	7	-	44.1	-	52
Rivoli Islands	5	-	58.2	-	49
Rockingham	1	-	82.3	-	18
Rosemary Island	20	9	25.5	27.6	306
Rottnest Island	2	-	78.5	-	35
Round Island	33	-	39.7	-	63

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Sandy Islet	44	13	55.6	81.2	202
	Scott Reef North	43	10	58.3	81.2	193
	Scott Reef South	48	13	53.9	81.0	215
	Seringapatam Reef	45	-	61.8	-	83
	Serrurier Island	51	1	39.2	87.1	109
	Shark Bay	6	5	81.1	81.1	3,833
	Stirling	-	-	-	-	3
	Sunday Island	50	-	40.0	-	73
	Table Island	34	-	39.8	-	60
	Thevenard Island	23	-	38.0	-	76
	Tortoise Island	10	-	44.9	-	50
	Twin Island	7	-	52.3	-	19
	Wallabi Group	2	-	81.4	-	22
	Wanneroo	-	-	-	-	8
	Waroona	-	-	-	-	3
	West Lewis Island	11	3	27.5	65.0	123
	Whalebone Island	-	-	-	-	8
	Wyndham - East Kimberley	2	2	108.4	108.5	276
	Indonesia	4	-	85.3	-	50
State Waters	Western Australia State Waters	93	81	8.8	10.2	6,812

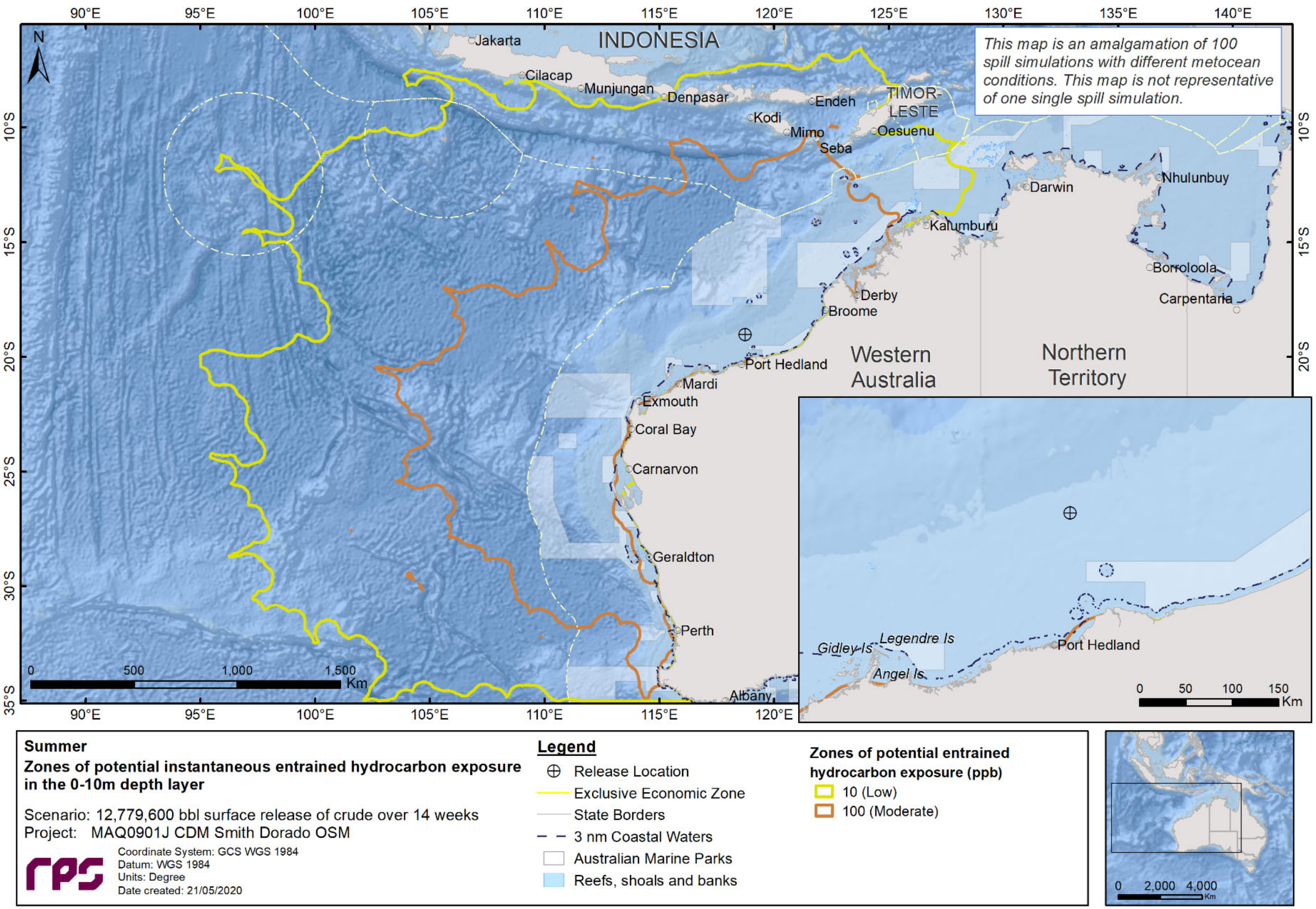


Figure 9.45 Predicted entrained hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

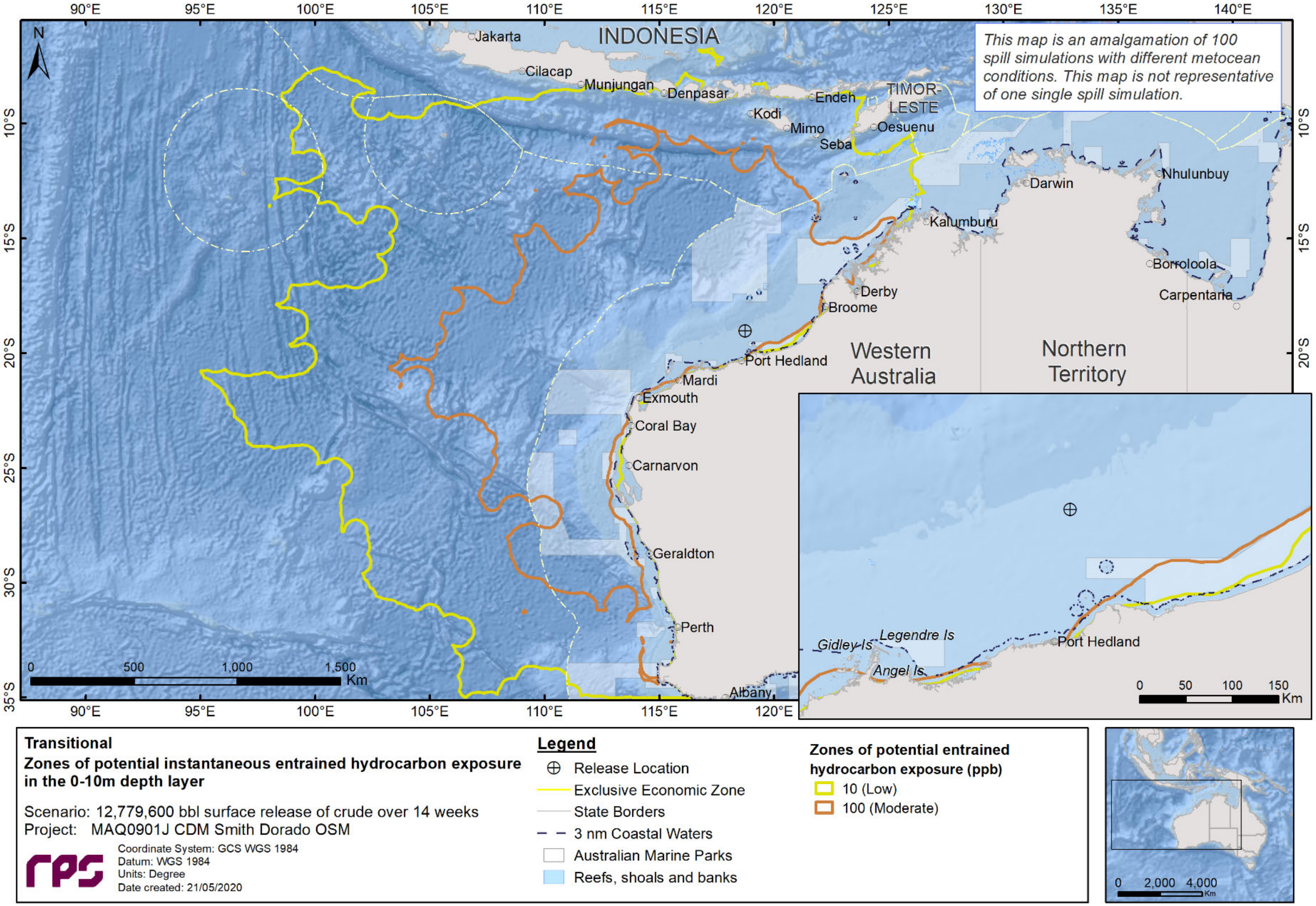


Figure 9.46 Predicted entrained hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

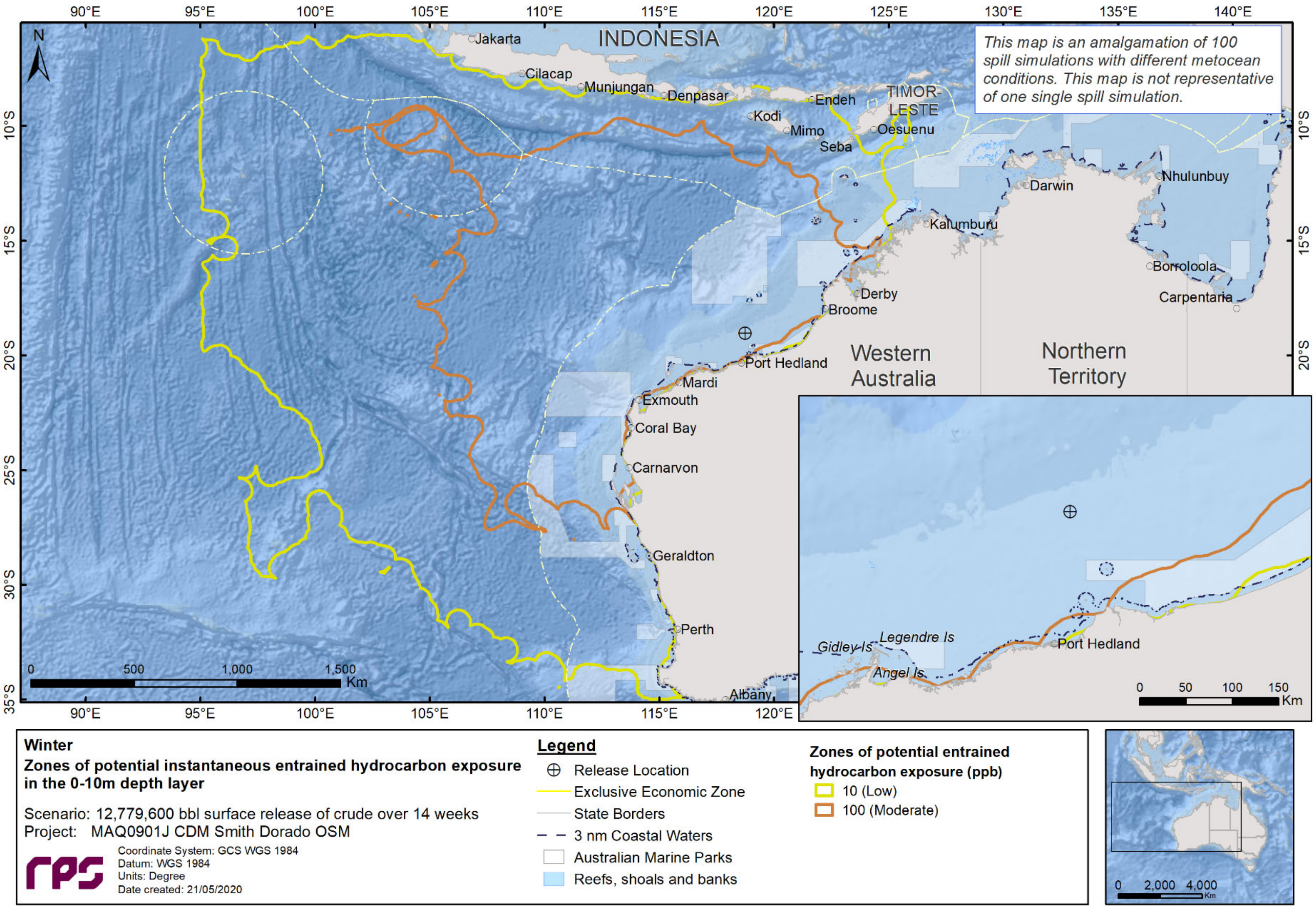


Figure 9.47 Predicted entrained hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.2.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones are depicted in Figure 9.48, Figure 9.49 and Figure 9.50. for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The maximum distance from the spill site to the low exposure threshold (10-50 ppb) for summer, transitional and winter results were 1,509 km (west-southwest), 1,334 km (west southwest) and 1,334 km (west), respectively. This distance reduced to 1,265 km (southwest; summer), 1,117 km (west southwest; transitional) and 1,181 km (west; winter) as the threshold increased to moderate (50 – 400 ppb). Based on the high threshold (≥400 ppb) the distance reduced further to 892 km (west southwest; summer), 509 km (west; transitional) and 975 km (southwest; winter).

Table 9.24 to Table 9.26 summarise the probability of exposure to receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

The low exposure zone surrounded 12 AMPs during summer conditions, 11 for transitional and winter conditions. The Argo-Rowley Terrace AMP recorded the highest probability of exposure at 78% during winter conditions. The shortest time for exposure at low threshold to an AMP was recorded at Dampier during transitional conditions as 2.67 days.

Three KEFs are within the low exposure zone for summer conditions and two during transitional conditions. There were no KEFs exposed during winter conditions. Commonwealth waters adjacent to Ningaloo Reef KEF recorded the highest probability of exposure at the low threshold during summer conditions (24%), while Western rock lobster recorded a 2% probability during transitional conditions.

Across the 3 seasons, there are 42 RSBs with the low exposure zone. The highest probability of exposure predicted at Rankin Shoal during summer conditions (70%). The shortest time before low exposure at an RSB receptor was 3.96 days at Madeleine Shoals during transitional conditions.

Dissolved hydrocarbons at the low threshold were predicted to cross into WA State Waters during every season with probabilities ranging from 39-64%. The minimum time before dissolved hydrocarbons at the low threshold crossed the WA State Waters boundary was 2.88 days, for a spill commencing during transitional conditions.

Table 9.24 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	6	1	-	29.92	57.88	-	61
AMP	Argo-Rowley Terrace	44	26	8	7.50	7.50	7.54	3,000
AMP	Carnarvon Canyon	14	6	-	23.08	26.92	-	341
AMP	Dampier	15	12	2	11.38	11.38	11.46	1,325
AMP	Eighty Mile Beach	21	9	2	12.25	12.25	12.38	1,037
AMP	Gascoyne	43	17	2	15.50	15.58	16.13	1,132

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Kimberley	24	12	2	17.96	18.04	31.17	945
	Mermaid Reef	22	8	-	21.42	23.08	107.08	234
	Montebello	64	35	3	12.17	12.83	13.13	1,366
	Ningaloo	28	14	1	15.63	16.25	55.96	644
	Roebuck	3	-	-	50.38	-	-	29
	Shark Bay	17	8	-	20.63	22.96	-	227
EEZ	Indonesian Exclusive Economic Zone	2	1	-	22.21	24.88	-	118
IBRA	Cape Range	12	11	2	14.58	15.58	39.88	1,558
	Chichester	11	10	3	11.71	11.83	11.92	902
	Edel	2	-	-	33.71	-	-	21
	Mitchell	1	-	-	65.08	-	-	17
	Pindanland	12	7	1	13.21	13.33	63.33	714
	Roebourne	13	10	4	11.54	11.54	11.83	1,556
	Wooramel	-	-	-	-	-	-	2
IMCRA	Abrolhos Islands	2	-	-	57.25	-	-	32
	Canning	6	1	-	29.92	50.38	-	78
	Central West Coast	1	-	-	58.75	-	-	15
	Eighty Mile Beach	13	9	2	12.25	12.29	12.38	1,037
	Kimberley	3	-	-	60.58	-	-	31
	King Sound	1	-	-	66.13	-	-	15
	Ningaloo	29	15	1	15.54	15.71	17.88	598
	Pilbara (nearshore)	14	10	4	11.46	11.46	11.46	1,485
	Pilbara (offshore)	68	44	11	3.29	3.33	4.83	2,409
	Shark Bay	1	-	-	33.50	-	-	21
	Zuytdorp	19	8	-	19.58	19.92	-	374
KEF	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	2	-	-	33.83	-	-	32
	Commonwealth waters adjacent to Ningaloo Reef	24	5	-	15.63	16.25	-	215
	Glomar Shoals	7	3	-	7.71	11.29	-	334

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Western rock lobster	2	-	-	57.46	-	-	32
MP	Barrow Island	5	1	-	26.58	60.33	-	144
	Eighty Mile Beach	13	9	3	13.21	13.21	13.38	851
	Jurien Bay	1	-	-	66.58	-	-	15
	Lalang-garram / Camden Sound	-	-	-	-	-	-	5
	Montebello Islands	13	9	3	14.17	15.25	47.04	1,124
	Ningaloo	17	7	-	16.83	18.08	-	339
	North Kimberley	-	-	-	-	-	-	1
	North Lalang-garram	-	-	-	-	-	-	2
	Rowley Shoals	39	18	1	8.88	10.38	10.92	982
	Shark Bay	-	-	-	33.71	-	-	7
	Yawuru Nagulagun / Roebuck Bay	1	-	-	50.38	-	-	19
NR	Great Sandy Island	12	4	-	17.38	48.88	-	187
	Scott Reef	1	-	-	112.04	-	-	10
	Thevenard Island	8	-	-	15.71	-	-	36
RAMSAR	Eighty-mile Beach	12	5	-	13.21	13.25	-	393
	Roebuck Bay	1	-	-	90.25	-	-	11
RSB	Albert Reef	-	-	-	-	-	-	4
	Ashworth Shoal	1	-	-	98.58	-	-	14
	Barcoo Shoal	-	-	-	-	-	-	5
	Barrow Island Reefs and Shoals	12	5	-	16.71	48.88	-	271
	Beagle and Dingo Reefs	-	-	-	-	-	-	4
	Brewis Reef	2	-	-	67.50	-	-	24
	Brue Reef	2	-	-	85.13	-	-	18
	Churchill Reef	-	-	-	-	-	-	3
	Clerke Reef	28	9	1	21.38	21.88	56.88	454
	Cockell and Nicolle Reefs	-	-	-	-	-	-	1
	Courtenay Shoal	3	-	-	46.63	-	-	21
	Eliassen Rocks	1	-	-	99.58	-	-	10

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Fairway Reef	-	-	-	-	-	-	4
	Fortescue Reef	2	-	-	43.04	-	-	32
	Glomar Shoal	6	1	-	11.25	11.38	-	83
	Hammersley Shoal	7	3	-	39.63	48.58	-	70
	Herald Reef	6	-	-	66.25	-	-	27
	Hood Reef	-	-	-	-	-	-	7
	Imperieuse Reef	38	14	1	10.83	10.83	31.42	982
	Lightfoot Reef	2	1	-	99.38	99.38	-	117
	Little Shoals	4	-	-	48.96	-	-	39
	Madeleine Shoals	10	3	-	19.38	21.42	-	124
	Mavis Reef	-	-	-	-	-	-	5
	McLennan Bank	8	1	-	39.46	68.46	-	72
	Meda Reef	3	1	-	43.17	51.38	-	86
	Mermaid Reef	20	4	-	21.79	23.25	107.38	115
	Montebello Shoals	12	8	-	14.58	19.75	-	193
	Moresby Shoals	6	-	-	66.71	-	-	19
	Ningaloo Reef	10	2	-	17.88	42.21	-	123
	O'Grady Shoal	7	-	-	44.00	-	-	37
	Poivre Reef	11	5	-	16.83	43.38	-	126
	Rainbow Shoals	-	-	-	-	-	-	<1
	Rankin Bank	70	44	4	12.88	12.96	13.58	1,469
	Ripple Shoals	12	3	-	15.54	39.79	-	227
	Robroy Reefs	-	-	-	-	-	-	<1
	Rosily Shoals	7	1	-	17.13	99.92	-	256
	Southwest Patch	2	-	-	69.04	-	-	16
	Taunton Reef	7	3	-	40.33	40.33	-	120
	Tongue Shoals	2	-	-	68.58	-	-	14
	Trap Reef	9	1	-	18.54	99.33	-	94
	Tryal Rocks	16	8	-	14.46	14.46	-	204
	Ward Reef	2	-	-	88.17	-	-	15
	Wildcat Reefs	-	-	-	-	-	-	1
Nearshore	Adele Island	-	-	-	-	-	-	5

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Airlie Island	9	3	-	17.17	40.50	-	166
Angel Island	5	2	-	21.58	68.88	-	75
Ashburton	6	-	-	66.25	-	-	30
Ashburton Island	3	-	-	67.67	-	-	30
Barrow Island	12	11	2	15.58	15.58	39.88	1,558
Bedout Island	10	5	-	14.67	30.75	-	290
Bermier Island	-	-	-	-	-	-	3
Bessieres Island	2	-	-	71.96	-	-	31
Bezout Island	11	8	-	11.71	15.75	-	231
Boodie Island	12	7	-	15.67	15.71	-	270
Broome	12	5	-	31.75	31.92	-	384
Cape Bruguieres	7	3	-	20.42	47.50	69.29	243
Carnarvon	-	-	-	-	-	-	2
Clerke Reef	26	8	1	21.88	22.04	56.88	453
Cohen Island	8	3	-	21.38	47.54	-	155
Conzinc Island	-	-	-	-	-	-	9
Cunningham Island	35	10	-	11.88	11.88	-	338
Delambre Island	11	8	1	11.75	11.75	11.83	555
Derby - West Kimberely	1	-	-	65.08	-	-	17
Direction Island	9	1	-	46.38	99.96	-	65
Dirk Hartog Island	1	-	-	33.71	-	-	20
Dolphin Island	10	6	2	11.75	11.83	67.83	1,096
Dorre Island	2	-	-	54.00	-	-	21
Eaglehawk Island	4	-	-	42.67	-	-	18
East Pilbara	12	7	1	13.21	13.33	63.33	714
Enderby Island	-	-	-	-	-	-	6
Exmouth	11	2	-	17.88	41.92	-	146
Flat Island	3	1	-	40.88	41.17	-	84
Gidley Island	7	3	-	18.42	47.50	69.29	268
Goodwyn Island	-	-	-	-	-	-	3
Haury Island	10	9	4	11.54	11.54	43.00	1,476
Hermite Island	12	9	1	15.54	18.33	50.00	457

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Imperieuse Reef	37	11	1	11.88	11.88	31.50	402
Karratha	11	10	3	11.71	11.75	11.92	902
Keast Island	10	4	-	18.29	47.17	-	320
Kendrew Island	2	-	-	43.50	106.13	-	33
Lacepede Islands	2	-	-	46.50	-	-	13
Legendre Island	11	9	4	11.54	11.54	11.96	1,556
Lowendal Island	11	6	1	15.63	40.75	40.75	823
Malus Island	1	-	-	68.17	-	-	17
Mary Anne Group	4	2	-	63.17	99.58	-	109
Mermaid Reef	15	2	-	23.42	43.25	-	65
Middle Island	12	6	-	15.63	15.67	-	189
Murion Islands	6	1	-	39.79	69.75	-	67
North Turtle Island	6	2	1	14.29	14.42	62.25	523
Passage Islands	10	3	-	15.88	42.63	-	151
Peak Island	4	1	-	41.04	41.50	-	84
Port Hedland	13	10	3	13.21	30.54	30.79	894
Ragnard Islands	4	1	-	42.46	113.21	-	51
Rosemary Island	5	2	-	42.42	68.04	-	70
Round Island	-	-	-	-	-	-	9
Sandy Islet	2	-	-	68.92	-	-	18
Scott Reef North	2	-	-	69.46	-	-	27
Scott Reef South	2	-	-	68.88	-	-	31
Seringapatam Reef	1	-	-	71.21	-	-	15
Serrurier Island	2	-	-	40.88	-	-	29
Shark Bay	-	-	-	-	-	-	5
Sunday Island	3	-	-	50.17	-	-	34
Thevenard Island	9	-	-	15.71	-	-	46
Tortoise Island	3	-	-	67.79	-	-	24
Twin Island	7	2	-	66.21	87.83	-	54
West Lewis Island	-	-	-	-	-	-	3
Wyndham - East Kimberley	-	-	-	-	-	-	1

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
State Waters	Western Australia State Waters	39	18	5	8.92	10.38	10.92	1,799

Table 9.25 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	6	1	-	37.75	100.08	-	123
	Argo-Rowley Terrace	47	23	3	10.50	11.04	13.67	1,449
	Carnarvon Canyon	8	3	-	28.38	94.54	-	149
	Dampier	5	2	-	2.67	2.75	-	390
	Eighty Mile Beach	7	2	-	17.75	17.79	-	199
	Gascoyne	37	9	-	21.75	23.67	-	358
	Kimberley	29	13	1	4.04	4.58	21.17	489
	Mermaid Reef	34	9	1	10.79	15.75	31.54	505
	Montebello	57	26	1	4.17	5.29	25.04	608
	Ningaloo	6	1	-	25.08	34.83	-	73
	Roebuck	-	-	-	-	-	-	<1
	Shark Bay	3	1	-	36.38	46.75	-	74
EEZ	Indonesian Exclusive Economic Zone	1	-	-	46.79	-	-	18
IBRA	Cape Range	2	1	-	9.58	12.33	-	64
	Chichester	1	1	1	2.96	2.96	3.46	699
	Edel	-	-	-	-	-	-	1
	Mitchell	5	2	-	88.71	91.83	-	66
	Pindanland	5	-	-	81.29	-	-	27
	Roebourne	3	1	1	2.92	3.29	3.92	650
	Wooramel	-	-	-	-	-	-	<1
IMCRA	Abrolhos Islands	1	-	-	63.00	-	-	17
	Canning	9	5	-	54.58	57.67	-	296
	Central West Coast	2	-	-	58.92	-	-	35
	Eighty Mile Beach	1	-	-	115.04	-	-	24
	Kimberley	8	5	-	85.58	86.38	-	206
	King Sound	-	-	-	-	-	-	3
	Ningaloo	14	1	-	22.79	25.21	-	76

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Pilbara (nearshore)	5	1	1	2.92	2.92	3.46	699
	Pilbara (offshore)	82	60	22	2.63	2.63	4.88	5,399
	Shark Bay	-	-	-	-	-	-	<1
	Zuytdorp	3	1	-	36.63	42.75	-	72
KEF	Ancient coastline at 125 m depth contour	100	100	94	1.46	1.46	1.88	5,374
	Ancient coastline at 90-120m depth	1	-	-	60.42	-	-	18
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	2	-	-	39.75	-	-	40
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	25	6	-	20.33	23.71	-	346
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	1	-	-	63.00	-	-	25
	Commonwealth waters adjacent to Ningaloo Reef	6	1	-	25.08	34.83	-	73
	Continental Slope Demersal Fish Communities	72	43	2	7.58	8.08	16.25	762
	Exmouth Plateau	49	14	1	17.00	18.79	30.92	499
	Glomar Shoals	81	61	5	3.96	3.96	4.00	1,607
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	47	19	3	10.75	15.38	17.21	1,075
	Perth Canyon and adjacent shelf break, and other west coast canyons	1	-	-	72.04	-	-	11
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	-	-	-	-	-	-	1
	Wallaby Saddle	5	1	-	93.08	102.63	-	54
	Western demersal slope and	4	-	-	39.08	-	-	48

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	associated fish communities							
	Western rock lobster	2	-	-	59.67	-	-	28
MP	Barrow Island	4	-	-	48.58	-	-	37
	Eighty Mile Beach	-	-	-	-	-	-	<1
	Jurien Bay	-	-	-	-	-	-	1
	Lalang-garram / Camden Sound	5	2	-	93.38	96.46	-	105
	Montebello Islands	5	1	-	8.58	11.08	-	115
	Ningaloo	2	-	-	25.92	79.00	-	22
	North Kimberley	3	-	-	102.58	-	-	29
	North Lalang-garram	5	-	-	100.71	-	-	43
	Rowley Shoals	46	14	1	13.50	16.88	17.83	571
	Shark Bay	-	-	-	-	-	-	<1
	Yawuru Nagulagun / Roebuck Bay	-	-	-	-	-	-	<1
NR	Great Sandy Island	-	-	-	-	-	-	3
	Scott Reef	-	-	-	-	-	-	<1
	Thevenard Island	-	-	-	-	-	-	4
RAMSAR	Eighty-mile Beach	-	-	-	-	-	-	<1
	Roebuck Bay	-	-	-	-	-	-	<1
RSB	Albert Reef	5	2	-	90.67	93.46	-	68
	Ashworth Shoal	-	-	-	-	-	-	<1
	Barcoo Shoal	5	-	-	89.21	-	-	39
	Barrow Island Reefs and Shoals	-	-	-	-	-	-	<1
	Beagle and Dingo Reefs	5	1	-	91.50	107.79	-	65
	Brewis Reef	-	-	-	-	-	-	3
	Brue Reef	5	4	-	87.92	89.04	-	86
	Churchill Reef	5	1	-	90.54	101.25	-	69
	Clerke Reef	27	13	1	13.75	17.29	17.83	433
	Cockell and Nicolle Reefs	2	-	-	109.33	-	-	11
	Courtenay Shoal	1	-	-	103.21	-	-	14

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Eliassen Rocks	-	-	-	-	-	-	<1
Fairway Reef	-	-	-	-	-	-	3
Fortescue Reef	-	-	-	-	-	-	<1
Glomar Shoal	78	59	5	4.00	4.17	12.17	1,005
Hammersley Shoal	2	-	-	4.25	-	-	35
Herald Reef	-	-	-	-	-	-	<1
Hood Reef	-	-	-	-	-	-	1
Imperieuse Reef	42	11	-	15.92	19.54	-	184
Lightfoot Reef	-	-	-	-	-	-	<1
Little Shoals	-	-	-	-	-	-	<1
Madeleine Shoals	3	1	-	3.96	7.04	-	61
Mavis Reef	5	4	-	91.38	93.42	-	92
McLennan Bank	-	-	-	-	-	-	2
Meda Reef	-	-	-	-	-	-	<1
Mermaid Reef	34	7	-	11.08	19.25	41.75	281
Montebello Shoals	1	-	-	10.46	14.71	-	27
Moresby Shoals	-	-	-	-	-	-	<1
Ningaloo Reef	1	-	-	77.79	-	-	11
O'Grady Shoal	-	-	-	-	-	-	1
Poivre Reef	1	-	-	87.75	-	-	10
Rainbow Shoals	1	-	-	108.79	-	-	14
Rankin Bank	62	30	1	6.79	6.96	17.46	555
Ripple Shoals	-	-	-	-	-	-	1
Robroy Reefs	2	-	-	111.96	-	-	13
Rosily Shoals	-	-	-	-	-	-	7
Southwest Patch	-	-	-	-	-	-	<1
Taunton Reef	-	-	-	-	-	-	<1
Tongue Shoals	-	-	-	-	-	-	<1
Trap Reef	-	-	-	-	-	-	4
Tryal Rocks	8	-	-	11.58	96.67	-	42
Ward Reef	-	-	-	-	-	-	<1
Wildcat Reefs	3	-	-	99.08	-	-	23

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Nearshore	Adele Island	5	-	-	90.17	-	-	45
	Airlie Island	-	-	-	-	-	-	1
	Angel Island	1	-	-	103.71	-	-	13
	Ashburton	-	-	-	-	-	-	<1
	Ashburton Island	-	-	-	-	-	-	<1
	Barrow Island	2	-	-	63.71	-	-	14
	Bedout Island	2	1	-	18.00	18.88	-	70
	Bermier Island	-	-	-	-	-	-	<1
	Bessieres Island	-	-	-	-	-	-	8
	Bezout Island	1	1	-	2.96	2.96	-	261
	Boodie Island	-	-	-	-	-	-	7
	Broome	4	-	-	94.46	-	-	25
	Cape Bruguieres	2	-	-	3.96	-	-	45
	Carnarvon	-	-	-	-	-	-	<1
	Clerke Reef	25	13	1	16.50	17.58	19.29	434
	Cohen Island	2	1	-	3.96	4.25	-	130
	Conzinc Island	-	-	-	-	-	-	8
	Cunningham Island	37	7	-	18.08	32.54	-	111
	Delambre Island	2	1	-	3.08	10.63	-	58
	Derby - West Kimberely	5	2	-	88.71	91.83	-	66
	Direction Island	-	-	-	-	-	-	<1
	Dirk Hartog Island	-	-	-	-	-	-	1
	Dolphin Island	2	-	-	6.38	-	-	16
	Dorre Island	-	-	-	-	-	-	<1
	Eaglehawk Island	-	-	-	-	-	-	6
	East Pilbara	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	9
	Exmouth	1	-	-	26.50	-	-	18
	Flat Island	1	-	-	91.83	-	-	13
	Gidley Island	2	-	-	6.38	-	-	23
	Goodwyn Island	-	-	-	-	-	-	9
	Haury Island	2	1	-	3.83	12.04	-	76

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Hermite Island	2	1	-	9.58	12.33	-	64
Imperieuse Reef	38	6	-	18.13	32.42	-	150
Karratha	1	1	1	2.96	3.08	3.46	699
Keast Island	3	1	-	3.96	3.96	-	232
Kendrew Island	-	-	-	-	-	-	9
Lacepede Islands	5	-	-	81.29	-	-	27
Legendre Island	4	1	-	3.83	3.96	-	282
Lowendal Island	1	-	-	27.46	-	-	14
Malus Island	1	-	-	103.63	-	-	18
Mary Anne Group	-	-	-	-	-	-	<1
Mermaid Reef	31	6	-	11.17	19.54	-	227
Middle Island	-	-	-	52.54	-	-	8
Murion Islands	-	-	-	73.17	-	-	9
North Turtle Island	-	-	-	-	-	-	<1
Passage Islands	-	-	-	-	-	-	3
Peak Island	-	-	-	72.75	-	-	8
Port Hedland	1	-	-	3.08	-	-	33
Ragnard Islands	-	-	-	-	-	-	3
Rosemary Island	1	-	-	103.42	-	-	16
Round Island	1	-	-	92.04	-	-	10
Sandy Islet	-	-	-	-	-	-	1
Scott Reef North	-	-	-	-	-	-	1
Scott Reef South	-	-	-	-	-	-	1
Seringapatam Reef	-	-	-	-	-	-	<1
Serrurier Island	-	-	-	91.92	-	-	9
Shark Bay	-	-	-	-	-	-	<1
Sunday Island	-	-	-	73.92	-	-	3
Thevenard Island	-	-	-	-	-	-	3
Tortoise Island	-	-	-	-	-	-	<1
Twin Island	-	-	-	-	-	-	<1
West Lewis Island	1	-	-	104.58	-	-	11
Wyndham - East Kimberley	2	-	-	107.25	-	-	20

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
State Waters	Western Australia State Waters	46	14	1	2.88	2.92	3.46	699

Table 9.26 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Abrolhos	4	1	-	60.79	78.71	-	100
	Argo-Rowley Terrace	78	33	2	15.75	16.42	17.79	937
	Carnarvon Canyon	4	2	-	54.08	62.79	-	133
	Dampier	14	6	3	21.46	23.46	60.25	1,320
	Eighty Mile Beach	13	8	1	6.71	7.67	8.25	980
	Gascoyne	18	7	2	23.96	25.25	66.63	1,322
	Kimberley	10	5	1	71.04	82.75	85.17	576
	Mermaid Reef	40	10	-	29.42	29.88	-	307
	Montebello	52	12	3	18.33	20.04	42.29	2,387
	Ningaloo	4	2	-	32.75	54.46	-	116
	Roebuck	-	-	-	-	-	-	9
	Shark Bay	4	2	-	74.88	82.54	-	139
EEZ	Indonesian Exclusive Economic Zone	5	2	-	58.33	84.42	-	115
IBRA	Cape Range	6	4	2	28.04	30.42	66.71	607
	Chichester	1	1	-	76.46	76.67	-	102
	Edel	4	1	-	82.58	105.25	-	59
	Mitchell	-	-	-	-	-	-	2
	Pindanland	3	1	-	81.75	105.63	-	64
	Roebourne	6	3	-	11.75	13.88	-	354
	Wooramel	4	1	-	82.71	91.88	-	77
IMCRA	Abrolhos Islands	-	-	-	103.63	-	-	2
	Canning	4	2	-	81.13	81.13	-	316
	Central West Coast	-	-	-	102.33	-	-	8
	Eighty Mile Beach	-	-	-	67.38	-	-	5
	Kimberley	-	-	-	-	-	-	3
	King Sound	-	-	-	-	-	-	<1
	Ningaloo	7	1	-	29.54	30.46	-	82

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Pilbara (nearshore)	10	4	1	23.83	24.08	86.38	649
	Pilbara (offshore)	78	56	17	2.71	3.38	4.13	2,955
	Shark Bay	5	3	-	82.58	82.58	-	161
	Zuytdorp	5	3	-	74.29	75.00	-	193
KEF	Ancient coastline at 125 m depth contour	100	100	100	0.88	0.88	0.92	7,116
	Ancient coastline at 90-120m depth	-	-	-	-	-	-	<1
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	6	2	-	48.63	91.63	-	144
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	15	7	2	27.42	28.00	66.63	1,322
	Commonwealth marine environment surrounding the Houtman Abrolhos Islands	-	-	-	103.63	-	-	1
	Commonwealth waters adjacent to Ningaloo Reef	4	2	-	32.75	54.46	-	116
	Continental Slope Demersal Fish Communities	72	29	2	11.79	14.13	25.79	1,751
	Exmouth Plateau	38	9	1	17.08	19.08	67.04	420
	Glomar Shoals	94	67	3	9.33	9.67	11.96	1,214
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	67	37	2	10.50	15.83	17.79	937
	Perth Canyon and adjacent shelf break, and other west coast canyons	-	-	-	-	-	-	1
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	1	-	-	97.96	-	-	12
	Wallaby Saddle	3	1	-	64.13	79.00	-	70
	Western demersal slope and	1	1	-	81.04	82.96	-	163

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	associated fish communities							
	Western rock lobster	-	-	-	102.33	-	-	8
MP	Barrow Island	4	-	-	26.71	-	-	38
	Eighty Mile Beach	-	-	-	-	-	-	1
	Jurien Bay	-	-	-	-	-	-	<1
	Lalang-garram / Camden Sound	-	-	-	-	-	-	2
	Montebello Islands	7	5	2	29.08	64.88	66.63	804
	Ningaloo	1	-	-	48.29	-	-	26
	North Kimberley	-	-	-	-	-	-	1
	North Lalang-garram	-	-	-	-	-	-	1
	Rowley Shoals	64	30	1	16.50	17.29	25.25	464
	Shark Bay	5	3	-	82.67	82.71	-	161
	Yawuru Nagulagun / Roebuck Bay	1	-	-	103.21	-	-	15
NR	Great Sandy Island	1	1	-	86.96	86.96	-	66
	Scott Reef	-	-	-	-	-	-	<1
	Thevenard Island	-	-	-	-	-	-	1
RAMSAR	Eighty-mile Beach	-	-	-	-	-	-	0
	Roebuck Bay	1	-	-	115.42	-	-	10
RSB	Albert Reef	-	-	-	-	-	-	<1
	Ashworth Shoal	-	-	-	-	-	-	<1
	Barcoo Shoal	-	-	-	-	-	-	<1
	Barrow Island Reefs and Shoals	1	1	-	86.46	86.46	-	229
	Beagle and Dingo Reefs	-	-	-	-	-	-	<1
	Brewis Reef	-	-	-	-	-	-	<1
	Brue Reef	-	-	-	-	-	-	<1
	Churchill Reef	-	-	-	-	-	-	1
	Clerke Reef	44	15	-	26.63	26.83	-	358
	Cockell and Nicolle Reefs	-	-	-	-	-	-	<1
	Courtenay Shoal	1	1	-	109.00	109.00	-	152

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Eliassen Rocks	-	-	-	-	-	-	2
Fairway Reef	1	-	-	65.29	-	-	10
Fortescue Reef	-	-	-	-	-	-	<1
Glomar Shoal	93	63	1	9.42	9.75	44.54	494
Hammersley Shoal	2	1	-	43.33	108.38	-	135
Herald Reef	-	-	-	-	-	-	<1
Hood Reef	1	-	-	65.92	-	-	15
Imperieuse Reef	62	25	-	17.33	18.38	-	331
Lightfoot Reef	-	-	-	-	-	-	1
Little Shoals	-	-	-	-	-	-	1
Madeleine Shoals	8	1	-	24.75	42.63	-	63
Mavis Reef	-	-	-	-	-	-	0
McLennan Bank	-	-	-	-	-	-	8
Meda Reef	1	-	-	95.92	-	-	10
Mermaid Reef	40	10	-	29.79	30.50	-	288
Montebello Shoals	5	2	-	56.54	64.96	-	293
Moresby Shoals	-	-	-	-	-	-	<1
Ningaloo Reef	-	-	-	-	-	-	7
O'Grady Shoal	-	-	-	-	-	-	6
Poivre Reef	1	-	-	28.58	-	-	32
Rainbow Shoals	-	-	-	-	-	-	<1
Rankin Bank	66	28	1	16.00	20.58	109.79	440
Ripple Shoals	-	-	-	-	-	-	7
Robroy Reefs	-	-	-	-	-	-	<1
Rosily Shoals	-	-	-	-	-	-	2
Southwest Patch	-	-	-	-	-	-	<1
Taunton Reef	-	-	-	-	-	-	4
Tongue Shoals	-	-	-	-	-	-	<1
Trap Reef	-	-	-	-	-	-	1
Tryal Rocks	8	2	-	30.38	65.00	-	166
Ward Reef	-	-	-	-	-	-	<1
Wildcat Reefs	-	-	-	-	-	-	<1

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Nearshore	Adele Island	-	-	-	-	-	-	<1
	Airlie Island	-	-	-	-	-	-	6
	Angel Island	1	1	-	108.92	109.00	-	204
	Ashburton	-	-	-	-	-	-	1
	Ashburton Island	-	-	-	-	-	-	<1
	Barrow Island	4	1	-	28.04	30.42	-	85
	Bedout Island	7	2	-	11.75	13.88	-	296
	Bermier Island	4	-	-	90.13	105.25	-	46
	Bessieres Island	-	-	-	-	-	-	1
	Bezout Island	1	1	-	77.25	78.88	-	64
	Boodie Island	3	1	-	29.25	29.79	-	53
	Broome	3	-	-	81.75	-	-	49
	Cape Bruguieres	2	1	-	24.88	108.42	-	354
	Carnarvon	2	-	-	94.88	-	-	26
	Clerke Reef	41	13	-	27.04	39.25	-	262
	Cohen Island	3	1	-	25.13	108.33	-	178
	Conzinc Island	1	-	-	110.50	-	-	36
	Cunningham Island	46	18	-	24.04	24.46	-	225
	Delambre Island	7	3	-	32.92	61.54	-	307
	Derby - West Kimberely	-	-	-	-	-	-	<1
	Direction Island	-	-	-	-	-	-	<1
	Dirk Hartog Island	2	-	-	82.58	-	-	41
	Dolphin Island	3	1	-	24.96	109.42	-	68
	Dorre Island	4	1	-	82.63	105.63	-	59
	Eaglehawk Island	-	-	-	-	-	-	3
	East Pilbara	-	-	-	-	-	-	<1
	Enderby Island	1	-	-	72.63	-	-	14
	Exmouth	-	-	-	54.54	-	-	6
	Flat Island	1	-	-	65.33	-	-	32
	Gidley Island	2	1	-	24.96	108.92	-	231
	Goodwyn Island	2	-	-	96.46	-	-	19
	Haury Island	4	-	-	24.50	87.75	-	47

Receptors	Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
Hermite Island	6	3	2	29.08	64.92	66.71	607
Imperieuse Reef	55	25	-	18.13	24.04	-	232
Karratha	2	1	-	61.46	76.67	-	102
Keast Island	4	1	-	24.83	108.29	-	179
Kendrew Island	4	1	-	44.54	96.92	-	59
Lacepede Islands	3	1	-	88.83	105.63	-	64
Legendre Island	6	1	-	24.50	26.33	-	87
Lowendal Island	1	-	-	86.21	-	-	29
Malus Island	1	-	-	108.92	-	-	49
Mary Anne Group	-	-	-	-	-	-	2
Mermaid Reef	36	7	-	31.00	35.42	-	166
Middle Island	3	1	-	29.33	29.79	-	67
Murion Islands	1	-	-	31.54	-	-	23
North Turtle Island	-	-	-	-	-	-	4
Passage Islands	2	1	-	88.42	88.96	-	115
Peak Island	2	-	-	29.42	-	-	17
Port Hedland	-	-	-	-	-	-	4
Ragnard Islands	-	-	-	-	-	-	2
Rosemary Island	4	1	-	29.33	96.38	-	54
Round Island	1	-	-	65.38	-	-	19
Sandy Islet	-	-	-	-	-	-	2
Scott Reef North	-	-	-	-	-	-	3
Scott Reef South	-	-	-	-	-	-	2
Seringapatam Reef	-	-	-	-	-	-	6
Serrurier Island	1	-	-	65.04	-	-	19
Shark Bay	4	1	-	82.75	91.88	-	77
Sunday Island	1	-	-	47.25	-	-	10
Thevenard Island	-	-	-	-	-	-	1
Tortoise Island	-	-	-	-	-	-	1
Twin Island	-	-	-	-	-	-	<1
West Lewis Island	1	-	-	109.42	-	-	19
Wyndham - East Kimberley	-	-	-	-	-	-	2

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
State Waters	Western Australia State Waters	64	28	3	10.75	12.17	25.25	1,735

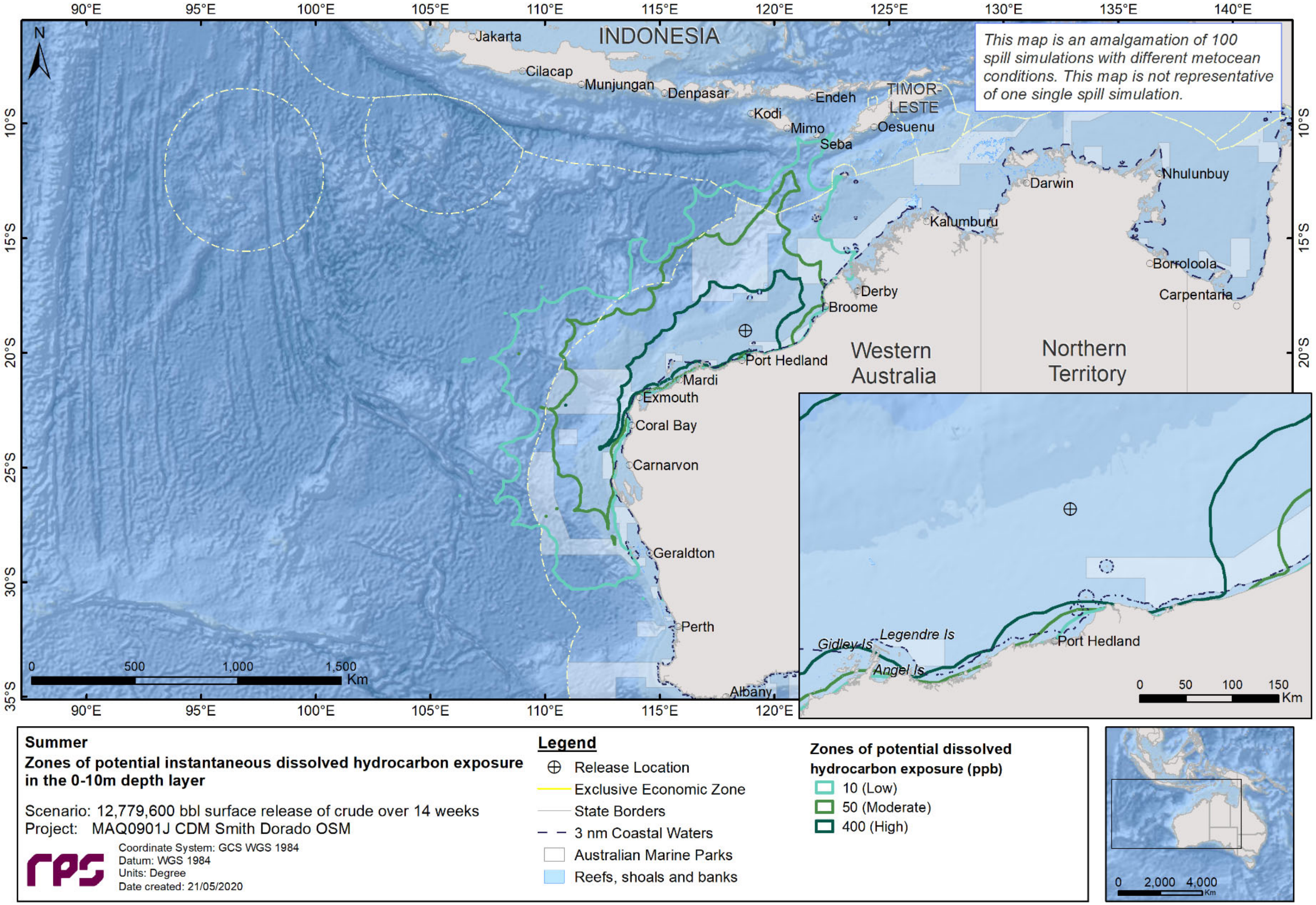


Figure 9.48 Predicted dissolved hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

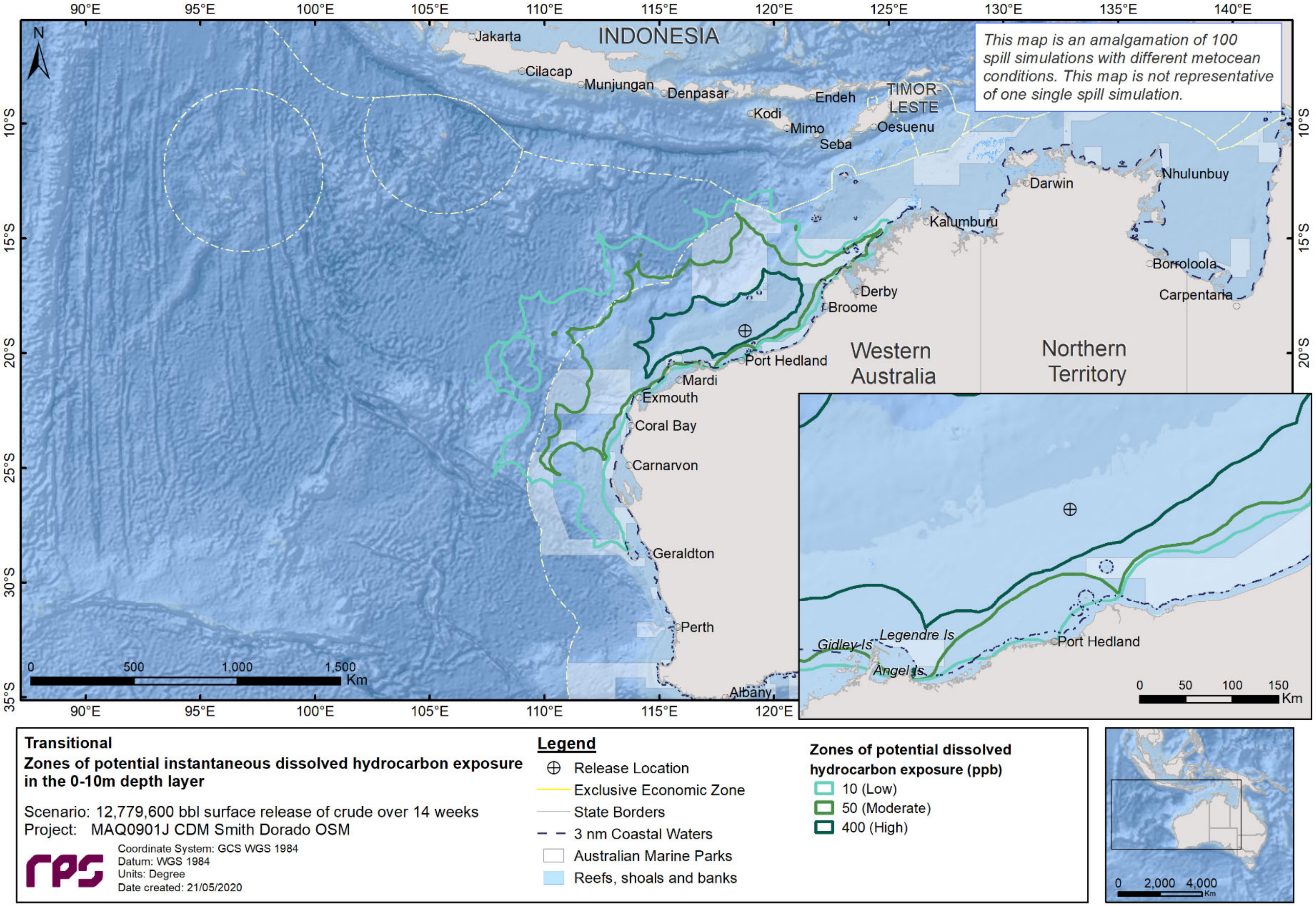


Figure 9.49 Predicted dissolved hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m³) of crude from the WHP. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

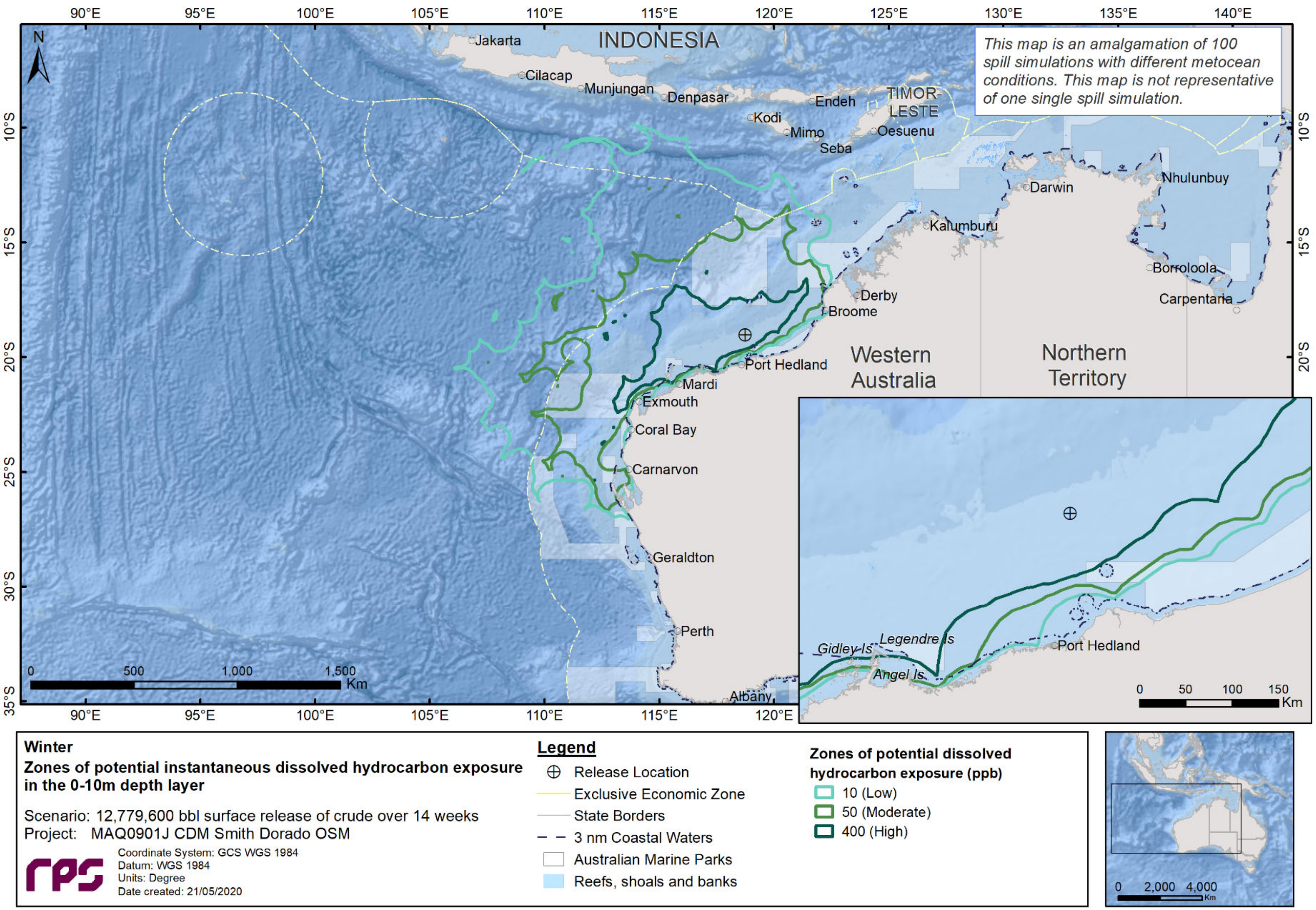


Figure 9.50 Predicted dissolved hydrocarbon exposure zones resulting from a surface blowout over 14 weeks, releasing a total 12,779,600 bbl (2,031,794 m^3) of crude from the WHP. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.3 Scenario 3: Simulation of a 1-hour subsea release of crude from the export pipeline between the FPSO and WHP

This scenario examined a 1,080 m^3 subsea release of crude over 1 hour, tracked for 35 days. A total of 300 simulations were run across three seasons; summer, transitional and winter (i.e. 100 spills per season). These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Sections 9.3.1 presents overview of the EMBA based on combining the 300 spill simulations and Section 9.3.3 shows the seasonal (or stochastic) analysis. As there was no shoreline accumulation predicted for any spills during this scenario, the deterministic analysis (i.e. a single spill simulation) results presented in Section 9.3.2 are based on the largest area of floating oil (above 50 g/m^2) and the largest area of entrained hydrocarbons.

9.3.1 Overview

Figure 9.51 and Figure 9.52 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.53 and Figure 9.54 show the annualised extent of floating oil and in-water (entrained and dissolved) exposure based on the low and moderate exposure thresholds, respectively, derived from combining the results from all 300 spill simulations.

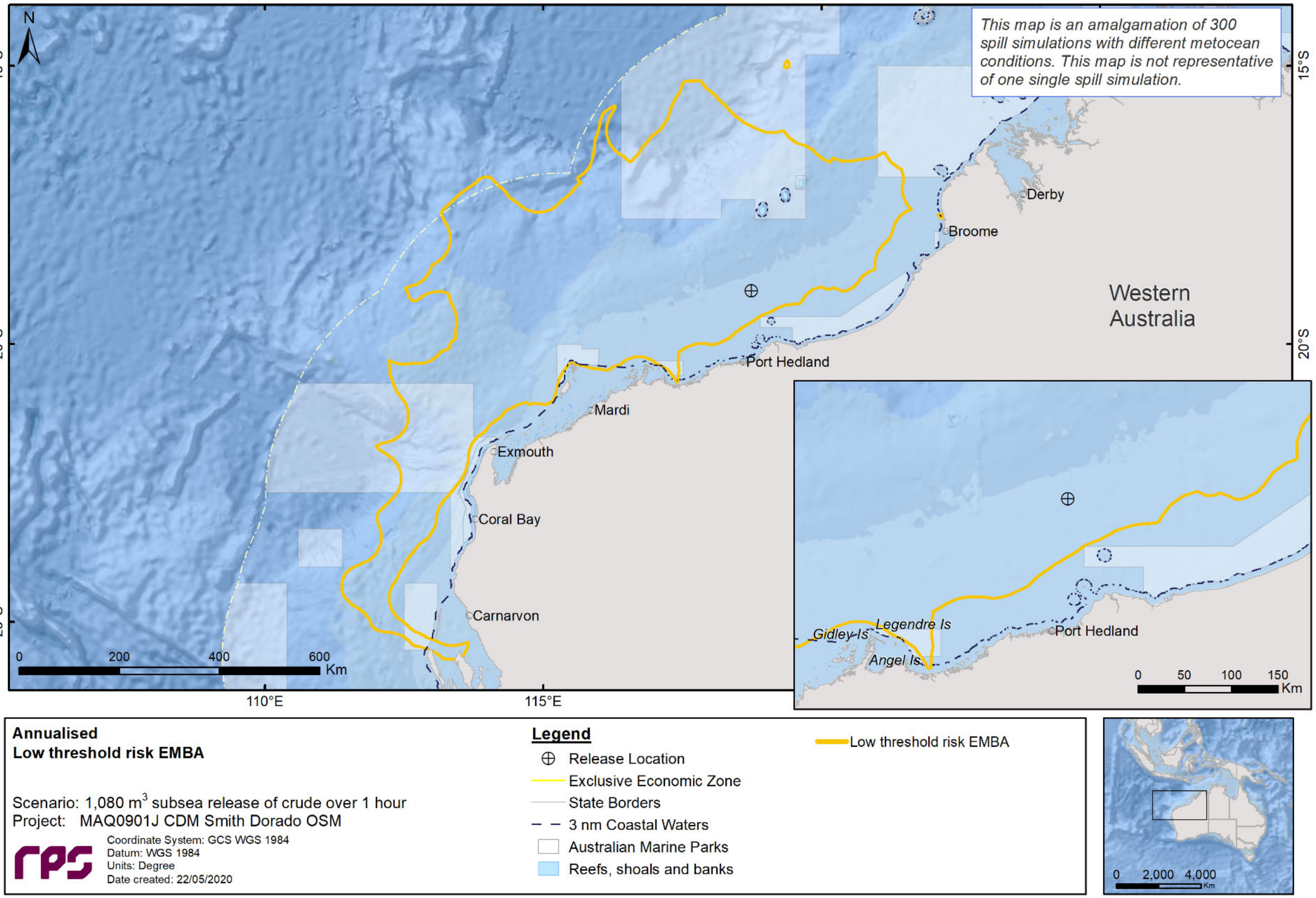


Figure 9.51 Predicted low threshold risk EMBA resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The annualised results were calculated from 300 spill simulations, which were tracked for 35 days.

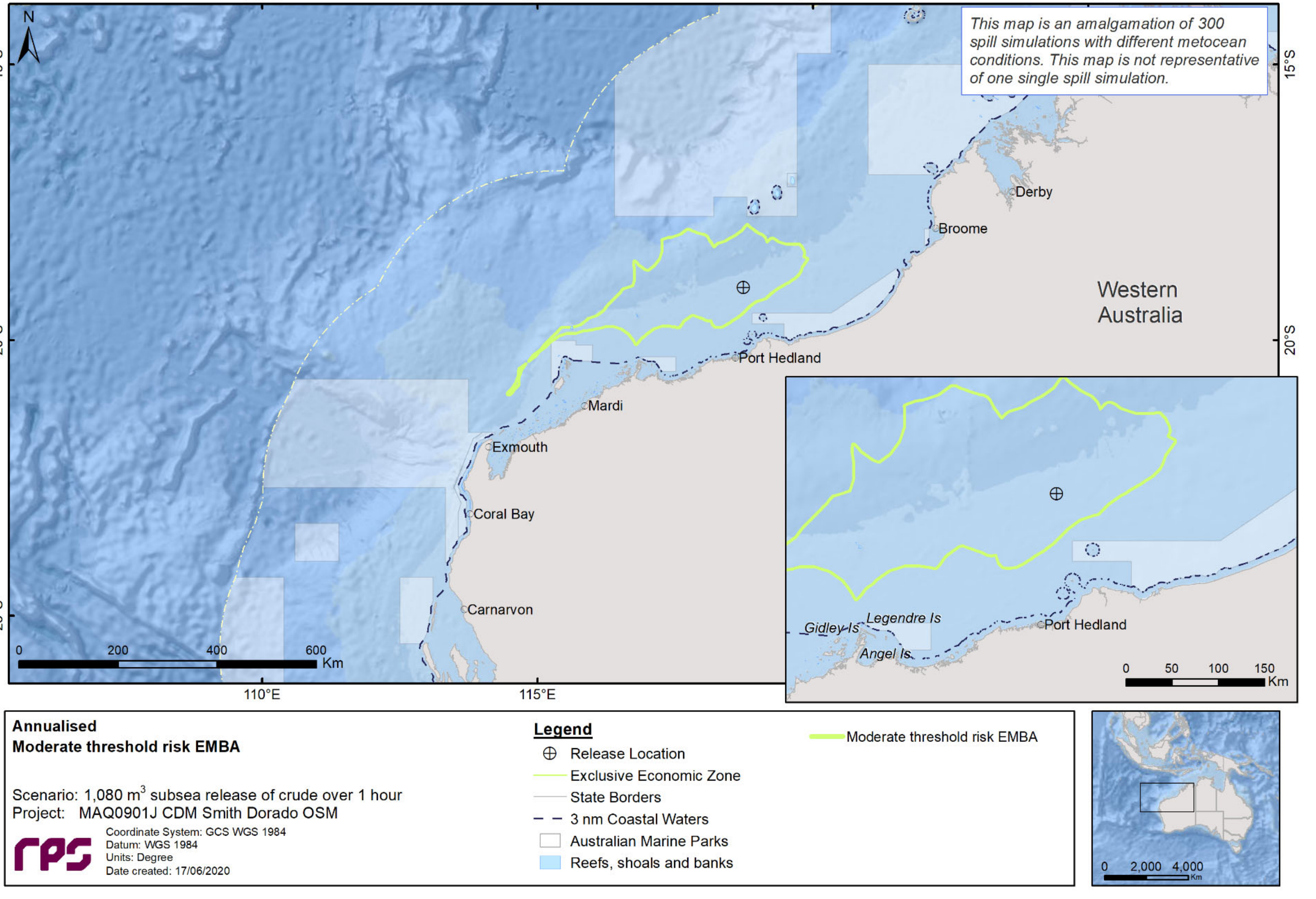


Figure 9.52 Predicted moderate threshold risk EMBA resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The annualised results were calculated from 300 spill simulations, which were tracked for 35 days.

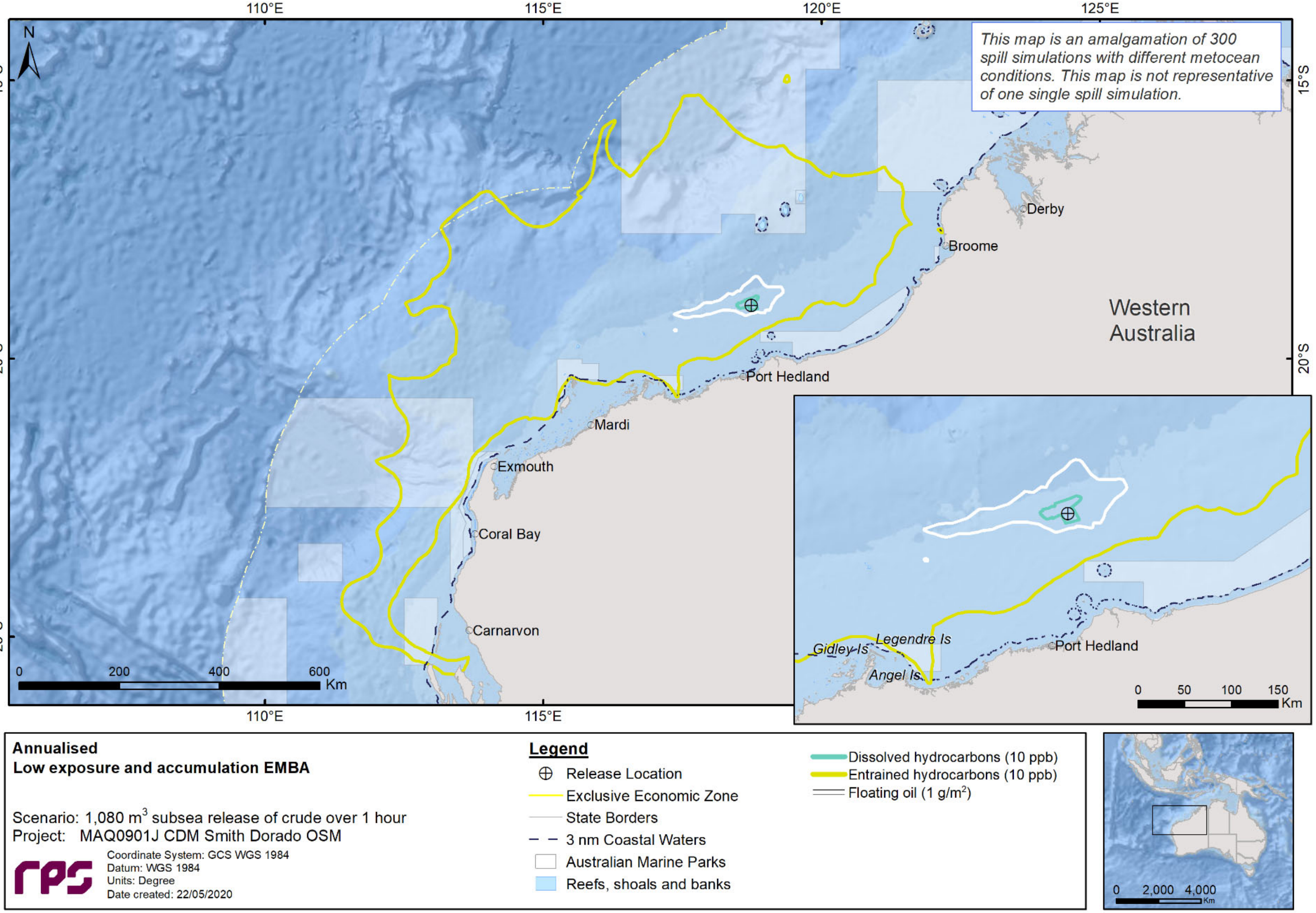


Figure 9.53 Annualised low threshold oil exposure resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The annualised results were calculated from 300 spill simulations, which were tracked for 35 days.

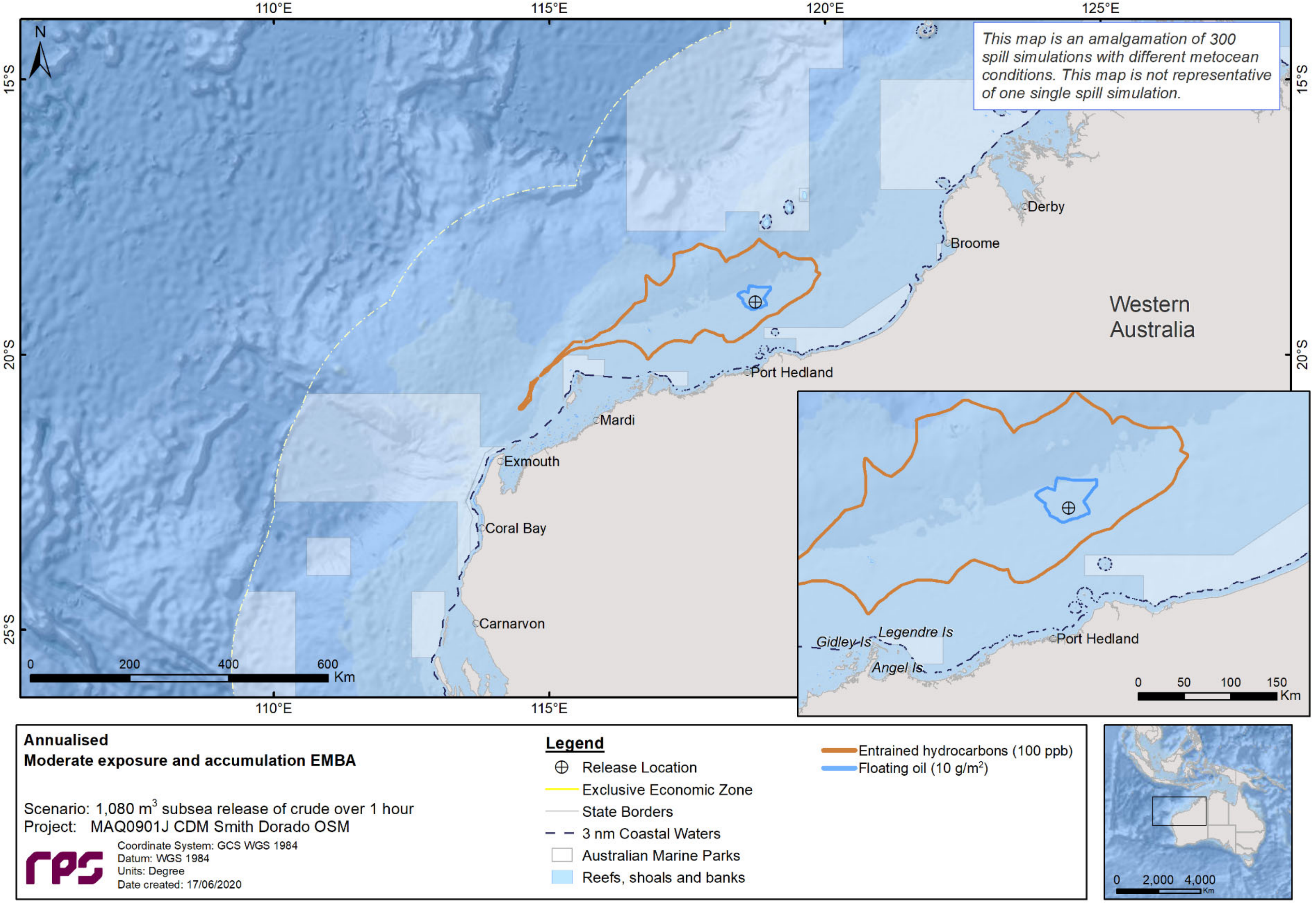


Figure 9.54 Annualised moderate threshold oil exposure resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The annualised results were calculated from 300 spill simulations, which were tracked for 35 days.

9.3.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest area of floating oil above 50 g/m^2 (actionable floating oil); and

b. Largest area of entrained hydrocarbon exposure

9.3.2.1 Deterministic Case: Largest Area of Floating Oil above 50 g/m^2

The deterministic simulation that resulted in the largest area of floating oil above 50 g/m^2 (high or actionable surface oil threshold) was identified during winter conditions as run number 18, which commenced at 2 pm on the 18th of July 2016.

Exposure from floating oil (swept area) over the entire 35 day simulation is presented in Figure 9.55. Floating oil exposure was predicted north from the release location up to a maximum distance of approximately 37 km at the low (1-10 g/m^2) threshold. Floating oil at the moderate (10-50 g/m^2) and high (≥50 g/m^2) thresholds were predicted to extend approximately 32 km and 15 km north of the release location, respectively.

Figure 9.56 displays the time series of the area of visible oil (≥1 g/m^2) and actionable floating oil (≥50 g/m^2) exposure on the sea surface over the 35-day simulation. The maximum area of coverage of visible oil on the sea surface was predicted to occur 2 days after the spill started and covered approximately 23 km^2.

Figure 9.57 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 837 m^3 (78%) spilled oil was lost to the atmosphere through evaporation. Approximately 129 m^3 (12%) of the crude was predicted to have decayed, while approximately 113 m^3 (10%) was predicted to remain within the water column.

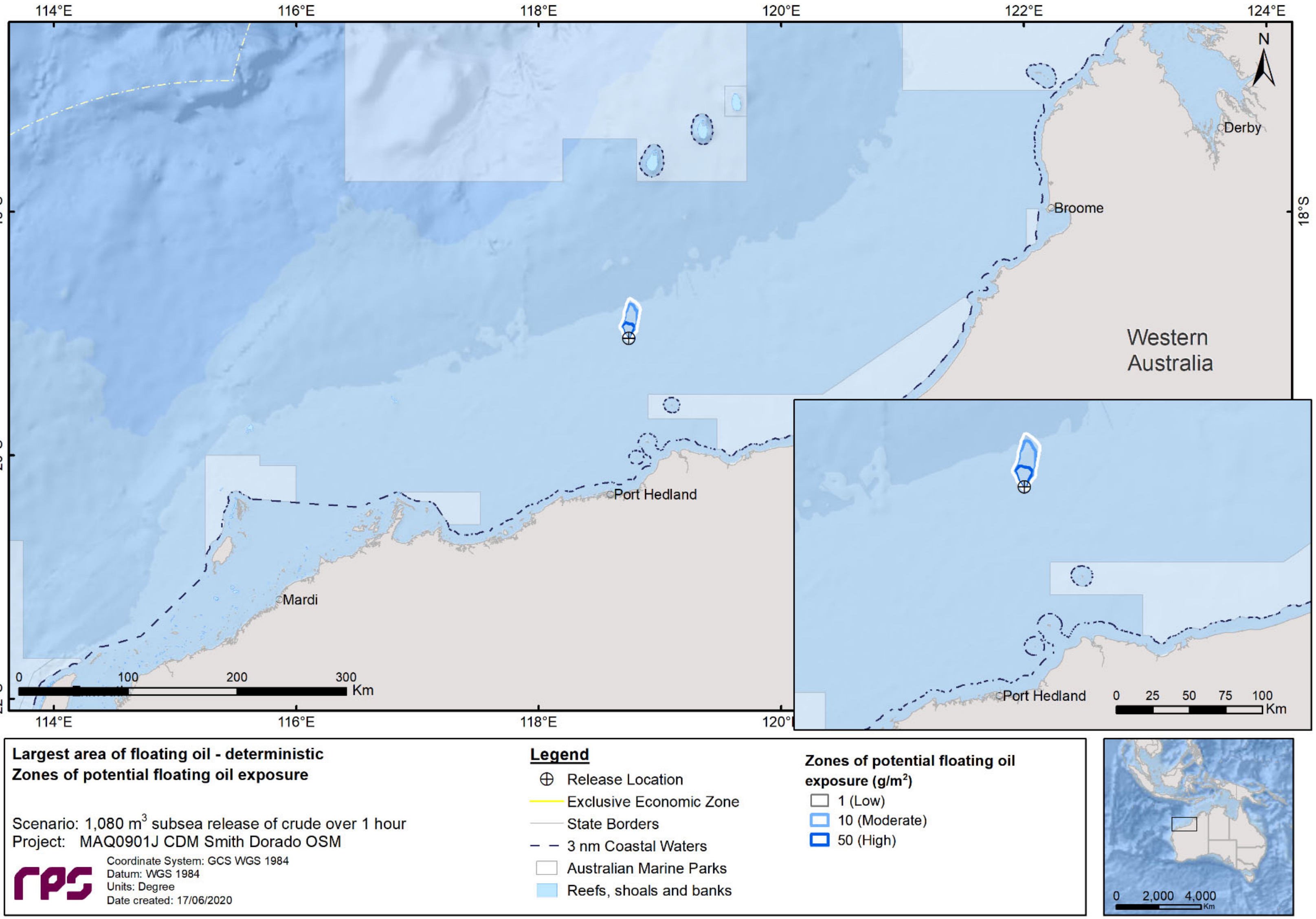


Figure 9.55 Exposure from floating oil (over the 35 day simulation) for the simulation with the largest area of floating oil above 50 g/m^2. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline, starting 2 pm on the 18th of July 2016.

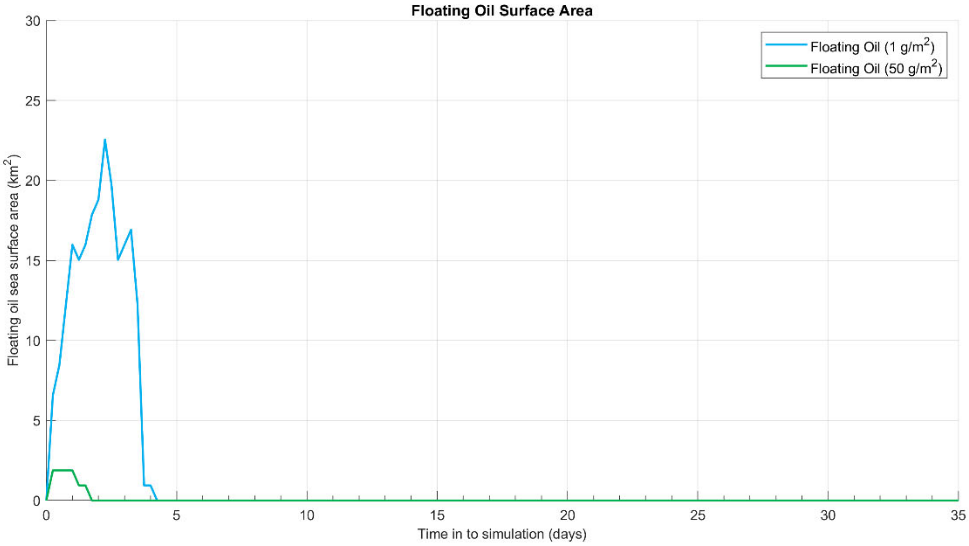


Figure 9.56 Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface for the simulation with the largest area of floating oil above 50 g/m². Results are based on a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline, tracked for 35 days, 2 pm on the 18th of July 2016.

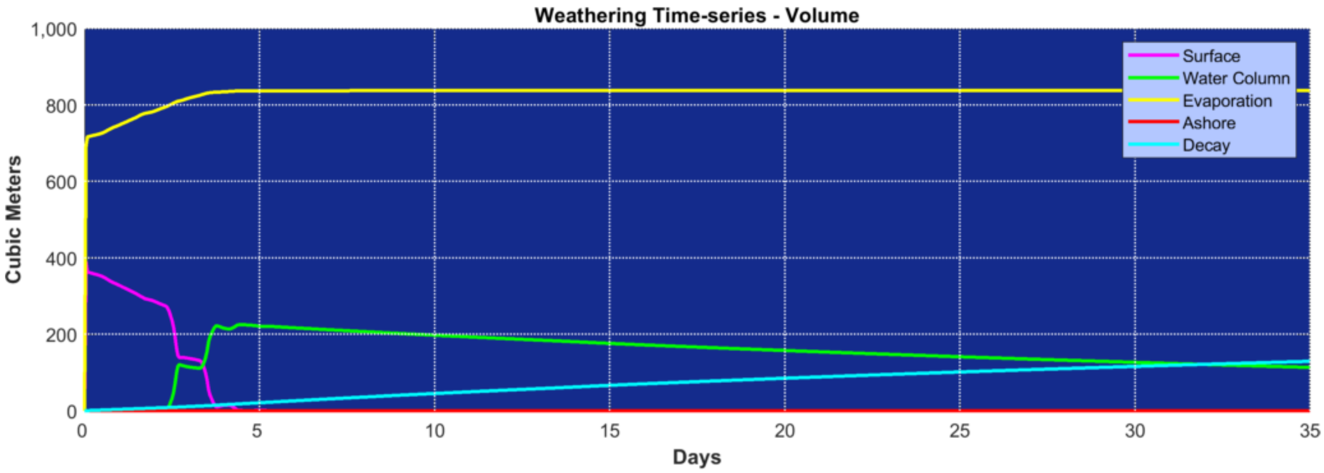


Figure 9.57 Predicted weathering and fates graph for the single spill simulation with the largest area of floating oil above 50 g/m². Results are based on a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline, tracked for 35 days, 2 pm on the 18th of July 2016.

9.3.2.2 Deterministic Case: Largest Area of Entrained Hydrocarbons

The deterministic simulation that resulted in the largest area of entrained hydrocarbons was identified during transitional conditions as run number 18, which commenced at 9 pm on the 15th of September 2018.

Exposure from floating oil (swept area) over the entire 35 day simulation are presented in Figure 9.58. Floating oil exposure was predicted to remain within approximately 18 km west of the release location.

Figure 9.59 presents instantaneous entrained hydrocarbon exposure zones in the 0-10 m depth layer for the entire simulation. Entrained hydrocarbons at the low threshold (10-100 ppb) were predicted to extend a maximum distance of approximately 11,019 km southwest from the release location and approximately 524 km southwest at the high threshold.

No dissolved hydrocarbon exposure above the low (10-50 ppb) threshold was predicted for this simulation.

Figure 9.60 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 734 m^3 (68%) spilled oil was lost to the atmosphere through evaporation. Approximately 192 m^3 (18%) of the crude was predicted to have decayed, while approximately 153 m^3 (14%) was predicted to remain within the water column.

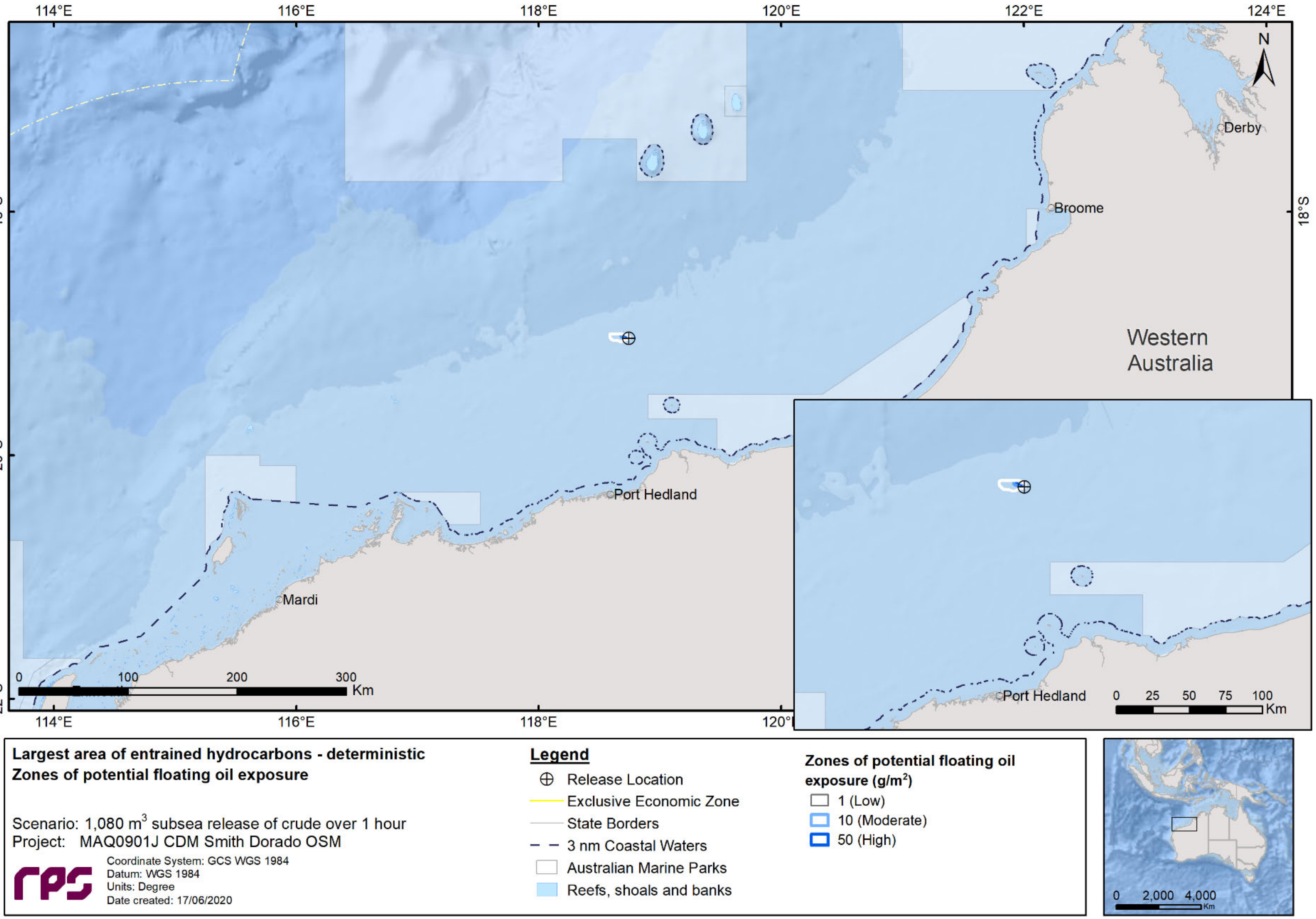


Figure 9.58 Exposure from floating oil (over the 35 day simulation) for the simulation with the largest area of entrained hydrocarbons. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline, starting 9 pm on the 15th of September 2018.

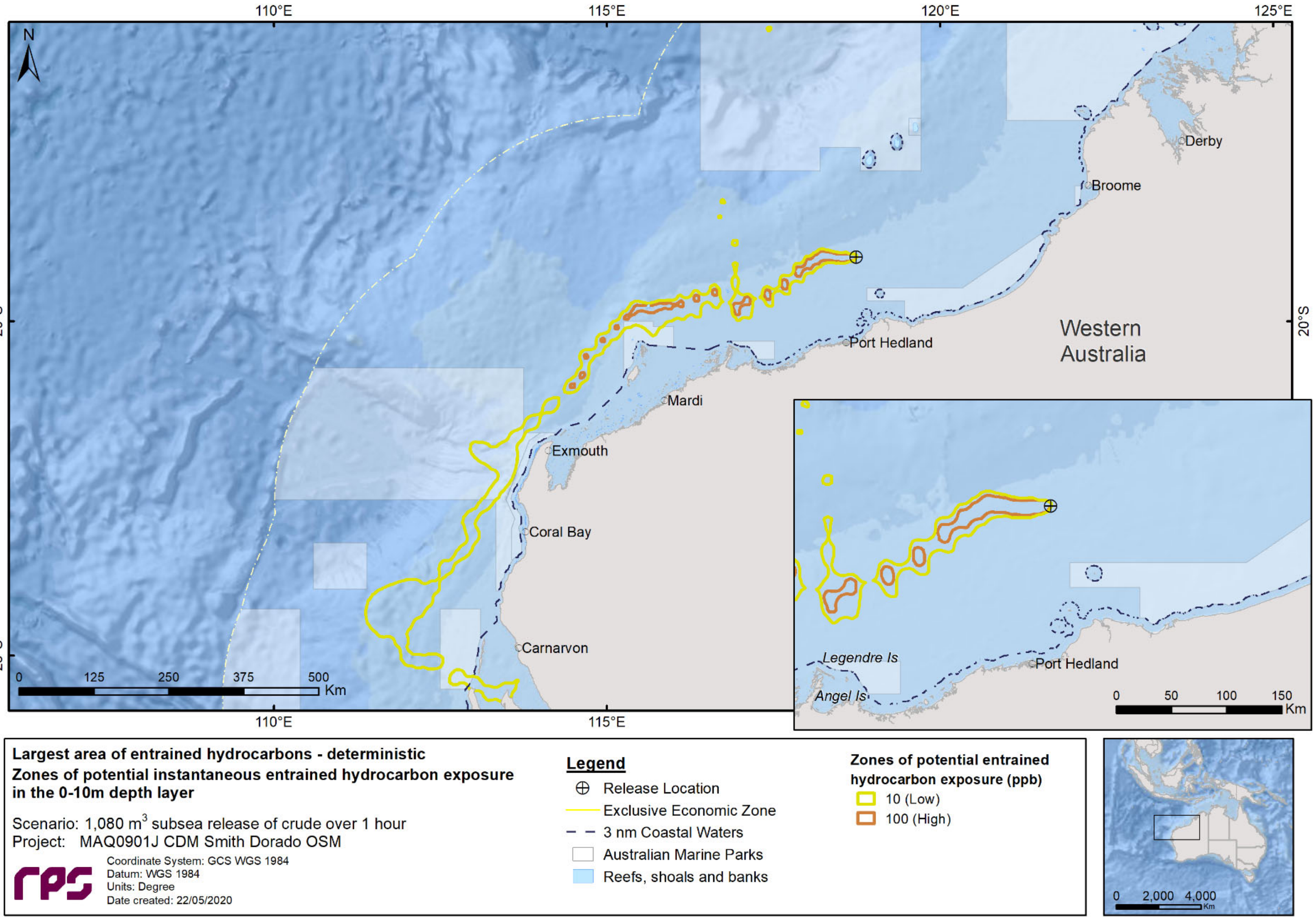


Figure 9.59 Predicted entrained hydrocarbon exposure zones in the 0-10 m depth layer for the simulation with the largest area of entrained hydrocarbons. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline, tracked for 35 days, 9 pm on the 15th of September 2018.

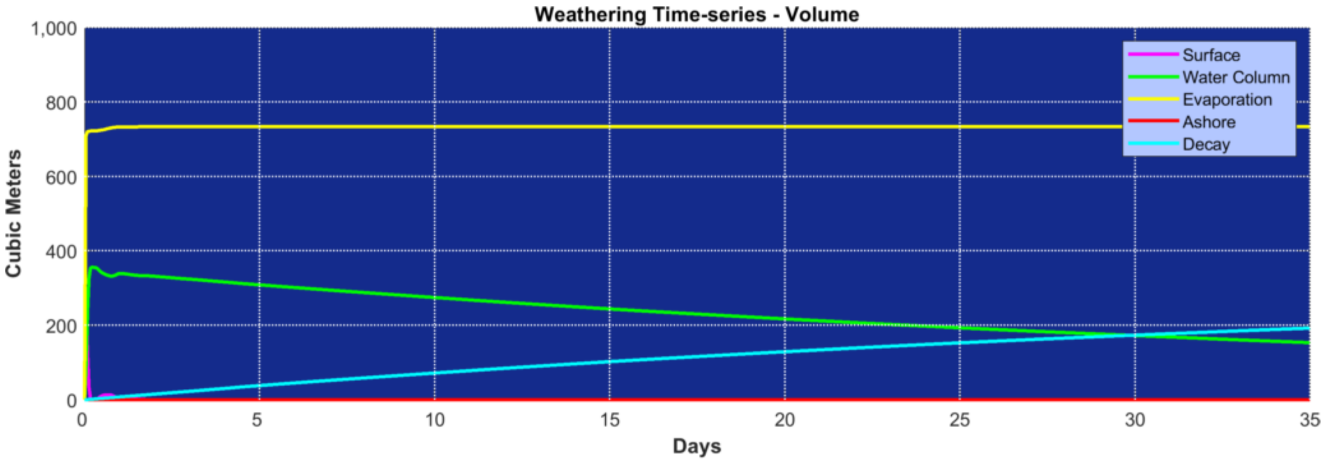


Figure 9.60 Predicted weathering and fates graph for the single spill simulation with the largest area of entrained hydrocarbons. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline, tracked for 35 days, 9 pm on the 15th of September 2018.

9.3.3 Seasonal analysis

9.3.3.1 Floating Oil Exposure

Table 9.27 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 153.1 km west-southwest (transitional), 40.5 km northeast (winter) and 34.6 km west-northwest (transitional), respectively.

Images of floating oil exposure zones are depicted in Figure 9.61, Figure 9.62 and Figure 9.63 for the combined 100 spills commencing during summer, transitional and winter conditions, respectively. There was no floating oil exposure to any of the receptors assessed.

Table 9.27 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	146	25.3	19.8
	Max distance from release site (km) (99th percentile)	128.6	23.1	17.7
	Direction	West	Northwest	West-Northwest
Transitional	Max. distance from release site (km)	153.1	35.9	34.6
	Max distance from release site (km) (99th percentile)	63.3	20.5	15.1
	Direction	West-Southwest	West-Northwest	West-Northwest
Winter	Max. distance from release site (km)	57.4	40.5	21.1
	Max distance from release site (km) (99th percentile)	51.9	37.1	18.9
	Direction	North	Northeast	North-Northeast

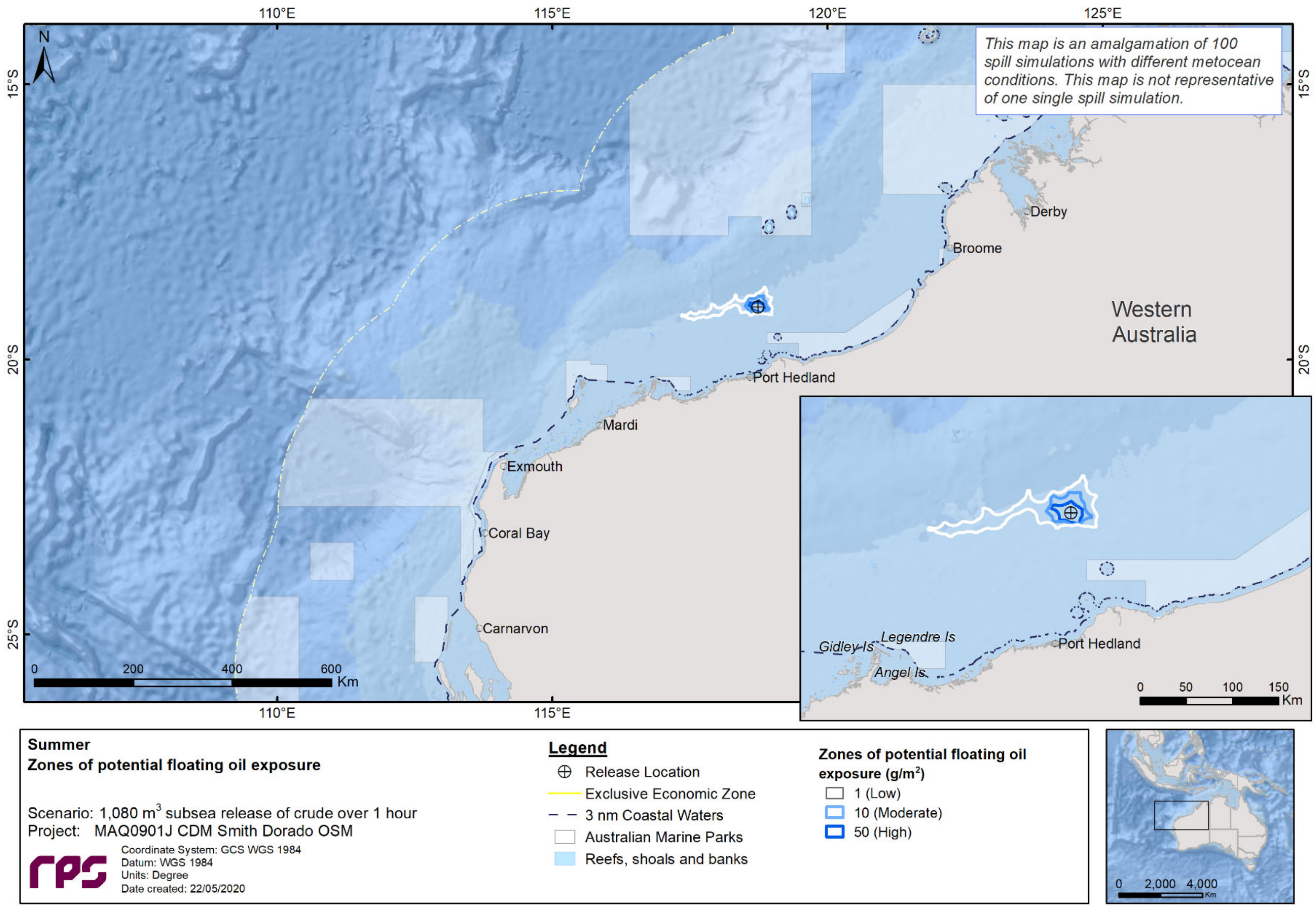


Figure 9.61 Predicted zones of potential floating oil resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

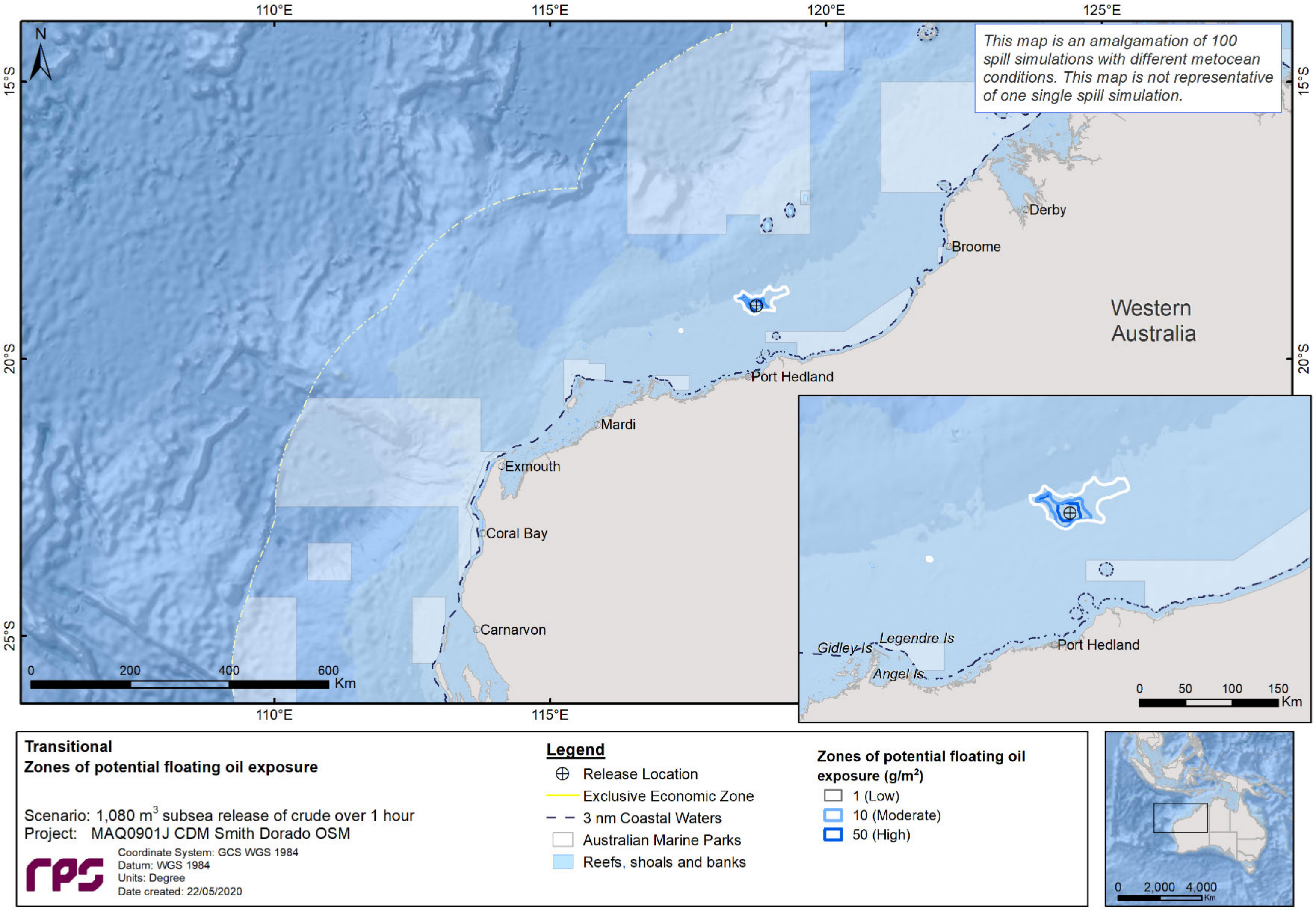


Figure 9.62 Predicted zones of potential floating oil resulting from a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

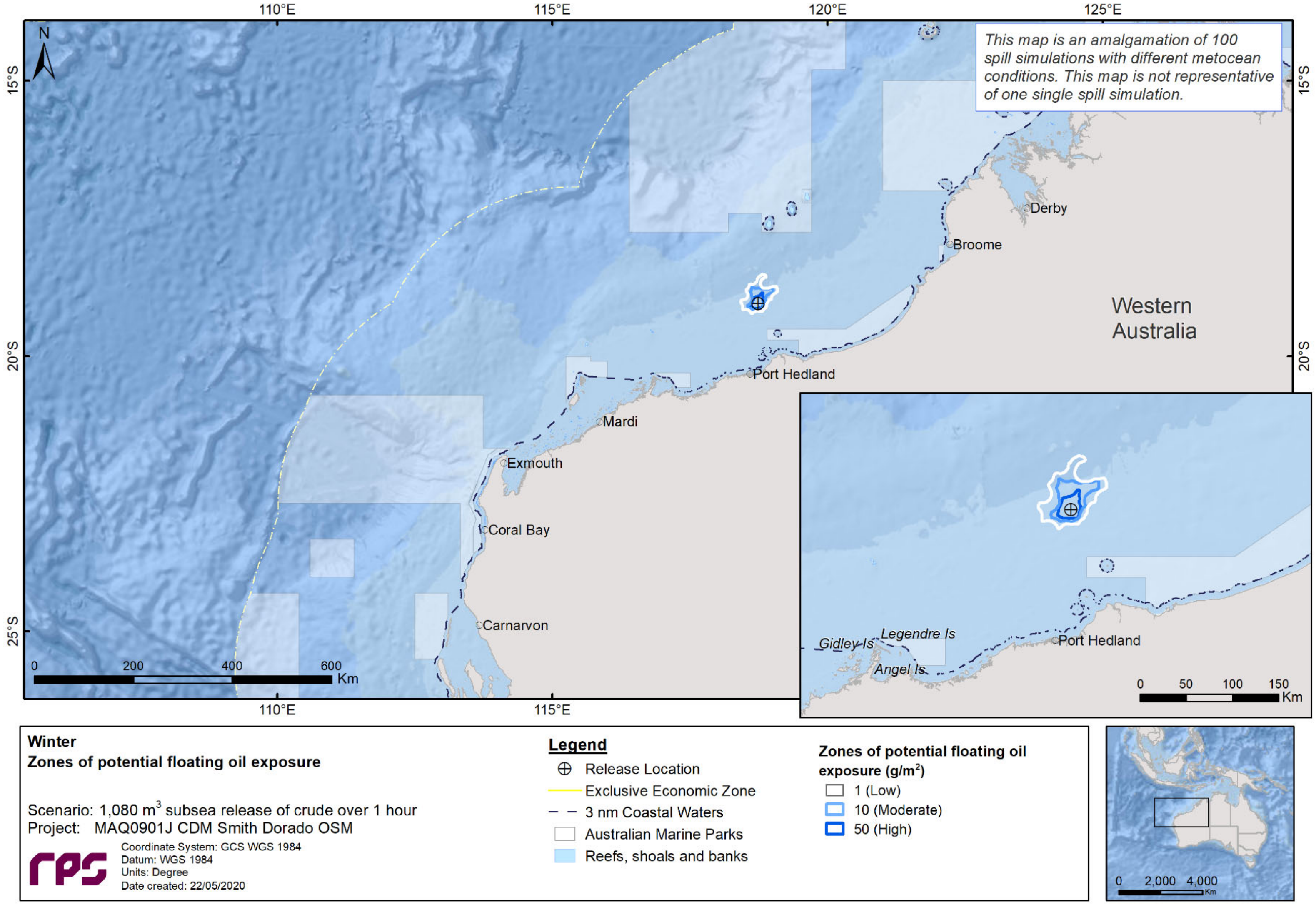


Figure 9.63 Predicted floating oil exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.3.3.2 Shoreline Accumulation

There was no shoreline accumulation predicted for any spills during this scenario at, or above, the low threshold (≥10 g/m^2).

9.3.3.3 Entrained Hydrocarbons

Images of entrained hydrocarbon exposure in the 0-10 m depth layer are depicted in Figure 9.64, Figure 9.65 and Figure 9.66 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 972 km (southwest) from the spill site during transitional conditions. This distance reduced to 497 km (west-southwest) as the threshold increased to moderate in transitional conditions. The maximum distances for summer and winter conditions at the low threshold were 586 km and 624 m, respectively. The maximum distances at the moderate threshold were reduced to 210 km for summer and 217 km for winter conditions.

Table 9.28 to

Table 9.30 summarise the probability of exposure to individual sensitive receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

A combined total of 7 AMPs are within the low exposure zone across the 3 seasons, with the Montebello AMP recording the highest probability of exposure of 7% during transitional conditions. The shortest time for exposure at the low threshold to an AMP was recorded at Dampier during transitional conditions at 0.88 days (21 hours).

No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold.

Four RSBs are within the low threshold zone across the 3 seasons and the highest probability of exposure was predicted at Rankin Shoal at 7% during transitional conditions, with a corresponding minimum time of 5.6 days before contact.

Entrained hydrocarbons at the low threshold were predicted to cross into WA State Waters during every season with probabilities ranging from 2-6%. The minimum time before oil crossed the WA State Waters boundary was 1.08 days (26 hours), for a spill commencing during transitional conditions.

Table 9.28 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	4	-	13.0	-	37
	Dampier	-	-	-	-	-
	Gascoyne	1	-	27.6	-	14
	Kimberley	2	-	17.6	-	13
	Mermaid Reef	2	-	24.8	-	14
	Montebello	2	-	18.6	-	45
	Shark Bay	-	-	-	-	-
IBRA	Edel	-	-	-	-	-
	Pindanland	1	-	10.1	-	12
	Wooramel	-	-	-	-	-
IMCRA	Canning	1	-	9.9	-	12
	Pilbara (nearshore)	-	-	-	-	-
	Pilbara (offshore)	7	2	1.2	1.2	672
	Shark Bay	-	-	-	-	-
	Zuytdorp	-	-	-	-	-
MP	Rowley Shoals	2	-	19.2	-	18
	Shark Bay	-	-	-	-	-
RSB	Clerke Reef	1	-	25.4	-	18
	Imperieuse Reef	2	-	19.9	-	15
	Mermaid Reef	1	-	25.9	-	11
	Rankin Bank	-	-	-	-	-
Nearshore	Broome	1	-	10.1	-	12
	Clerke Reef	1	-	25.8	-	16
	Cunningham Island	1	-	20.1	-	15
	Dirk Hartog Island	-	-	-	-	-
	Imperieuse Reef	1	-	19.9	-	15
	Mermaid Reef	-	-	-	-	-
	Shark Bay	-	-	-	-	-
State Waters	Western Australia State Waters	2	-	9.9	-	18

Table 9.29 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m³ of crude from the export pipeline during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	6	-	7.2	-	54
	Dampier	1	-	0.9	-	57
	Gascoyne	6	-	7.4	-	99
	Kimberley	-	-	-	-	-
	Mermaid Reef	5	-	16.5	-	36
	Montebello	7	-	5.6	-	67
	Shark Bay	2	-	26.8	-	25
IBRA	Edel	1	-	26.9	-	16
	Pindanland	-	-	-	-	-
	Wooramel	2	-	27.0	-	28
IMCRA	Canning	-	-	-	-	-
	Pilbara (nearshore)	1	-	1.0	-	16
	Pilbara (offshore)	8	1	0.8	2.3	163
	Shark Bay	2	-	26.9	-	28
	Zuytdorp	2	-	25.5	-	30
MP	Rowley Shoals	6	-	13.7	-	40
	Shark Bay	2	-	26.9	-	28
RSB	Clerke Reef	6	-	14.0	-	39
	Imperieuse Reef	-	-	-	-	-
	Mermaid Reef	4	-	17.1	-	33
	Rankin Bank	7	1	5.6	6.4	151
Nearshore	Broome	-	-	-	-	-
	Clerke Reef	6	-	14.3	-	38
	Cunningham Island	-	-	-	-	-
	Dirk Hartog Island	1	-	26.9	-	16
	Imperieuse Reef	-	-	-	-	-
	Mermaid Reef	4	-	17.6	-	33
	Shark Bay	2	-	27.0	-	28
State Waters	Western Australia State Waters	6	-	1.1	-	40

Table 9.30 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	6	-	12.8	-	76
	Dampier	-	-	-	-	-
	Gascoyne	2	-	24.3	-	13
	Kimberley	-	-	-	-	-
	Mermaid Reef	2	-	25.9	-	17
	Montebello	6	-	16.6	-	35
	Shark Bay	-	-	-	-	-
IBRA	Edel	-	-	-	-	-
	Pindanland	-	-	-	-	-
	Wooramel	-	-	-	-	-
IMCRA	Canning	-	-	-	-	-
	Pilbara (nearshore)	-	-	-	-	-
	Pilbara (offshore)	7	-	5.7	-	80
	Shark Bay	-	-	-	-	-
	Zuytdorp	-	-	-	-	-
MP	Rowley Shoals	2	-	20.5	-	38
	Shark Bay	-	-	-	-	-
RSB	Clerke Reef	2	-	22.6	-	20
	Imperieuse Reef	1	-	20.9	-	22
	Mermaid Reef	2	-	26.9	-	15
	Rankin Bank	5	-	16.8	-	35
Nearshore	Broome	-	-	-	-	-
	Clerke Reef	2	-	24.2	-	20
	Cunningham Island	-	-	-	-	-
	Dirk Hartog Island	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-
	Mermaid Reef	2	-	27.7	-	15
	Shark Bay	-	-	-	-	-
State Waters	Western Australia State Waters	2	-	20.5	-	38

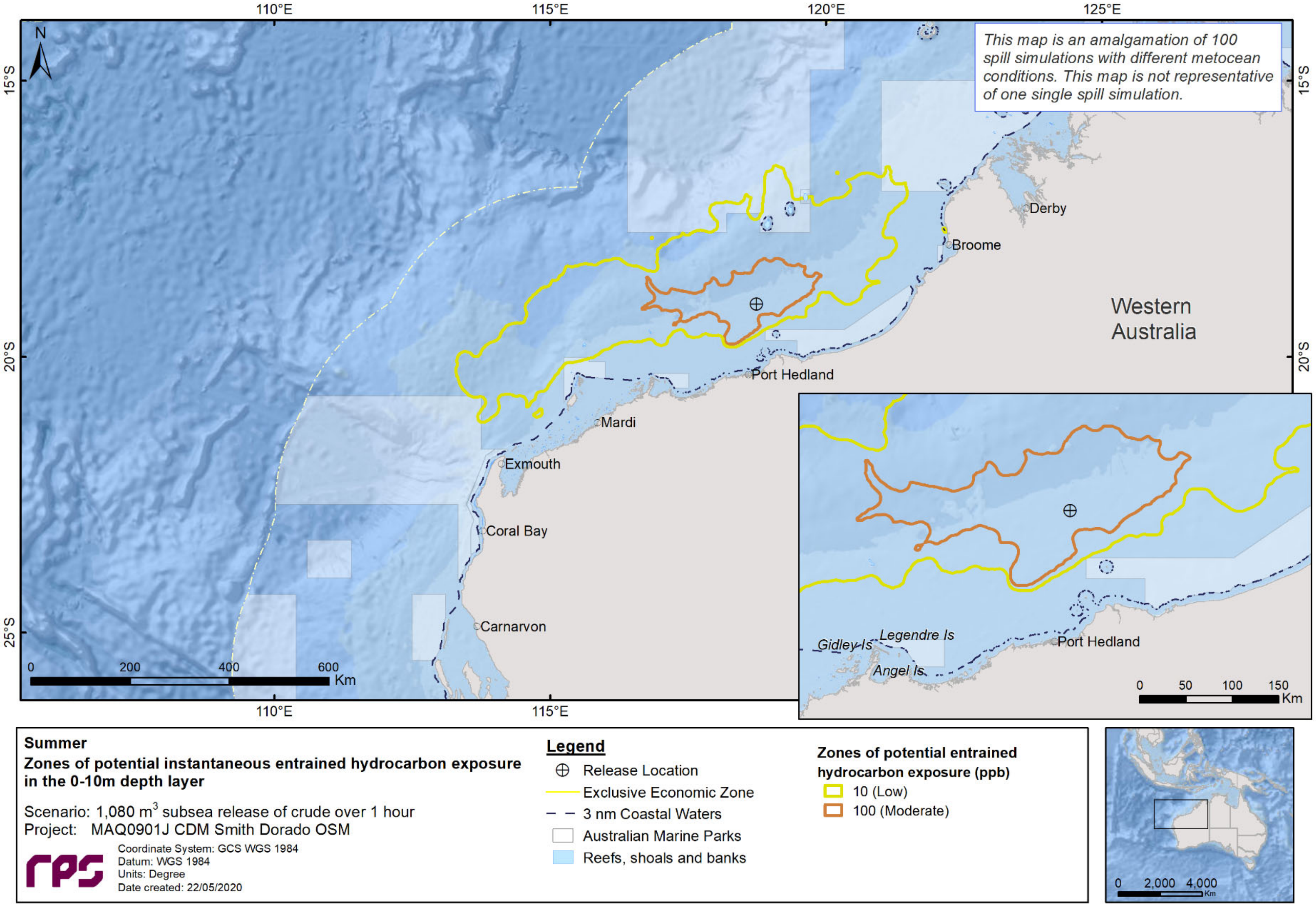


Figure 9.64 Predicted entrained hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

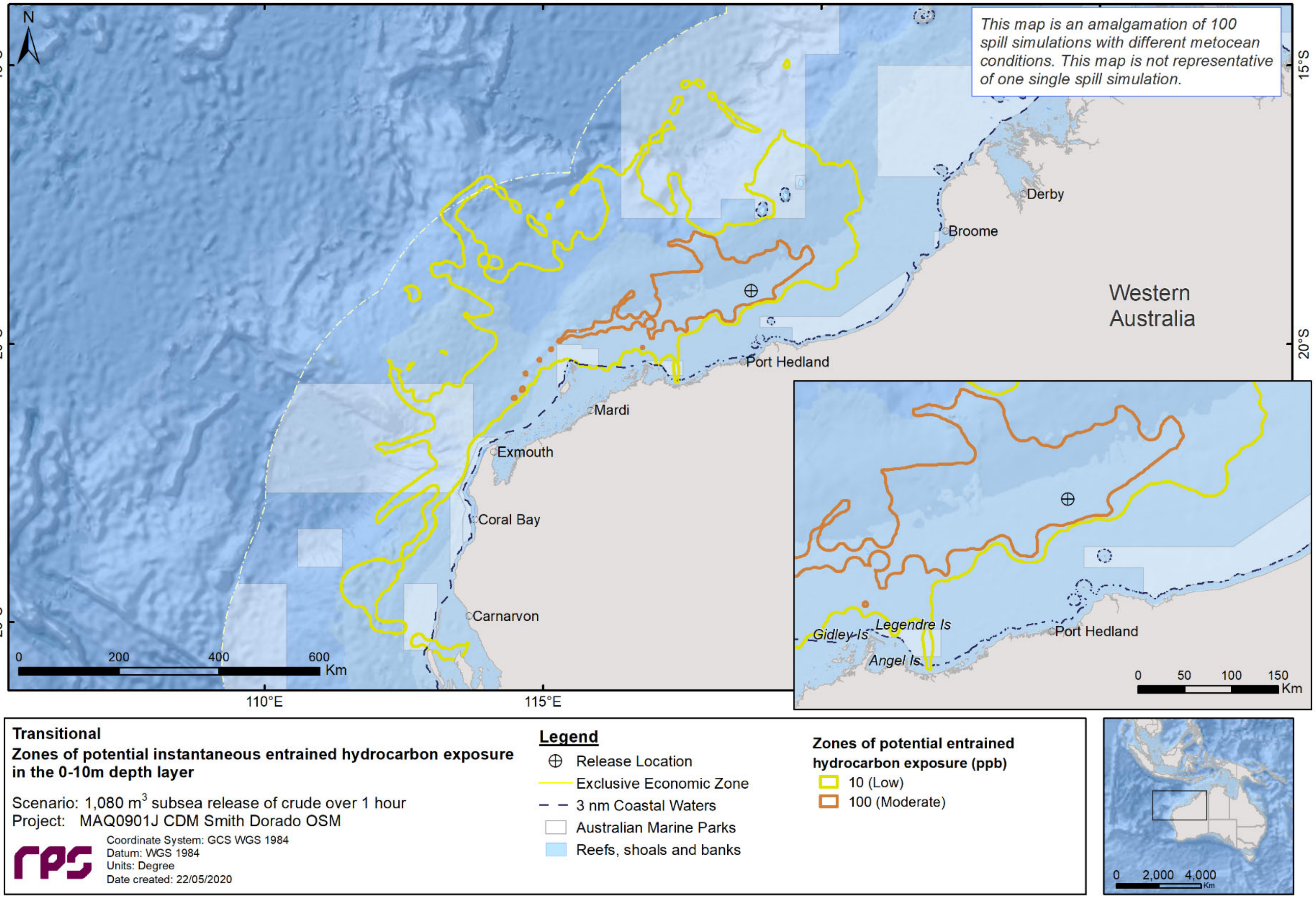


Figure 9.65 Predicted entrained hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

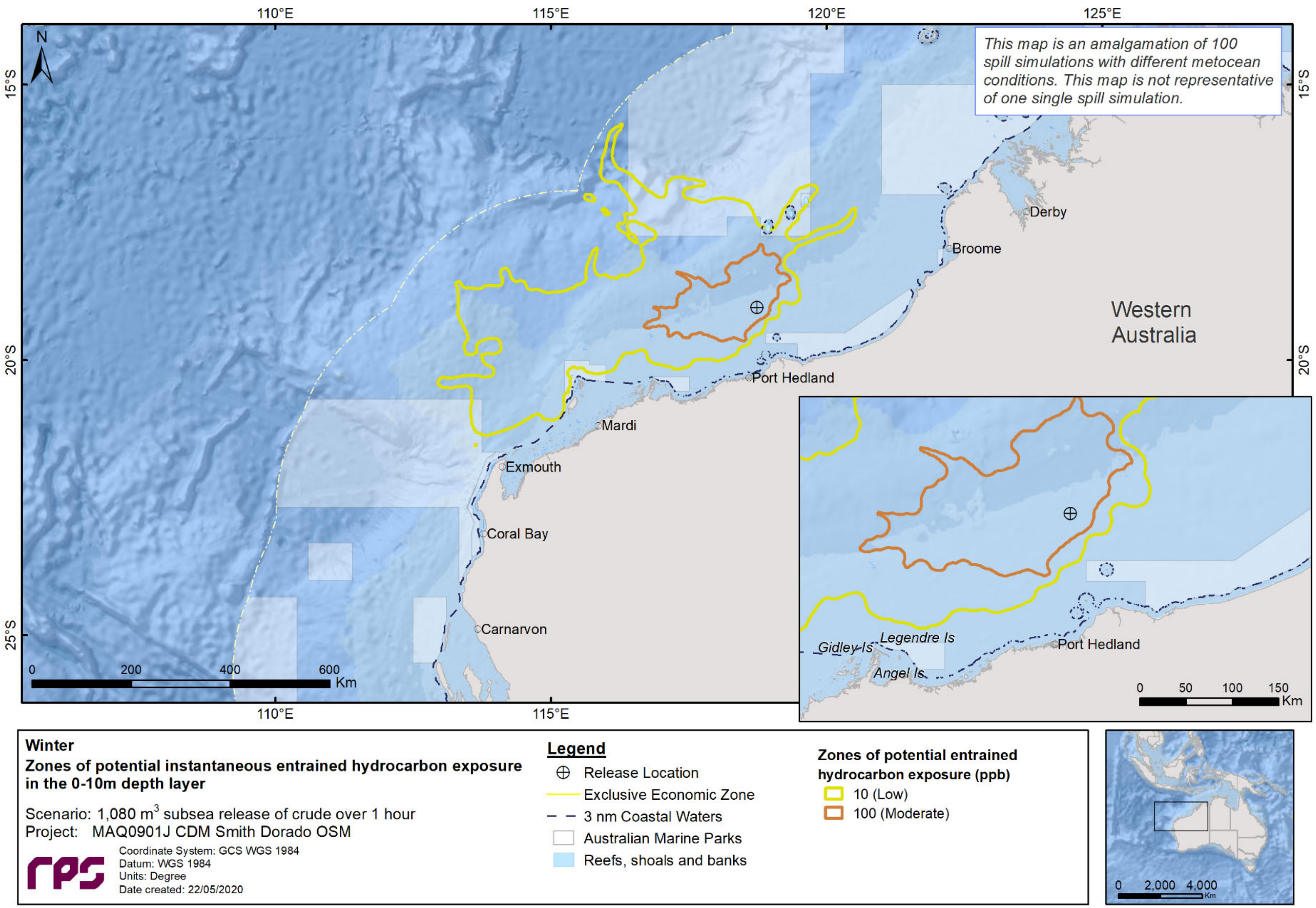


Figure 9.66 Predicted entrained hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.3.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones are depicted in Figure 9.67, Figure 9.68and Figure 9.69 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The results indicated that the low threshold (10-50 ppb) extended furthest up to a maximum distance of 28 km (west) from the release location during summer conditions. The maximum distances for transitional and winter conditions at the low threshold were 12 km and 20 m, respectively.

No exposure at the moderate (50-400 ppb) or high (≥ 400 ppb) thresholds was predicted in any of the assessed seasons.

Dissolved hydrocarbons were not predicted to impact any receptors (other than the Northwest Shelf IMCRA, which resides within the release location) at, or above, the low (10-50 ppb) threshold hence no tables are presented for this scenario.

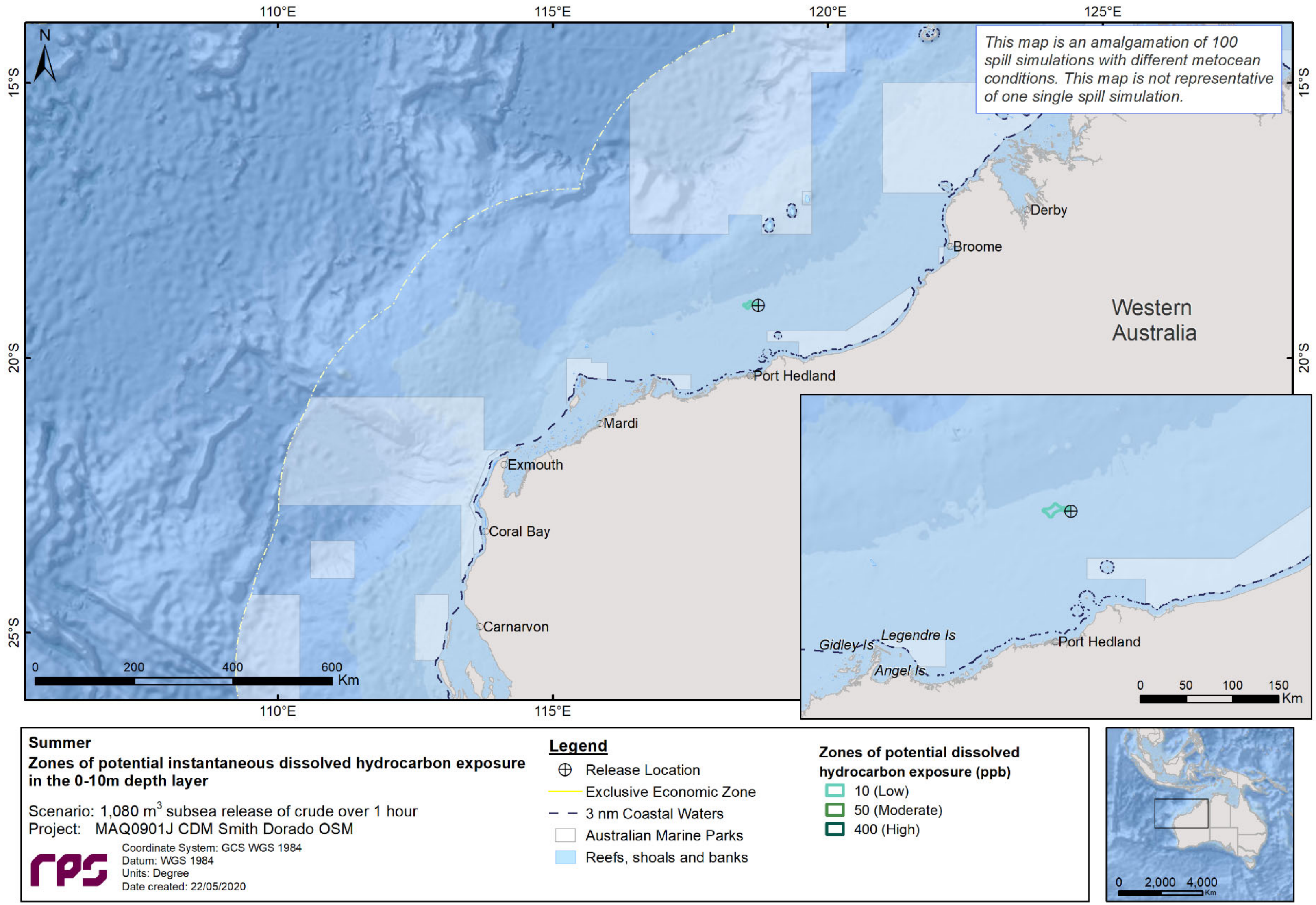


Figure 9.67 Predicted dissolved hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

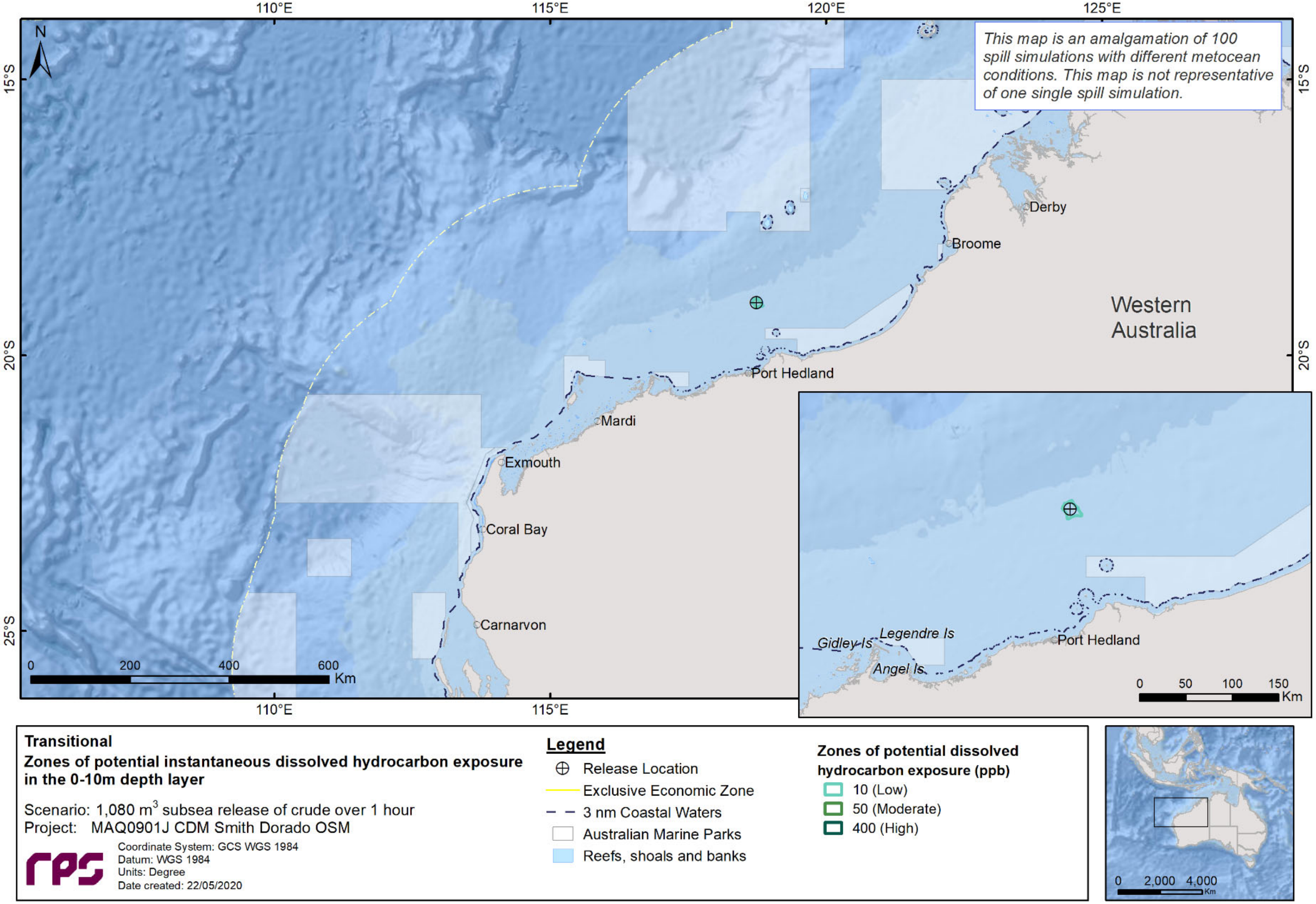


Figure 9.68 Predicted dissolved hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

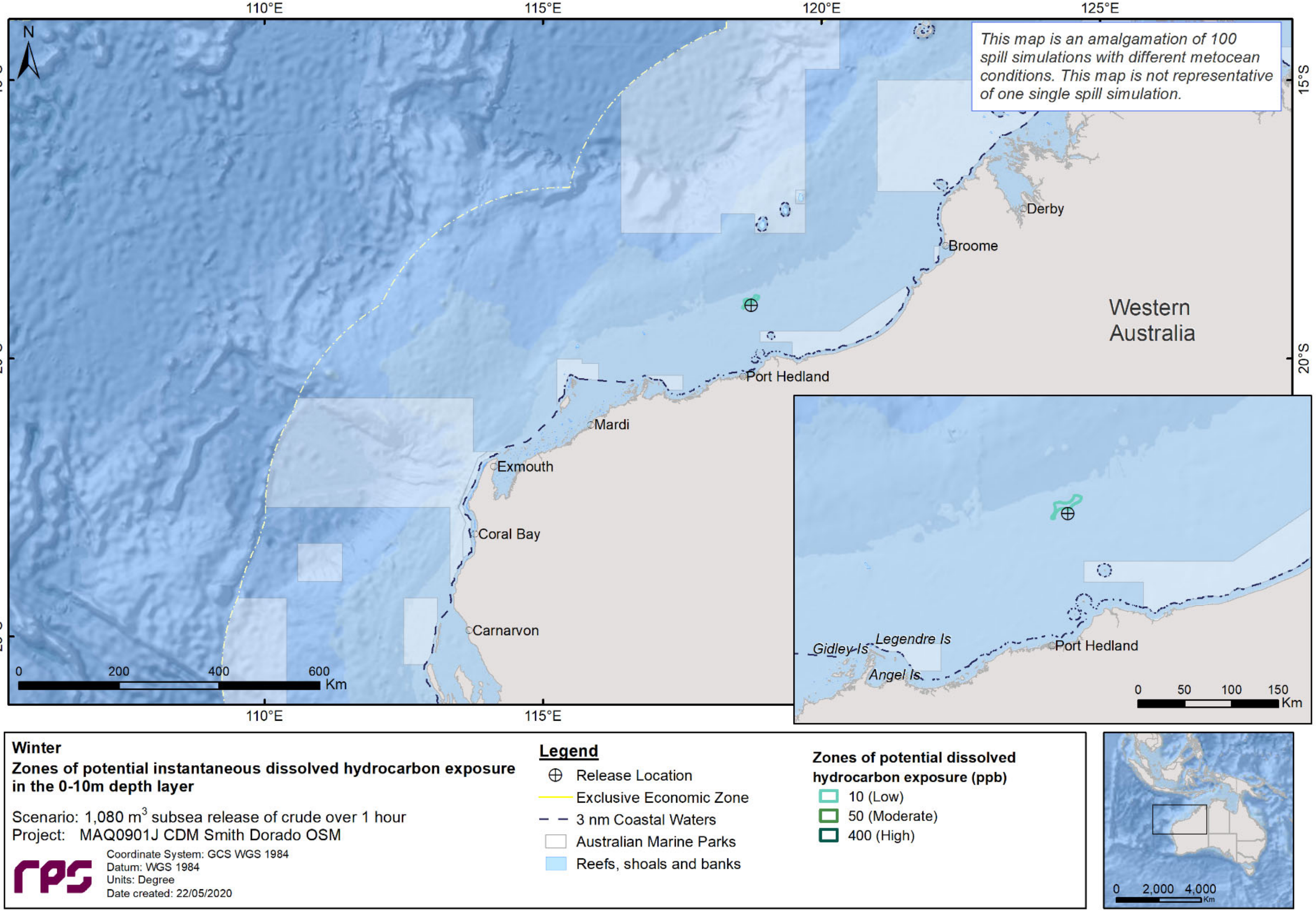


Figure 9.69 Predicted dissolved hydrocarbon exposure zones resulting from a subsea release over 1 hour, releasing a total of 1,080 m^3 of crude from the export pipeline. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.4 Scenario 4: Simulation of an instantaneous surface release of crude at the FPSO due to an offtake incident

This scenario examined an instantaneous 225 m^3 surface release of crude at the FPSO, tracked for 21 days. A total of 300 simulations were run across three seasons; summer, transitional and winter (i.e. 100 spills per season). These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Sections 9.4.1 presents overview of the EMBA based on combining the 300 spill simulations and Section 9.4.3 shows the seasonal (or stochastic) analysis. As there was no shoreline accumulation predicted for any spills during this scenario, the deterministic analysis results (i.e. a single spill simulation), presented in Section 9.4.2 are based on the largest area of floating oil (above 50 g/m^2) and the largest area of entrained hydrocarbons.

9.4.1 Overview

Figure 9.70 and Figure 9.71 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.72 and Figure 9.73 show the annualised extent of floating oil and in-water (entrained and dissolved) exposure based on the low and moderate exposure thresholds, respectively, derived from combining all 300 spill simulations.

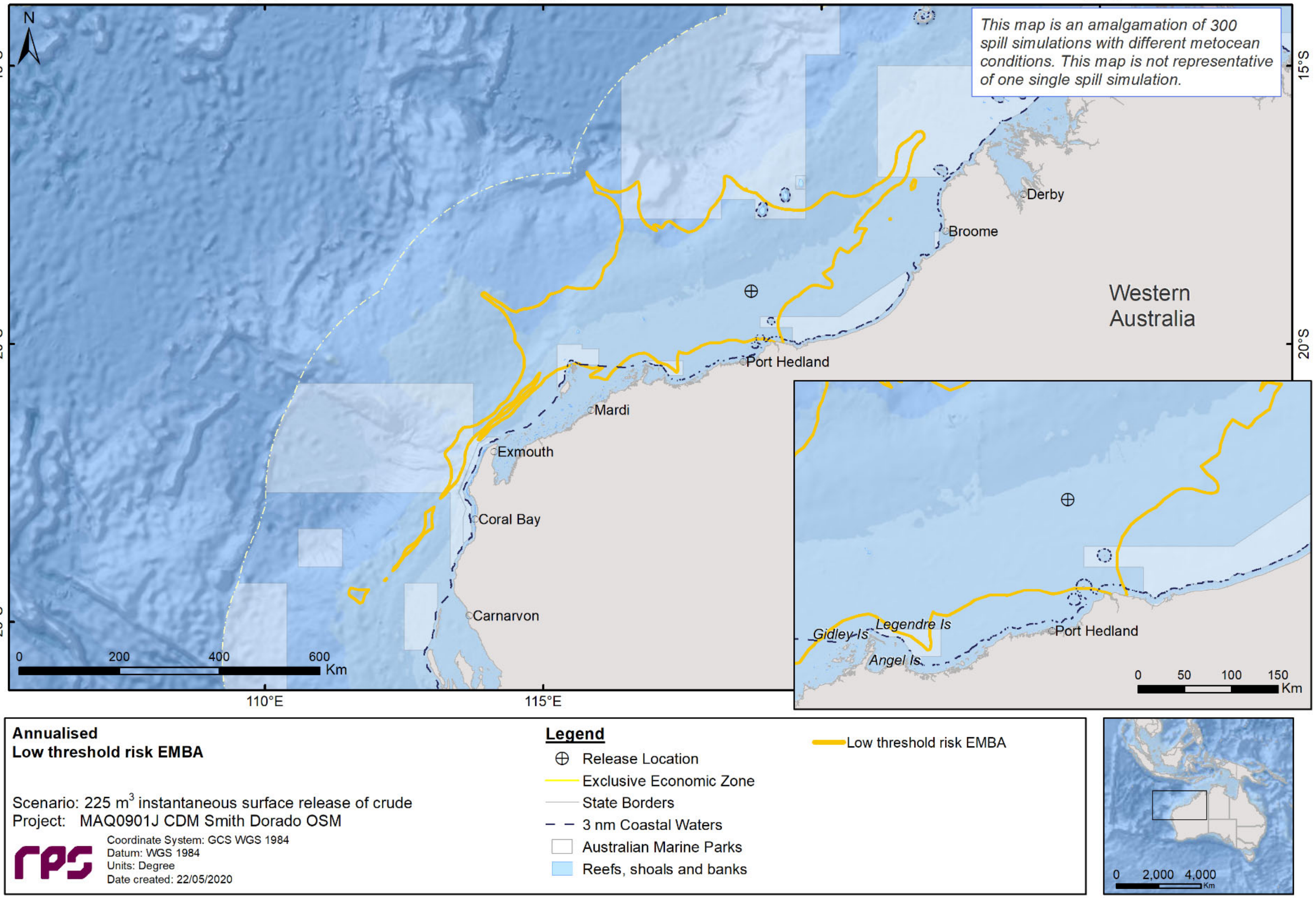


Figure 9.70 Predicted low threshold risk EMBA resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 21 days.

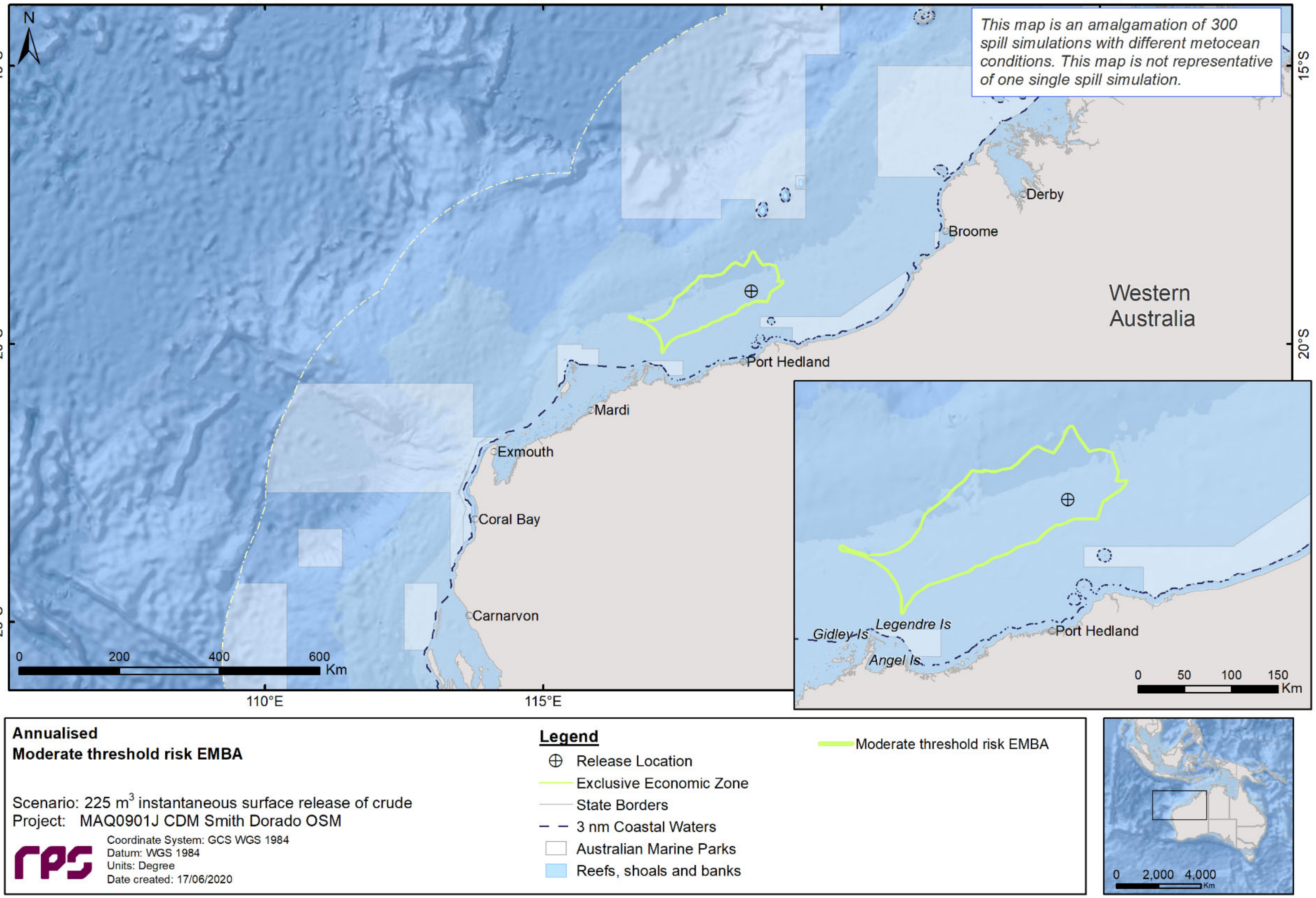


Figure 9.71 Predicted moderate threshold risk EMBA resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 21 days.

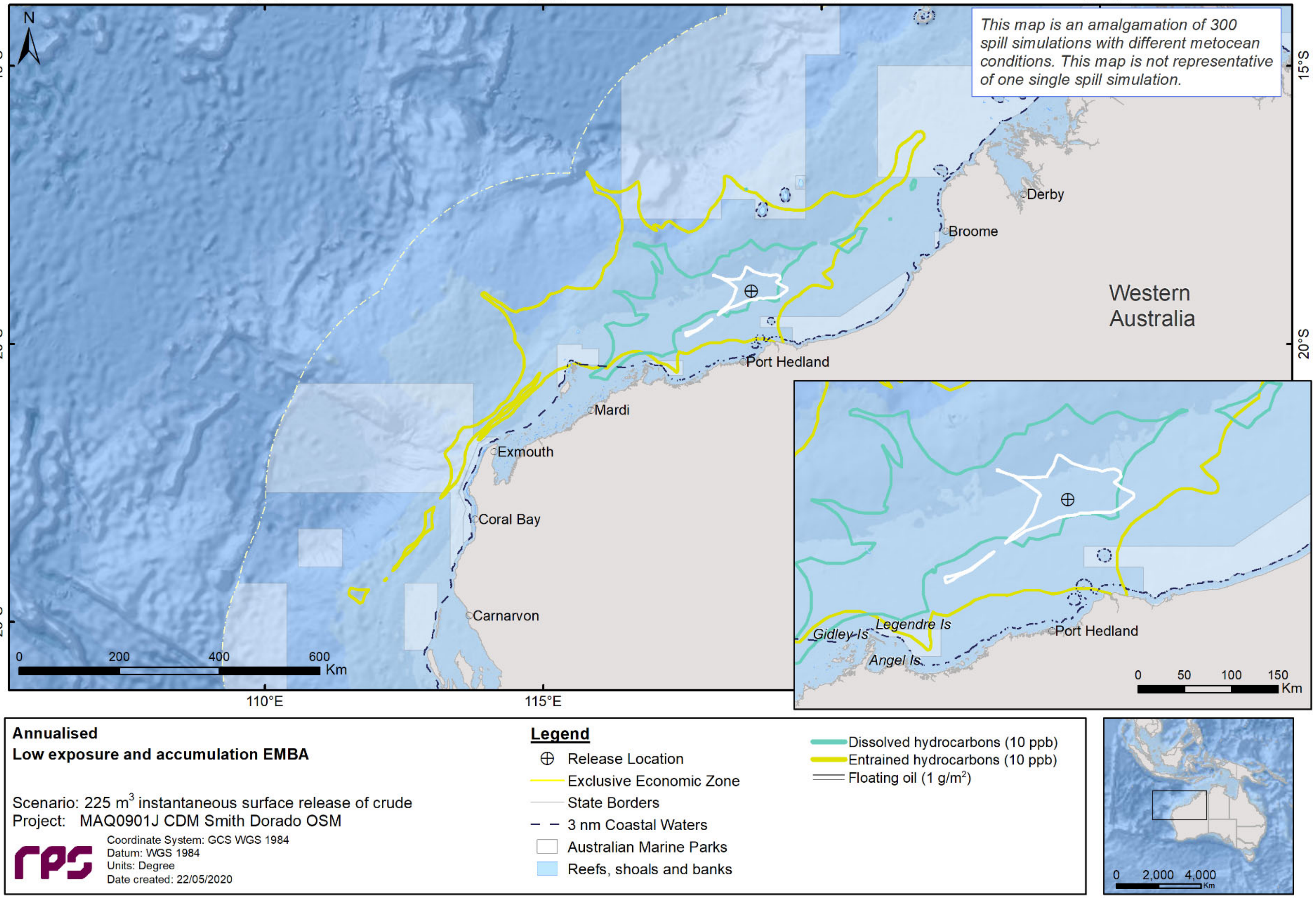


Figure 9.72 Annualised low threshold oil exposure resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 21 days.

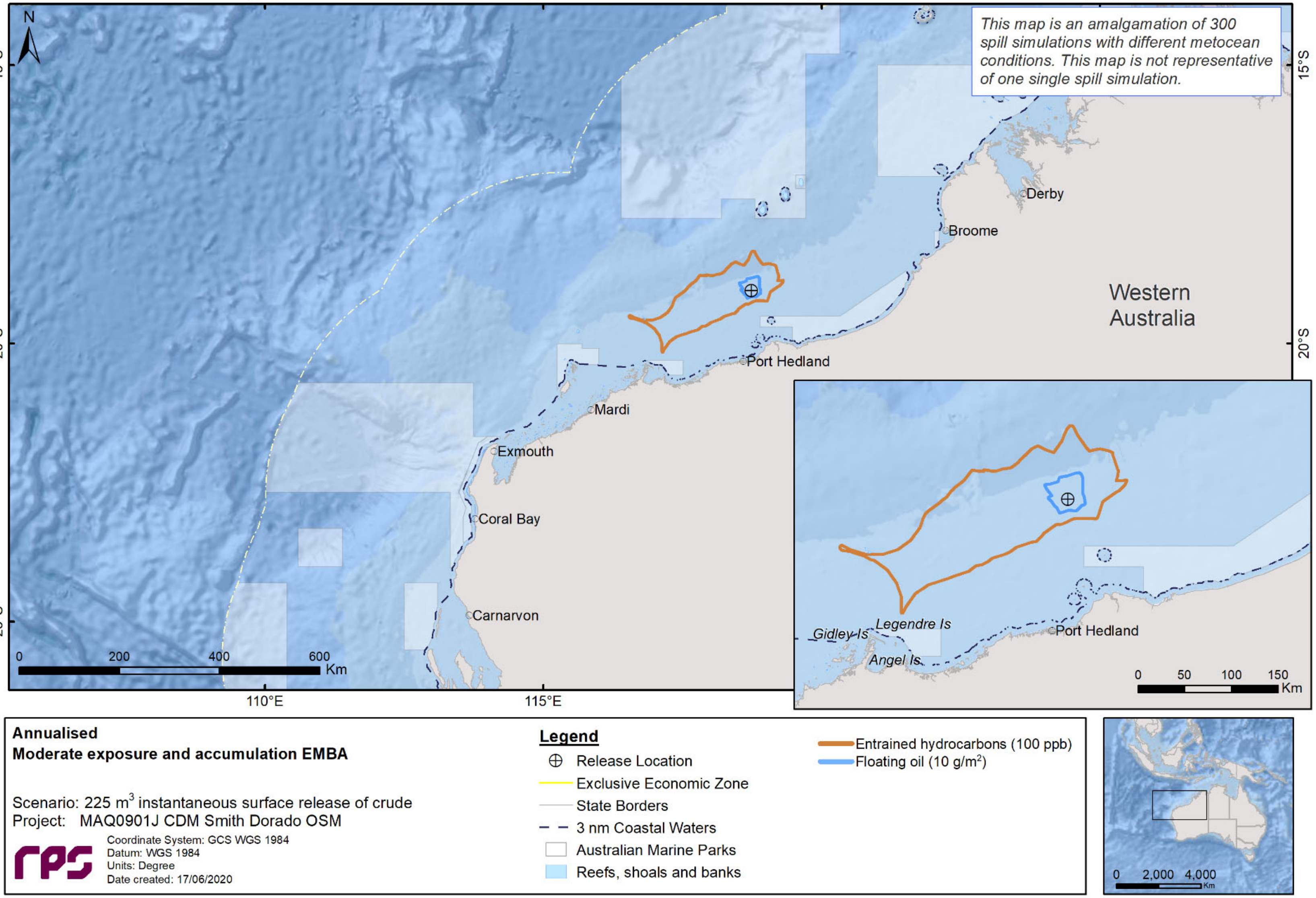


Figure 9.73 Annualised moderate threshold oil exposure resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 21 days.

9.4.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest area of floating oil above 50 g/m^2 (actionable floating oil); and

b. Largest area of entrained hydrocarbon exposure

9.4.2.1 Deterministic Case: Largest Area of Floating Oil above 50 g/m^2

The deterministic simulation that resulted in the largest area of floating oil above 50 g/m^2 (high or actionable floating oil threshold) was identified during transitional conditions as run number 44, which commenced at 5 am on the 6th of September 2016.

Exposure from floating oil (swept area) over the entire 21 day simulation is presented in Figure 9.74. Floating oil exposure was predicted north-northeast from the release location up to a maximum distance of approximately 15 km at the low (1-10 g/m^2) threshold. Floating oil at the moderate threshold (10-50 g/m^2) threshold was predicted to extend a maximum distance of approximately 10 km north of the release location, while at the high (≥50 g/m^2) threshold the extent remained within 8 km of the release location.

Figure 9.75 displays the time series of the area of visible oil (≥1 g/m^2) and actionable floating oil (≥50 g/m^2) exposure on the sea surface over the 21-day simulation. The maximum area of coverage of visible oil on the sea surface was predicted to occur 0.75 days (18 hours) after the spill started and covered approximately 6 km^2.

Figure 9.76 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 152 m^3 (68%) spilled oil was lost to the atmosphere through evaporation. Approximately 28 m^3 (12%) of the crude was predicted to have decayed, while approximately 45 m^3 (20%) was predicted to remain within the water column.

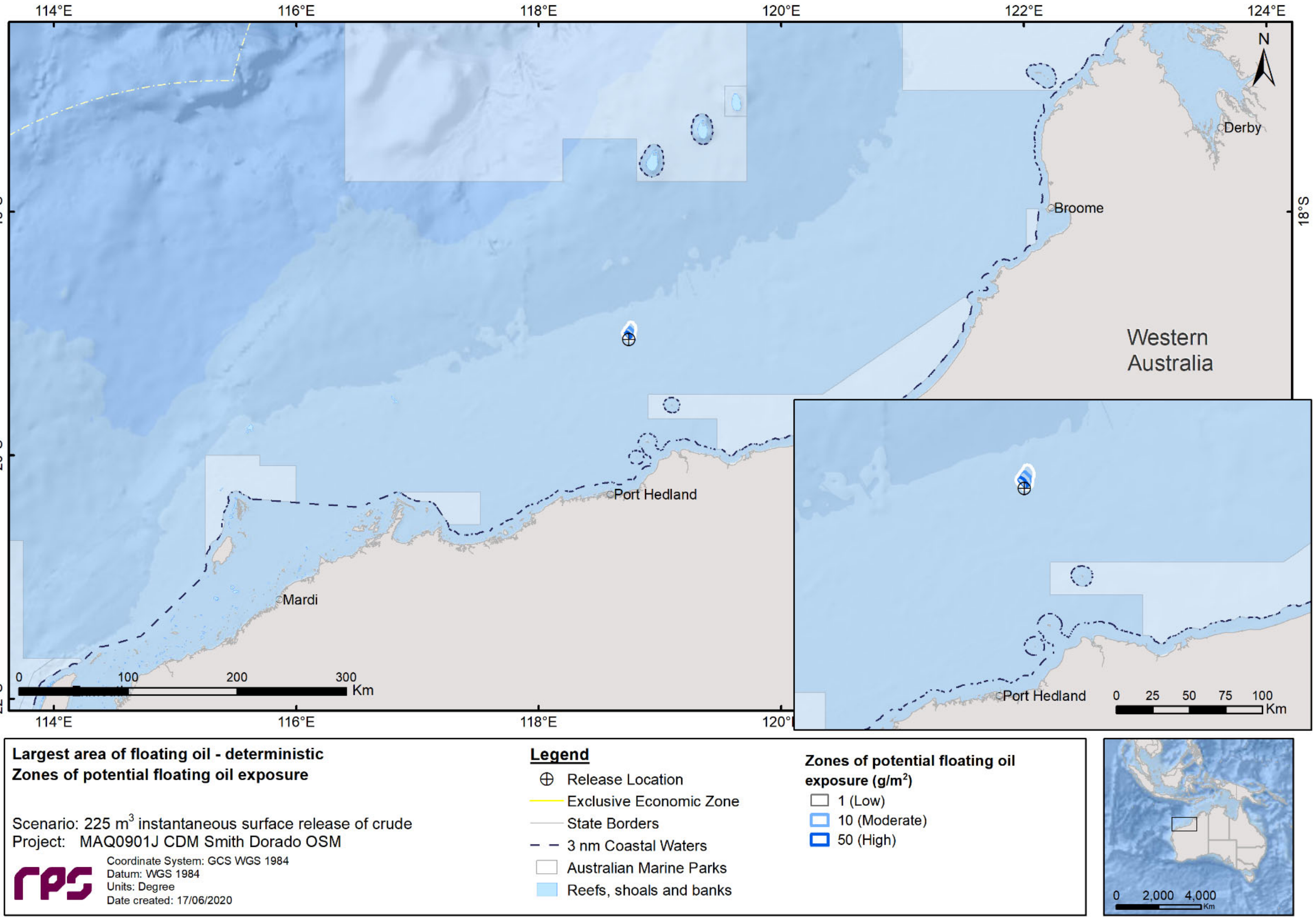


Figure 9.74 Exposure from floating oil (over the 21 day simulation) for the simulation with the largest area of floating oil above 50 g/m^2. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO, starting 5 am on the 6th of September 2016.

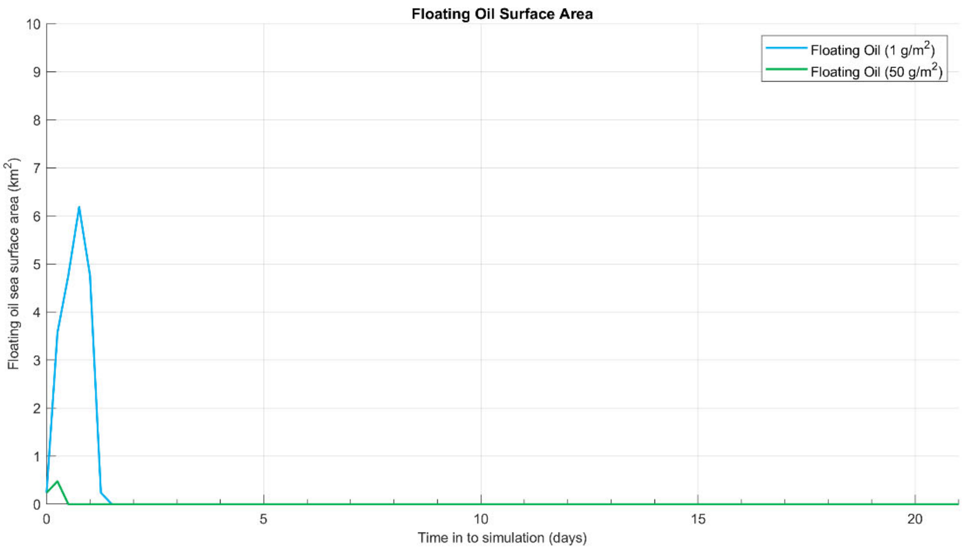


Figure 9.75 **Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface for the simulation with the largest area of floating oil above 50 g/m². Results are based on an instantaneous surface release of 225 m³ of crude at the FPSO, tracked for 21 days, 5 am on the 6th of September 2016.**

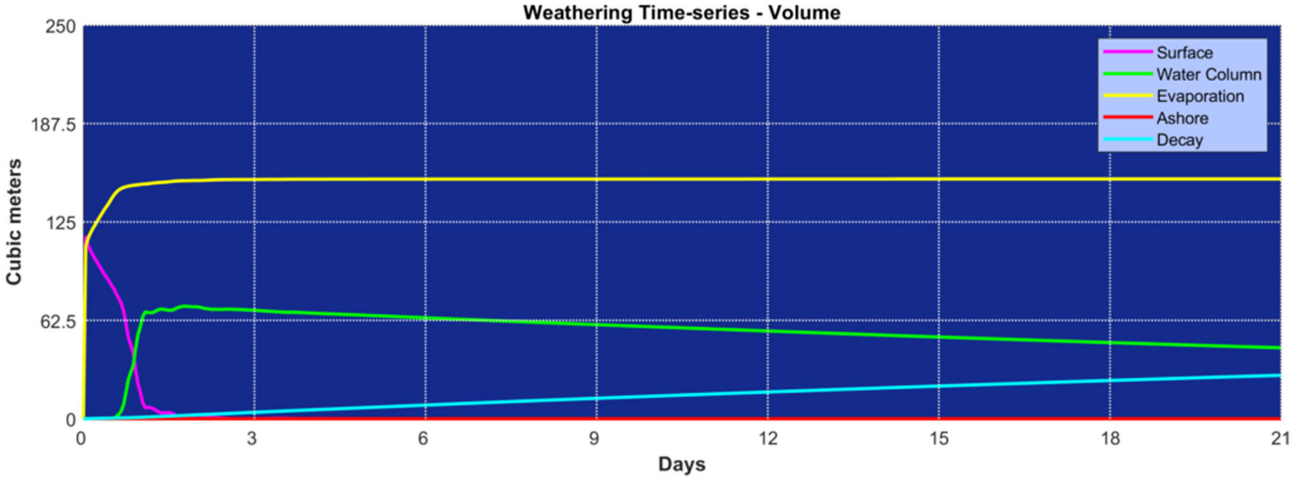


Figure 9.76 **Predicted weathering and fates graph for the single spill simulation with the largest area of floating oil above 50 g/m². Results are based on an instantaneous surface release of 225 m³ of crude at the FPSO, tracked for 21 days, 5 am on the 6th of September 2016.**

9.4.2.2 Deterministic Case: Largest Area of Entrained Hydrocarbons

The deterministic simulation that resulted in the largest area of entrained hydrocarbons was identified during transitional conditions as run number 88, which commenced at 8 pm on the 2nd of April 2012.

Exposure from floating oil (swept area) over the entire 21 day simulation are presented in Figure 9.77. The exposure from floating oil was predicted to be within 15 km of the release location.

Figure 9.78 presents the predicted entrained hydrocarbon exposure zones in the 0-10 m depth layer for the entire simulation. Entrained hydrocarbons at the low threshold (10-100 ppb) were predicted to extend a maximum distance of approximately 490 km west from the release location and approximately 23 km at the high threshold.

No dissolved hydrocarbon exposure above the low (10-50 ppb) threshold was predicted for this simulation.

Figure 9.79 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 150 m^3 (66%) spilled oil was lost to the atmosphere through evaporation. Approximately 28 m^3 (12%) of the crude was predicted to have decayed, while approximately 48 m^3 (21%) was predicted to remain within the water column.

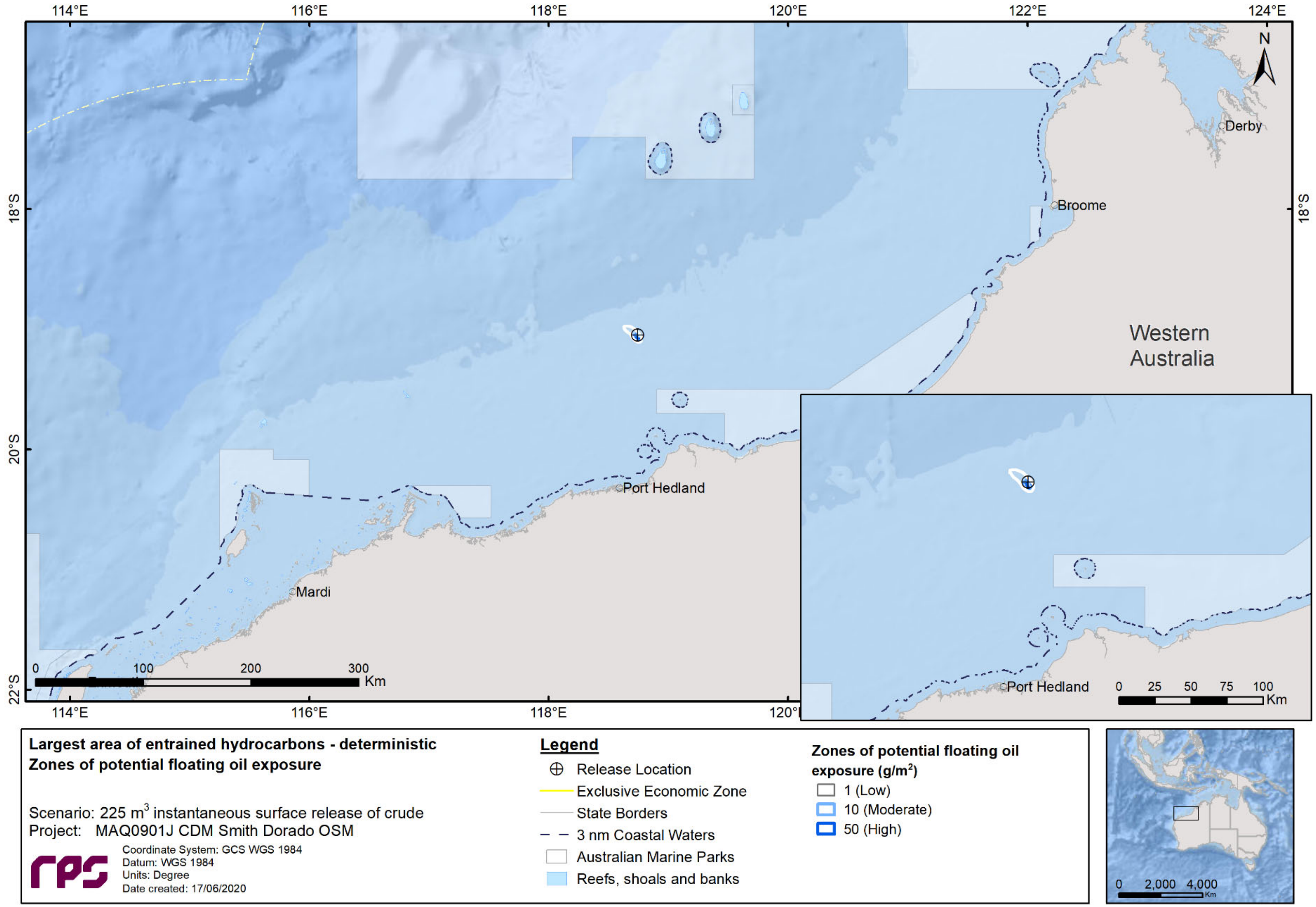


Figure 9.77 Exposure from floating oil (over the 21 day simulation) for the simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO, starting 8 pm on the 2nd of April 2012.

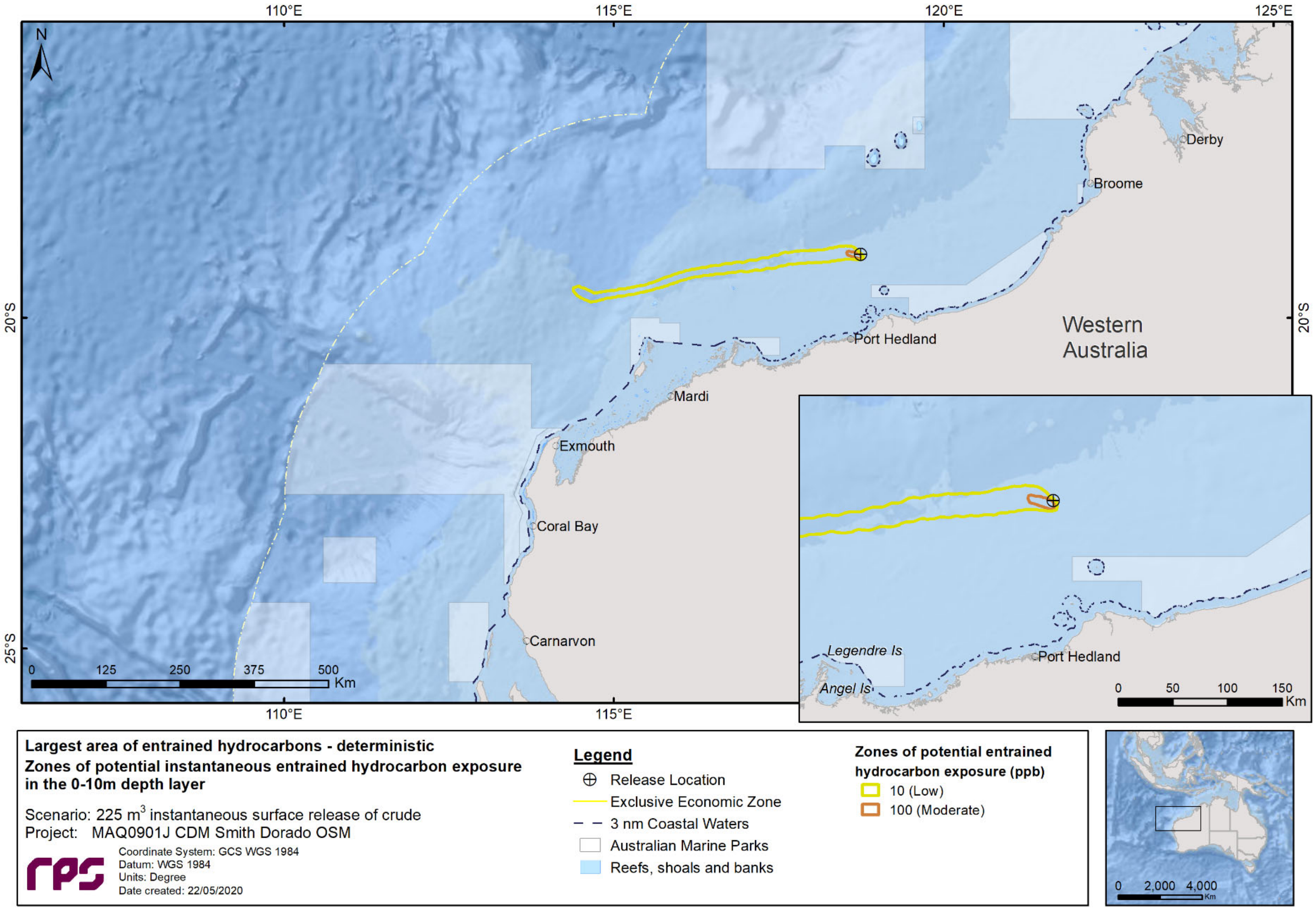


Figure 9.78 Predicted entrained hydrocarbon exposure zones in the 0-10 m depth layer for the simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO, tracked for 21 days, 8 pm on the 2nd of April 2012.

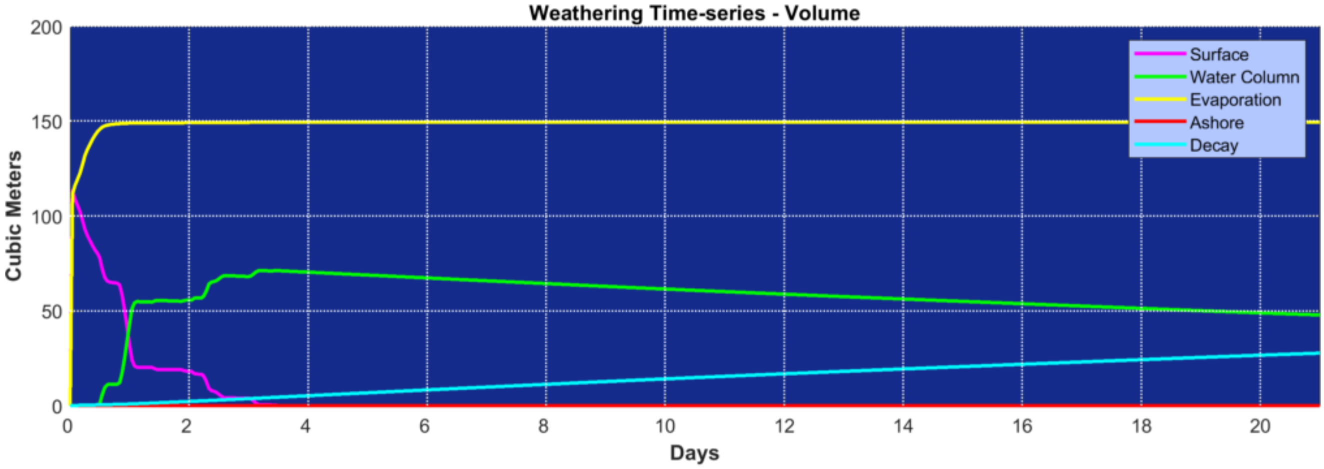


Figure 9.79 Predicted weathering and fates graph for the single spill simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO, tracked for 21 days, 8 pm on the 2nd of April 2012.

9.4.3 Seasonal analysis

9.4.3.1 Floating Oil Exposure

Table 9.31 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 151.8 km southwest (transitional), 30.2 km north-northeast (winter) and 17.2 km northwest (summer), respectively.

Images of floating oil exposure zones are depicted in Figure 9.80, Figure 9.81 and Figure 9.82 for the combined 100 spills commencing during summer, transitional and winter conditions, respectively.

There was no floating oil exposure to any of the receptors assessed.

Table 9.31 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	78.1	27.5	17.2
	Max distance from release site (km) (99th percentile)	36.3	19.6	11.9
	Direction	West-Northwest	West-Northwest	Northwest
Transitional	Max. distance from release site (km)	151.8	19.7	11.6
	Max distance from release site (km) (99th percentile)	54.1	15.3	11.2
	Direction	Southwest	West	Northwest
Winter	Max. distance from release site (km)	66.3	30.2	11.2
	Max distance from release site (km) (99th percentile)	54.3	25.8	10.6
	Direction	East	North-Northeast	North-Northwest

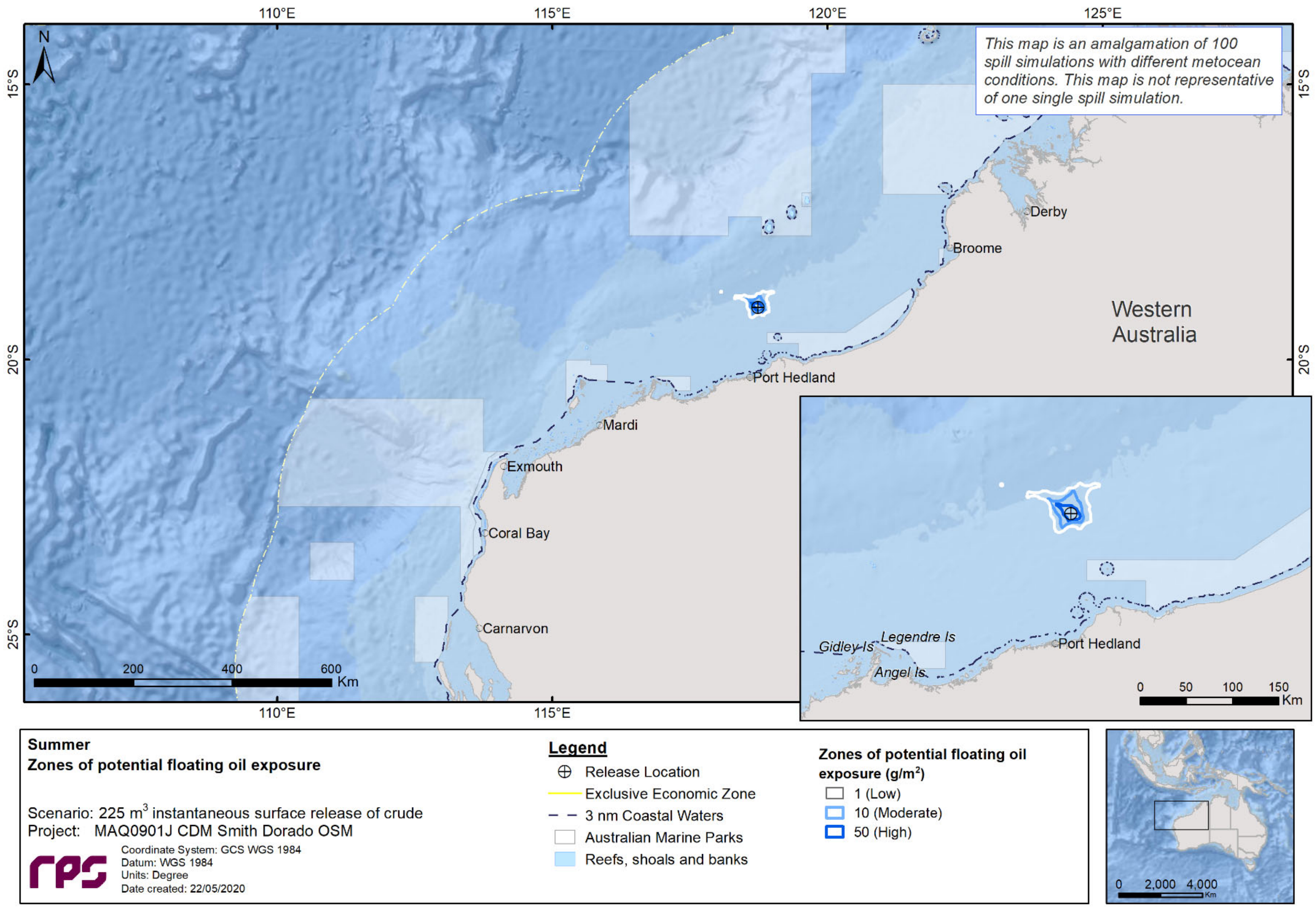


Figure 9.80 Predicted zones of potential floating oil resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

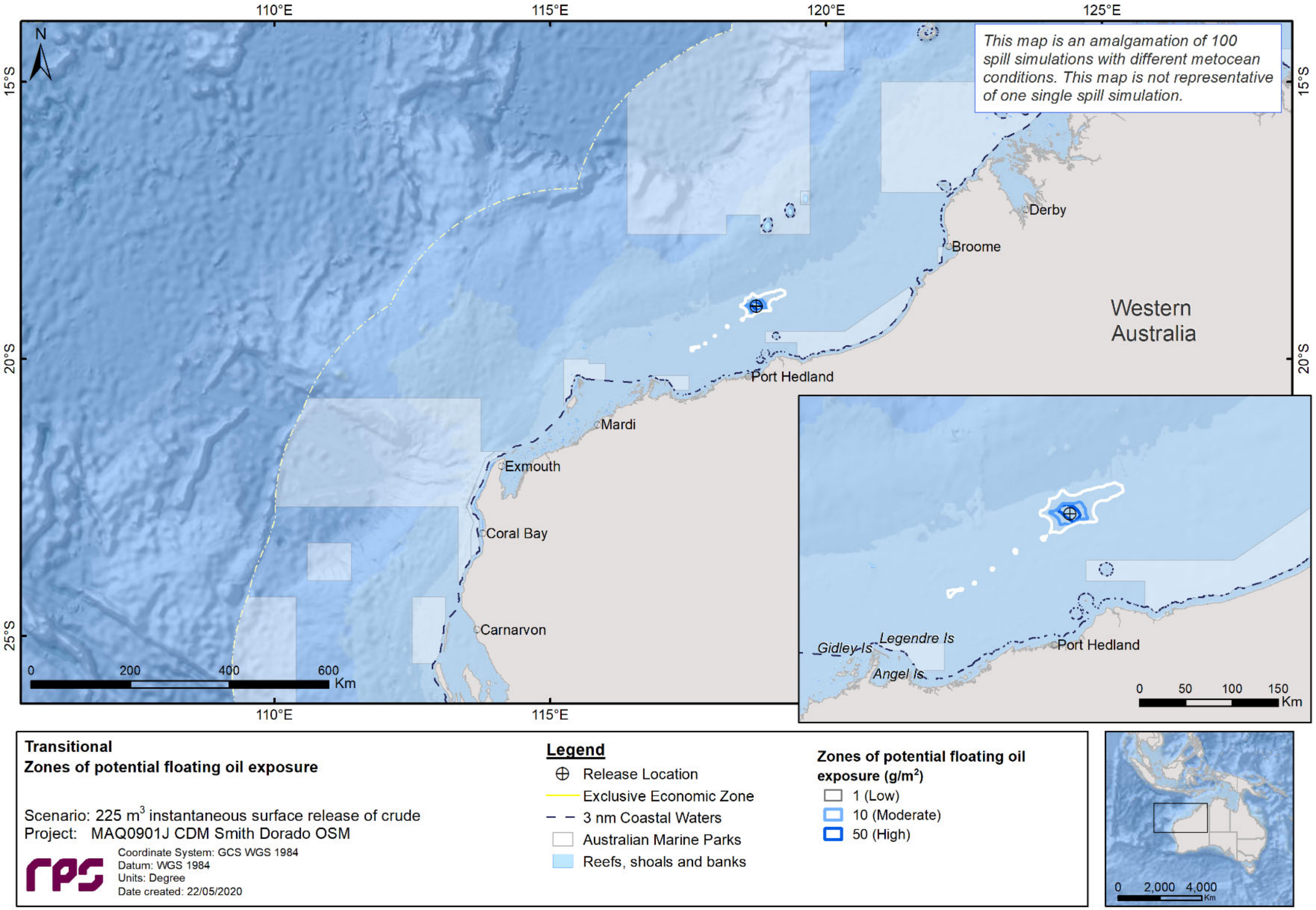


Figure 9.81 Predicted zones of potential floating oil resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

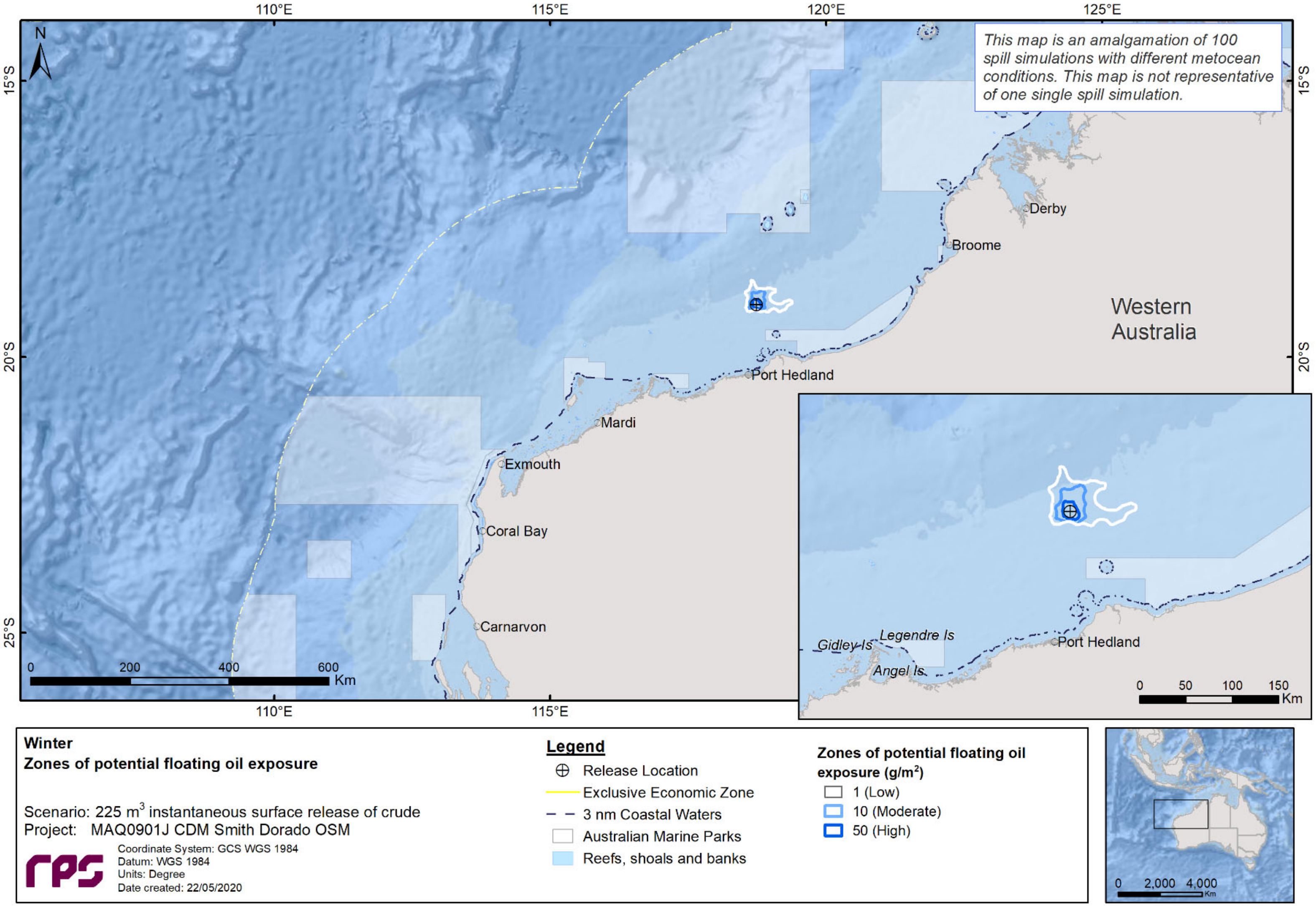


Figure 9.82 Predicted floating oil exposure zones resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.4.3.2 Shoreline Accumulation

There was no shoreline accumulation predicted for any spills during this scenario at or above the low threshold (≥10 g/m^2).

9.4.3.3 Entrained Hydrocarbons

Images of entrained hydrocarbon exposure in the 0-10m depth layer in Figure 9.83, Figure 9.84 and Figure 9.85 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 962 km (southwest) from the spill site during transitional conditions. This distance reduced to 237 km (west-southwest) as the threshold increased to moderate in transitional conditions. The maximum distances for summer and winter conditions at the low threshold were 591 km and 461 m, respectively. The maximum distances at the moderate threshold were reduced to 157 km for summer and 98 km for winter conditions.

Table 9.32 to Table 9.34 summarise the probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

A total of 5 AMPs are within the low exposure zone for the summer and transitional results and the probability of exposure was between 1 – 2%. The shortest time for entrained hydrocarbons to reach an AMP at the low threshold was recorded at Dampier during transitional conditions as 0.96 days (23 hours).

No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold.

Rankin Bank was the only RSB predicted to be exposed by entrained hydrocarbons at the low threshold during transitional (2%) and winter (1%) conditions, while Imperieuse Reef was the only receptor exposed during summer conditions (1%). The quickest time before exposure at the low threshold was predicted at Rankin Bank (5.58 days) during transitional conditions.

Entrained hydrocarbons at the low threshold were predicted to cross into WA State Waters during summer and transitional conditions with probabilities of only 1%. The minimum time before oil crossed the WA State Waters boundary was 2.42 days, for a spill commencing during transitional conditions.

Table 9.32 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m³ of crude at the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	2	-	7.5	-	35
	Dampier	-	-	-	-	-
	Gascoyne	1	-	10.3	-	11
	Kimberley	2	-	6.0	-	32
	Montebello	1	-	5.7	-	17
IBRA	Roebourne	1	-	14.5	-	22
IMCRA	Pilbara (nearshore)	1	-	14.5	-	22
	Pilbara (offshore)	3	1	2.3	2.8	122
MP	Rowley Shoals	1	-	11.8	-	20
RSB	Imperieuse Reef	1	-	11.8	-	16
	Rankin Bank	-	-	-	-	-
Nearshore	Cunningham Island	1	-	11.8	-	16
	Imperieuse Reef	1	-	11.8	-	14
	North Turtle Island	1	-	14.5	-	10
	Port Hedland	1	-	14.6	-	22
State Waters	Western Australia State Waters	1	-	11.8	-	22

Table 9.33 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m³ of crude at the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	1	-	7.3	-	16
	Dampier	1	-	1.0	-	25
	Gascoyne	2	-	7.6	-	20
	Kimberley	-	-	-	-	-
	Montebello	2	-	5.0	-	53
IBRA	Roebourne	-	-	-	-	-

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
IMCRA	Pilbara (nearshore)	-	-	-	-	-
	Pilbara (offshore)	2	1	1.0	3.5	102
MP	Rowley Shoals	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-
	Rankin Bank	2	-	5.6	-	24
Nearshore	Cunningham Island	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-
	North Turtle Island	-	-	-	-	-
	Port Hedland	-	-	-	-	-
State Waters	Western Australia State Waters	1	-	2.4	-	23

Table 9.34 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m³ of crude at the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	-	-	-	-	-
	Dampier	-	-	-	-	-
	Gascoyne	-	-	-	-	-
	Kimberley	-	-	-	-	-
	Montebello	-	-	-	-	-
IBRA	Roebourne	-	-	-	-	-
IMCRA	Pilbara (nearshore)	-	-	-	-	-
	Pilbara (offshore)	4	-	3.0	-	64
MP	Rowley Shoals	-	-	-	-	-
RSB	Imperieuse Reef	-	-	-	-	-
	Rankin Bank	1	-	18.8	-	11
Nearshore	Cunningham Island	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-
	North Turtle Island	-	-	-	-	-
	Port Hedland	-	-	-	-	-
State Waters	Western Australia State Waters	-	-	-	-	-

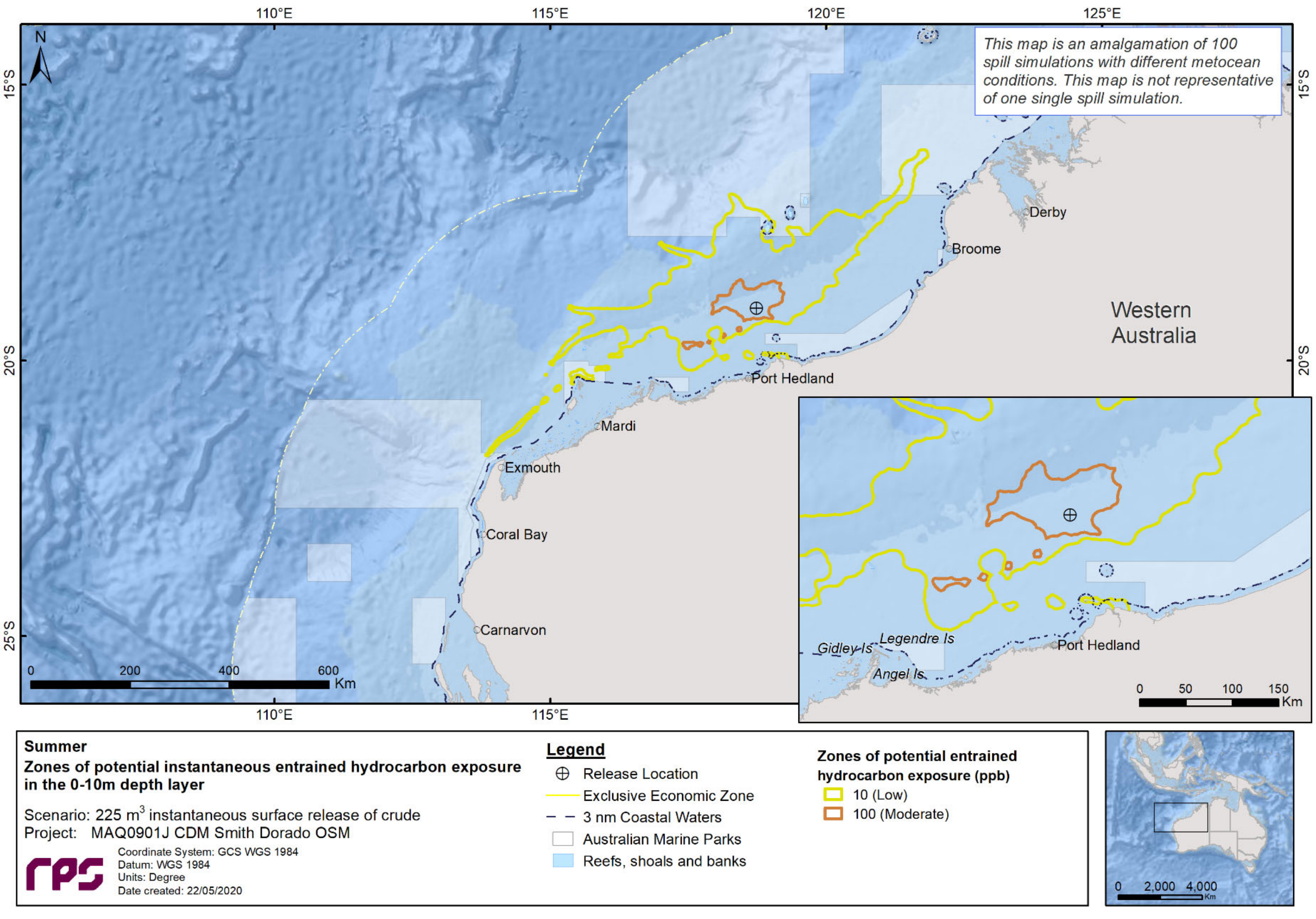


Figure 9.83 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

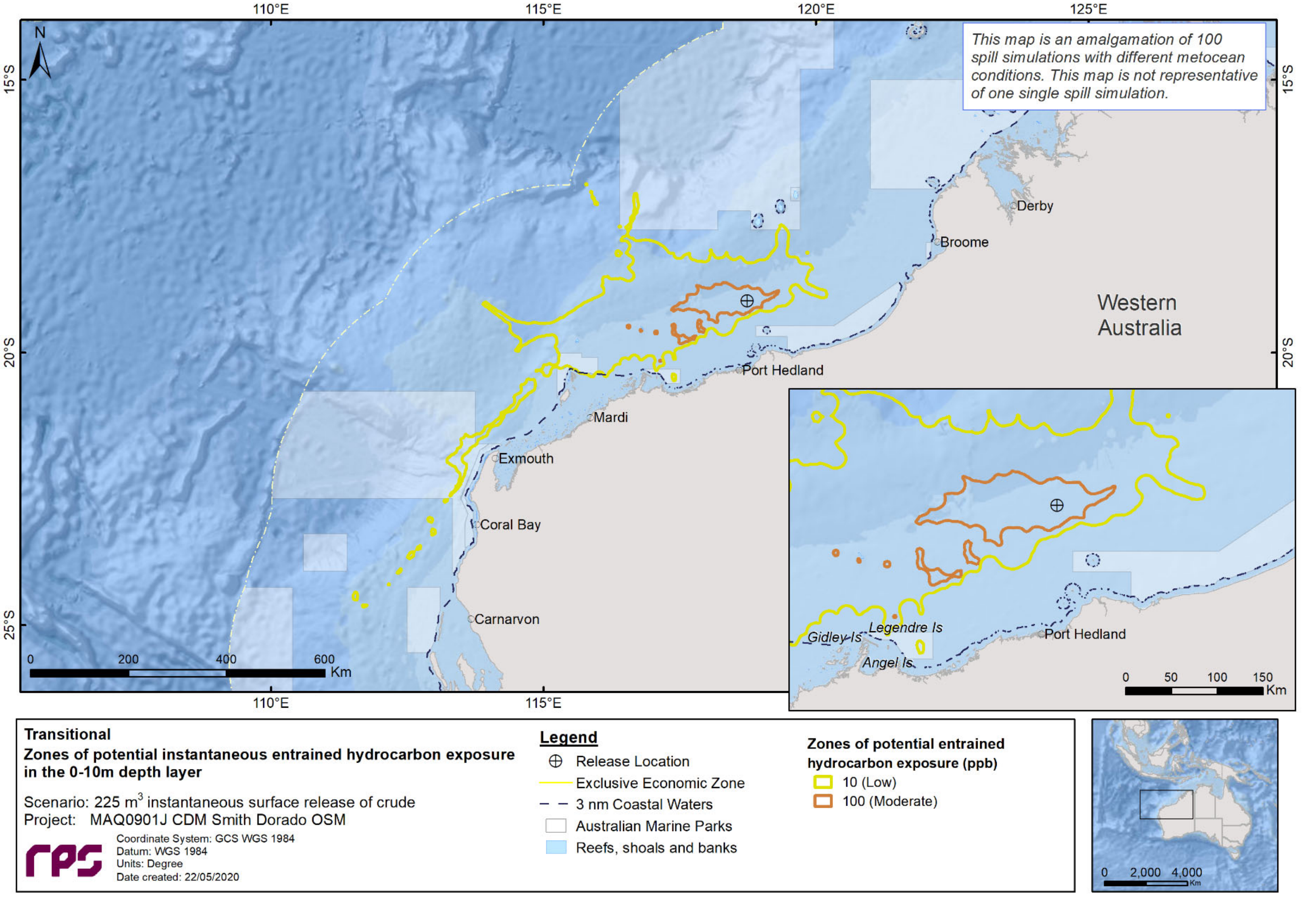


Figure 9.84 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

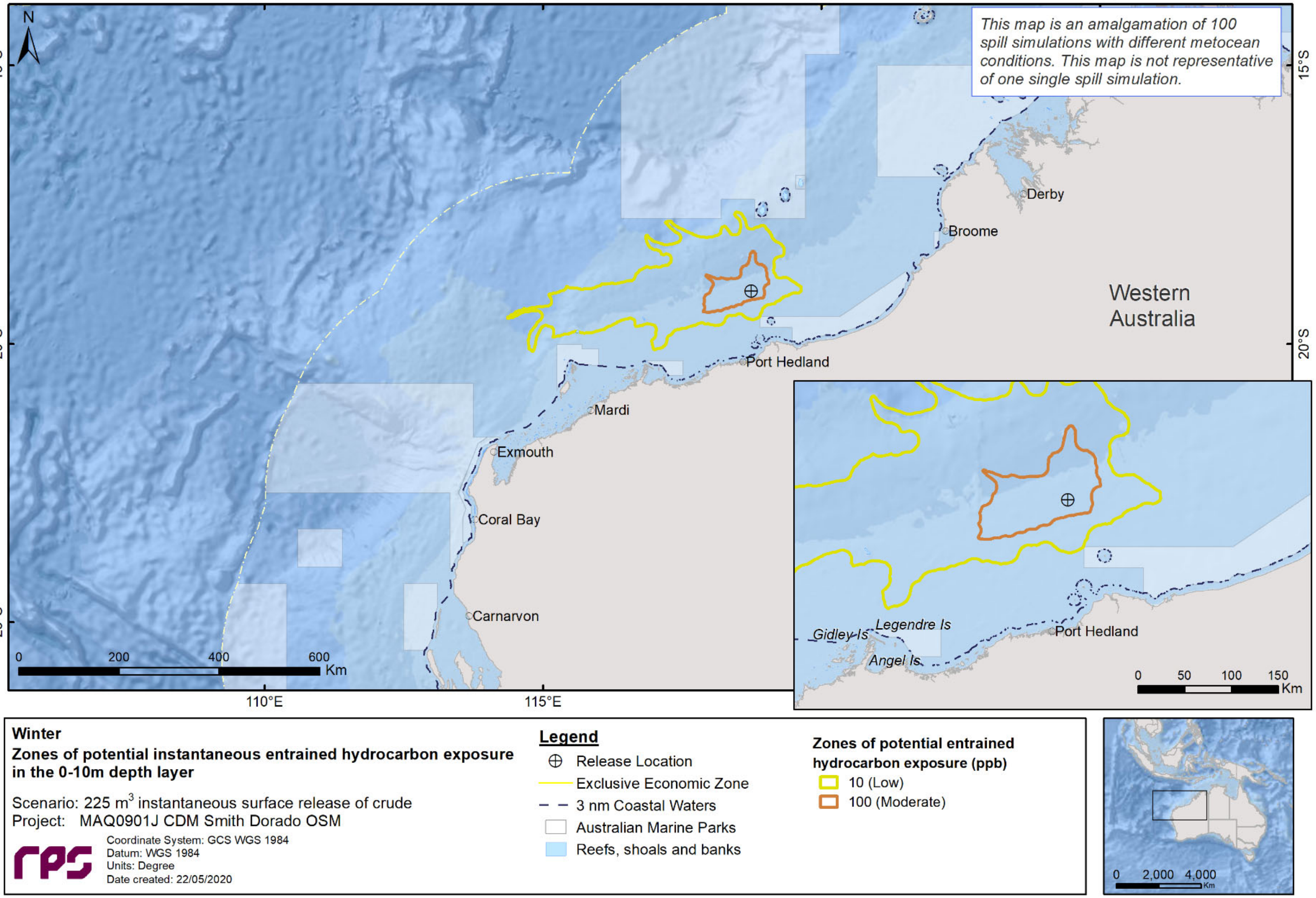


Figure 9.85 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.4.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones are depicted in Figure 9.86, Figure 9.87 and Figure 9.88 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The results indicated that the low threshold (10-50 ppb) was predicted to occur up to a maximum distance of 381 km (northeast) from the release location during summer conditions. The maximum distances for transitional and winter conditions at the low threshold were 346 km and 259 m, respectively. No exposure at the moderate (50-400 ppb) or high (≥ 400 ppb) thresholds was predicted in any of the seasons assessed.

Table 9.35 to Table 9.37 summarise the probability of exposure to receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer, across all seasonal conditions. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

The Argo-Rowley Terrace AMP was the only AMP to be exposed to dissolved hydrocarbons at the low threshold, with a probability of 1% predicted in summer conditions with a minimum time of 8.17 days before exposure.

No KEF or RSB receptors were predicted to be exposed by dissolved hydrocarbons at the low threshold.

Dissolved hydrocarbons at the low threshold were predicted to cross into WA State Waters during the transitional season with a probability of 1%, after 2.33 days.

Table 9.35 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	1	-	-	8.2	-	-	12
IMCRA	Pilbara (offshore)	1	-	-	5.8	-	-	11
State Waters	Western Australia State Waters	-	-	-	-	-	-	7

Table 9.36 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	-	-	-	-	-	-	7
IMCRA	Pilbara (offshore)	1	-	-	2.2	-	-	18
State Waters	Western Australia State Waters	1	-	-	2.3	-	-	17

Table 9.37 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 225 m^3 of crude at the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	-	-	-	-	-	-	3
IMCRA	Pilbara (offshore)	-	-	-	-	-	-	7
State Waters	Western Australia State Waters	-	-	-	-	-	-	1

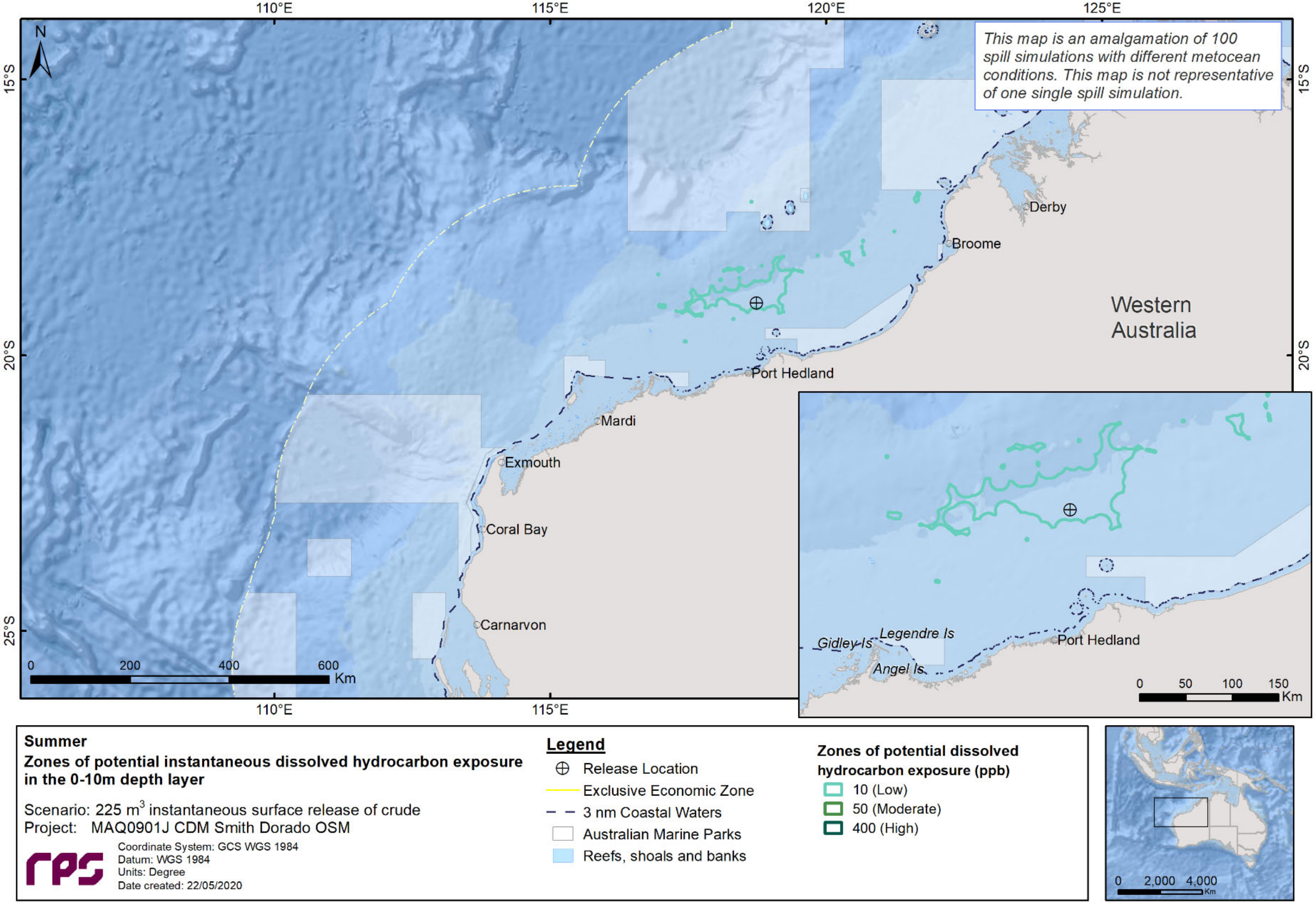


Figure 9.86 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

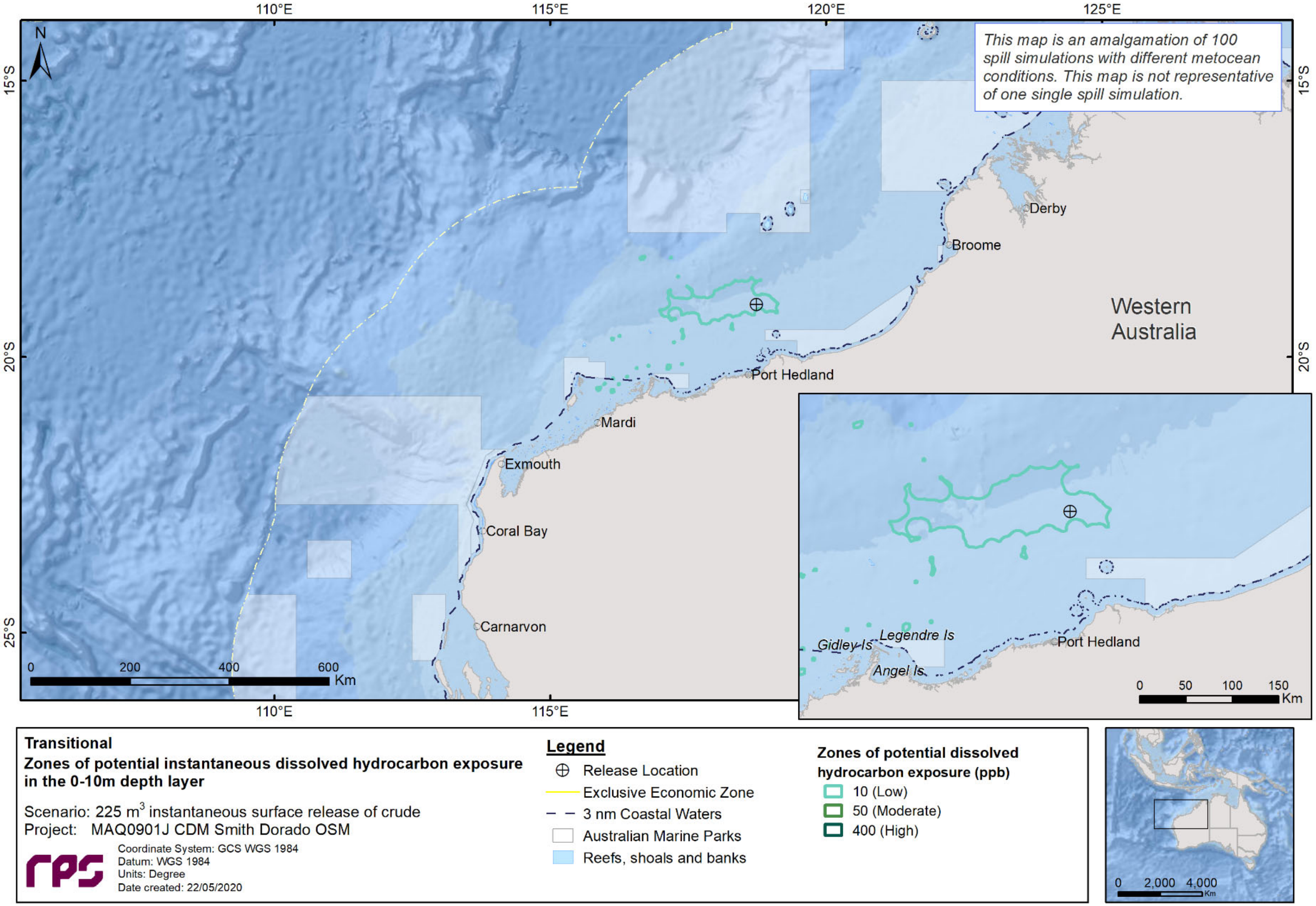


Figure 9.87 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m^3 of crude at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

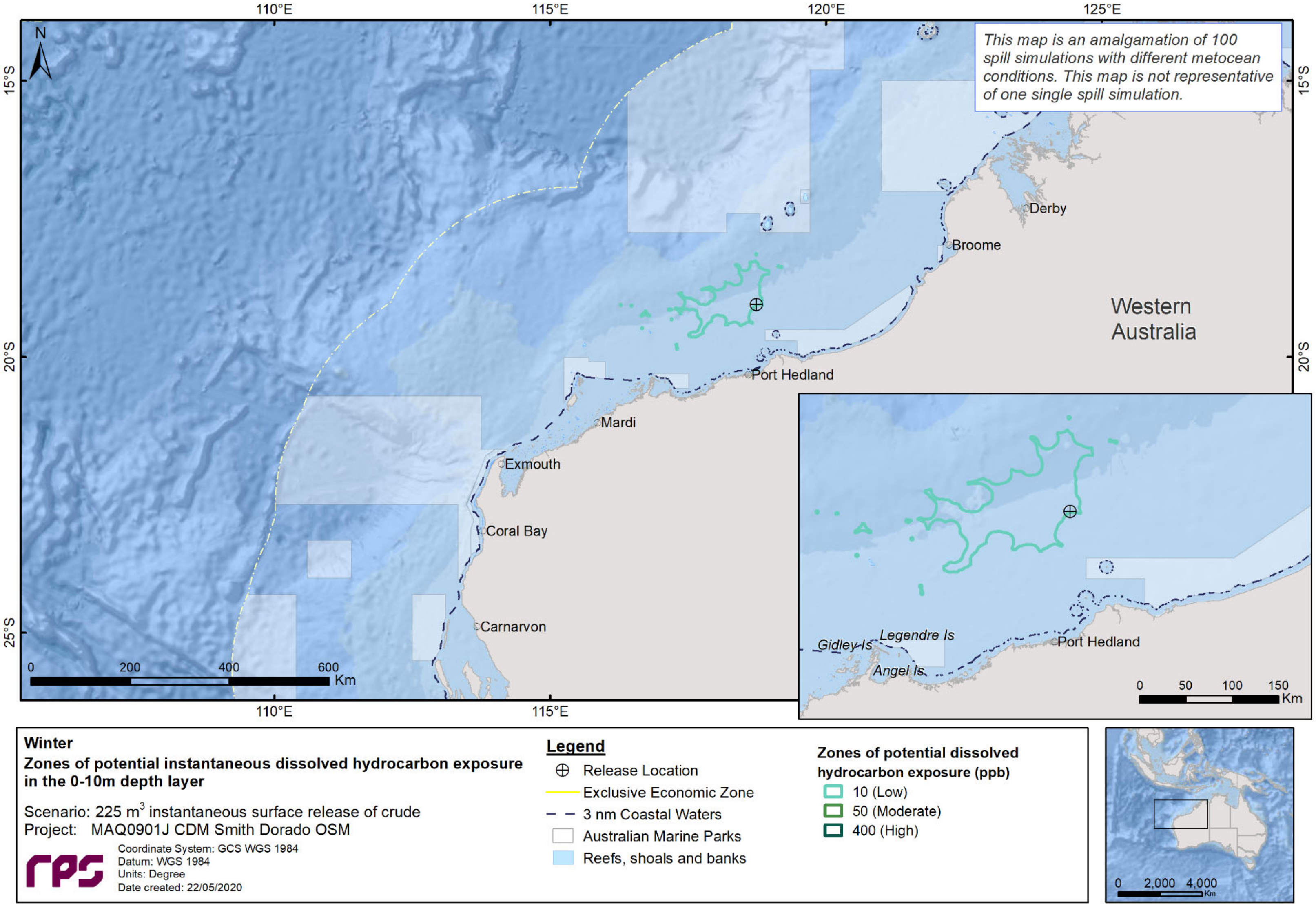


Figure 9.88 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 225 m³ of crude at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.5 Scenario 5: Simulation of an instantaneous surface release of HFO due to a tanker collision with the FPSO

This scenario examined an instantaneous 1,800 m^3 surface release of HFO at the FPSO, tracked for 56 days. A total of 300 simulations were run across three seasons; summer, transitional and winter (i.e. 100 spills per season). These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Section 9.5.1 presents an overview of the EMBA based on combining the 300 spill simulations and Section 9.5.3 shows the seasonal (or stochastic) analysis, while Section 9.5.2 presents the deterministic analysis results (i.e. a single spill simulation), based on largest volume ashore and longest results, based on largest volume ashore and longest length of oiled shoreline.

9.5.1 Overview

Figure 9.89 and Figure 9.90 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.91 and Figure 9.92 show the annualised extent of floating oil and in-water (entrained and dissolved) exposure as well as shoreline accumulation based on the low and moderate exposure thresholds, respectively, derived from combining all 300 spill simulations.

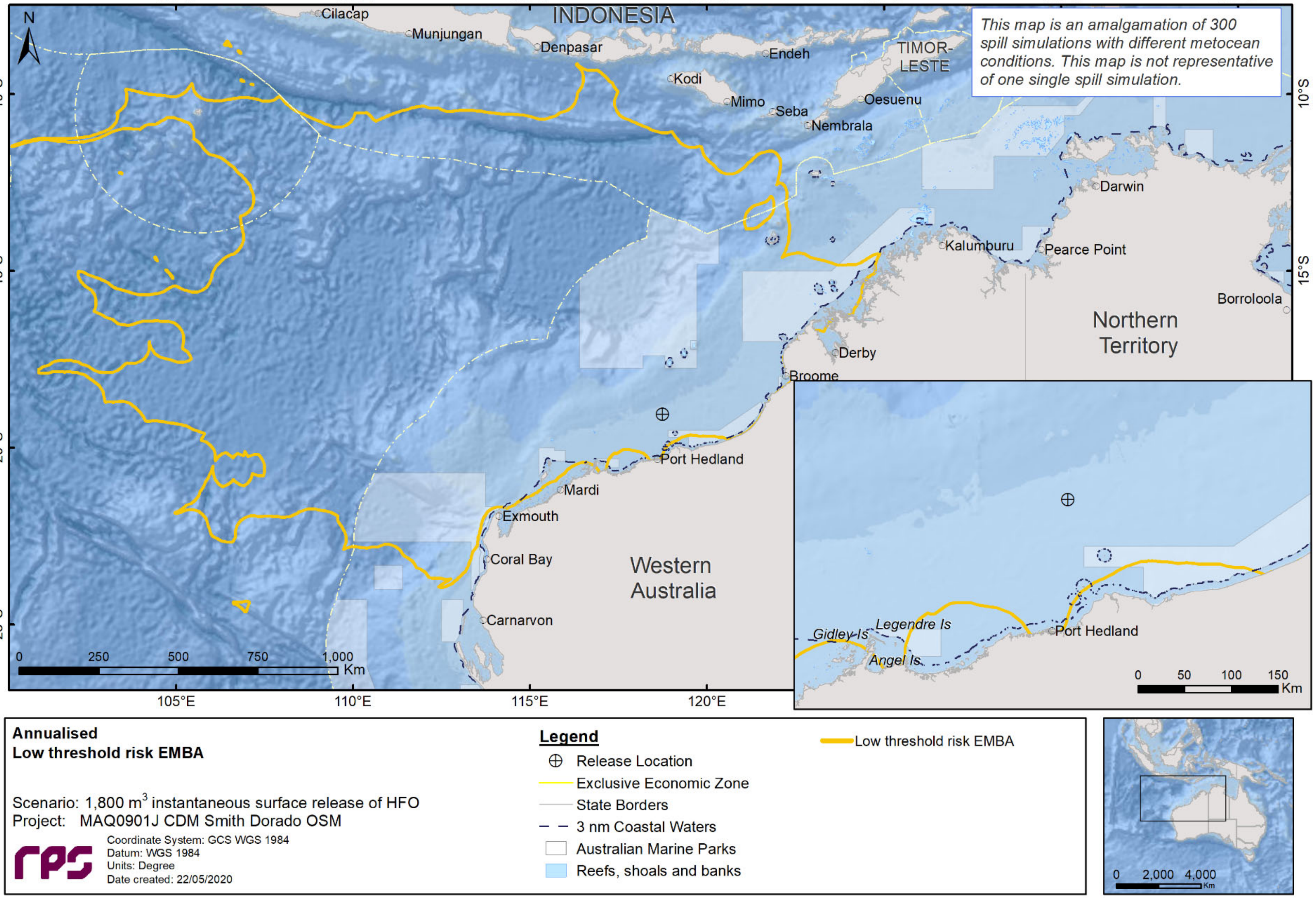


Figure 9.89 Predicted low threshold risk EMBA resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 56 days.

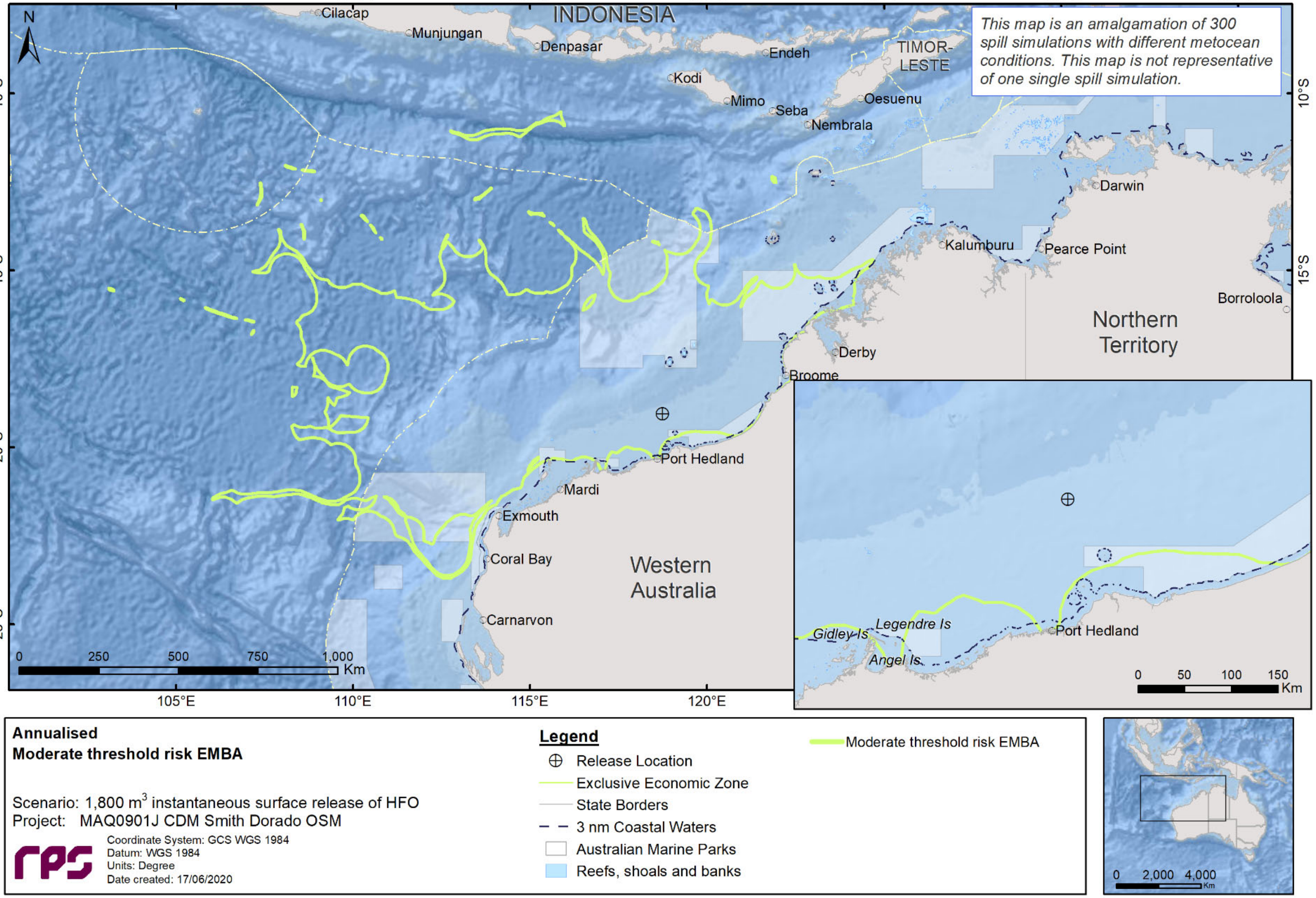


Figure 9.90 Predicted moderate threshold risk EMBA resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 56 days.

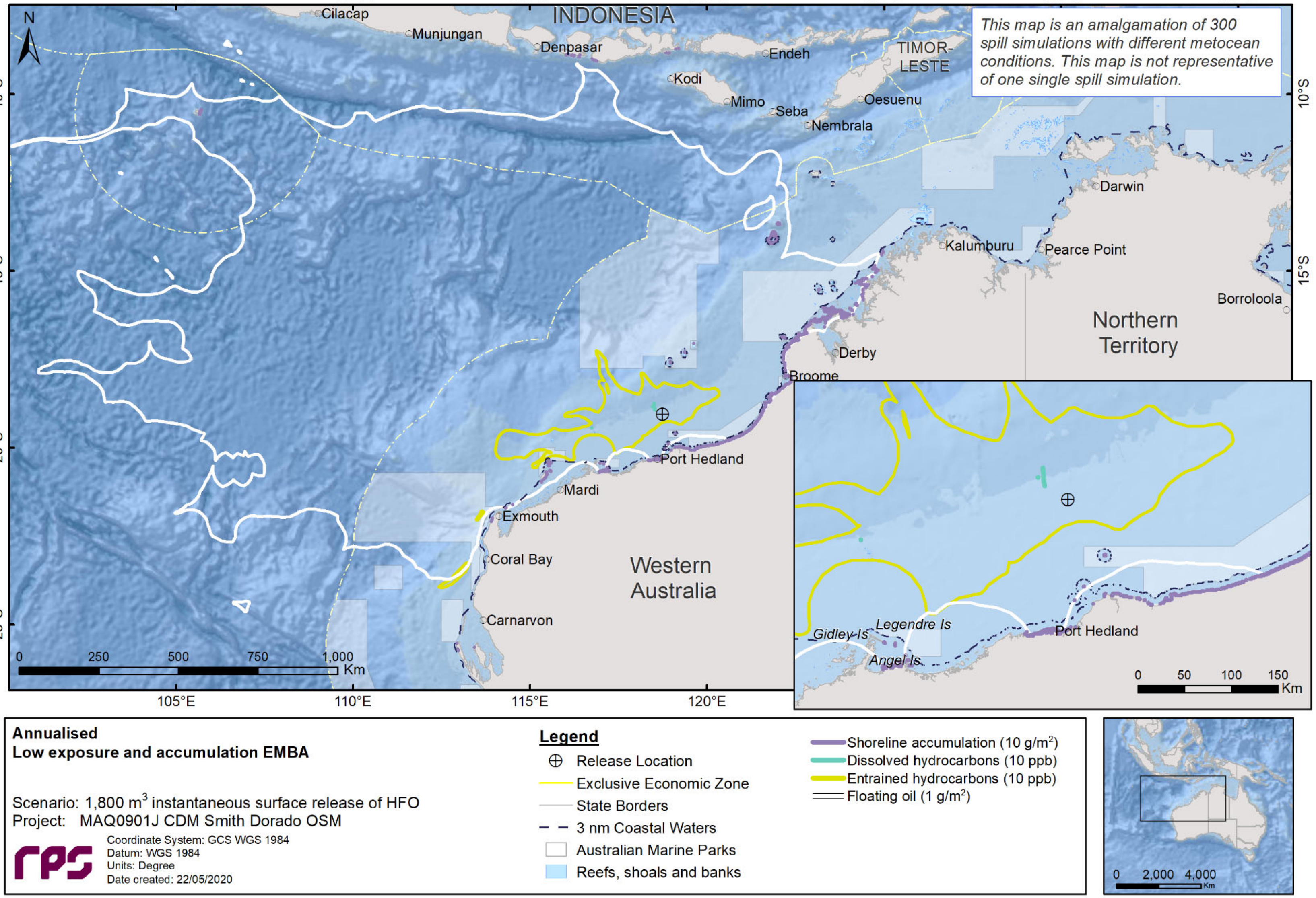


Figure 9.91 Annualised low threshold oil exposure and shoreline accumulation resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 56 days.

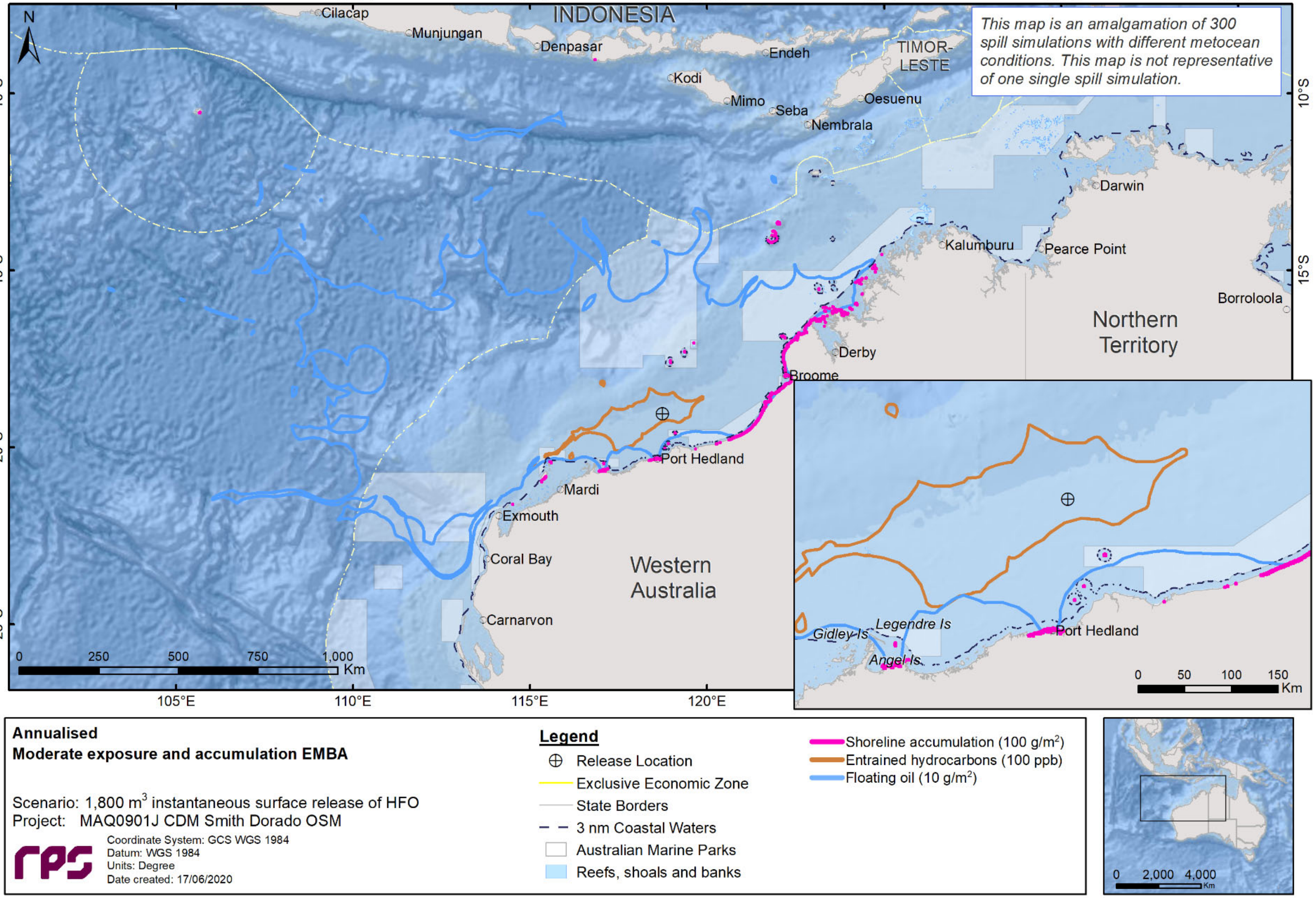


Figure 9.92 Annualised moderate threshold oil exposure and shoreline accumulation resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 56 days.

9.5.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest volume of oil ashore; and

b. Longest length of oil shoreline.

9.5.2.1 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that recorded the largest volume of oil ashore was identified during summer conditions as run number 86 which commenced at 8 am on the 19th of December 2015. The maximum volume ashore was 1,684 m^3, which occurred 16 days after the initial release.

Exposure from floating oil (swept area) and potential shoreline accumulation over the entire 56 day simulation are presented in Figure 9.93 and Figure 9.94. Floating oil exposure was predicted to the northeast from the release location with oil accumulation occurring on the Broome shoreline.

Figure 9.95 the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and actionable shoreline oil (≥100 g/m^2) over the 56-day simulation.

Figure 9.96 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9.97 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 215 m^3 (12%) spilled oil was lost to the atmosphere through evaporation. Approximately 664 m^3 (37%) of the HFO was predicted to have decayed, while 0.1 m^3 (<0.1%) remained within the water column and 921 m^3 (51%) was predicted to remain on the shoreline.

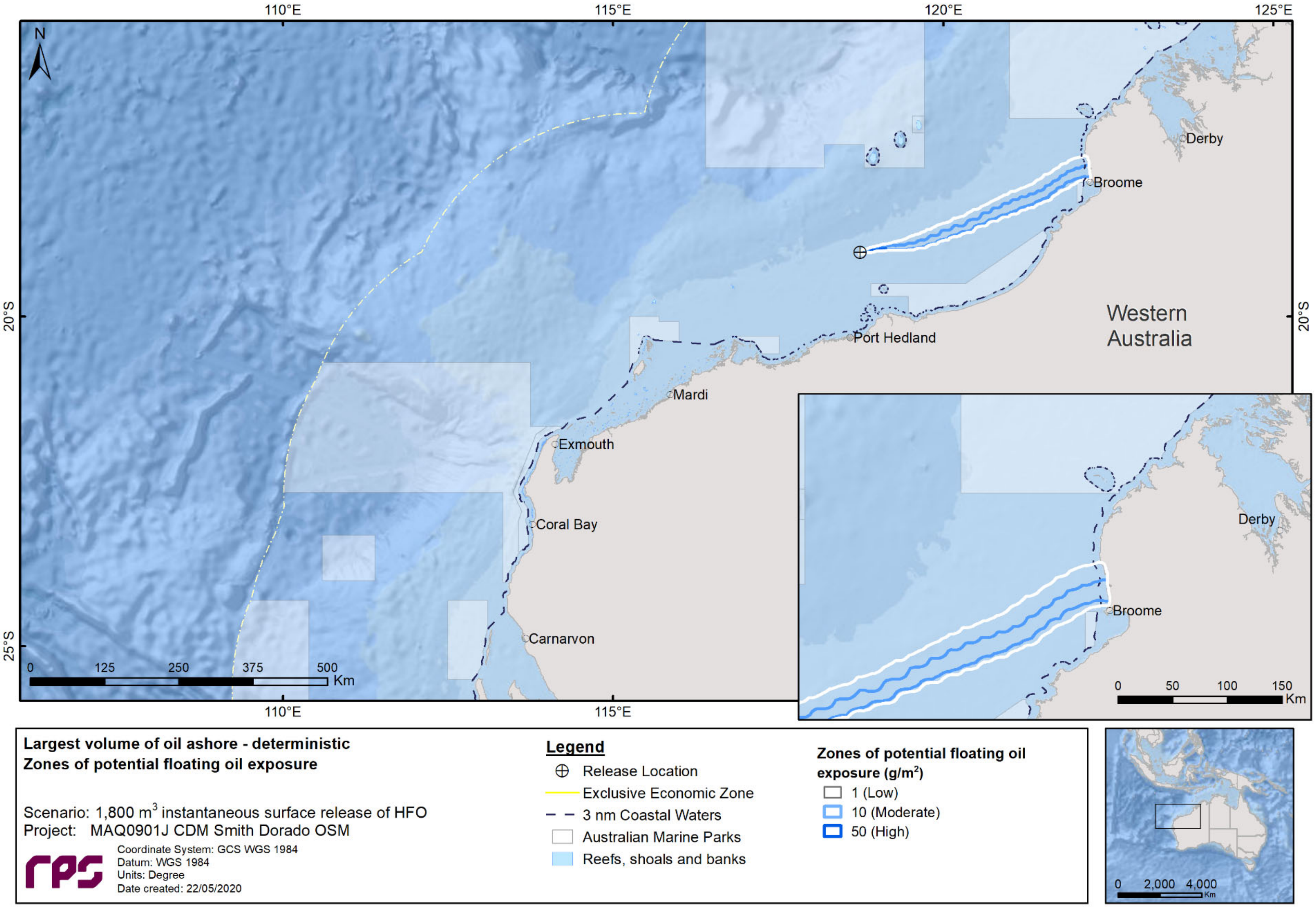


Figure 9.93 Exposure from floating oil (over the 56 day simulation) for the simulation with the largest volume of oil ashore. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO, starting 8 am on the 19th of December 2015.

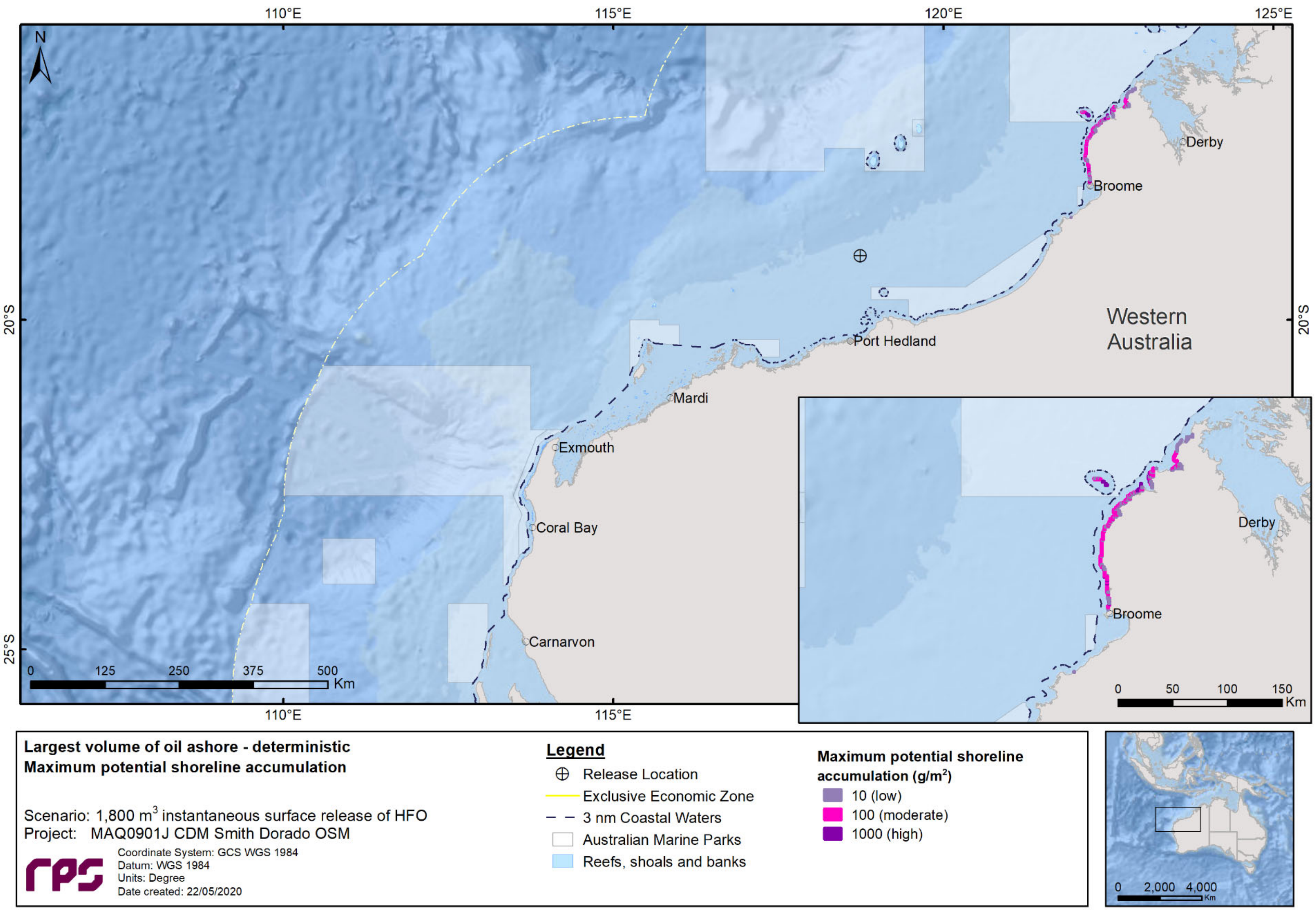


Figure 9.94 Potential shoreline accumulation for the simulation with the largest volume of oil ashore. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO, tracked for 56 days, 8 am on the 19th of December 2015.

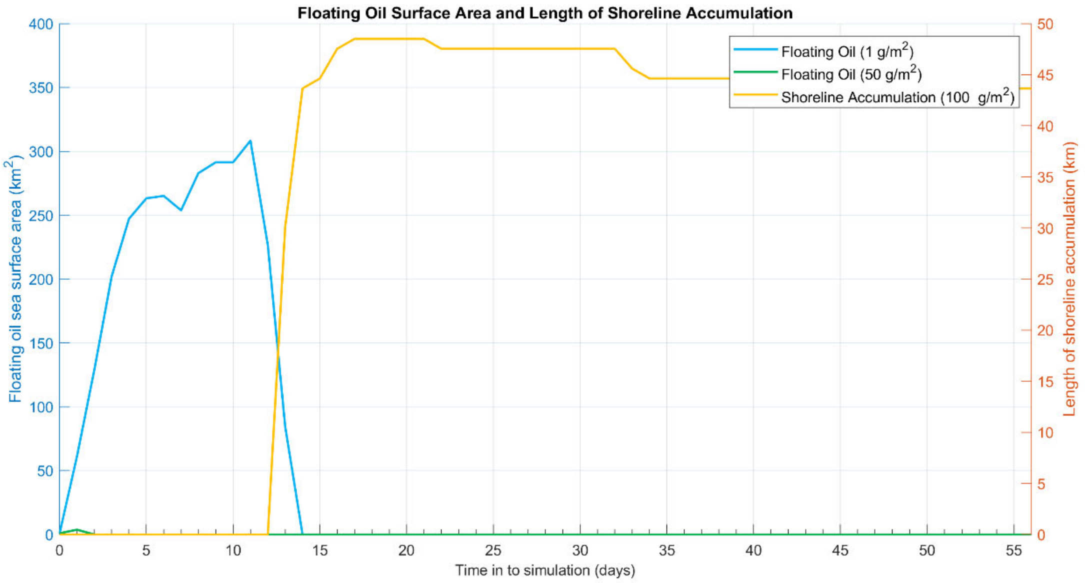


Figure 9.95 Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface and length of actionable shoreline oil (≥100 g/m²) for the simulation with the largest volume of oil ashore. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO, tracked for 56 days, 8 am on the 19th of December 2015.

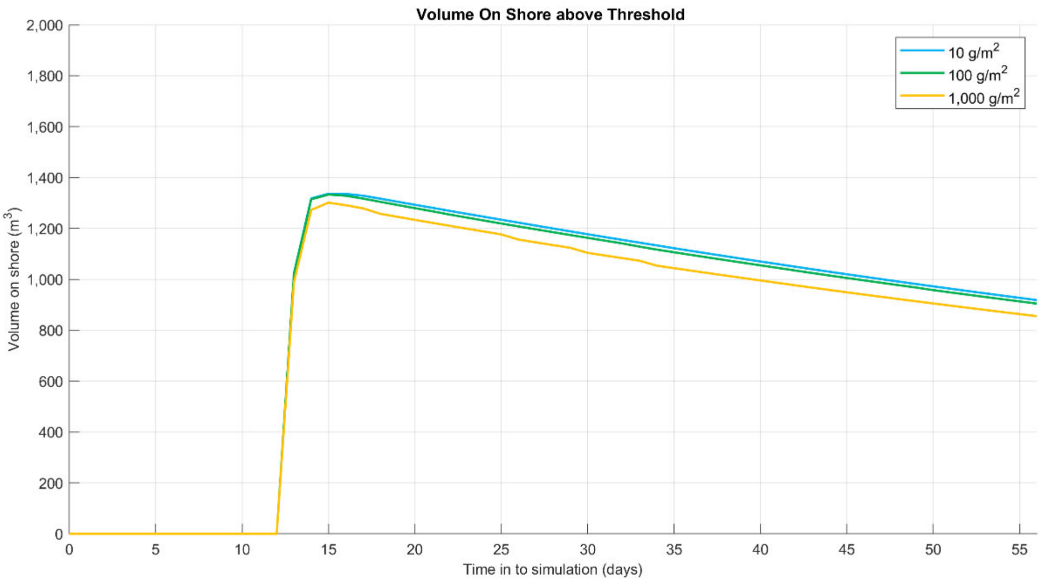


Figure 9.96 Time series of the volume on shore at the low (10-100 g/m²), moderate (100-1,000 g/m²) and high (≥ 1,000 g/m²) thresholds for the simulation with the largest volume of oil ashore. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO, tracked for 56 days, 8 am on the 19th of December 2015.

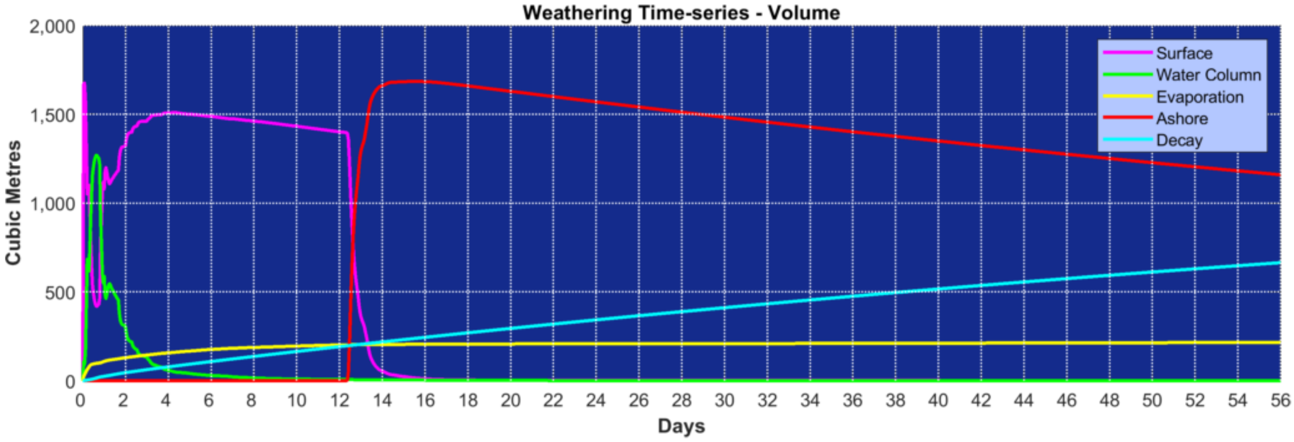


Figure 9.97 Predicted weathering and fates graph for the single spill simulation with the largest volume of oil ashore. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO, tracked for 56 days, 8 am on the 19th of December 2015.

9.5.2.2 Deterministic Case: Longest length of oiled shoreline

The deterministic simulation that resulted in the longest length of oiled shoreline above 100 g/m^2 was identified during summer conditions as run number 19, which commenced at 5 pm on the 5th of December 2014.

Exposure from floating oil (swept area) and potential shoreline accumulation over the entire simulation are presented in Figure 9.98 and Figure 9.99. Floating oil exposure was predicted to the northeast from the release location with shoreline accumulation occurring on the Broome coastline.

Figure 9.100 displays the time series of the area and length of visible oil (≥1 g/m^2) and actionable floating oil exposure on the sea surface (≥50 g/m^2) and actionable shoreline oil (≥100 g/m^2) over the 56-day simulation. The maximum area of visible oil on the sea surface was predicted to occur 12 days after the spill started and covered approximately 424 km^2. While the maximum length of actionable shoreline oiled (above 100 g/m^2) at any given time was 154 km, approximately 50 days into the simulation.

Figure 9.101 is a time series of the volume on shore at the low (10-100 g/m^2), moderate (100-1,000 g/m^2) and high (≥ 1,000 g/m^2) thresholds.

Figure 9**.**102 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 245 m^3 (13%) spilled oil was lost to the atmosphere through evaporation. Approximately 661 m^3 (37%) of the HFO was predicted to have decayed, while <0.1 m^3 (<0.1%) remained within the water column and 895 m^3 (50%) was predicted to remain on the shoreline.

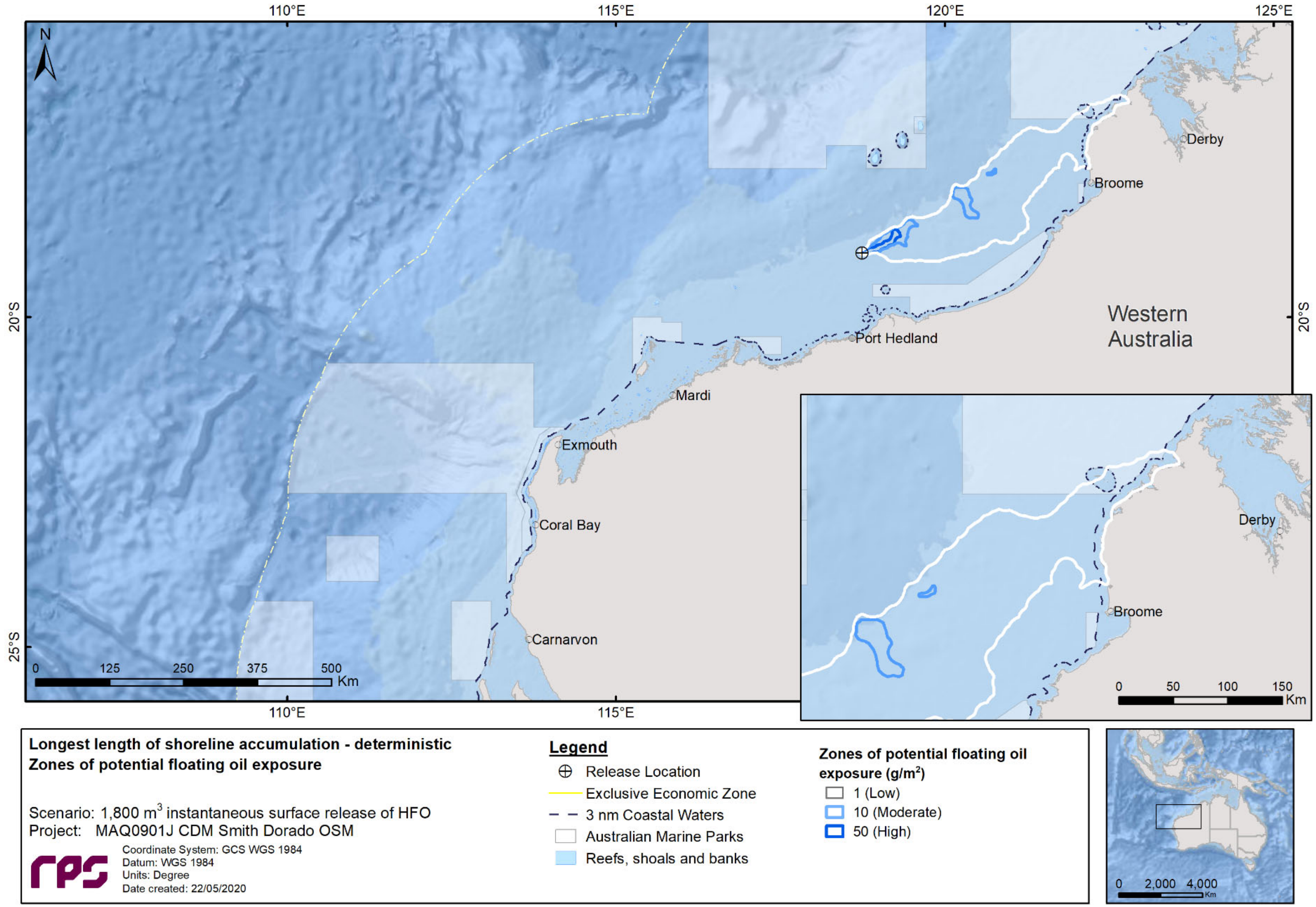


Figure 9.98 Exposure from floating oil (over the 56 day simulation) for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO, starting 5 pm on the 5th of December 2014.

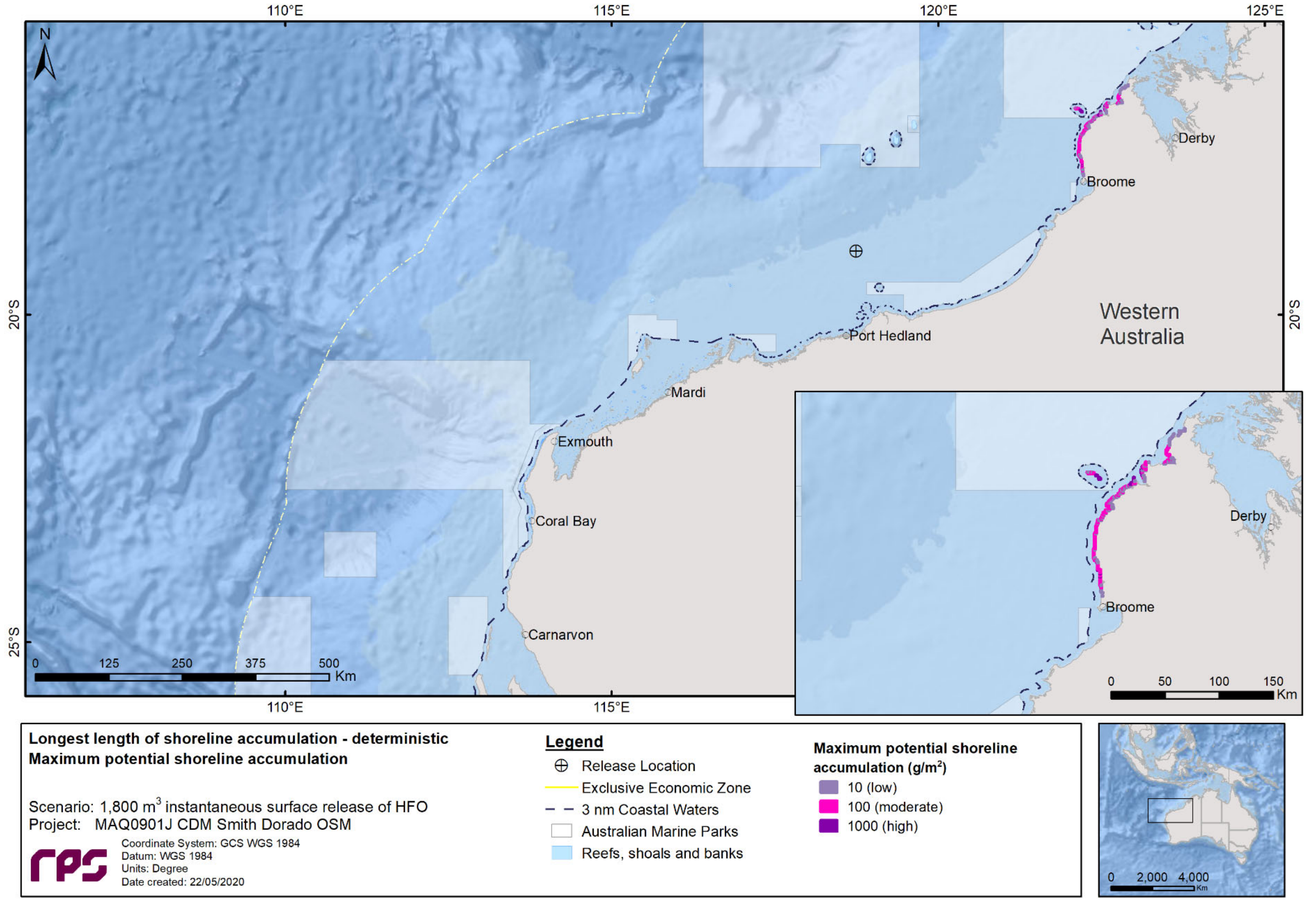


Figure 9.99 Potential shoreline loading for the simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO, tracked for 56 days, 5 pm on the 5th of December 2014.

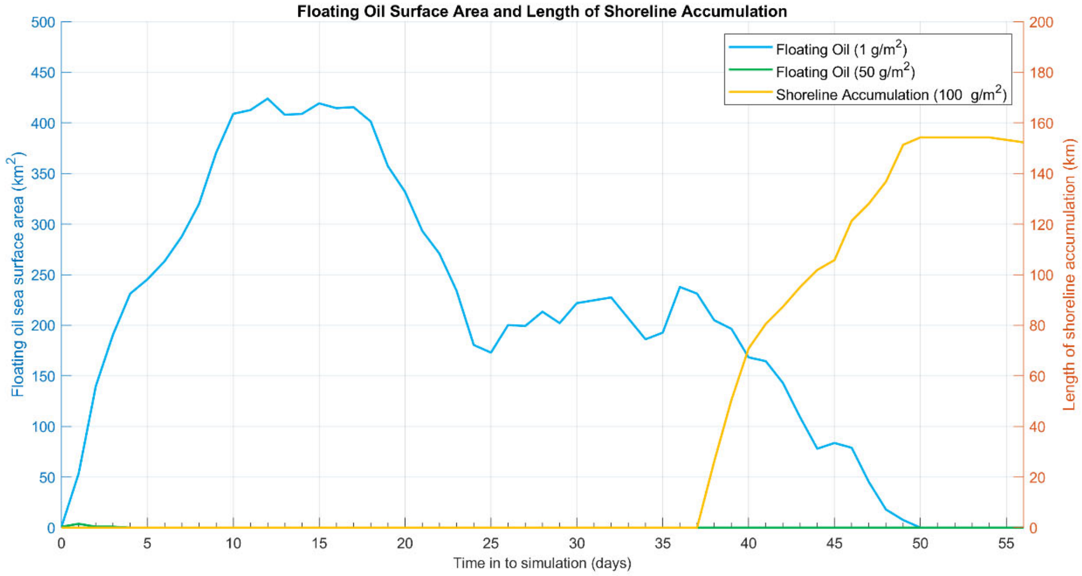


Figure 9.100 Time series of the area of visible (≥1 g/m²) and actionable floating oil (≥50 g/m²) on the sea surface and length of actionable shoreline oil (≥100 g/m²) for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO, tracked for 56 days, 5 pm on the 5th of December 2014.

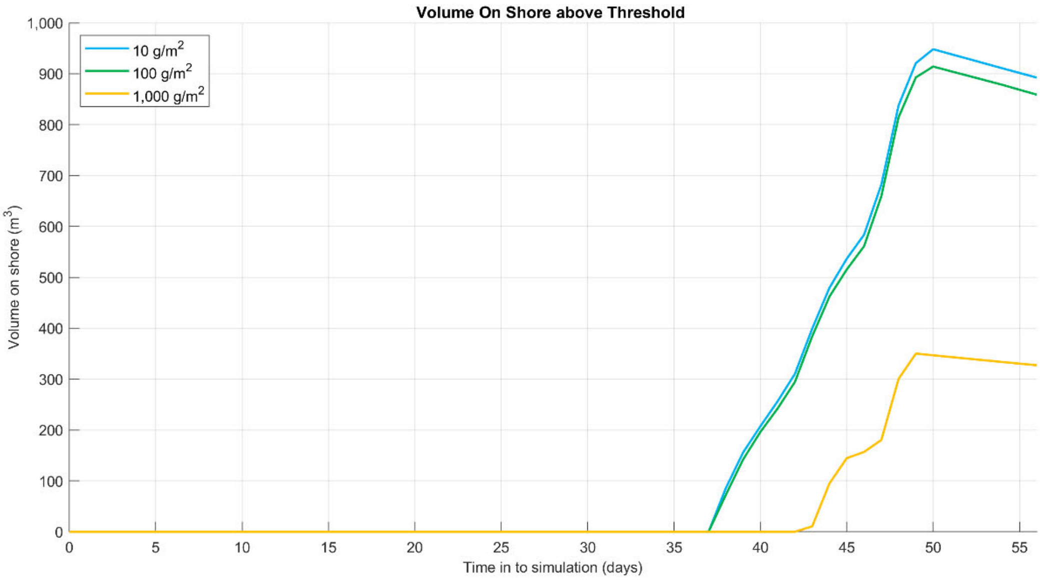


Figure 9.101 Time series of the mass on shore at the low (10-100 g/m²), moderate (100-1,000 g/m²) and high (≥ 1,000 g/m²) thresholds for the simulation with the longest length of shoreline with accumulation above 100 g/m². Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO, tracked for 56 days, 5 pm on the 5th of December 2014.

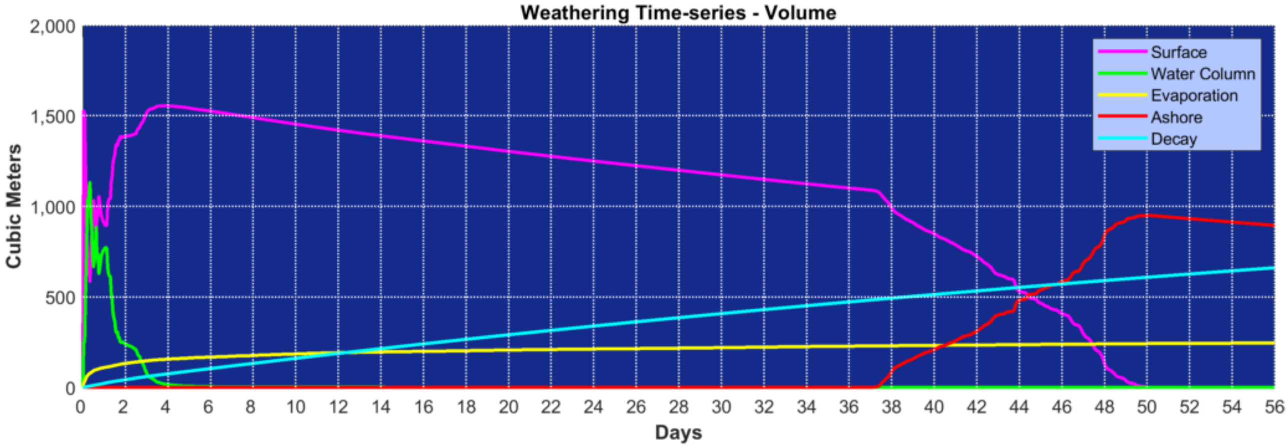


Figure 9.102 Predicted weathering and fates graph for the single spill simulation with the longest length of shoreline with accumulation above 100 g/m^2. Results are based an instantaneous surface release of 1,800 m^3 of HFO at the FPSO, tracked for 56 days, 5 pm on the 5th of December 2014.

9.5.3 Seasonal analysis

9.5.3.1 Floating Oil Exposure

Table 9.38 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 2,143.4 km west-northwest (transitional), 1,707.1 km west-northwest (winter) and 1,013.6 km west-southwest (transitional), respectively.

Images of floating oil exposure zones are depicted in Figure 9.103, Figure 9.104 and Figure 9.105 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively.

Table 9.39 to Table 9.41 summarise the potential floating oil exposure to individual sensitive receptors (refer Section 7.3) for each season.

Nine AMPs are within the predicted zone of floating oil exposure (at the low threshold) during summer conditions, 6 for transitional and 5 for winter conditions. The Argo-Rowley Terrace AMP recorded the highest probability of exposure of 53% during transitional conditions. The shortest time before exposure at AMPs was recorded at Montebello, which was predicted to take 3.88 days during transitional conditions.

There are 14 RSB within the low exposure zone across the 3 seasons and 13 during summer. Imperieuse Reef recorded the highest probability of exposure at 20%, which occurred during transitional conditions, with the minimum time before exposure at 11.6 days.

Floating oil was predicted to cross WA State Waters during every season at the low threshold, with probabilities ranging from 12% (winter) to 69% (summer). The minimum time before oil crossed the WA State Waters boundary was 10.25 days, recorded for a spill commencing during transitional conditions.

Table 9.38 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	1,433.5	1,010.9	984
	Max distance from release site (km) (99th percentile)	1,222.6	844.1	707.4
	Direction	West-Northwest	West-Southwest	West-Southwest
Transitional	Max. distance from release site (km)	2,143.4	1,489.4	1,013.6
	Max distance from release site (km) (99th percentile)	1,611.5	1,152.5	933.6
	Direction	West-Northwest	West-Northwest	West-Southwest
Winter	Max. distance from release site (km)	1,923.9	1,707.1	695.4
	Max distance from release site (km) (99th percentile)	1,581.0	1,096.6	566.0
	Direction	West-Northwest	West-Northwest	West

Table 9.39 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	27	12	1	11.08	11.58	12
	Dampier	1	1	1	18.17	18.21	18.25
	Eighty Mile Beach	22	15	1	4.58	5.08	14.08
	Gascoyne	7	5	1	6.71	6.71	6.71
	Kimberley	25	16	1	16.08	16.79	40.04
	Mermaid Reef	7	2	1	19.79	20	20.38
	Montebello	5	5	5	5	5	5
	Ningaloo	4	-	-	32.46	-	-
	Roebuck	13	5	-	17.58	18.04	-
EEZ	Christmas Island Exclusive Economic Zone	-	-	-	-	-	-
	Indonesian Exclusive Economic Zone	-	-	-	-	-	-
IBRA	Cape Range	2	-	-	30.04	-	-
	Chichester	1	1	-	19.46	19.54	-
	Mitchell	4	1	-	43.96	54.63	-
	Pindanland	42	30	2	12.29	12.33	17.67
	Roebourne	2	2	1	17.33	17.67	18.67
IMCRA	Canning	46	38	3	8.29	8.83	16.46
	Eighty Mile Beach	15	12	-	12.13	12.58	-
	Kimberley	10	5	-	32.5	33.58	-
	King Sound	1	-	-	45.17	-	-
	Ningaloo	4	-	-	29.88	-	-
	Pilbara (nearshore)	2	2	1	18.54	18.54	18.58
	Pilbara (offshore)	18	15	11	1.63	1.67	1.92
MP	Eighty Mile Beach	7	4	-	15.63	15.75	-
	Lalang-garram / Camden Sound	5	1	-	39.71	40.29	-
	Lalang-garram / Horizontal Falls	1	-	-	53.67	-	-
	Montebello Islands	4	1	-	29.5	34.21	-
	North Kimberley	1	1	-	54.04	54.58	-
	North Lalang-garram	3	1	-	52.42	53.58	-
	Rowley Shoals	15	3	-	12.13	12.46	-

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Yawuru Nagulagun / Roebuck Bay	15	7	1	17.67	18.08	18.63
NR	Scott Reef	-	-	-	-	-	-
Ramsar	Eighty-mile Beach	8	4	-	16.29	16.46	-
	Roebuck Bay	14	7	-	18.67	19.17	-
RSB	Albert Reef	5	1	-	39.96	44.79	-
	Barcoo Shoal	4	-	-	43.08	-	-
	Beagle and Dingo Reefs	3	1	-	45.54	46.63	-
	Brue Reef	3	-	-	38.58	-	-
	Churchill Reef	3	-	-	40.04	-	-
	Clerke Reef	5	-	-	18.75	-	-
	Cockell and Nicolle Reefs	1	-	-	43.75	-	-
	Imperieuse Reef	11	3	-	12.54	12.96	-
	Mavis Reef	4	-	-	40.88	-	-
	Mermaid Reef	5	2	1	20.13	20.21	20.38
	Rainbow Shoals	1	-	-	54.79	-	-
	Rankin Bank	-	-	-	-	-	-
	Rosily Shoals	2	-	-	30.63	-	-
	Wildcat Reefs	2	-	-	46.63	-	-
Nearshore	Adele Island	2	-	-	43.96	-	-
	Bedout Island	1	1	-	17.33	17.58	-
	Broome	42	31	2	12.29	12.33	17.67
	Clerke Reef	3	-	-	27.42	-	-
	Cunningham Island	4	-	-	20.46	-	-
	Delambre Island	1	1	1	18.63	18.67	18.71
	Derby - West Kimberely	3	1	-	44.54	54.63	-
	Imperieuse Reef	8	1	-	12.92	18.17	-
	Karratha	1	1	-	19.46	19.54	-
	King Leopold Ranges	1	-	-	53.13	-	-
	Kingfisher Islands	1	-	-	53.67	-	-
	Lacepede Islands	5	1	-	18.33	35.21	-
	Mermaid Reef	5	1	-	20.17	20.29	-
	Peak Island	2	-	-	30.04	-	-
	Port Hedland	1	1	-	30.79	31.21	-
	Scott Reef North	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Seringapatam Reef	-	-	-	-	-	-
	Wyndham - East Kimberley	2	-	-	48.75	-	-
State Waters	Western Australia State Waters	69	44	4	11.83	11.88	17.33

Table 9.40 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	53	40	10	7.38	7.5	7.71
	Dampier	-	-	-	-	-	-
	Eighty Mile Beach	-	-	-	-	-	-
	Gascoyne	22	11	6	8.67	8.67	8.71
	Kimberley	16	4	1	16.83	16.88	18.33
	Mermaid Reef	10	-	-	14.29	-	-
	Montebello	7	4	3	3.88	3.88	3.88
	Ningaloo	-	-	-	-	-	-
	Roebuck	1	-	-	35.17	-	-
EEZ	Christmas Island Exclusive Economic Zone	5	1	-	30.92	52.58	-
	Indonesian Exclusive Economic Zone	19	5	1	19.83	25.79	35.29
IBRA	Cape Range	-	-	-	-	-	-
	Chichester	-	-	-	-	-	-
	Mitchell	-	-	-	-	-	-
	Pindanland	2	2	-	33.54	34.58	-
	Roebourne	-	-	-	-	-	-
IMCRA	Canning	10	5	1	17.21	17.25	18.33
	Eighty Mile Beach	-	-	-	-	-	-
	Kimberley	3	-	-	33.83	-	-
	King Sound	-	-	-	-	-	-
	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	-	-	-	-	-	-
	Pilbara (offshore)	7	4	3	1.88	1.88	1.88
MP	Eighty Mile Beach	-	-	-	-	-	-
	Lalang-garram / Camden Sound	-	-	-	-	-	-
	Lalang-garram / Horizontal Falls	-	-	-	-	-	-
	Montebello Islands	-	-	-	-	-	-
	North Kimberley	-	-	-	-	-	-
	North Lalang-garram	-	-	-	-	-	-
	Rowley Shoals	23	9	2	10.25	11.04	12.63

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Yawuru Nagulagun / Roebuck Bay	1	1	-	33.58	35.13	-
NR	Scott Reef	-	-	-	-	-	-
Ramsar	Eighty-mile Beach	-	-	-	-	-	-
	Roebuck Bay	1	-	-	36.29	-	-
RSB	Albert Reef	-	-	-	-	-	-
	Barcoo Shoal	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Brue Reef	-	-	-	-	-	-
	Churchill Reef	-	-	-	-	-	-
	Clerke Reef	10	2	-	16.25	21.38	-
	Cockell and Nicolle Reefs	-	-	-	-	-	-
	Imperieuse Reef	20	6	1	11.58	11.96	14.04
	Mavis Reef	-	-	-	-	-	-
	Mermaid Reef	9	-	-	17.67	-	-
	Rainbow Shoals	-	-	-	-	-	-
	Rankin Bank	1	-	-	14.17	-	-
	Rosily Shoals	-	-	-	-	-	-
	Wildcat Reefs	-	-	-	-	-	-
Nearshore	Adele Island	-	-	-	-	-	-
	Bedout Island	-	-	-	-	-	-
	Broome	2	2	-	33.54	34.58	-
	Clerke Reef	8	-	-	16.63	-	-
	Cunningham Island	16	2	-	13.63	13.92	-
	Delambre Island	-	-	-	-	-	-
	Derby - West Kimberely	-	-	-	-	-	-
	Imperieuse Reef	16	2	1	13.67	13.79	14
	Karratha	-	-	-	-	-	-
	King Leopold Ranges	-	-	-	-	-	-
	Kingfisher Islands	-	-	-	-	-	-
	Lacepede Islands	-	-	-	-	-	-
	Mermaid Reef	5	-	-	32.63	-	-
	Peak Island	-	-	-	-	-	-
	Port Hedland	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Seringapatam Reef	-	-	-	-	-	-
	Wyndham - East Kimberley	-	-	-	-	-	-
State Waters	Western Australia State Waters	25	11	2	10.25	11.04	12.63

Table 9.41 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
AMP	Argo-Rowley Terrace	49	30	3	7.63	7.67	7.71
	Dampier	-	-	-	-	-	-
	Eighty Mile Beach	-	-	-	-	-	-
	Gascoyne	6	-	-	21.79	-	-
	Kimberley	5	2	-	23.5	27.63	-
	Mermaid Reef	4	3	-	13.13	13.54	-
	Montebello	-	-	-	-	-	-
	Ningaloo	-	-	-	-	-	-
	Roebuck	-	-	-	-	-	-
EEZ	Christmas Island Exclusive Economic Zone	4	1	-	47.83	55.21	-
	Indonesian Exclusive Economic Zone	13	-	-	36.96	-	-
IBRA	Cape Range	-	-	-	-	-	-
	Chichester	-	-	-	-	-	-
	Mitchell	-	-	-	-	-	-
	Pindanland	-	-	-	-	-	-
	Roebourne	-	-	-	-	-	-
IMCRA	Canning	-	-	-	-	-	-
	Eighty Mile Beach	-	-	-	-	-	-
	Kimberley	-	-	-	-	-	-
	King Sound	-	-	-	-	-	-
	Ningaloo	-	-	-	-	-	-
	Pilbara (nearshore)	-	-	-	-	-	-
	Pilbara (offshore)	2	2	-	13.63	13.75	-
MP	Eighty Mile Beach	-	-	-	-	-	-
	Lalang-garram / Camden Sound	-	-	-	-	-	-
	Lalang-garram / Horizontal Falls	-	-	-	-	-	-
	Montebello Islands	-	-	-	-	-	-
	North Kimberley	-	-	-	-	-	-
	North Lalang-garram	-	-	-	-	-	-
	Rowley Shoals	10	6	-	12.21	12.71	-

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Yawuru Nagulagun / Roebuck Bay	-	-	-	-	-	-
NR	Scott Reef	1	-	-	40.13	-	-
Ramsar	Eighty-mile Beach	-	-	-	-	-	-
	Roebuck Bay	-	-	-	-	-	-
RSB	Albert Reef	-	-	-	-	-	-
	Barcoo Shoal	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Brue Reef	-	-	-	-	-	-
	Churchill Reef	-	-	-	-	-	-
	Clerke Reef	3	-	-	18.83	-	-
	Cockell and Nicolle Reefs	-	-	-	-	-	-
	Imperieuse Reef	8	1	-	13.38	13.38	-
	Mavis Reef	-	-	-	-	-	-
	Mermaid Reef	4	2	-	14.58	22.33	-
	Rainbow Shoals	-	-	-	-	-	-
	Rankin Bank	-	-	-	-	-	-
	Rosily Shoals	-	-	-	-	-	-
	Wildcat Reefs	-	-	-	-	-	-
Nearshore	Adele Island	-	-	-	-	-	-
	Bedout Island	-	-	-	-	-	-
	Broome	-	-	-	-	-	-
	Clerke Reef	1	-	-	19.08	-	-
	Cunningham Island	6	-	-	13.92	-	-
	Delambre Island	-	-	-	-	-	-
	Derby - West Kimberely	-	-	-	-	-	-
	Imperieuse Reef	5	1	-	13.42	13.46	-
	Karratha	-	-	-	-	-	-
	King Leopold Ranges	-	-	-	-	-	-
	Kingfisher Islands	-	-	-	-	-	-
	Lacepede Islands	-	-	-	-	-	-
	Mermaid Reef	2	1	-	20.96	26.83	-
	Peak Island	-	-	-	-	-	-
	Port Hedland	-	-	-	-	-	-
	Scott Reef North	1	-	-	38.17	-	-
	Scott Reef South	1	-	-	35.46	-	-

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)	Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (≥50 g/m²)
	Seringapatam Reef	1	-	-	39.63	-	-
	Wyndham - East Kimberley	-	-	-	-	-	-
State Waters	Western Australia State Waters	12	6	-	12.21	12.71	-

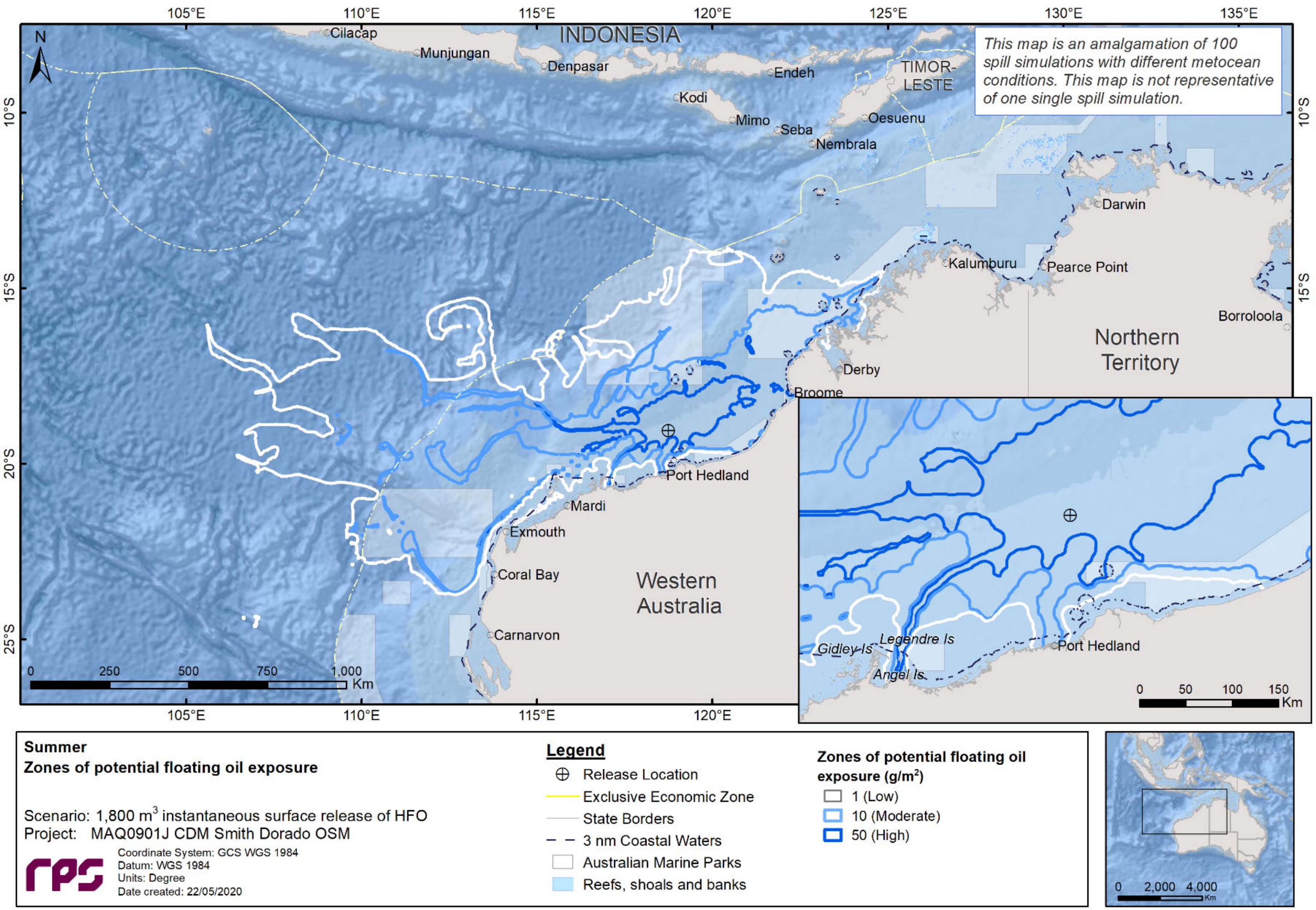


Figure 9.103 Predicted zones of potential floating oil resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

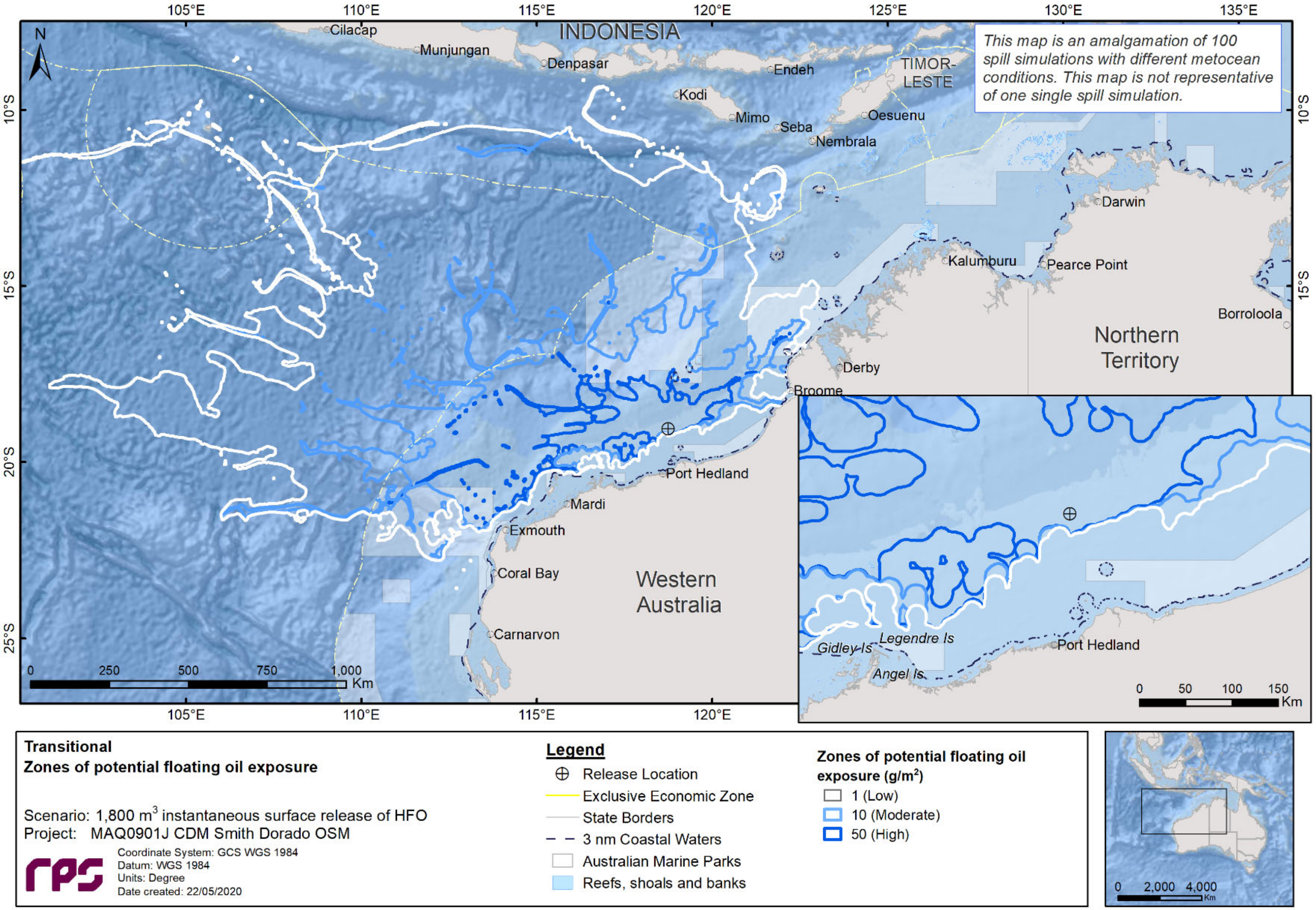


Figure 9.104 Predicted zones of potential floating oil resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

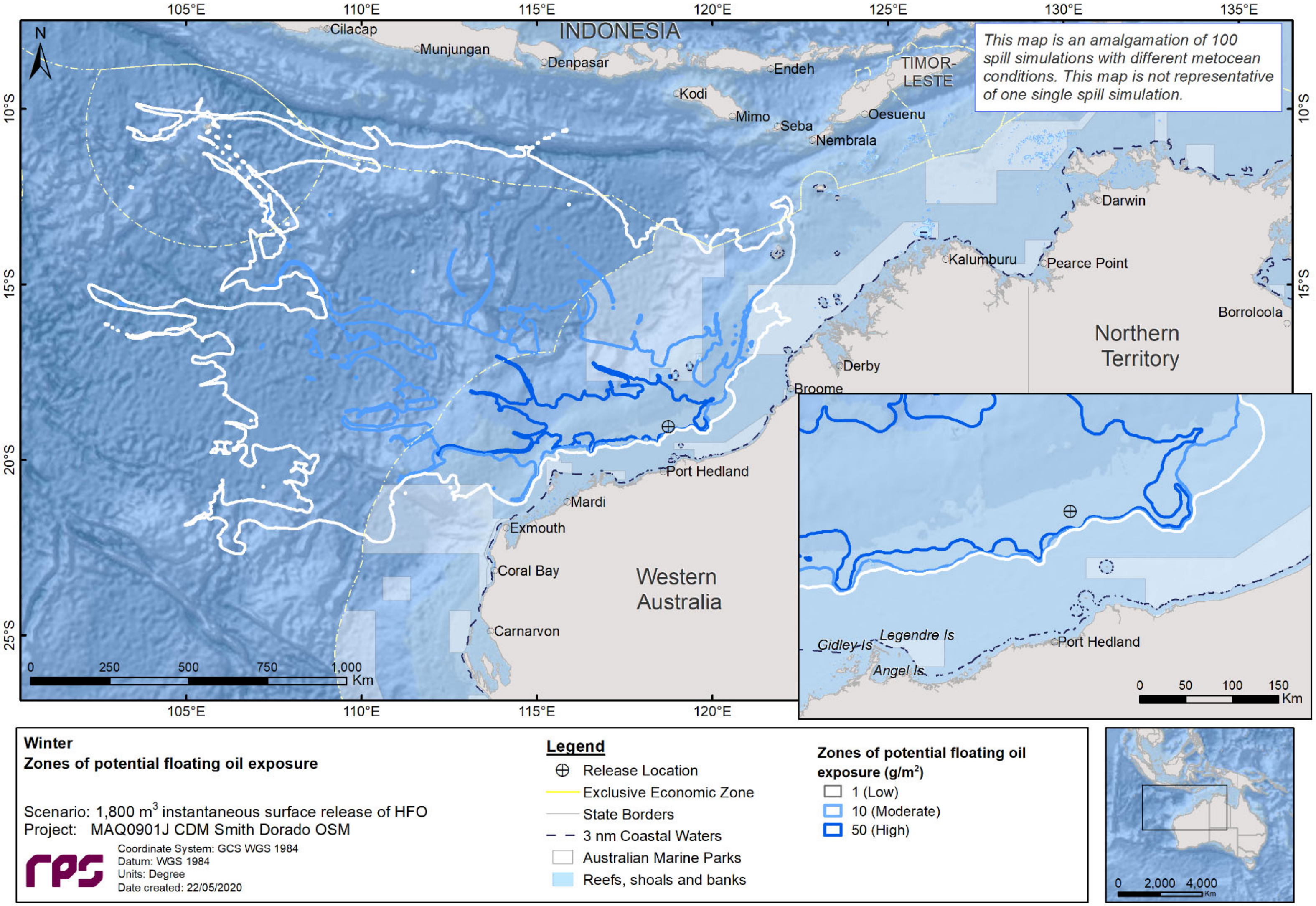


Figure 9.105 Predicted floating oil exposure zones resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.5.3.2 Shoreline Accumulation

Table 9.42 presents a summary of the predicted oil accumulation on any shoreline for all three seasons assessed. The probability of oil accumulation at, or above, the low threshold (10-100 g/m^2) during summer, transitional and winter seasons was 72%, 31% and 16%, respectively. The minimum time before oil accumulation above the low threshold was approximately 11.67 days during transitional conditions. The greatest volume of oil ashore was 1,684.5 m^3 for a spill commencing in the summer period.

Table 9.43 to Table 9.45 summarise the oil accumulation to individual shoreline receptors assessed for all seasonal conditions. Based on the 100 simulations per season and across the 3 seasons, a total of 36 sensitive (refer Section 7.3) receptors were predicted to record oil accumulation at the low threshold, with Broome recording the highest probability of 45% during summer conditions. The quickest time before shoreline accumulation was predicted during transitional conditions (11.67 days) at Imperieuse Reef. The greatest volume of oil ashore of 1,684.5 m^3 and the maximum length of shoreline with accumulation at the low threshold was 252.3 km, both occurred at Broome during summer conditions.

The maximum potential shoreline loading at low, moderate and high accumulation thresholds are depicted in Figure 9.106, Figure 9.107 and Figure 9.108 for spills commencing during summer, transitional and winter conditions, respectively.

Table 9.42 Summary of oil accumulation on any shoreline. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during all seasonal conditions. The results were calculated from 100 spill simulations per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of shoreline accumulation at, or above **10 g/m^2** (%)	72	31	16
Minimum time before shoreline accumulation at, or above **10 g/m^2** (days)	12.3	11.7	13.42
Maximum volume of oil ashore (m^3) from a single simulation	1,684.5	1,383.0	957.8
Average volume of oil ashore (m^3) for all simulations predicted to reach the shorelines	812.3	142.0	128.8
Maximum length of shoreline accumulation at or above **10 g/m^2** (km) from a single simulation	259.0	159.0	112.0
Average length of shoreline accumulation at or above **10 g/m^2** (km) for all simulations predicted to reach the shorelines	85.7	29.3	24.4
Maximum length of shoreline accumulation at or above **100 g/m^2** (km) from a single simulation	160.0	77.0	84.0
Average length of shoreline accumulation at or above **100 g/m^2** (km) for all simulations predicted to reach the shorelines	53.6	15.2	12.9
Maximum length of shoreline accumulation at or above **1,000 g/m^2** (km) from a single simulation	44.0	31.0	28.0
Average length of shoreline accumulation at or above **1,000 g/m^2** (km) for all simulations predicted to reach the shorelines	25.5	6.7	7.7

Table 9.43 Summary of oil accumulation on individual shorelines. Results are based on an instantaneous surface release of 1,800 m³ of HFO at the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Adele Island	4	3	2	40.0	43.8	44.5	422.1	1,832.1	0.9	55.8	2.3	2.3	2.0	3.0	3.0	3.0
Barrow Island	4	4	-	29.7	29.7	-	91.2	535.3	0.8	29.7	13.0	6.5	-	16.0	10.0	-
Bedout Island	2	1	1	17.3	17.4	17.6	2,271.8	14,233.5	4.3	424.9	3.0	4.0	4.0	4.0	4.0	4.0
Bezout Island	1	-	-	21.6	-	-	31.6	31.6	0.4	0.4	1.0	-	-	1.0	-	-
Boodie Island	4	3	-	29.7	29.7	-	145.6	384.3	0.2	9.0	2.8	2.3	-	3.0	3.0	-
Broome	45	44	41	12.3	12.4	12.4	868.0	17,532.0	514.1	1,684.5	112.5	68.7	28.8	252.3	148.2	44.1
Clerke Reef	13	7	2	20.5	24.5	27.5	327.0	4,238.5	3.1	126.2	3.8	4.7	4.0	6.0	6.0	4.0
Cunningham Island	14	10	2	18.0	20.6	22.1	592.2	4,293.5	2.2	98.5	1.8	2.0	2.0	2.0	2.0	2.0
Delambre Island	1	1	1	18.7	18.7	18.7	17,517.7	17,517.7	517.8	517.8	4.0	4.0	4.0	4.0	4.0	4.0
Derby - West Kimberely	7	6	2	35.5	36.1	45.4	85.1	7,609.1	11.9	870.5	37.5	16.4	12.0	145.2	69.1	20.0
Dirk Hartog Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Pilbara	1	1	-	23.5	26.5	-	114.5	114.5	23.3	23.3	54.1	1.0	-	54.1	1.0	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haury Island	1	-	-	19.0	-	-	42.0	42.0	0.7	0.7	2.0	-	-	2.0	-	-
Hermite Island	4	4	-	29.7	29.7	-	72.3	865.2	0.6	28.5	11.8	3.3	-	18.0	5.0	-
Imperieuse Reef	17	12	5	12.8	13.0	18.2	523.4	4,885.3	6.1	152.6	4.1	4.4	3.2	5.0	5.0	5.0
Karratha	1	1	1	19.5	19.5	19.6	17,520.5	17,520.5	1,092.3	1,092.3	53.1	35.0	15.0	53.1	35.0	15.0
King Leopold Ranges	1	1	1	44.8	52.8	53.6	1,075.4	1,075.4	54.2	54.2	16.0	11.0	1.0	16.0	11.0	1.0
Kingfisher Islands	1	1	1	53.4	53.4	53.7	5,591.9	5,591.9	208.5	208.5	12.0	9.0	6.0	12.0	9.0	6.0
Lacepede Islands	16	7	6	18.3	18.3	18.7	510.0	15,849.6	17.0	589.5	8.6	12.6	5.2	16.0	16.0	10.0
Legendre Island	1	-	-	19.1	-	-	14.0	14.0	0.2	0.2	1.0	-	-	1.0	-	-
Little Turtle Islet	1	1	-	48.4	49.5	-	248.8	248.8	2.9	2.9	1.0	1.0	-	1.0	1.0	-
Lowendal Island	3	-	-	29.8	-	-	12.0	42.1	<0.1	0.8	2.0	-	-	3.0	-	-

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Mermaid Reef	10	6	3	20.1	20.2	20.3	1,388.9	9,778.1	3.2	215.8	1.9	2.0	2.0	2.0	2.0	2.0
Middle Island	4	3	-	29.7	29.7	-	146.5	426.6	0.2	10.6	3.0	2.0	-	3.0	2.0	-
Murion Islands	2	-	-	32.9	-	-	16.6	63.5	<0.1	0.8	1.5	-	-	2.0	-	-
North Turtle Island	1	1	-	46.1	46.3	-	159.8	159.8	1.9	1.9	1.0	1.0	-	1.0	1.0	-
Peak Island	4	1	-	30.0	34.7	-	71.8	125.6	<0.1	1.5	1.0	1.0	-	1.0	1.0	-
Port Hedland	3	1	1	28.5	30.8	31.3	361.1	12,652.4	10.8	1,073.9	33.7	49.1	22.0	73.1	49.1	22.0
Scott Reef North	1	-	-	51.1	-	-	15.6	15.6	0.7	0.7	2.0	-	-	2.0	-	-
Scott Reef South	1	-	-	50.7	-	-	80.3	80.3	6.4	6.4	21.0	-	-	21.0	-	-
Seringapatam Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shark Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wyndham - East Kimberley	6	4	-	39.8	48.0	-	42.8	877.9	1.9	142.6	23.2	10.8	-	92.1	32.0	-
Indonesia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 9.44 Summary of oil accumulation on individual shorelines. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Adele Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bedout Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bezout Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Broome	8	5	2	16.3	33.6	34.5	154.4	10,648.6	24.2	1,383.0	61.6	32.8	29.0	118.1	74.1	31.0
Clerke Reef	17	10	5	16.7	16.7	18.9	394.3	6,276.6	5.2	236.4	4.5	4.3	2.2	6.0	6.0	5.0
Cunningham Island	21	16	6	12.1	13.8	13.9	846.7	3,990.9	4.4	75.1	1.9	2.0	1.8	2.0	2.0	2.0
Delambre Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Derby - West Kimberely	1	-	-	52.0	-	-	10.2	10.2	0.2	0.2	1.0	-	-	1.0	-	-
Dirk Hartog Island	1	-	-	34.9	-	-	43.9	43.9	1.7	1.7	3.0	-	-	3.0	-	-
East Pilbara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	1	-	-	27.2	-	-	80.3	80.3	3.4	3.4	7.0	-	-	7.0	-	-
Haury Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hermite Island	2	-	-	12.0	-	-	15.7	34.7	<0.1	1.2	2.5	-	-	4.0	-	-
Imperieuse Reef	21	16	12	11.7	13.7	13.8	1,109.0	17,468.5	15.1	440.0	4.3	4.1	2.8	5.0	5.0	5.0
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
King Leopold Ranges	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kingfisher Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lacepede Islands	6	2	-	46.2	46.6	-	50.4	602.3	0.6	32.9	11.0	5.5	-	15.0	9.0	-
Legendre Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Little Turtle Islet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Mermaid Reef	16	10	5	18.1	18.3	33.7	554.2	2,293.7	2.1	44.5	1.9	1.9	1.4	2.0	2.0	2.0
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Turtle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	1	-	-	51.6	-	-	15.6	15.6	0.2	0.2	1.0	-	-	1.0	-	-
Port Hedland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scott Reef North	5	2	-	40.1	40.1	-	26.7	356.1	0.2	8.1	8.2	1.5	-	12.0	2.0	-
Scott Reef South	3	-	-	43.5	-	-	7.1	15.9	<0.1	1.0	2.7	-	-	4.0	-	-
Seringapatam Reef	3	1	-	42.0	52.5	-	42.7	236.1	0.3	22.6	10.3	10.0	-	17.0	10.0	-
Shark Bay	1	-	-	35.3	-	-	12.4	12.4	0.2	0.2	1.0	-	-	1.0	-	-
Wyndham - East Kimberley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indonesia	4	1	-	48.0	50.4	-	14.4	169.4	0.1	3.3	5.0	1.0	-	10.0	1.0	-

Table 9.45 Summary of oil accumulation on individual shorelines. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Adele Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bedout Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bezout Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Broome	2	1	-	50.8	54.4	-	18.7	292.0	0.3	30.0	24.5	7.0	-	46.1	7.0	-
Clerke Reef	8	4	1	18.9	19.1	19.5	375.0	6,634.6	2.1	179.5	4.1	3.3	5.0	6.0	5.0	5.0
Cunningham Island	10	7	3	13.9	14.0	21.6	859.4	4,974.6	2.0	109.5	1.9	2.0	1.7	2.0	2.0	2.0
Delambre Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Derby - West Kimberely	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dirk Hartog Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Pilbara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haury Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	9	7	5	13.4	13.5	13.6	715.6	4,558.0	4.6	161.9	4.3	4.3	2.4	5.0	5.0	3.0
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
King Leopold Ranges	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kingfisher Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lacepede Islands	3	-	-	46.6	-	-	16.0	53.2	0.1	3.3	9.7	-	-	11.0	-	-
Legendre Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Little Turtle Islet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline receptor	Maximum probability of shoreline accumulation (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline accumulation (km)			Maximum length of shoreline accumulation (km)		
	Low	Mod.	High	Low	Mod.	High	Mean	Peak	Mean	Peak	Low	Mod.	High	Low	Mod.	High
Mermaid Reef	10	5	2	14.7	15.5	21.8	1,733.7	10,149.7	4.1	225.3	2.0	1.8	2.0	2.0	2.0	2.0
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Turtle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Port Hedland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scott Reef North	2	1	-	38.1	38.2	-	177.8	937.7	1.3	122.6	20.5	19.0	-	29.0	19.0	-
Scott Reef South	2	2	1	34.4	35.2	35.9	521.4	3,734.9	7.3	661.6	54.1	32.0	24.0	58.1	45.1	24.0
Seringapatam Reef	3	1	1	39.7	39.7	40.7	224.4	1,725.2	1.8	178.8	11.3	20.0	4.0	24.0	20.0	4.0
Shark Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wyndham - East Kimberley	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indonesia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

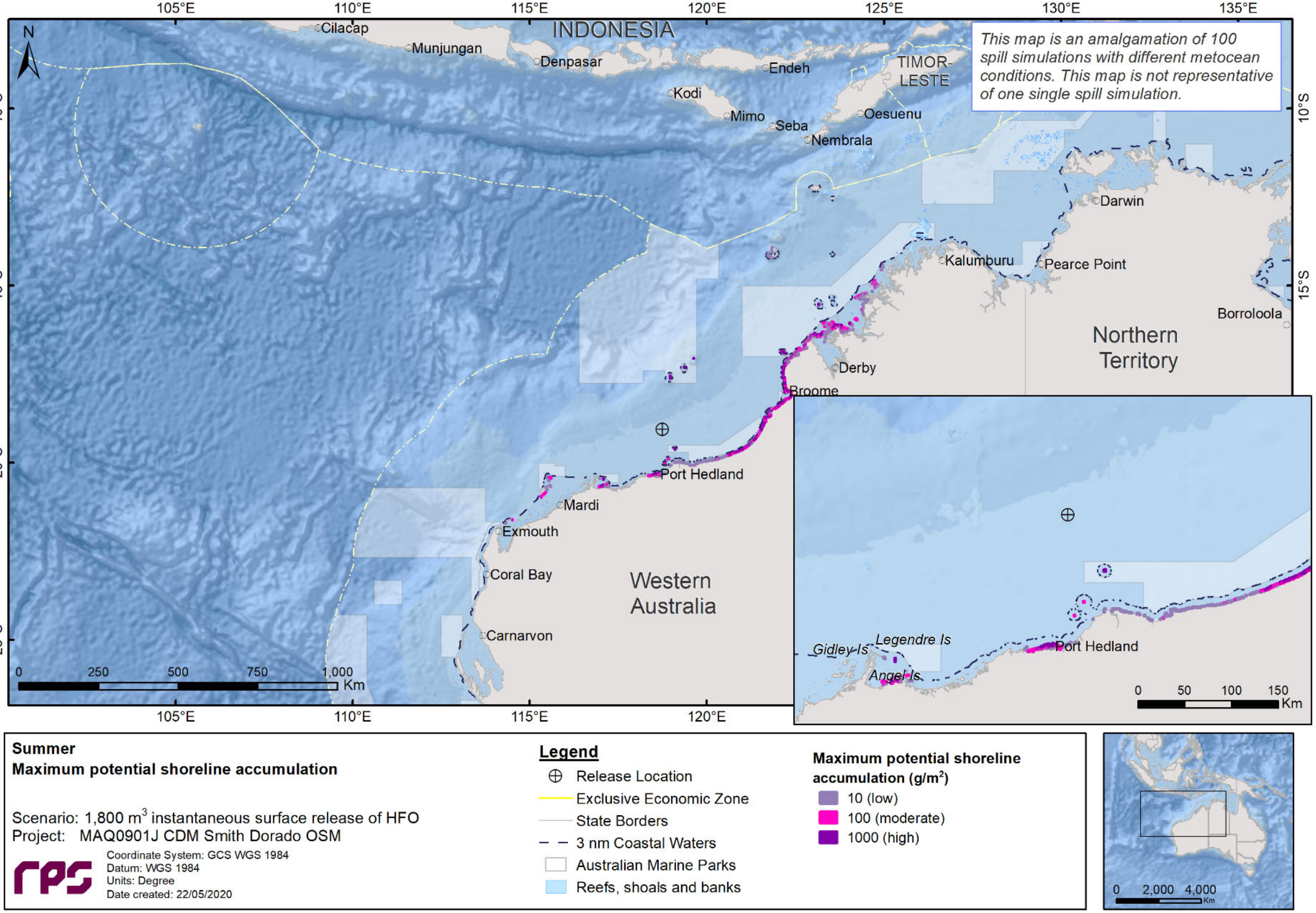


Figure 9.106 Predicted maximum shoreline loading resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

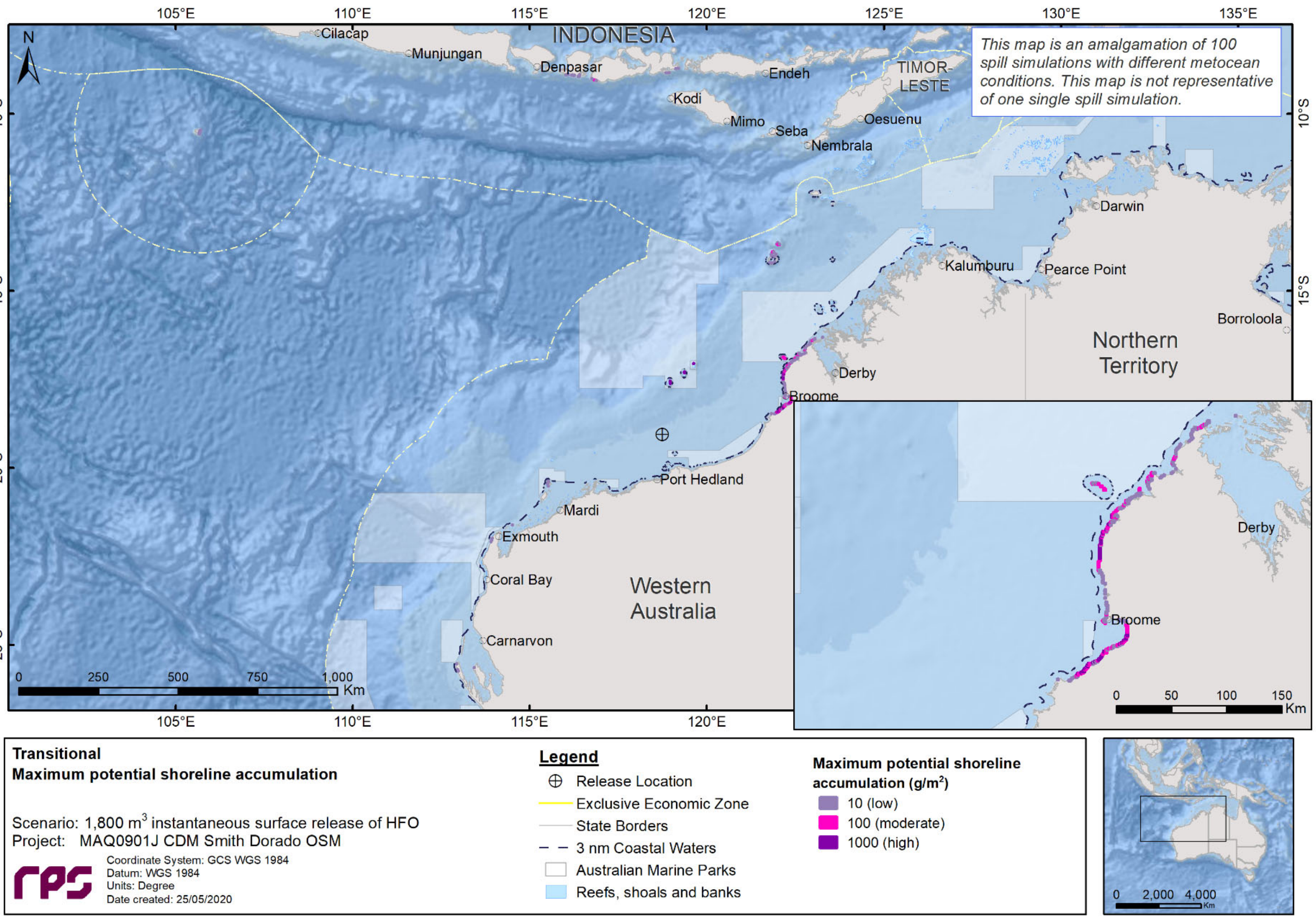


Figure 9.107 Predicted maximum shoreline loading resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

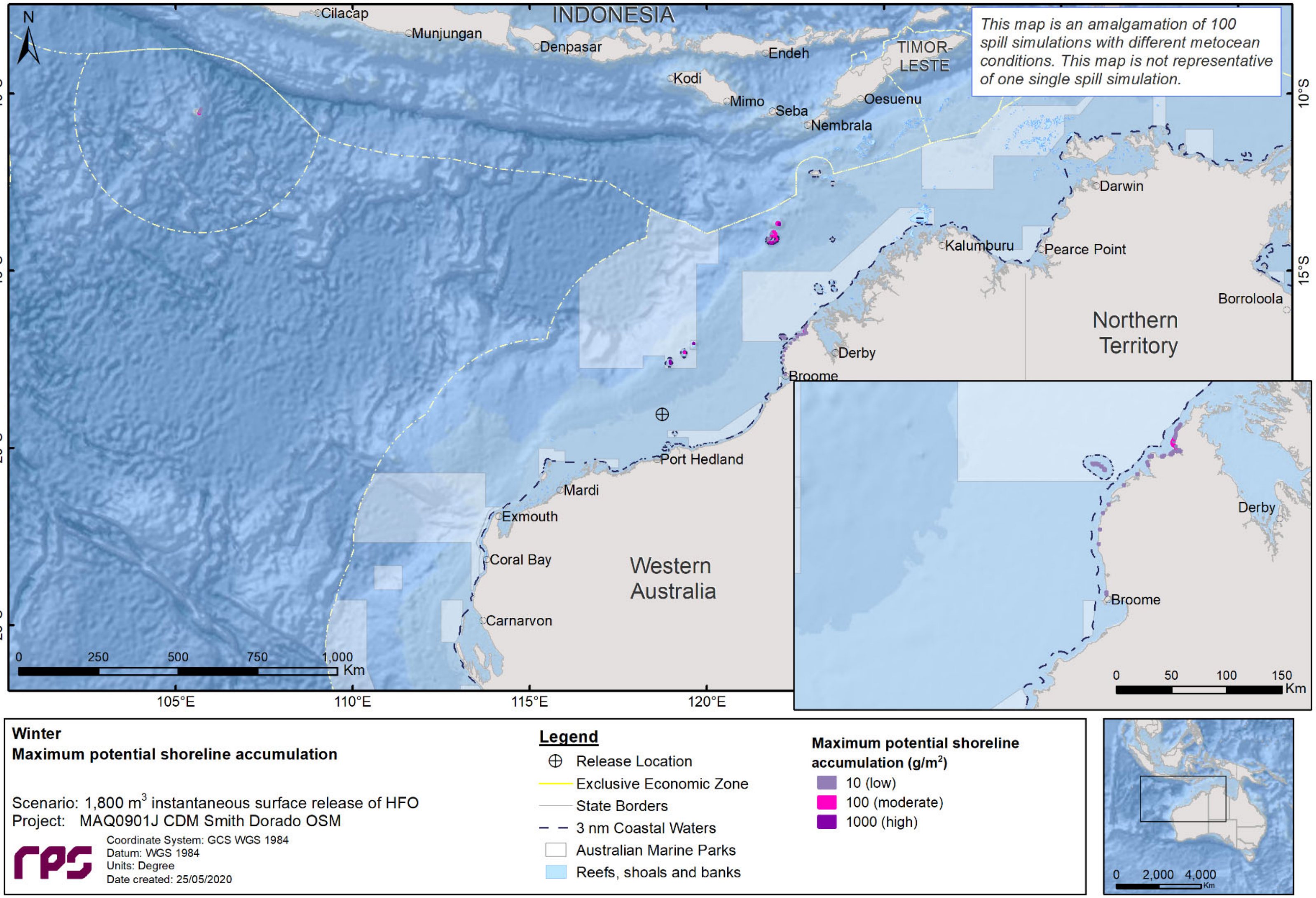


Figure 9.108 Predicted maximum shoreline loading resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.5.3.3 Entrained Hydrocarbons

Images of entrained hydrocarbon exposure zones in the 0-10 m depth layer are depicted in Figure 9.109, Figure 9.110 and Figure 9.111 for the combined 100 spill simulations each commencing during summer, transitional and winter conditions, respectively. The results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 850 km (southwest) from the spill site during summer conditions. This distance reduced to 411 km (west-southwest) as the contact threshold increased to 100 ppb in summer conditions. The maximum distances for transitional and winter conditions at the low threshold were 506 km and 290 km, respectively. The maximum distances at the moderate threshold were reduced to 175 km for transitional and 125 km for winter conditions.

Table 9.46 to Table 9.48 summarise the probability of exposure to individual sensitive receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

Three AMPs are within the low exposure zone for summer and 1 AMP (Montebello) during transitional conditions. Montebello AMP recorded the highest probability of exposure of 2% and the shortest time for entrained hydrocarbons to reach an AMP at the low threshold of 6.25 days, both during transitional conditions. No AMPs were predicted to be exposed from spills at the low threshold occurring during winter conditions.

No KEF receptors were predicted to be exposed by entrained hydrocarbons at the low threshold.

Entrained hydrocarbon exposure at the low threshold was predicted at Rankin Bank only during transitional conditions with a probability of 2%. The quickest time before exposure was 7 days.

Entrained hydrocarbons at the low (10-100 ppb) threshold were not predicted to cross into WA State Waters during any season.

Table 9.46 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	1	-	11.9	-	26
	Gascoyne	1	-	6.9	-	16
	Montebello	1	1	5.0	5.0	141
IMCRA	Ningaloo	1	-	9.7	-	34
	Pilbara (offshore)	4	1	1.9	1.9	1,929
RSB	Rankin Bank	-	-	-	-	-

Table 9.47 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	-	-	-	-	-
	Gascoyne	-	-	-	-	-
	Montebello	2	-	6.3	-	92
IMCRA	Ningaloo	-	-	-	-	-
	Pilbara (offshore)	2	2	3.2	3.4	182
RSB	Rankin Bank	2	-	7.0	-	37

Table 9.48 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 1,800 m^3 of HFO at the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	-	-	-	-	-
	Gascoyne	-	-	-	-	-
	Montebello	-	-	-	-	-
IMCRA	Ningaloo	-	-	-	-	-
	Pilbara (offshore)	-	-	-	-	-
RSB	Rankin Bank	-	-	-	-	-

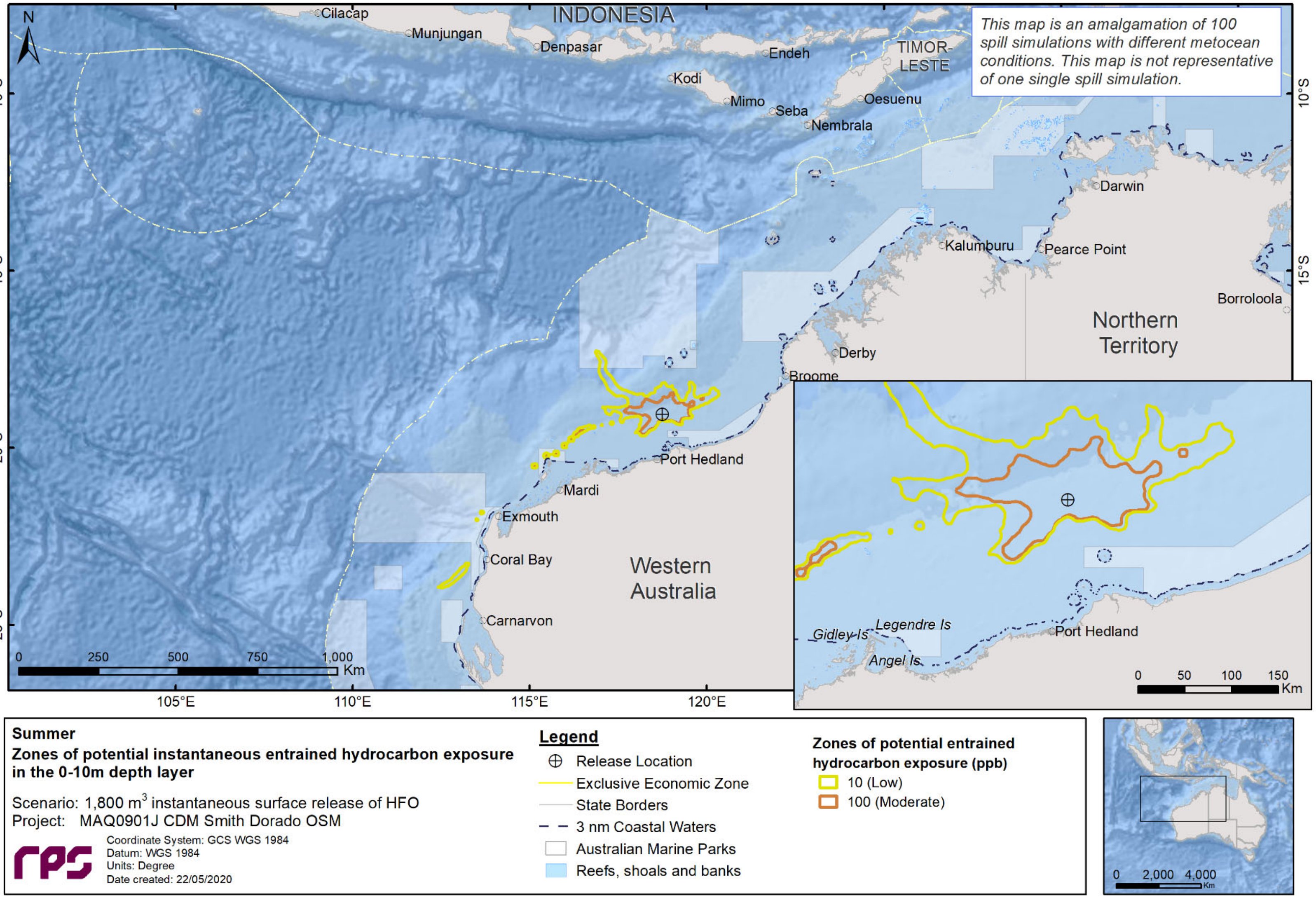


Figure 9.109 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

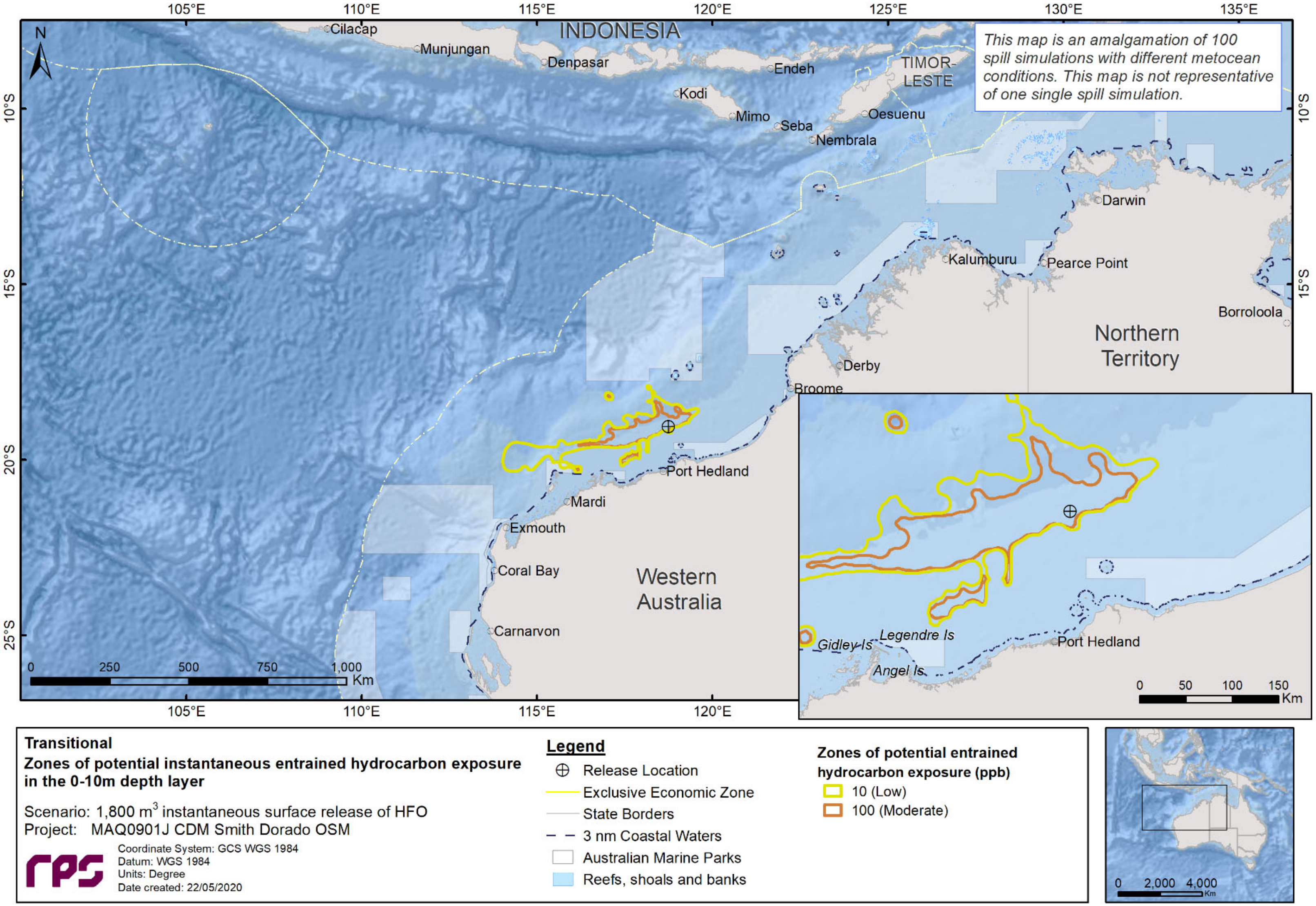


Figure 9.110 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

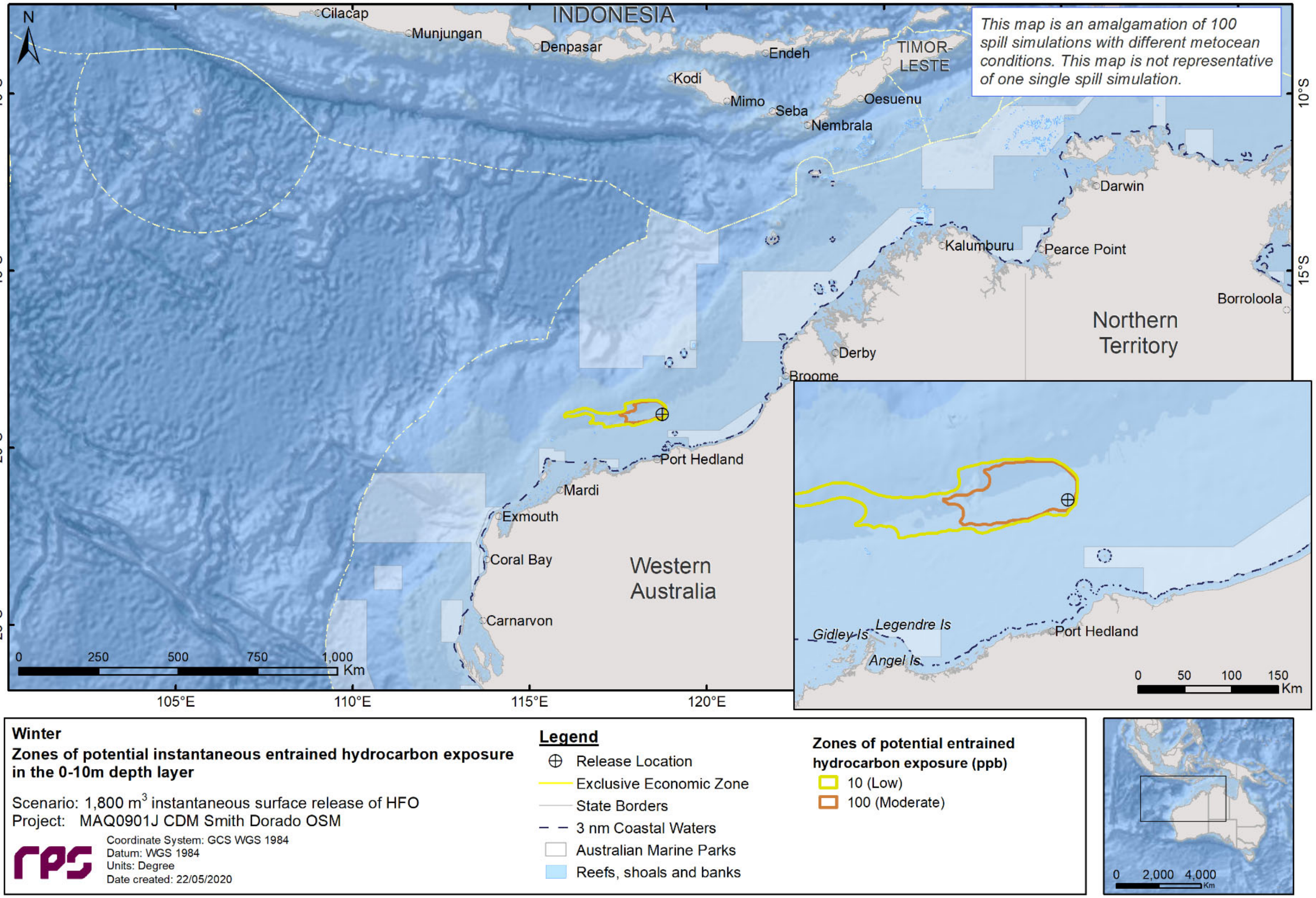


Figure 9.111 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 1,800 m^3 of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.5.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones are depicted in Figure 9.112 and Figure 9.113 for the combined 100 spills each commencing during summer and transitional conditions, respectively. There was no dissolved hydrocarbon exposure during the winter conditions.

The results indicated exposure for the low threshold (10-50 ppb) was predicted to occur up to a distance of 42 km (northwest) and 215 km (west) from the spill site during summer and transitional conditions, respectively. No exposure at the moderate (50-400 ppb) or high (≥ 400 ppb) thresholds was predicted in any of the assessed seasons.

No KEF or RSB receptors were predicted to be exposed by dissolved hydrocarbons at the low threshold.

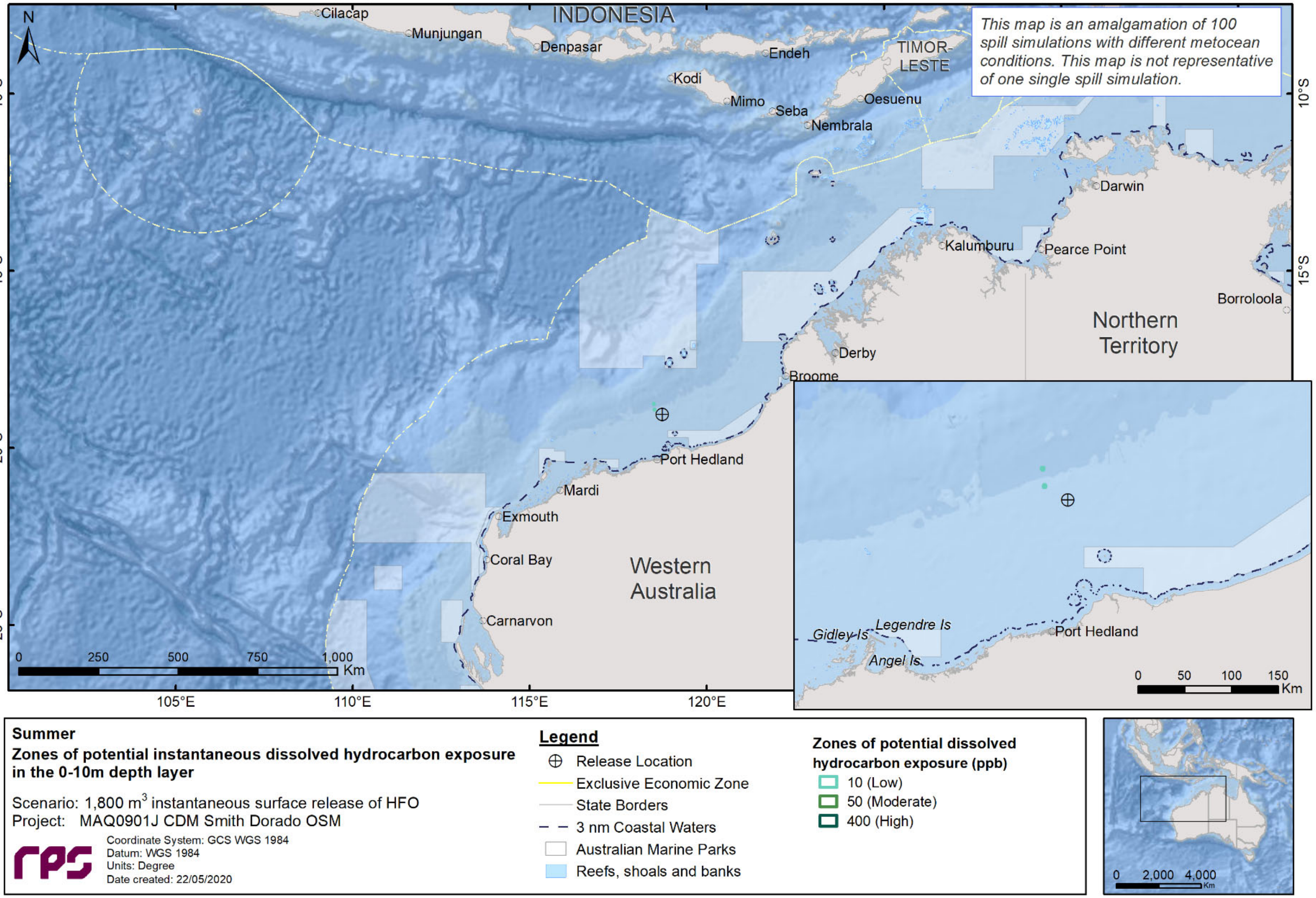
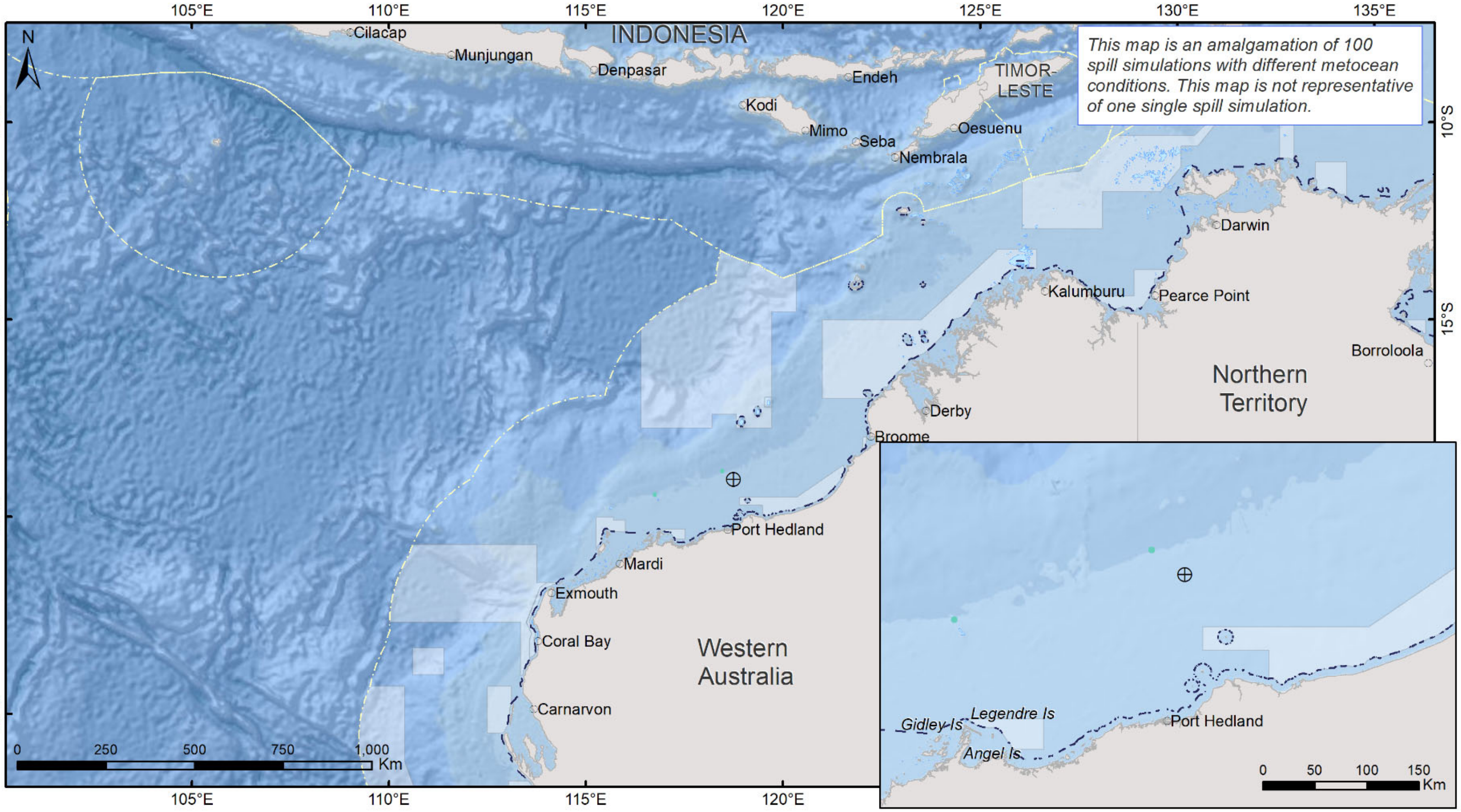


Figure 9.112 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.



Transitional
Zones of potential instantaneous dissolved hydrocarbon exposure in the 0-10m depth layer

Scenario: 1,800 m^3 instantaneous surface release of HFO
Project: MAQ0901J CDM Smith Dorado OSM

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 22/05/2020

Legend
- Release Location
- Exclusive Economic Zone
- State Borders
- 3 nm Coastal Waters
- Australian Marine Parks
- Reefs, shoals and banks

Zones of potential dissolved hydrocarbon exposure (ppb)
- 10 (Low)
- 50 (Moderate)
- 400 (High)

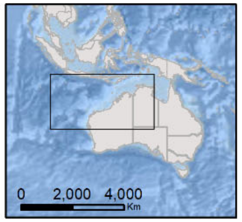


Figure 9.113 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 1,800 m³ of HFO at the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

9.6 Scenario 6: Simulation of an instantaneous surface release of crude representing a loss of contents from the FPSO

This scenario examined an instantaneous 10,108 m^3 surface release of crude from the FPSO, tracked for 42 days. A total of 300 simulations were run across three seasons; summer, transitional and winter (i.e. 100 spills per season). These are then combined and presented as exposures zones for each season (cumulative of 100 simulations) for the low, moderate and high thresholds.

Sections 9.6.1 presents overview of the EMBA based on combining the 300 spill simulations and Section 9.6.3 shows the seasonal (or stochastic) analysis. As there was no shoreline accumulation predicted for any spills during this scenario, the deterministic analysis (i.e. a single spill simulation) results presented in Section 9.6.2 are based on the largest area of floating oil (above 50 g/m^2) and the largest area of entrained hydrocarbons.

9.6.1 Overview

Figure 9.114 and Figure 9.115 are maps which encompass the full geographic EMBA derived by overlaying the combined results from all 300 spill simulations at both the low and moderate exposure thresholds, respectively.

Figure 9.116 and Figure 9.117 shows the annualised extent of floating oil and in-water (entrained and dissolved) exposure based on the low and moderate exposure thresholds, respectively, derived from all 300 spill simulations.

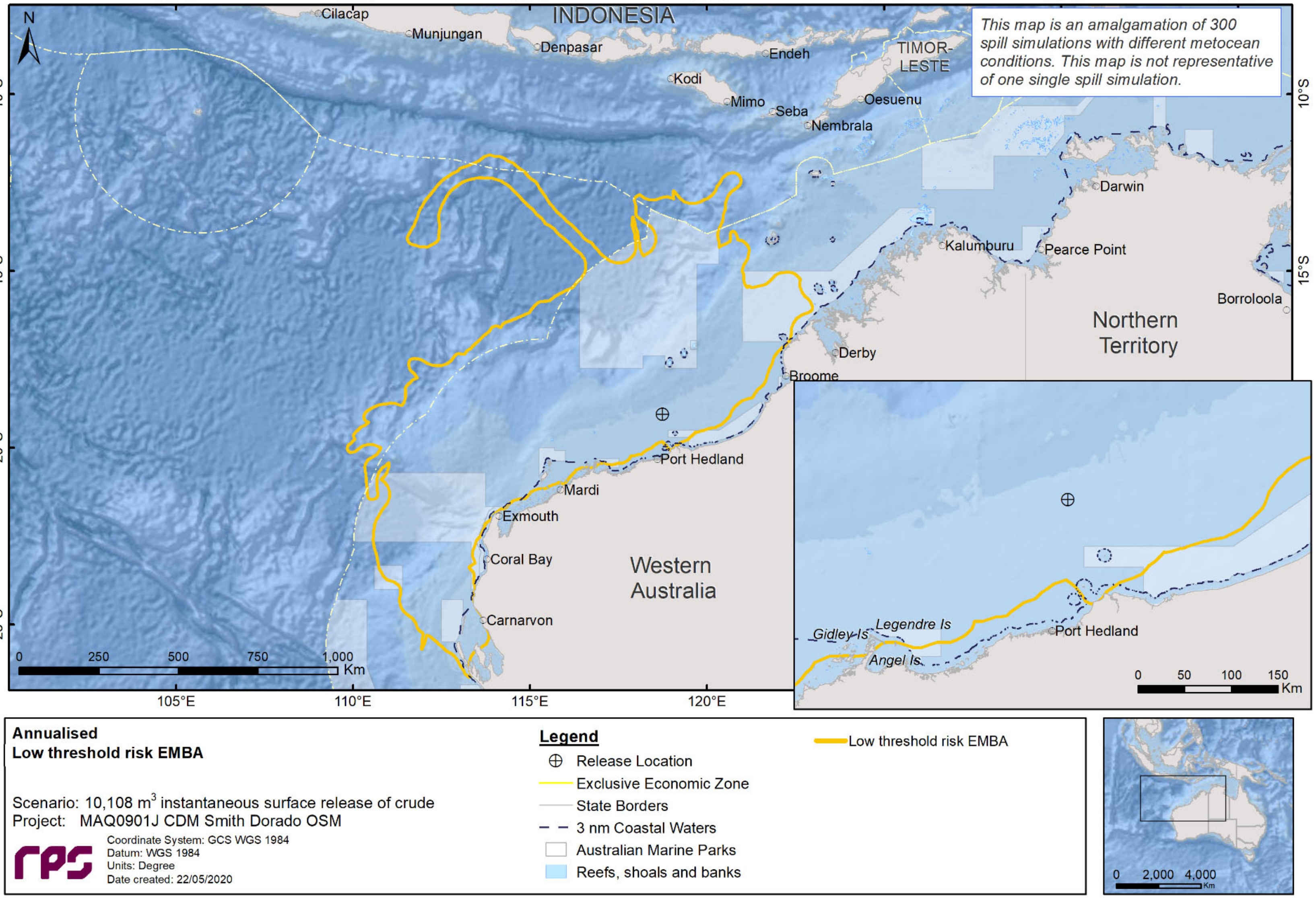


Figure 9.114 Predicted low threshold risk EMBA resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 42 days.

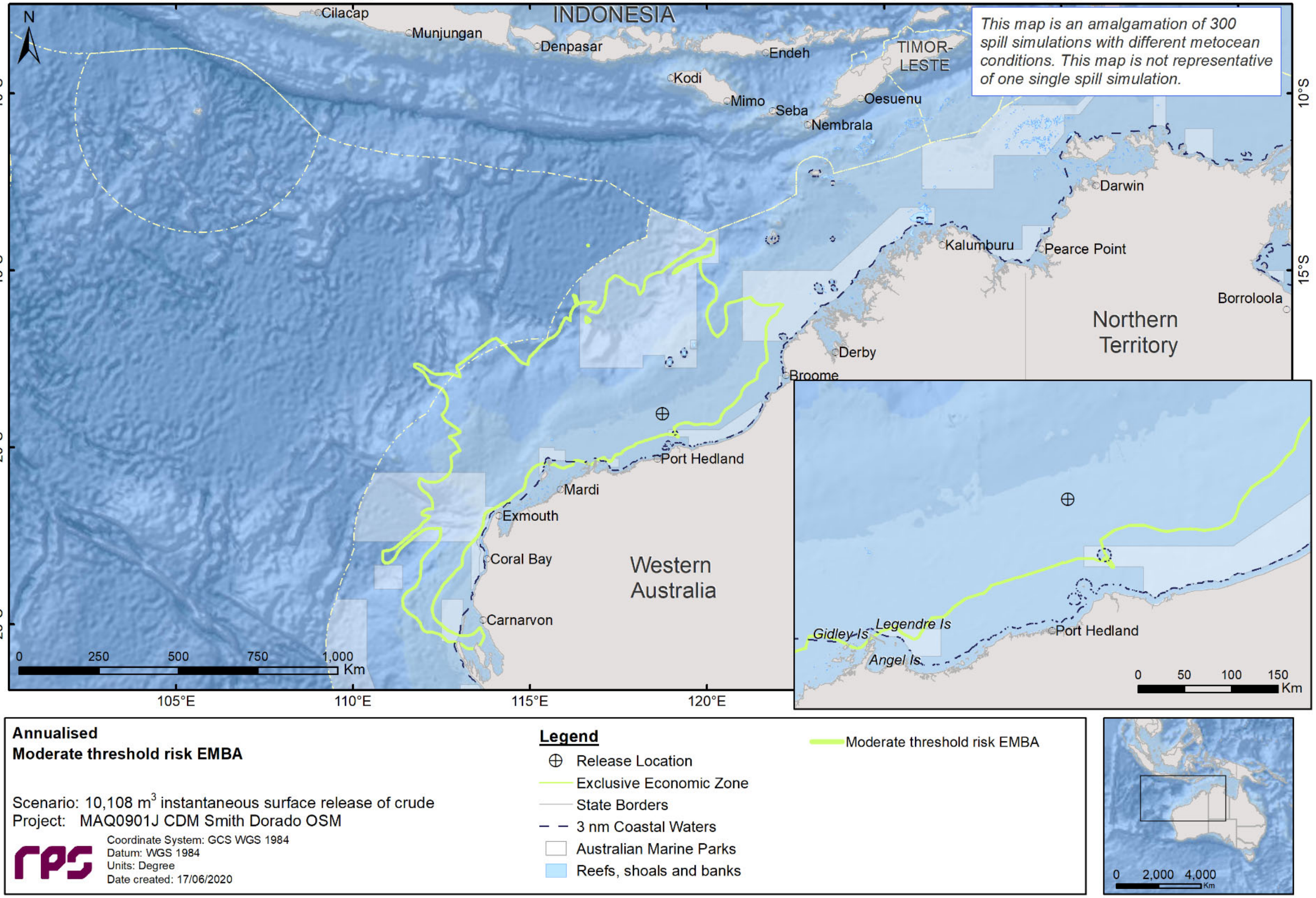


Figure 9.115 Predicted moderate threshold risk EMBA resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 42 days.

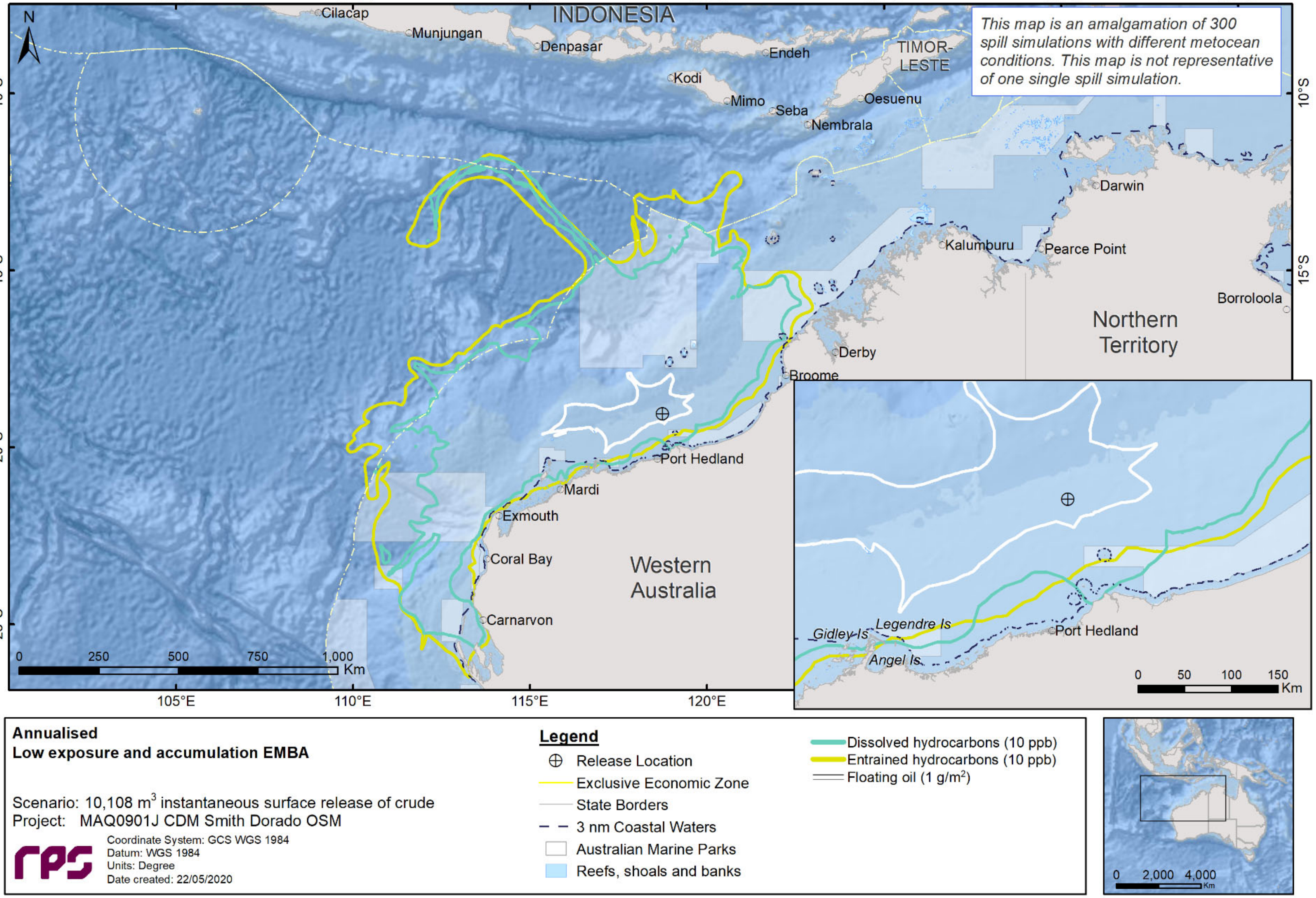


Figure 9.116 Annualised low threshold oil exposure resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 42 days.

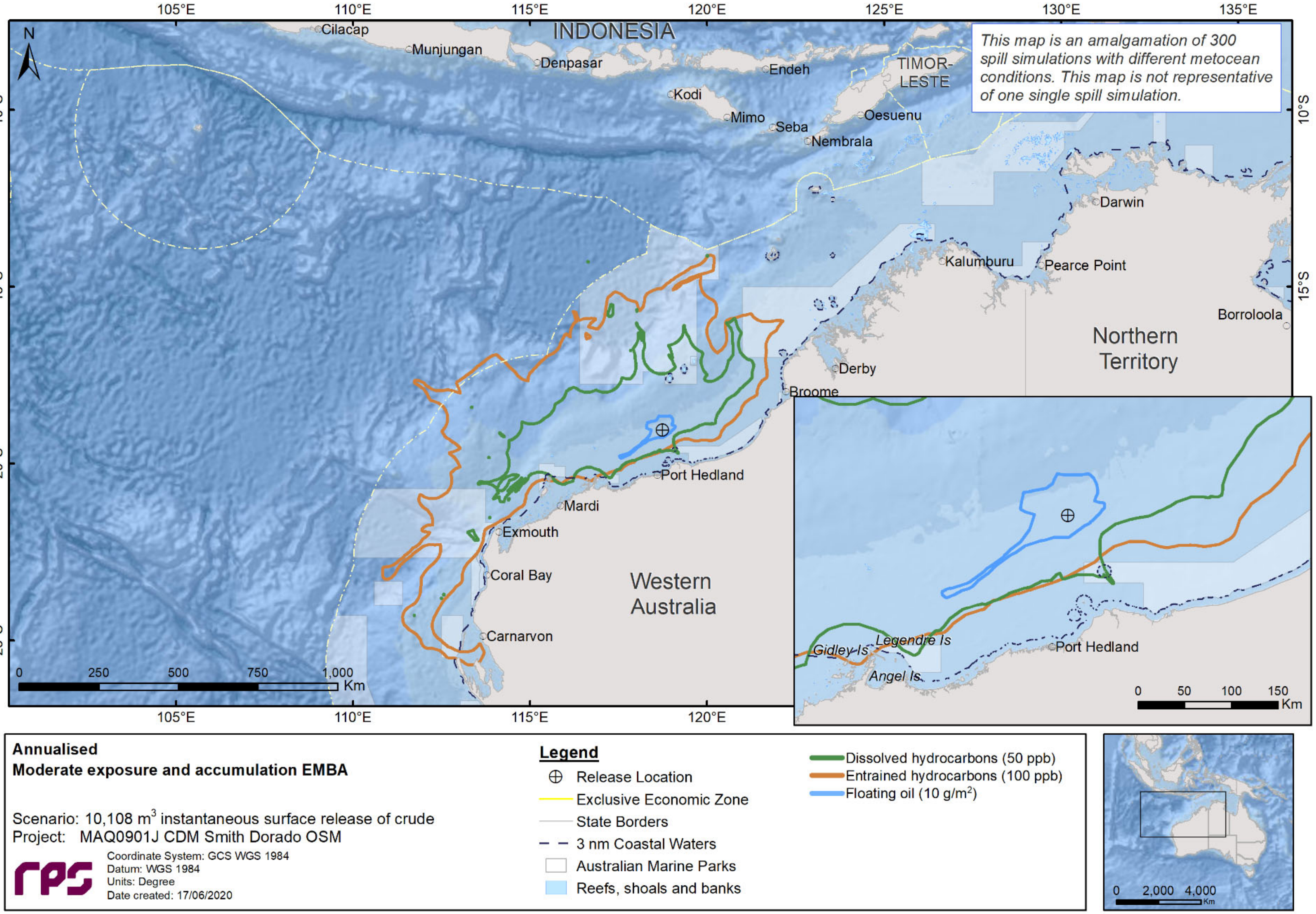


Figure 9.117 Annualised moderate threshold oil exposure resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The annualised results were calculated from 300 spill simulations, which were tracked for 42 days.

9.6.2 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic runs were identified and presented below based on the following criteria;

a. Largest area of floating oil above 50 g/m^2 (actionable floating oil); and

b. Largest area of entrained hydrocarbon exposure

9.6.2.1 Deterministic Case: Largest Area of Floating Oil above 50 g/m^2

The deterministic simulation that resulted in the largest area of floating oil above 50 g/m^2 (high or actionable surface oil threshold) was identified during summer conditions as run number 47, which commenced at 3 pm on the 26th of March 2017.

Exposure from floating oil (swept area) over the entire 42 day simulation is presented in Figure 9.118. Floating oil exposure was predicted to extend northwest from the release location up to a maximum distance of approximately 59 km at the low (1-10 g/m^2) threshold. Floating oil at the moderate (10-50 g/m^2) and high (≥50 g/m^2) thresholds were predicted to extend approximately 54 km and 47 km northeast of the release location, respectively.

Figure 9.119 displays the time series of the area of visible oil (≥1 g/m^2) and actionable floating oil (≥50 g/m^2) exposure on the sea surface over the 42-day simulation. The maximum area of coverage of visible oil on the sea surface was predicted to occur 4 days after the spill started and covered approximately 86 km^2.

Figure 9.120 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 6,724 m^3 (66%) spilled oil was lost to the atmosphere through evaporation. Approximately 2,012 m^3 (20%) of the crude was predicted to have decayed, while approximately 1,372 m^3 (14%) was predicted to remain within the water column.

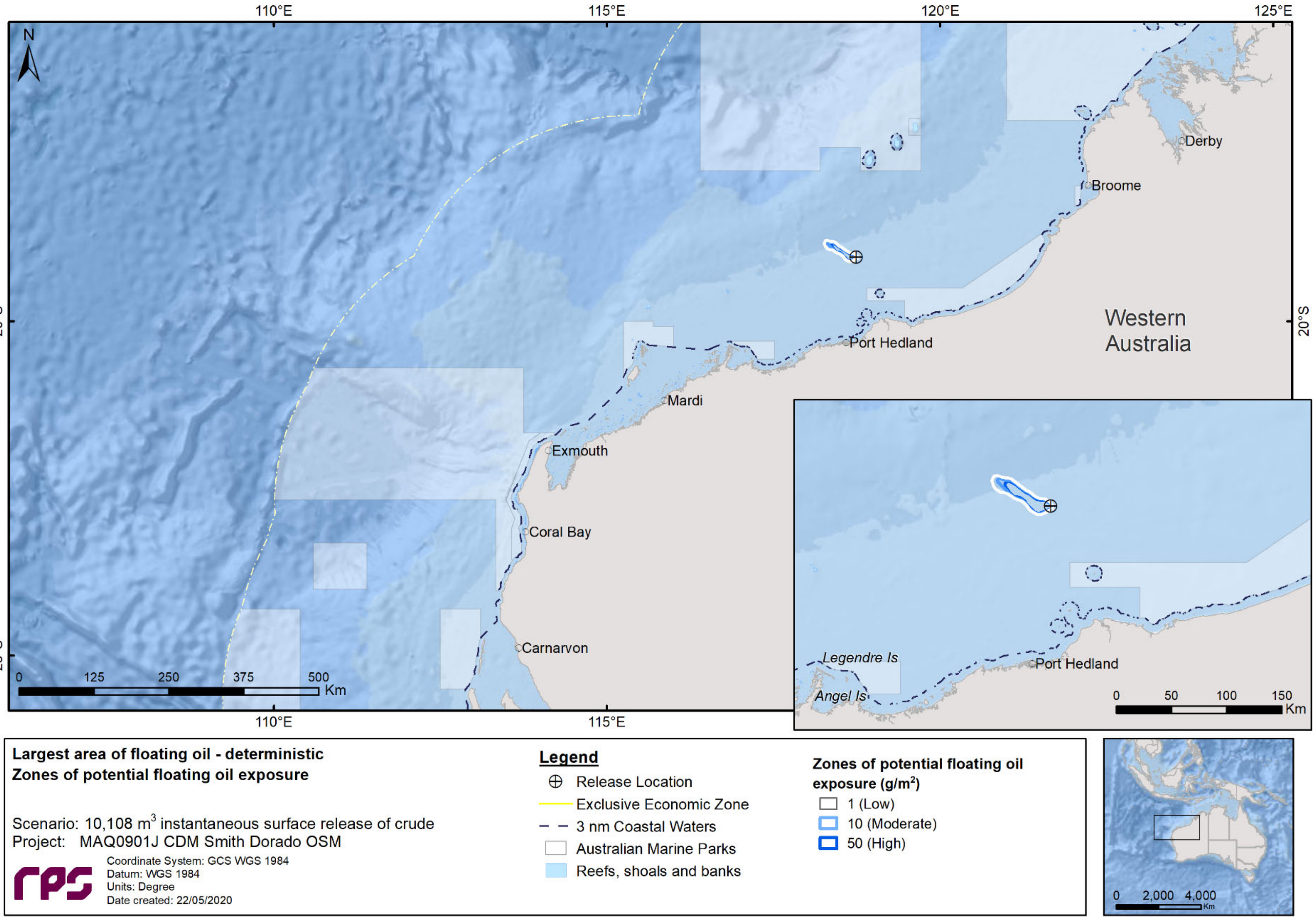


Figure 9.118 Exposure from floating oil (over the 42 day simulation) for the simulation with the largest area of floating oil above 50 g/m^2. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO, starting 3 pm on the 26th of March 2017.

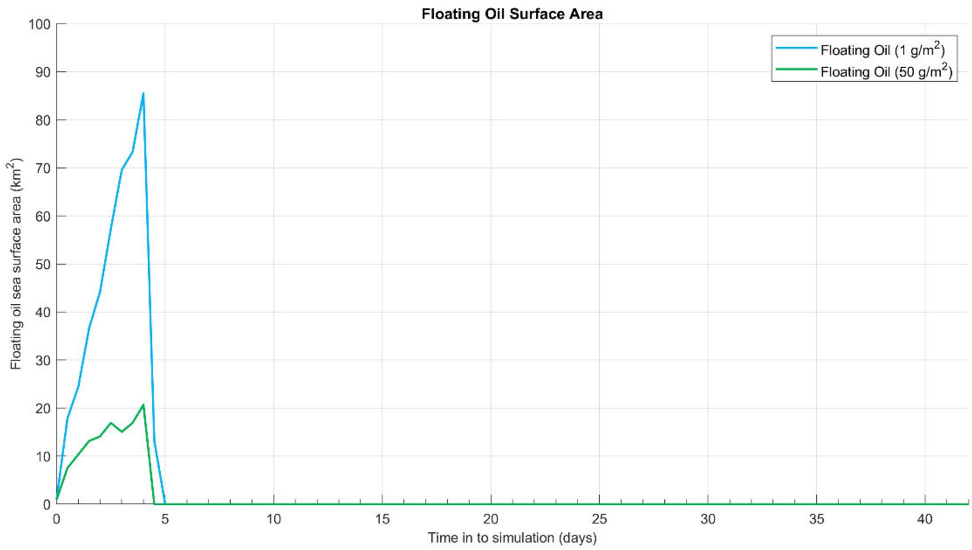


Figure 9.119 Time series of the area of visible (≥1 g/m^2) and actionable floating oil (≥50 g/m^2) on the sea surface for the simulation with the largest area of floating oil above 50 g/m^2. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO, tracked for 42 days, 3 pm on the 26th of March 2017.

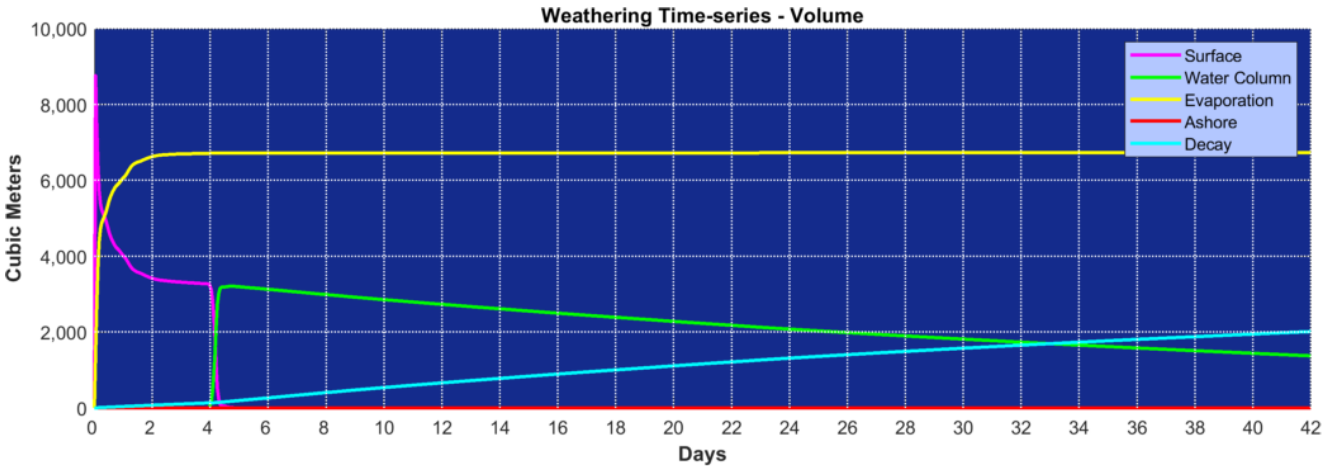


Figure 9.120 Predicted weathering and fates graph for the single spill simulation with the largest area of floating oil above 50 g/m^2. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO, tracked for 42 days, 3 pm on the 26th of March 2017.

9.6.2.2 Deterministic Case: Largest Area of Entrained Hydrocarbons

The deterministic simulation that resulted in the largest area of entrained hydrocarbons was identified during winter conditions as run number 54, which commenced at 6 am on the 23rd of August 2018.

Exposure from floating oil over the entire 42 day simulation are presented in Figure 9.121. The exposure from floating oil was predicted to be within 19 km of the release location.

Figure 9.122 presents the predicted entrained hydrocarbon exposure zones in the 0-10 m depth layer for the entire simulation. Entrained hydrocarbons at the low threshold (10-100 ppb) were predicted to extend a maximum distance of approximately 1,010 km northwest from the release location and approximately 459 km northwest at the high threshold.

Figure 9.123 presents the predicted dissolved hydrocarbon exposure zones in the 0-10 m depth layer for the entire simulation. Dissolved hydrocarbons at the low threshold (10-50 ppb) were predicted to extend a maximum distance of approximately 984 km northwest from the release location and approximately 413 km northwest and 41 km west-northwest at the moderate (50 – 400 ppb) and high (≥400 ppb) thresholds, respectively.

Figure 9.124 presents the fates and weathering graph for the corresponding single spill simulation. At the conclusion of the simulation period, approximately 4,098 m^3 (41%) spilled oil was lost to the atmosphere through evaporation. Approximately 4,391 m^3 (43%) of the crude was predicted to have decayed, while approximately 1,619 m^3 (16%) was predicted to remain within the water column.

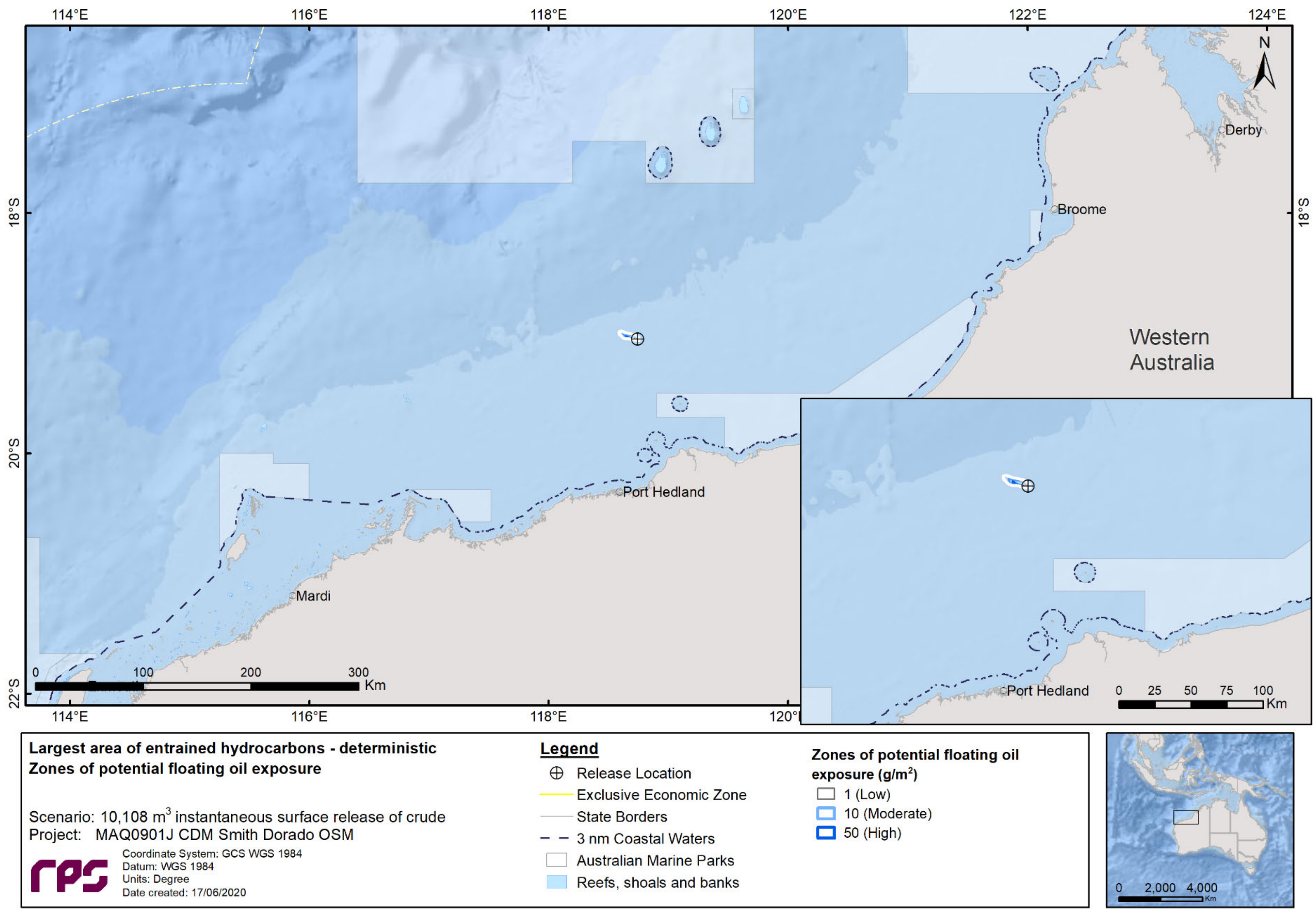


Figure 9.121 Exposure from floating oil (over the 42 day simulation) for the simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 10,108 m³ of crude from the FPSO, starting 6 am on the 23rd of August 2018.

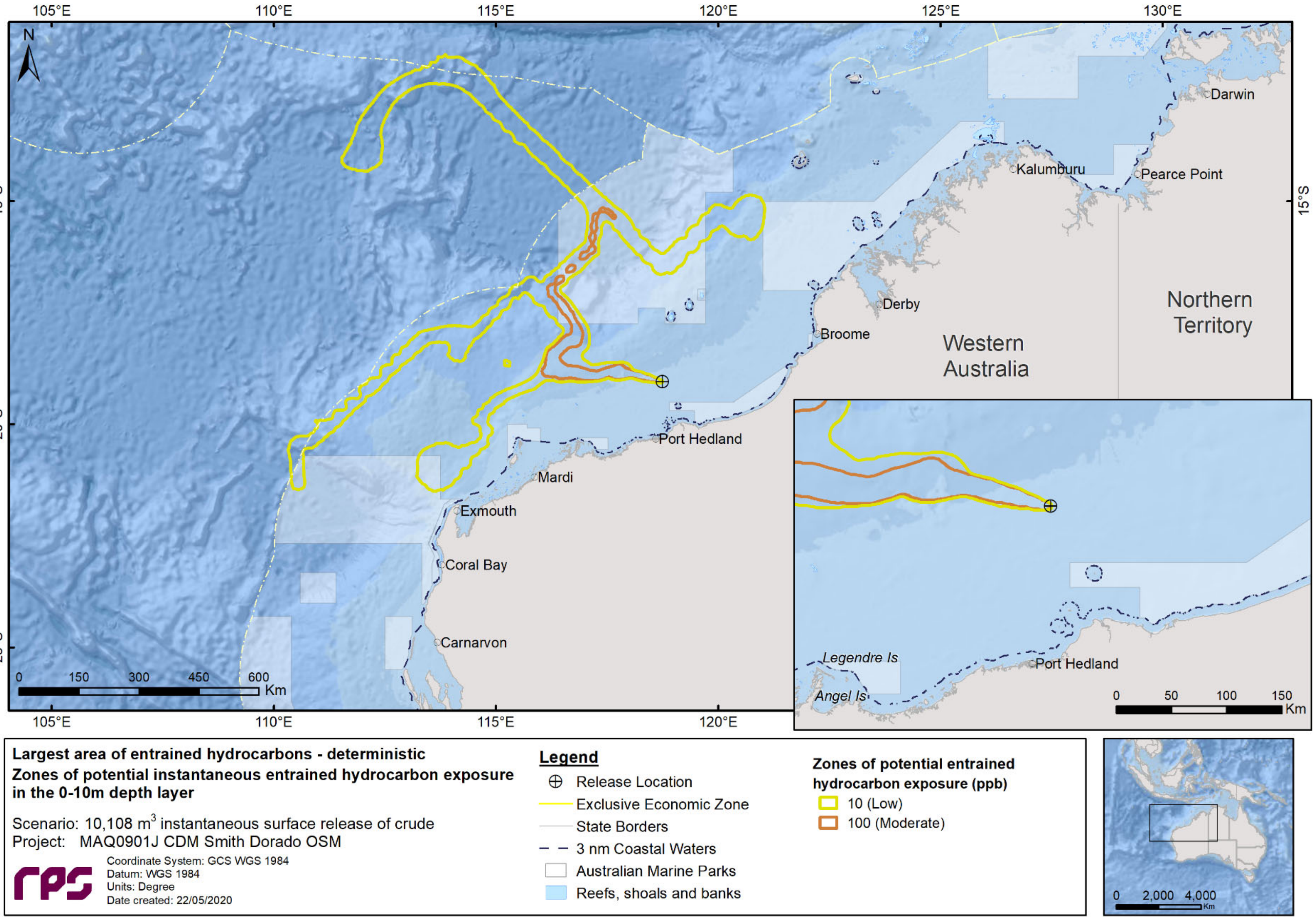


Figure 9.122 Predicted entrained hydrocarbon exposure zones in the 0-10 m depth layer for the simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 10,108 m³ of crude from the FPSO, tracked for 42 days, 6 am on the 23rd of August 2018.

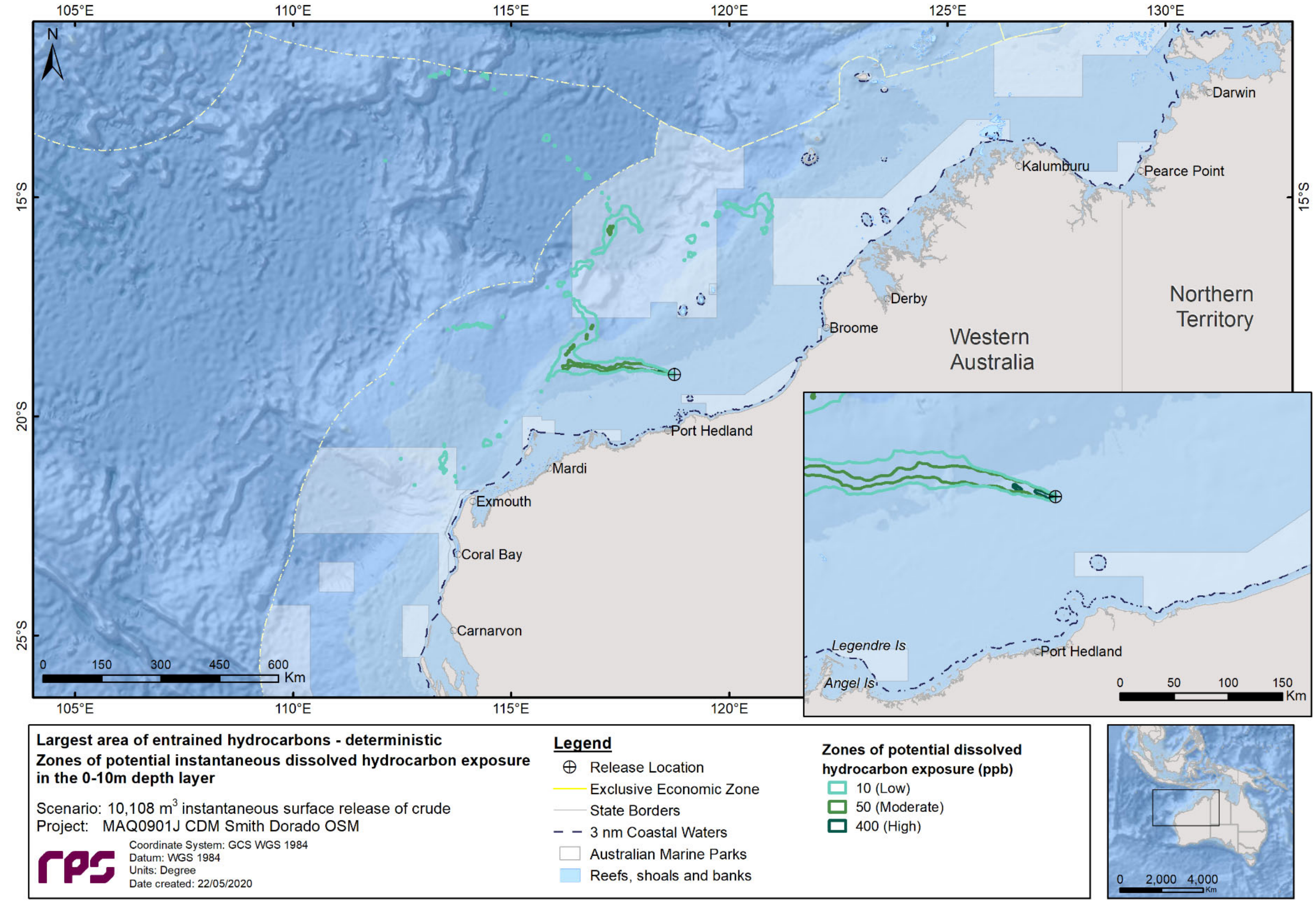


Figure 9.123 Zones of potential instantaneous dissolved hydrocarbon exposure in the 0-10 m depth layer for the simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO, tracked for 42 days, 6 am on the 23rd of August 2018.

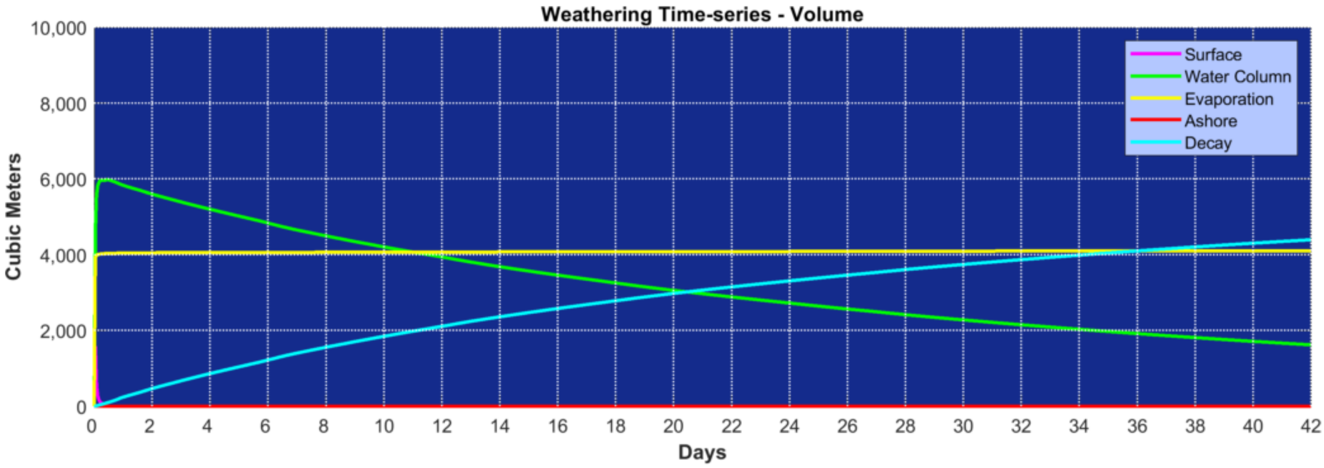


Figure 9.124 Predicted weathering and fates graph for the single spill simulation with the largest area of entrained hydrocarbons. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO, tracked for 42 days, 6 am on the 23rd of August 2018.

9.6.3 Seasonal analysis

9.6.3.1 Floating Oil Exposure

Table 9.49 summarises the maximum distances from the release location to floating oil exposure zones for each season. The maximum distance from the release location to the low (1–10 g/m^2), moderate (10–50 g/m^2) and high (≥ 50 g/m^2) exposure thresholds was 361.3 km west, 152.3 km west-southwest and 151.5 km west-southwest, respectively, all during transitional conditions.

Images of floating oil exposure zones are depicted in Figure 9.125, Figure 9.126 and Figure 9.127 for the combined 100 spill simulations commencing during summer, transitional and winter conditions, respectively.

Table 9.50 to Table 9.52 summarise the potential floating oil exposure to individual sensitive receptors for each season. Exposure at the low threshold was predicted at 1 AMP (Mermaid Reef) during the summer season only with a probability of 1% and a time of exposure of 24.5 days.

Floating oil exposure at the low threshold was predicted at 2 RSBs (Clerke Reef and Mermaid Reef), only during summer conditions and the probability of exposure was 1% for both RSBs. The shortest time before exposure was predicted at Clerke Reef, taking 12.71 days.

Low (1-10 g/m^2) floating oil was only predicted to cross WA State Waters during summer with a probability of 1%. It took 12.71 days for the oil to cross into WA State Waters.

Table 9.49 Maximum distance and direction from the release location to floating oil exposure thresholds. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations per season.

Season	Distance and direction	Exposure from floating oil		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
Summer	Max. distance from release site (km)	326	50.5	43.3
	Max distance from release site (km) (99th percentile)	138.5	46.3	41.0
	Direction	West-Southwest	West-Northwest	West-Northwest
Transitional	Max. distance from release site (km)	361.3	152.3	151.5
	Max distance from release site (km) (99th percentile)	249.1	150.1	149.9
	Direction	West	West-Southwest	West-Southwest
Winter	Max. distance from release site (km)	163	48.1	39.5
	Max distance from release site (km) (99th percentile)	114.1	43.6	38.3
	Direction	Northwest	Northeast	West-Southwest

Table 9.50 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)	Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
AMP	Mermaid Reef	1	-	-	24.50	-	-
IMCRA	Pilbara (offshore)	-	-	-	-	-	-
MP	Rowley Shoals	1	-	-	12.71	-	-
RSB	Clerke Reef	1	-	-	12.71	-	-
	Mermaid Reef	1	-	-	24.50	-	-
Nearshore	Clerke Reef	1	-	-	12.71	-	-
	Mermaid Reef	1	-	-	24.50	-	-
State Waters	Western Australia State Waters	1	-	-	12.71	-	-

Table 9.51 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptor		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)	Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
AMP	Mermaid Reef	-	-	-	-	-	-
IMCRA	Pilbara (offshore)	1	-	-	3.46	-	-
MP	Rowley Shoals	-	-	-	-	-	-
RSB	Clerke Reef	-	-	-	-	-	-
	Mermaid Reef	-	-	-	-	-	-
Nearshore	Clerke Reef	-	-	-	-	-	-
	Mermaid Reef	-	-	-	-	-	-
State Waters	Western Australia State Waters	-	-	-	-	-	-

Table 9.52 Summary of the potential floating oil exposure to individual receptors. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

	Receptor	Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)	Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (≥50 g/m^2)
AMP	Mermaid Reef	-	-	-	-	-	-
IMCRA	Pilbara (offshore)	1	-	-	2.21	-	-
MP	Rowley Shoals	-	-	-	-	-	-
RSB	Clerke Reef	-	-	-	-	-	-
	Mermaid Reef	-	-	-	-	-	-
Nearshore	Clerke Reef	-	-	-	-	-	-
	Mermaid Reef	-	-	-	-	-	-
State Waters	Western Australia State Waters	-	-	-	-	-	-

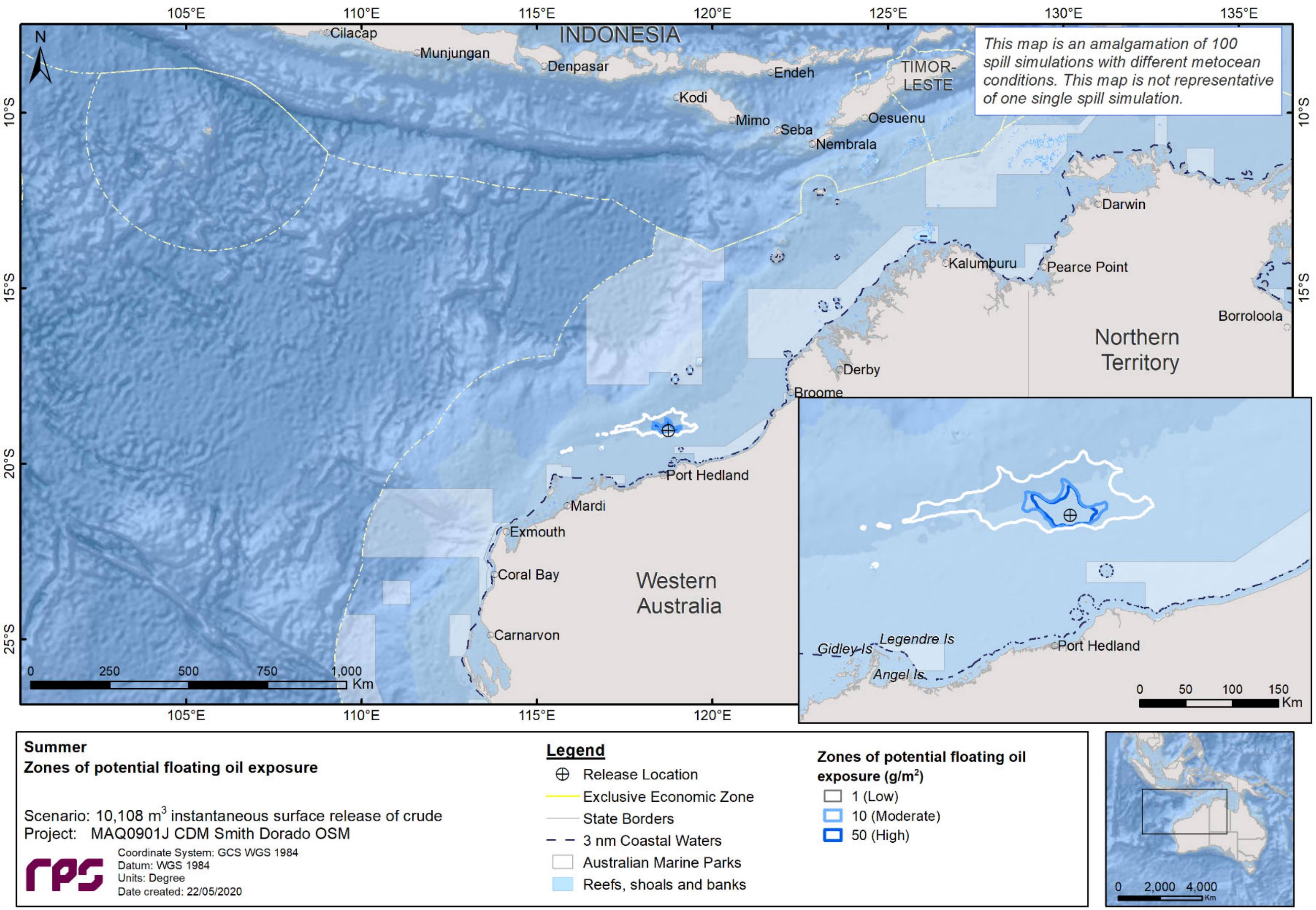


Figure 9.125 Predicted zones of potential floating oil resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

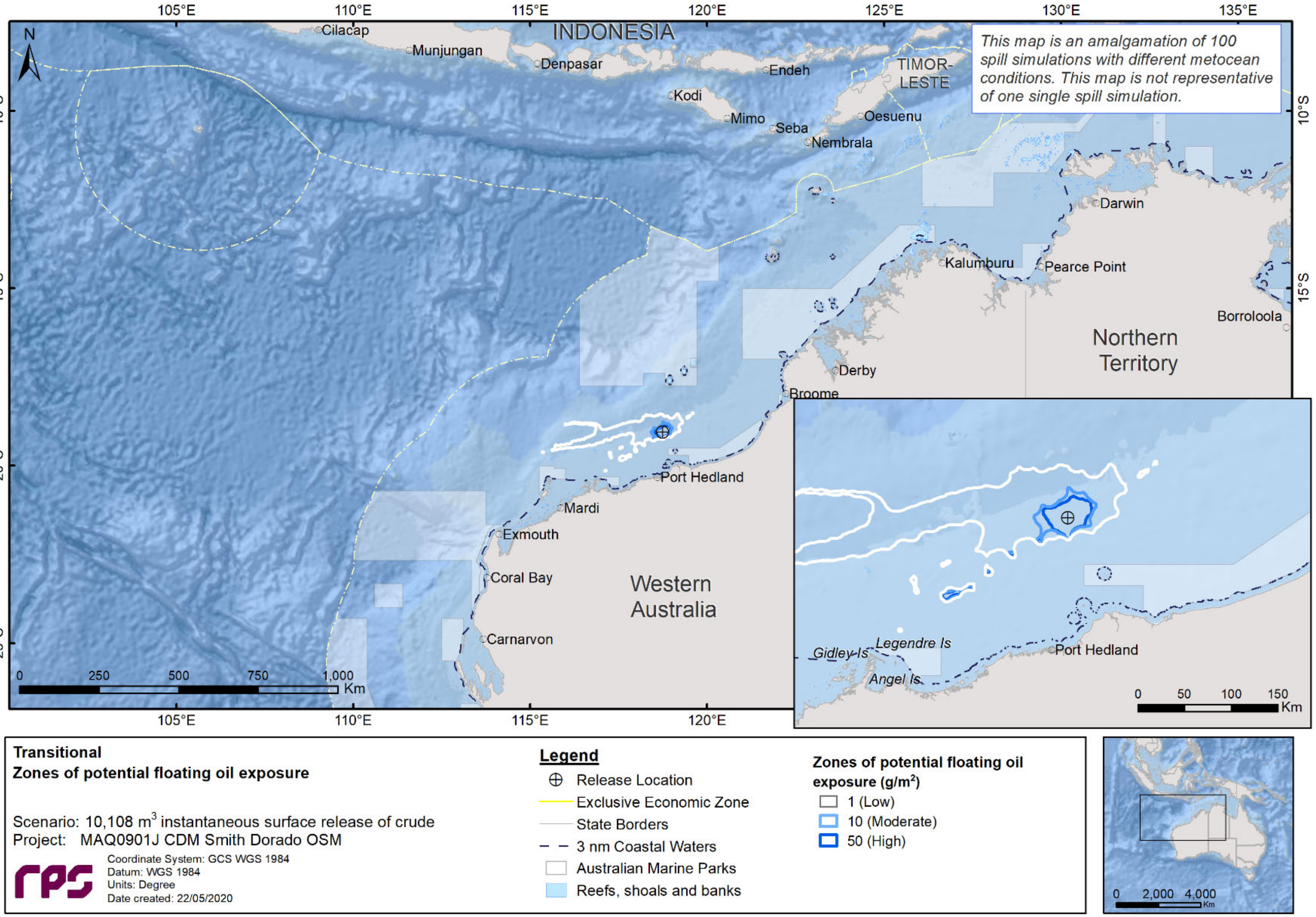


Figure 9.126 Predicted zones of potential floating oil resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

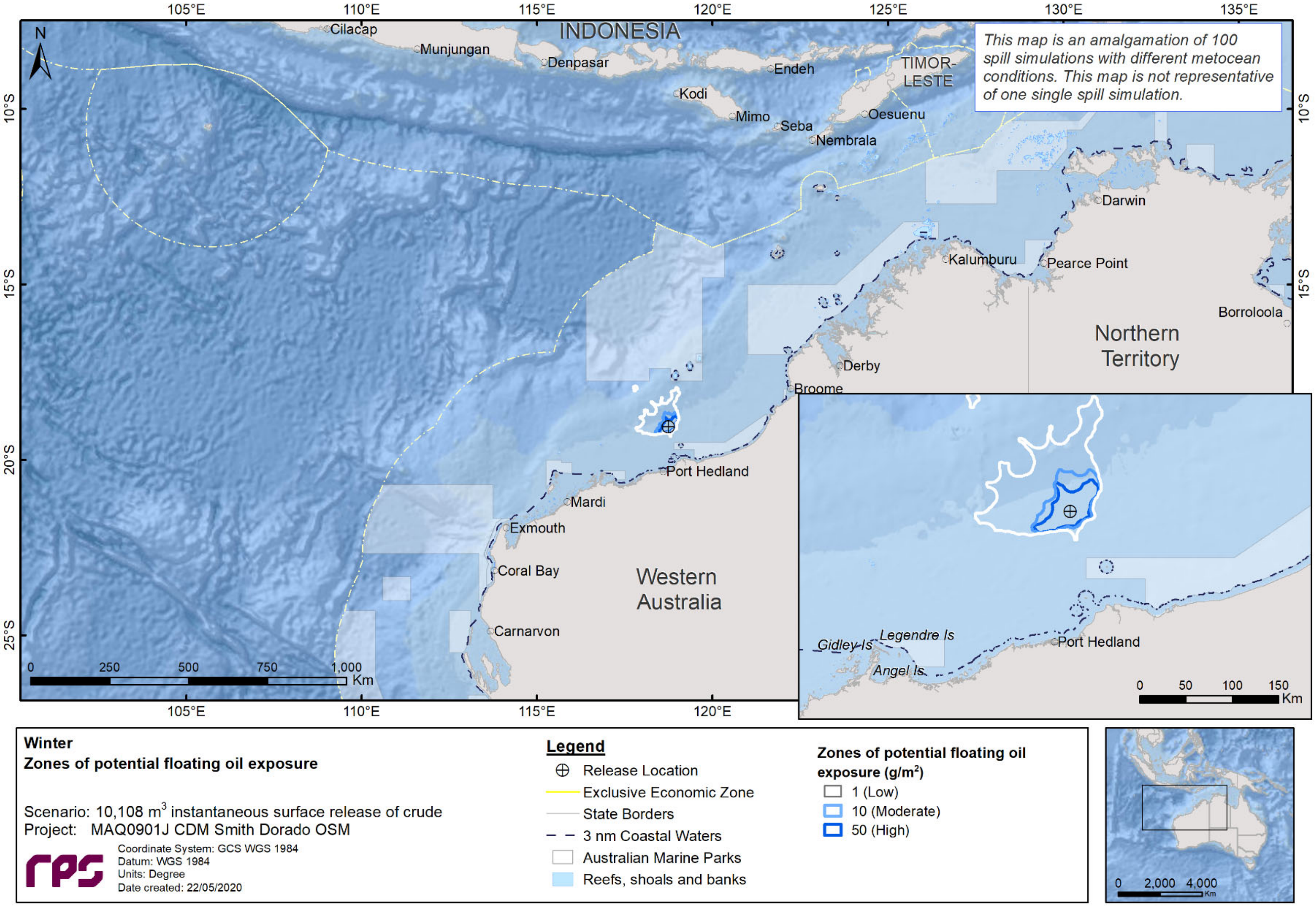


Figure 9.127 Predicted floating oil exposure zones resulting from an instantaneous surface release of 10,108 m³ of crude from the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.6.3.2 Shoreline Accumulation

There was no shoreline accumulation predicted for any spills during this scenario at, or above, the low threshold (≥10 g/m^2).

9.6.3.3 Entrained Hydrocarbons

Images of entrained hydrocarbon exposure in the 0-10 m depth layer are depicted in Figure 9.128, Figure 9.129 and Figure 9.130 for the combined 100 spills each commencing during summer, transitional and winter conditions, respectively. The seasonal results indicated that exposure at the low threshold was predicted to occur up to a maximum distance of 1,017 km (southwest) from the spill site during summer conditions. This distance reduced to 939 km (west-southwest) as the contact threshold increased to moderate (≥ 100 ppb) in summer conditions. The maximum distances for transitional and winter conditions at the low threshold were 999 km and 990 m, respectively. The maximum distances at the moderate threshold were reduced for transitional (973 km) and winter (754 km).

Table 9.53 to Table 9.55 summarise the probability of exposure to individual sensitive receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

Ten AMPs are within the low exposure zone across the 3 seasons, with the Montebello AMP recording the highest probability of exposure of 20% during winter conditions. The shortest time for entrained hydrocarbons at the low threshold to reach an AMP was recorded at Dampier during transitional conditions as 3.13 days.

Glomar Shoals was the only KEF exposed to entrained hydrocarbons at the low threshold during all 3 seasons with the probability varying from 21 to 24%. The Commonwealth waters adjacent to Ningaloo Reef KEF was the only other receptor exposed to entrained hydrocarbons at the low threshold during transitional conditions only (1% probability).

Twelve RSB are within the low exposure zone across the three seasons, with the greatest probability of exposure predicted at Ranking Bank during winter conditions (24%). The quickest time before exposure at the low threshold to an RSB receptor was predicted at Montebello Shoals, 7.9 days during winter conditions.

Entrained hydrocarbons at the low threshold were predicted to cross WA State Waters during all 3 seasons, with probabilities ranging from 8% (summer) to 15% (winter). The minimum time before oil crossed the WA State Waters boundary was 4.58 days, recorded during transitional conditions.

Table 9.53 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	10	5	7.96	8.29	1,107
	Carnarvon Canyon	2	-	32.63	-	70
	Dampier	-	-	-	-	6
	Eighty Mile Beach	2	1	33.00	35.04	131
	Gascoyne	8	3	18.50	25.54	413
	Kimberley	12	6	15.38	16.21	440
	Mermaid Reef	4	2	14.71	15.17	494
	Montebello	8	1	8.04	25.21	186
	Ningaloo	4	1	18.71	28.96	125

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Shark Bay	-	-	-	-	9
EEZ	Indonesian Exclusive Economic Zone	4	-	32.88	-	51
IBRA	Cape Range	2	1	13.00	25.25	175
	Edel	-	-	-	-	-
	Pindanland	1	-	38.96	-	47
	Roebourne	1	-	6.92	-	21
	Wooramel	-	-	-	-	<1
IMCRA	Canning	2	1	24.33	36.29	106
	Kimberley	1	-	38.63	-	70
	Ningaloo	5	1	17.58	27.83	248
	Pilbara (nearshore)	1	-	6.92	-	54
	Pilbara (offshore)	11	4	1.08	1.13	11,157
	Shark Bay	-	-	-	-	-
	Zuytdorp	1	-	35.25	-	11
KEF	Commonwealth waters adjacent to Ningaloo Reef	2	-	18.71	-	42
	Glomar Shoals	21	2	6.50	6.50	641
MP	Barrow Island	1	-	34.50	-	12
	Montebello Islands	2	1	10.92	25.25	188
	Ningaloo	2	-	21.25	-	32
	Rowley Shoals	8	3	10.92	11.00	1,082
	Shark Bay	-	-	-	-	-
NR	Great Sandy Island	1	-	37.75	-	12
RSB	Barrow Island Reefs and Shoals	1	-	36.17	-	12
	Clerke Reef	6	2	11.00	11.42	1,069
	Courtenay Shoal	-	-	-	-	1
	Glomar Shoal	-	-	-	-	-
	Hammersley Shoal	-	-	-	-	1
	Imperieuse Reef	5	3	14.67	16.46	124
	Madeleine Shoals	-	-	-	-	1
	McLennan Bank	1	-	25.33	-	20
	Mermaid Reef	4	2	15.25	15.50	482
	Montebello Shoals	2	-	14.50	-	78
	Poivre Reef	1	-	35.79	-	14

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Rankin Bank	12	6	8.13	8.13	466
	Tryal Rocks	1	-	25.29	-	26
Nearshore	Angel Island	-	-	-	-	1
	Barrow Island	1	-	31.63	-	27
	Bedout Island	-	-	-	-	6
	Bermier Island	-	-	-	-	-
	Boodie Island	1	-	34.25	-	21
	Cape Bruguieres	-	-	-	-	2
	Carnarvon	-	-	-	-	<1
	Clerke Reef	5	2	11.08	11.50	1,020
	Cohen Island	-	-	-	-	2
	Conzinc Island	-	-	-	-	1
	Cunningham Island	5	2	14.75	17.04	107
	Dirk Hartog Island	-	-	-	-	-
	Dolphin Island	-	-	-	-	4
	Dorre Island	-	-	-	-	-
	Gidley Island	-	-	-	-	2
	Goodwyn Island	-	-	-	-	1
	Haury Island	-	-	-	-	9
	Hermite Island	2	1	12.92	25.25	155
	Imperieuse Reef	5	-	15.63	-	89
	Karratha	-	-	-	-	3
	Keast Island	-	-	-	-	3
	Kendrew Island	-	-	-	-	1
	Lacepede Islands	1	-	38.96	-	47
	Legendre Island	1	-	6.92	-	11
	Lowendal Island	2	-	16.71	-	25
	Malus Island	-	-	-	-	1
	Mermaid Reef	4	1	15.38	15.79	302
	Middle Island	1	-	34.25	-	21
	Murion Islands	-	-	-	-	2
	Passage Islands	1	-	24.54	-	16
	Rosemary Island	-	-	-	-	1
	Shark Bay	-	-	-	-	-
	West Lewis Island	-	-	-	-	1

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
State Waters	Western Australia State Waters	8	3	6.92	11.00	1,082

Table 9.54 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	15	8	9.17	9.29	1,319
	Carnarvon Canyon	1	-	40.50	-	32
	Dampier	1	-	3.13	-	29
	Eighty Mile Beach	2	-	7.21	-	58
	Gascoyne	19	4	9.50	9.50	787
	Kimberley	2	-	13.42	-	70
	Mermaid Reef	10	6	12.96	13.33	830
	Montebello	15	3	4.63	4.63	2,305
	Ningaloo	1	-	16.17	-	56
	Shark Bay	1	1	24.04	25.42	302
EEZ	Indonesian Exclusive Economic Zone	1	-	36.38	-	58
IBRA	Cape Range	2	-	7.83	-	75
	Edel	1	1	25.46	25.50	238
	Pindanland	-	-	-	-	6
	Roebourne	1	1	11.46	24.21	110
	Wooramel	1	1	25.58	25.58	319
IMCRA	Canning	2	-	28.29	-	34
	Kimberley	-	-	-	-	3
	Ningaloo	2	-	31.29	-	18
	Pilbara (nearshore)	2	1	8.38	23.75	150
	Pilbara (offshore)	18	10	0.54	2.63	4,944
	Shark Bay	1	1	25.50	25.50	358
	Zuytdorp	1	1	23.96	24.04	356

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
KEF	Commonwealth waters adjacent to Ningaloo Reef	1	-	16.17	-	19
	Glomar Shoals	24	6	3.67	3.67	1,835
MP	Barrow Island	1	-	29.50	-	14
	Montebello Islands	2	1	7.83	7.83	232
	Ningaloo	1	-	39.58	-	15
	Rowley Shoals	11	9	11.25	11.54	950
	Shark Bay	1	1	25.50	25.50	319
NR	Great Sandy Island	1	-	24.04	-	23
RSB	Barrow Island Reefs and Shoals	-	-	-	-	7
	Clerke Reef	11	9	11.50	11.83	936
	Courtenay Shoal	1	1	23.75	23.96	115
	Glomar Shoal	25	11	6.88	11.25	469
	Hammersley Shoal	1	-	23.75	-	58
	Imperieuse Reef	10	-	16.75	-	66
	Madeleine Shoals	1	-	23.88	-	19
	McLennan Bank	-	-	-	-	6
	Mermaid Reef	9	4	13.71	14.29	662
	Montebello Shoals	2	-	7.88	-	42
	Poivre Reef	-	-	-	-	3
	Rankin Bank	13	2	7.79	14.83	235
	Tryal Rocks	3	1	7.92	7.92	183
Nearshore	Angel Island	1	-	23.83	-	56
	Barrow Island	1	-	24.08	-	38
	Bedout Island	1	-	11.46	-	14
	Bermier Island	1	-	26.38	-	12
	Boodie Island	-	-	-	-	4
	Cape Bruguieres	1	-	23.79	-	70
	Carnarvon	1	-	32.13	-	36
	Clerke Reef	11	9	11.83	12.13	888
	Cohen Island	1	-	23.75	-	59
	Conzinc Island	1	-	23.96	-	25
	Cunningham Island	10	-	22.00	-	64
	Dirk Hartog Island	1	1	25.50	25.50	238
	Dolphin Island	1	-	23.92	-	30

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Dorre Island	1	-	25.50	-	16
	Gidley Island	1	-	23.83	-	75
	Goodwyn Island	1	-	31.00	-	13
	Haury Island	1	-	24.92	-	11
	Hermite Island	2	-	7.83	-	75
	Imperieuse Reef	10	-	17.21	-	61
	Karratha	1	-	24.00	-	21
	Keast Island	1	-	23.83	-	42
	Kendrew Island	1	-	23.75	-	33
	Lacepede Islands	-	-	-	-	3
	Legendre Island	1	-	23.88	-	29
	Lowendal Island	1	-	24.96	-	19
	Malus Island	1	-	23.75	-	68
	Mermaid Reef	7	4	14.38	14.83	651
	Middle Island	-	-	-	-	5
	Murion Islands	-	-	-	-	2
	Passage Islands	1	-	24.00	-	23
	Rosemary Island	1	1	23.71	23.79	110
	Shark Bay	1	1	25.46	25.58	315
	West Lewis Island	1	-	23.92	-	36
State Waters	Western Australia State Waters	11	9	4.58	4.63	950

Table 9.55 Probability of exposure to individual receptors from instantaneous entrained hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	16	6	16.92	17.67	539
	Carnarvon Canyon	1	-	41.00	-	51
	Dampier	1	-	16.96	-	77
	Eighty Mile Beach	1	-	4.13	-	92
	Gascoyne	9	1	25.83	26.17	348
	Kimberley	1	-	40.00	-	18
	Mermaid Reef	4	1	27.54	28.17	119
	Montebello	20	5	9.13	9.33	505
	Ningaloo	1	-	30.83	-	22
	Shark Bay	-	-	-	-	-
EEZ	Indonesian Exclusive Economic Zone	1	-	35.08	-	34
IBRA	Cape Range	1	-	21.79	-	22
	Edel	-	-	-	-	-
	Pindanland	-	-	-	-	-
	Roebourne	1	-	27.33	-	23
	Wooramel	-	-	-	-	-
IMCRA	Canning	-	-	-	-	-
	Kimberley	-	-	-	-	-
	Ningaloo	2	-	29.38	-	27
	Pilbara (nearshore)	1	-	18.83	-	65
	Pilbara (offshore)	24	7	1.13	1.46	16,831
	Shark Bay	-	-	-	-	-
	Zuytdorp	-	-	-	-	-
KEF	Commonwealth waters adjacent to Ningaloo Reef	-	-	-	-	-
	Glomar Shoals	26	11	5.25	5.38	457
MP	Barrow Island	-	-	-	-	9
	Montebello Islands	1	-	21.29	-	27
	Ningaloo	1	-	33.33	-	13
	Rowley Shoals	15	5	18.71	20.63	227
	Shark Bay	-	-	-	-	-

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
NR	Great Sandy Island	-	-	-	-	1
RSB	Barrow Island Reefs and Shoals	-	-	-	-	2
	Clerke Reef	3	-	36.46	-	16
	Courtenay Shoal	-	-	-	-	1
	Glomar Shoal	29	14	5.29	5.38	1,369
	Hammersley Shoal	-	-	-	-	9
	Imperieuse Reef	13	4	19.25	21.17	221
	Madeleine Shoals	1	-	26.92	-	44
	McLennan Bank	-	-	-	-	1
	Mermaid Reef	3	-	28.00	-	99
	Montebello Shoals	1	-	21.92	-	17
	Poivre Reef	-	-	-	-	4
	Rankin Bank	24	5	8.58	14.42	258
	Tryal Rocks	3	-	21.88	-	23
Nearshore	Angel Island	-	-	-	-	1
	Barrow Island	-	-	-	-	6
	Bedout Island	-	-	-	-	1
	Bermier Island	-	-	-	-	-
	Boodie Island	-	-	-	-	4
	Cape Bruguieres	-	-	-	-	4
	Carnarvon	-	-	-	-	-
	Clerke Reef	1	-	37.33	-	16
	Cohen Island	1	-	28.38	-	13
	Conzinc Island	-	-	-	-	<1
	Cunningham Island	12	1	21.25	28.54	192
	Dirk Hartog Island	-	-	-	-	-
	Dolphin Island	-	-	-	-	2
	Dorre Island	-	-	-	-	-
	Gidley Island	-	-	-	-	3
	Goodwyn Island	-	-	-	-	2
	Haury Island	-	-	-	-	3
	Hermite Island	1	-	21.79	-	22
	Imperieuse Reef	12	1	20.67	28.04	222
	Karratha	-	-	-	-	1
	Keast Island	1	-	27.88	-	13

Receptors		Probability (%) of entrained hydrocarbon exposure		Minimum time (days) before hydrocarbon exposure at any depth		Maximum entrained hydrocarbon concentration (ppb)
		Low (10-100 ppb)	Moderate (≥ 100 ppb)	Low (10-100 ppb)	Moderate (≥ 100 ppb)	for a single simulation at any depth
	Kendrew Island	-	-	-	-	2
	Lacepede Islands	-	-	-	-	-
	Legendre Island	1	-	27.29	-	27
	Lowendal Island	-	-	-	-	1
	Malus Island	-	-	-	-	1
	Mermaid Reef	2	-	28.54	-	99
	Middle Island	-	-	-	-	4
	Murion Islands	1	-	33.79	-	11
	Passage Islands	-	-	-	-	1
	Rosemary Island	-	-	-	-	3
	Shark Bay	-	-	-	-	-
	West Lewis Island	-	-	-	-	1
State Waters	Western Australia State Waters	15	4	18.71	20.63	226

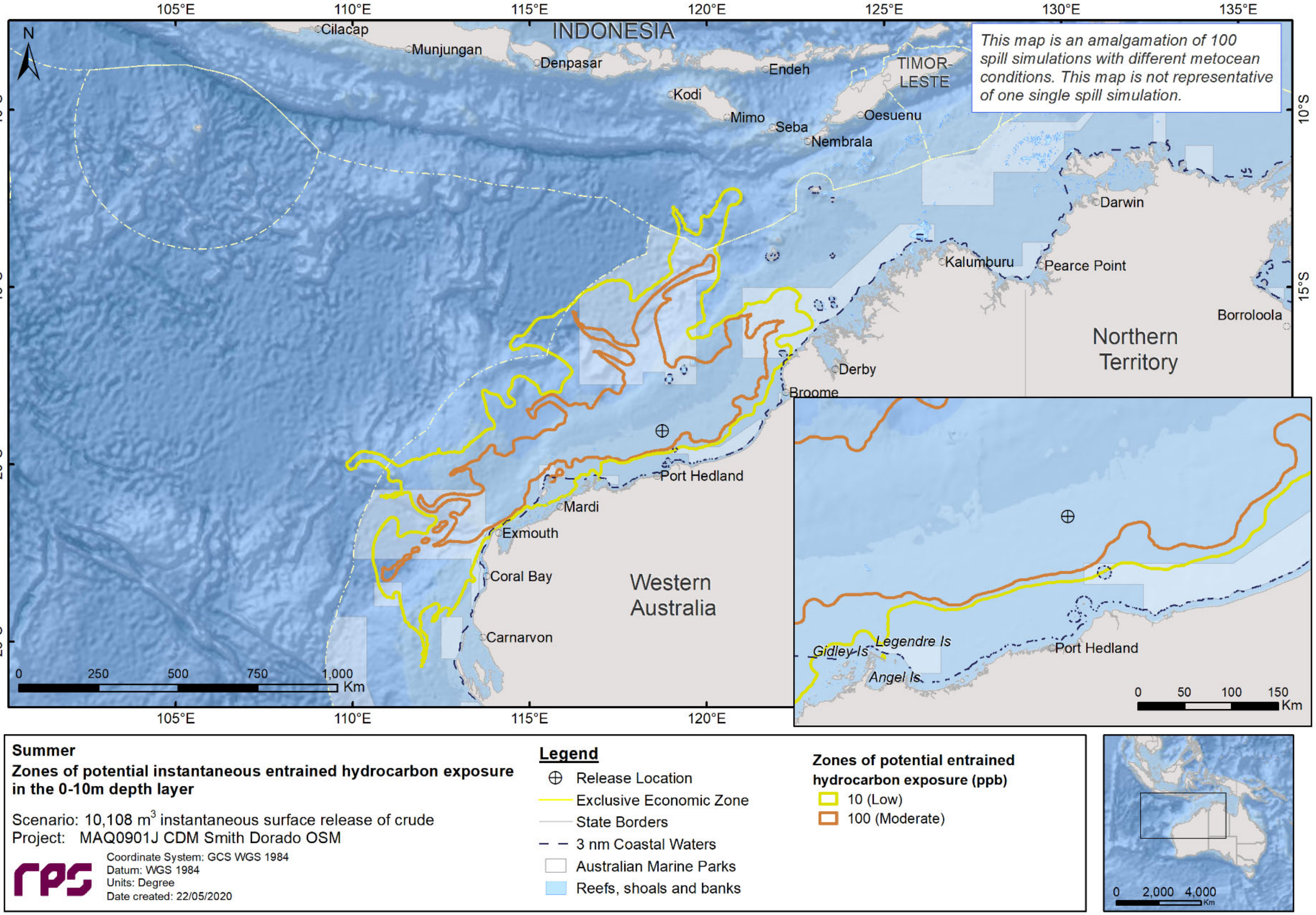


Figure 9.128 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

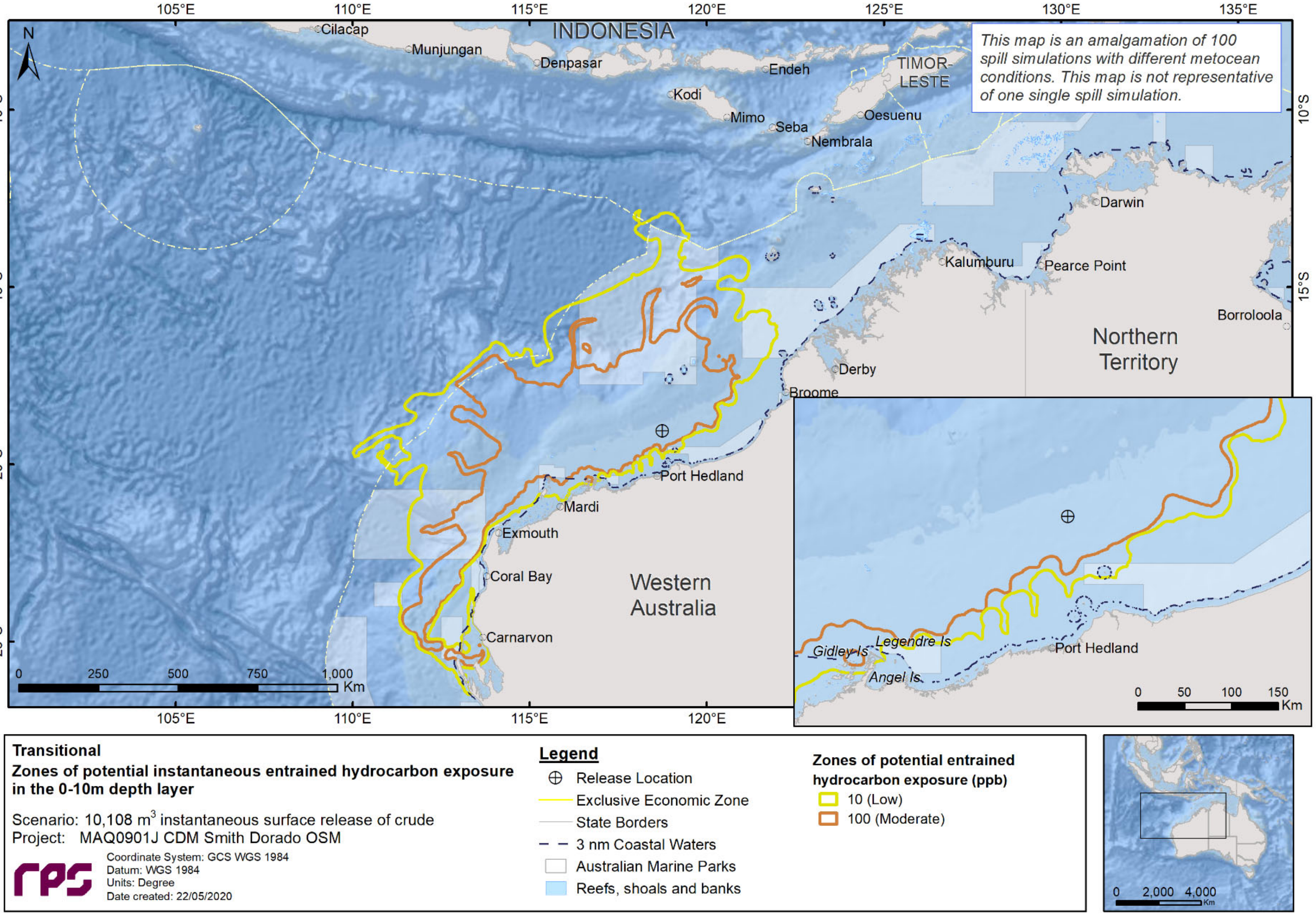


Figure 9.129 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

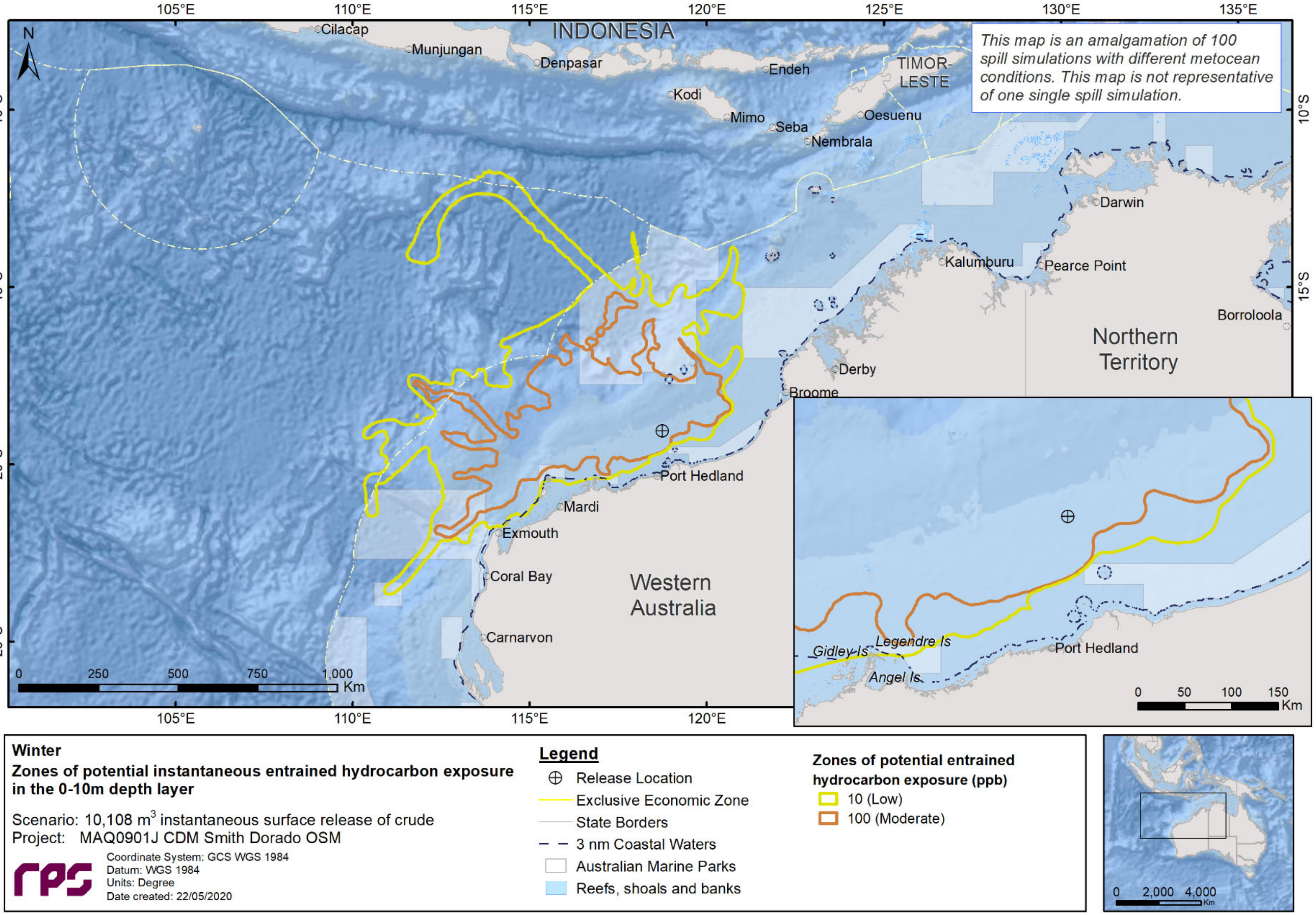


Figure 9.130 Predicted entrained hydrocarbon exposure zones resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

9.6.3.4 Dissolved Hydrocarbons

Images of dissolved hydrocarbon exposure zones are depicted in Figure 9.131, Figure 9.132 and Figure 9.133 for the combined 100 spill simulations each commencing during summer, transitional and winter conditions, respectively. The maximum distance from the spill site to the low exposure threshold (10-50 ppb) for summer, transitional and winter results were 940 km (west-southwest), 978 km (southwest) and 967 km (northwest), respectively. This distance reduced to 564 km (north northeast; summer), 931 km (southwest; transitional) and 573 km (west; winter) as the threshold increased to moderate (50 – 400 ppb). Based on the high threshold (≥400 ppb) the distance reduced further to 45 km (west southwest; summer), 58 km (west; transitional) and 88 km (west southwest; winter).

Table 9.56 to Table 9.58 summarise the probability of exposure to receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer, for each season. Note the probability and maximum concentrations for the KEFs and Glomar Shoals RSB were individually assessed at their shallowest depth from the sea surface.

Across the 3 seasons, 10 AMPs are within the low exposure zone, with Argo-Rowley Terrace AMP recording the highest probability of exposure of 7% during transitional conditions. Dampier AMP was predicted to be exposed quickest at 4.13 days during transitional conditions. Glomar Shoals was the only KEF to be exposed by dissolved hydrocarbons at the low threshold with probabilities between 1 – 6%.

Five RSB are within the low exposure zone across the three seasons, with the highest probability predicted at Clerke Reef during transitional conditions (6%). The minimum time before exposure at an RSB receptor was 7.9 days at Rankin Bank during transitional conditions.

Dissolved hydrocarbons at the low threshold were predicted to cross WA State Waters during every season with probabilities ranging from 3-7%. The minimum time before oil crossed the WA State Waters boundary was 4.63 days during transitional conditions.

Table 9.56 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during summer (October to March) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	5	2	-	8.33	9.54	-	154
	Carnarvon Canyon	-	-	-	-	-	-	8
	Dampier	-	-	-	-	-	-	<1
	Eighty Mile Beach	-	-	-	-	-	-	8
	Gascoyne	2	-	-	24.83	-	-	46
	Kimberley	5	-	-	16.96	-	-	47
	Mermaid Reef	3	-	-	15.92	16.88	-	38
	Montebello	1	-	-	8.04	-	-	39
	Ningaloo	1	-	-	30.21	-	-	14
	Shark Bay	-	-	-	-	-	-	2

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
EEZ	Indonesian Exclusive Economic Zone	1	-	-	33.67	-	-	11
IBRA	Cape Range	1	-	-	25.25	-	-	34
	Edel	-	-	-	-	-	-	-
	Roebourne	-	-	-	-	-	-	5
	Wooramel	-	-	-	-	-	-	<1
IMCRA	Canning	1	-	-	41.21	-	-	12
	Eighty Mile Beach	-	-	-	-	-	-	1
	Ningaloo	1	-	-	34.00	-	-	17
	Pilbara (nearshore)	-	-	-	-	-	-	5
	Pilbara (offshore)	3	1	-	1.58	1.67	-	156
	Shark Bay	-	-	-	-	-	-	-
	Zuytdorp	-	-	-	-	-	-	2
KEF	Glomar Shoals	1	-	-	1.13	-	-	15
MP	Montebello Islands	1	-	-	25.25	-	-	34
	Rowley Shoals	3	1	-	10.83	11.54	-	108
	Shark Bay	-	-	-	-	-	-	-
RSB	Clerke Reef	2	1	-	11.04	11.58	-	82
	Glomar Shoal	5	-	-	6.96	-	-	21
	Imperieuse Reef	3	-	-	15.13	-	-	47
	Mermaid Reef	3	-	-	16.33	17.38	-	38
	Montebello Shoals	1	-	-	25.29	-	-	21
	Rankin Bank	3	-	-	19.67	-	-	23
Nearshore	Barrow Island	-	-	-	-	-	-	7
	Bedout Island	-	-	-	-	-	-	<1
	Bermier Island	-	-	-	-	-	-	-
	Clerke Reef	2	1	-	11.63	12.25	-	82
	Cunningham Island	2	-	-	16.00	-	-	47
	Hermite Island	1	-	-	25.25	-	-	34
	Imperieuse Reef	2	-	-	16.00	-	-	33
	Mermaid Reef	1	-	-	16.79	-	-	16
	Port Hedland	-	-	-	-	-	-	-

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Rosemary Island	-	-	-	-	-	-	1
	Shark Bay	-	-	-	-	-	-	-
State Waters	Western Australia State Waters	3	1	-	8.21	11.54	-	108

Table 9.57 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during transitional (April and September) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	7	1	-	9.83	11.92	-	104
	Carnarvon Canyon	-	-	-	-	-	-	3
	Dampier	1	-	-	4.13	13.33	-	39
	Eighty Mile Beach	1	1	-	10.13	12.33	-	51
	Gascoyne	2	1	-	9.54	9.75	-	72
	Kimberley	1	-	-	20.58	-	-	13
	Mermaid Reef	4	1	-	14.38	15.58	-	109
	Montebello	3	1	-	4.63	4.63	-	163
	Ningaloo	-	-	-	-	-	-	9
	Shark Bay	1	-	-	24.17	-	-	32
EEZ	Indonesian Exclusive Economic Zone	-	-	-	-	-	-	9
IBRA	Cape Range	1	-	-	7.92	-	-	22
	Edel	1	-	-	25.46	-	-	21
	Roebourne	1	-	-	11.46	-	-	48
	Wooramel	1	-	-	25.96	-	-	21
IMCRA	Canning	-	-	-	-	-	-	3
	Eighty Mile Beach	1	-	-	15.83	-	-	18
	Ningaloo	-	-	-	-	-	-	9
	Pilbara (nearshore)	1	-	-	11.25	-	-	27
	Pilbara (offshore)	9	4	-	3.04	3.04	-	179
	Shark Bay	1	-	-	25.54	-	-	39
	Zuytdorp	1	-	-	24.04	-	-	36
KEF	Glomar Shoals	2	-	-	1.79	-	-	28
MP	Montebello Islands	1	-	-	7.88	-	-	25
	Rowley Shoals	7	1	-	12.33	13.29	-	79
	Shark Bay	1	-	-	25.83	-	-	39
RSB	Clerke Reef	6	1	-	12.50	19.38	-	53
	Glomar Shoal	4	-	-	12.29	-	-	35

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
	Imperieuse Reef	2	-	-	22.33	-	-	22
	Mermaid Reef	3	1	-	14.83	15.88	-	55
	Montebello Shoals	-	-	-	-	-	-	7
	Rankin Bank	3	-	-	7.92	-	-	20
Nearshore	Barrow Island	1	-	-	24.92	-	-	12
	Bedout Island	1	-	-	11.46	-	-	48
	Bermier Island	1	-	-	25.46	-	-	21
	Clerke Reef	6	-	-	12.88	-	-	46
	Cunningham Island	2	-	-	22.17	-	-	19
	Hermite Island	1	-	-	7.92	-	-	22
	Imperieuse Reef	2	-	-	22.42	-	-	22
	Mermaid Reef	2	1	-	15.54	15.88	-	55
	Port Hedland	1	-	-	11.50	-	-	22
	Rosemary Island	1	-	-	24.25	-	-	11
	Shark Bay	1	-	-	25.96	-	-	24
State Waters	Western Australia State Waters	7	1	-	4.63	4.63	-	112

Table 9.58 Probability of exposure to individual receptors from instantaneous dissolved hydrocarbons in the 0-10 m depth layer. Results are based on an instantaneous surface release of 10,108 m^3 of crude from the FPSO during winter (May to August) conditions. The results were calculated from 100 spill simulations.

Receptors		Probability (%) of dissolved hydrocarbon exposure			Minimum time (days) before hydrocarbon exposure at any depth			Maximum dissolved hydrocarbon concentration (ppb)
		Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	Low (10-50ppb)	Moderate (50-400 ppb)	High (≥400 ppb)	for a single simulation at any depth
AMP	Argo-Rowley Terrace	3	1	-	18.00	18.21	-	74
	Carnarvon Canyon	1	-	-	41.04	-	-	18
	Dampier	-	-	-	-	-	-	3
	Eighty Mile Beach	-	-	-	-	-	-	1
	Gascoyne	3	-	-	26.71	-	-	40
	Kimberley	-	-	-	-	-	-	8

	Mermaid Reef	1	-	-	28.54	-	-	17
	Montebello	6	1	-	10.04	12.13	-	64
	Ningaloo	-	-	-	-	-	-	9
	Shark Bay	-	-	-	-	-	-	-
EEZ	Indonesian Exclusive Economic Zone	-	-	-	36.54	-	-	6
IBRA	Cape Range	-	-	-	-	-	-	3
	Edel	-	-	-	-	-	-	-
	Roebourne	-	-	-	-	-	-	5
	Wooramel	-	-	-	-	-	-	-
IMCRA	Canning	-	-	-	-	-	-	-
	Eighty Mile Beach	-	-	-	-	-	-	<1
	Ningaloo	1	-	-	30.33	-	-	12
	Pilbara (nearshore)	1	-	-	33.00	-	-	12
	Pilbara (offshore)	7	1	-	1.54	1.58	-	156
	Shark Bay	-	-	-	-	-	-	-
	Zuytdorp	-	-	-	-	-	-	-
KEF	Glomar Shoals	6	1	-	0.83	1.29	-	63
MP	Montebello Islands	-	-	-	-	-	-	4
	Rowley Shoals	3	-	-	22.46	-	-	28
	Shark Bay	-	-	-	-	-	-	-
RSB	Clerke Reef	-	-	-	-	-	-	2
	Glomar Shoal	13	1	-	5.63	6.08	-	102
	Imperieuse Reef	2	-	-	22.67	-	-	18
	Mermaid Reef	1	-	-	40.33	-	-	10
	Montebello Shoals	-	-	-	-	-	-	1
	Rankin Bank	4	-	-	17.54	-	-	29
Nearshore	Barrow Island	-	-	-	-	-	-	1
	Bedout Island	-	-	-	-	-	-	<1
	Bermier Island	-	-	-	-	-	-	-
	Clerke Reef	-	-	-	-	-	-	3
	Cunningham Island	1	-	-	24.08	-	-	11
	Hermite Island	-	-	-	-	-	-	3
	Imperieuse Reef	1	-	-	23.46	-	-	13
	Mermaid Reef	-	-	-	-	-	-	7
	Port Hedland	-	-	-	-	-	-	<1
	Rosemary Island	-	-	-	-	-	-	1

	Shark Bay	-	-	-	-	-	-	-
State Waters	Western Australia State Waters	3	-	-	22.46	-	-	28

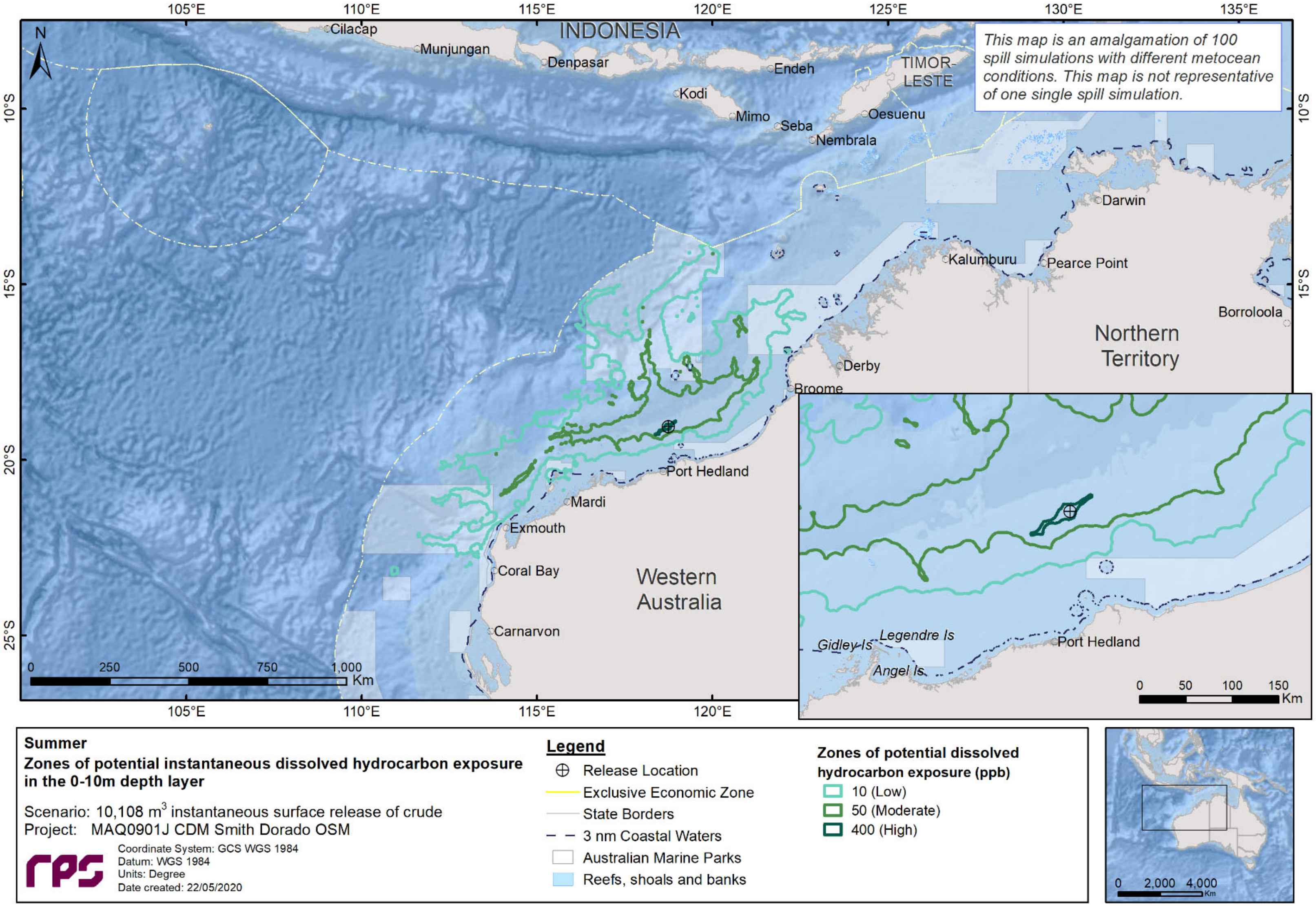


Figure 9.131 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during summer (October to March) conditions.

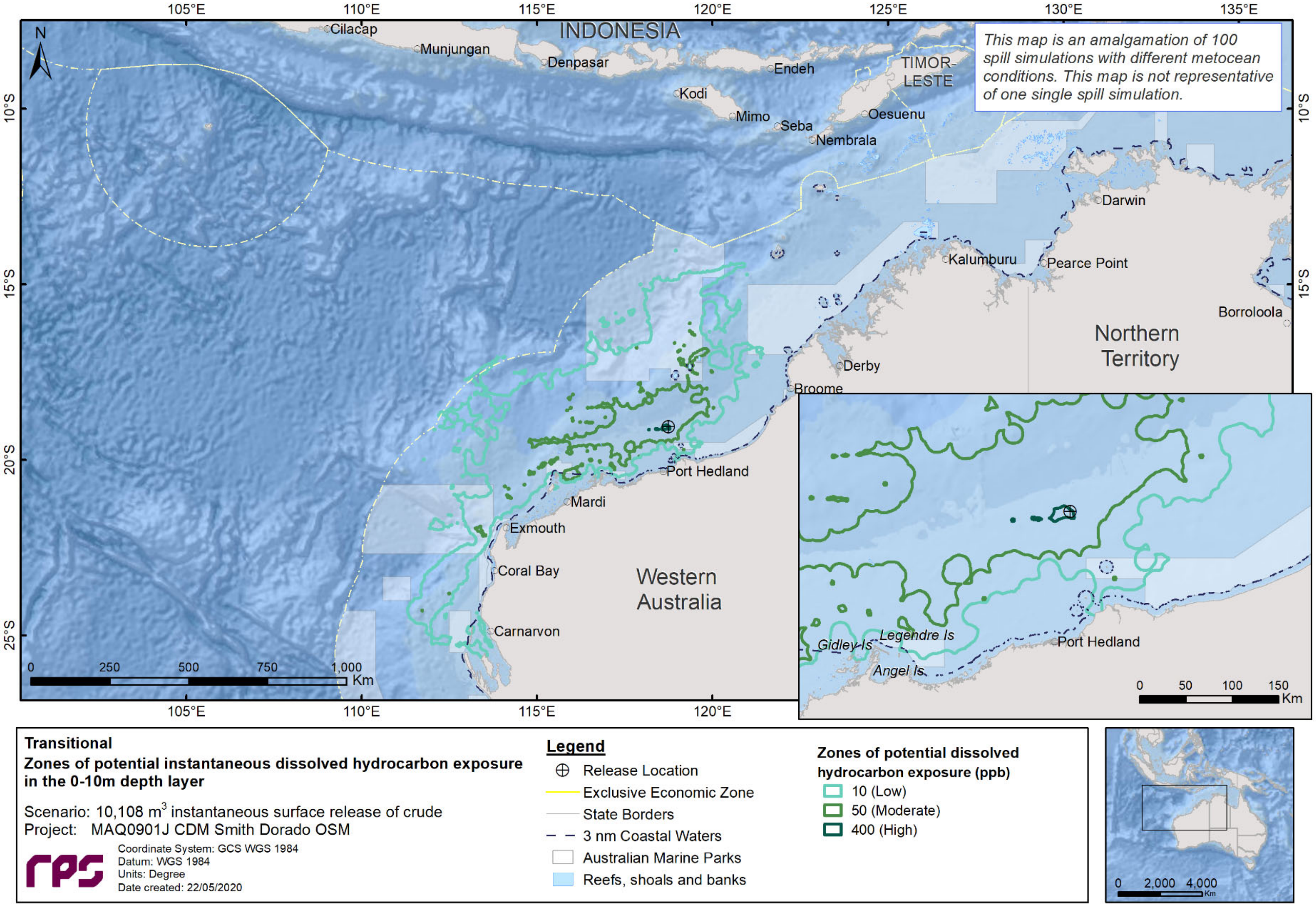


Figure 9.132 Predicted dissolved hydrocarbon exposure zones resulting from an instantaneous surface release of 10,108 m^3 of crude from the FPSO. The results were calculated from 100 spill simulations commencing during transitional (April and September) conditions.

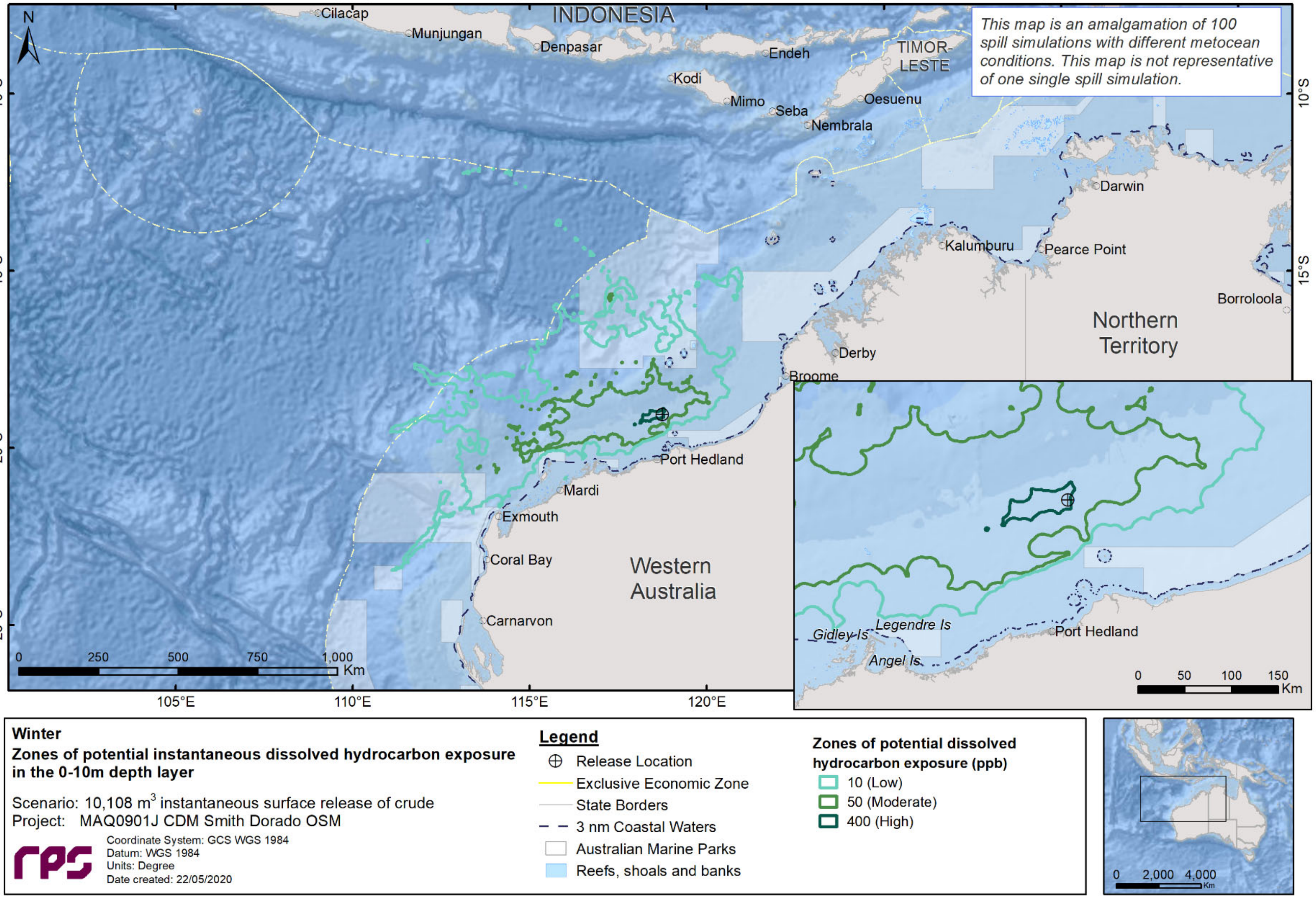


Figure 9.133 Predicted zones of potential dissolved hydrocarbon exposure resulting from an instantaneous surface release of 10,108 m³ of crude from the FPSO. The results were calculated from 100 spill simulations commencing during winter (May to August) conditions.

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Bedout Basin Multi-Well Exploration Drilling

Apus Loss of Well Control Oil Spill Modelling Report

Santos WA Energy Limited

17 January 2022

→ The Power of Commitment

GHD Pty Ltd | ABN 39 008 488 373

999 Hay Street, Level 10

Perth, Western Australia 6000, Australia

T +61 8 6222 8222 | **F** +61 8 6222 8555 | **E** permail@ghd.com | **ghd.com**

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Executive summary

Oil spill modelling was undertaken to predict the potential environmental impacts from four hypothetical Loss Of Well Control (LOWC) incidents related to the proposed Bedout Basin multi-well exploration drilling by Santos WA Energy Ltd (Santos). Santos defined four LOWC scenarios for assessment as follows:

– A LOWC at the Apus well location with the release of 10,982,250 STB (1,745,986 m^3) and 19,255 MMscf (545.25 million sm^3) gas at the seabed (Apus Base Case Subsea LOWC)
– A LOWC at the Apus well location with the release of 10,858,774 STB (1,746,355 m^3) and 19,039 MMscf (539.12 million sm^3) gas at the sea surface (Apus Base Case Surface LOWC)
– A LOWC from an alternate well design at the Apus well location with the release of 8,964,764 STB (1,425,241 m^3) and 15,718 MMscf (445.01 million sm^3) gas at the seabed (Apus Alternate Subsea LOWC)
– A LOWC from an alternate well design at the Apus well location with the release of 8,377,354 STB (1,331,852 m^3) and 14,688 MMscf (415.92 million sm^3) gas at the sea surface (Apus Alternate Surface LOWC)

Oil spill modelling was carried out with SINTEF's Oil Spill Contingency and Response (OSCAR) system. Modelling was undertaken in stochastic mode (total of 150 realisations per scenario) with start dates spaced approximately fortnightly over a five (5) year period. Inputs into the model were sourced from HYCOM (regional ocean currents, temperature and salinity profiles), TPXO9 (tidal currents) and CFSv2 (regional winds). Deterministic modelling was also carried out on several simulations to further characterise impacts and to inform response planning.

Analysis of the stochastic simulations was based on the following moderate thresholds:

– Accumulated shoreline oiling above 100 g/m^2.
– Surface hydrocarbons above 10 g/m^2.
– Total submerged oil (a combination of entrained + dissolved oil) above 100 ppb.
– Dissolved hydrocarbons above 50 ppb.

Additional interrogation of the modelling predictions also considered the following low and high thresholds:

– Accumulated shoreline oiling above 10 g/m^2 (low) and 1,000 g/m^2 (high).
– Surface hydrocarbons above 1 g/m^2 (low) and 50 g/m^2 (high).
– Total submerged oil (a combination of entrained and dissolved oil) above 10 ppb (low).
– Dissolved hydrocarbons above 10 ppb (low) and 400 ppb (high).

An overview of the shoreline loading predictions above the moderate threshold (100 g/m^2) from the scenarios includes the following:

– **Apus Base Case Subsea LOWC:** a 100% contact probability is predicted with a maximum accumulated shoreline load of 2,054 tonnes, a minimum arrival time of 3.5 days and a maximum length of oiled shoreline of 433 km.
– **Apus Base Case Surface LOWC:** a 100% contact probability is predicted with a maximum accumulated shoreline load of 5,125 tonnes, a minimum arrival time of 2.0 days and a maximum length of oiled shoreline of 500 km.
– **Apus Alternate Subsea LOWC:** a 100% contact probability is predicted with a maximum accumulated shoreline load of 984 tonnes, a minimum arrival time of 5.8 days and a maximum length of oiled shoreline of 318 km.
– **Apus Alternate Surface LOWC:** a 100% contact probability is predicted with a maximum accumulated shoreline load of 3,573 tonnes, a minimum arrival time of 2.0 days and a maximum length of oiled shoreline of 404 km.

Deterministic simulations of dispersant response strategies of the base case LOWC scenarios via subsea dispersant injection (SSDI) and surface dispersant application (SDA) predicted the following outcomes:

- SSDI of the subsea LOWC scenario generally had a negligible benefit. The high exit velocity of the subsea plumes from the well for these scenarios results in small, entrained oil droplets that are not materially affected by the application of chemical dispersants.
- The simulated SDA responses that were included for both subsea and surface LOWC scenarios generally had a greater benefit in reducing surface oil loads (via increased proportion of entrained oil with very small particle diameters) in comparison to the SSDI responses.
- SDA is predicted to generally provide moderate to significant reductions in shoreline loading.
- The incorporation of a 25 km radius exclusion zone around the well site (inside which no dispersants are applied) is effective in allowing a significant degree of natural evaporation to occur prior to treatment of the surface slick with chemical dispersant.
- The simulated maximum volume of chemical dispersant for any of the deterministic scenarios was 26,453 m^3 for the Apus Base Case Subsea Scenario #24, which results from the combined application of 15.587 m^3 via SSDI and 10,886 m^3 via SDA.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

Santos WA Energy Ltd (Santos) proposes to undertake multi-well exploration drilling activities (the activity) within the Bedout Basin, located in Commonwealth waters north of Port Hedland.

To proceed with the activity, Santos is required to submit an Environment Plan (EP) and Oil Pollution Emergency Plan (OPEP) for approval by NOPSEMA for the Bedout Basin Multi-Well Exploration Drilling activity. The EP will describe the potential environmental impacts and risks related to the activity, while the OPEP will outline the Santos approach to respond to potential oil pollution incidents.

Santos has identified a loss of well control (LOWC) as the worst-case type of credible oil release scenario that could potentially occur during the activity. A LOWC incident may discharge directly to the sea surface or at the seabed, depending on the type of failure that occurs.

Santos has submitted an EP for the activity to NOPSEMA (Santos, 2021), and is currently in the process of updating the EP to address NOPSEMA comments. Part of these updates include the previous LOWC oil spill modelling by GHD (2021) for surface and subsea LOWC scenarios at three (3) locations that spanned the proposed operational area for the exploration drilling campaign (at the time of the GHD [2021]). Santos has narrowed down the worst-case scenarios for assessment since the previous (GHD, 2021) modelling. The worst-case scenarios are based on LOWC events occurring at the Apus well location, which is the closest of the proposed wells to the receptors of Bedout Island and the Australian mainland. Surface and subsea LOWC scenarios are defined for two well designs; a base case and an alternate well design that results in reduced flow rates of oil and gas during a hypothetical LOWC incident. The worst-case discharge scenarios defined by Santos adopt simulated flow rates from the Pavo well and apply them to the Apus location. The Pavo and Apus well locations are displayed in Figure 1.

1.2 Purpose of this report

Santos engaged GHD Pty Ltd (GHD) to perform oil spill modelling for the updated worst-case LOWC incidents related to the Bedout Basin Multi-Well Exploration Drilling activity to inform preparation of the updated EP and OPEP. This report details the oil spill modelling methodology, model inputs and simulated results of four LOWC scenarios.

1.3 Scope and limitations

The following worst-case credible oil spill scenarios were assessed:

- A LOWC at the Apus well location with the release of 10,982,250 STB (1,745,986 m^3) and 19,255 MMscf (545.25 million sm^3) gas at the seabed (Apus Base Case Subsea LOWC)
- A LOWC at the Apus well location with the release of 10,858,774 STB (1,746,355 m^3) and 19,039 MMscf (539.12 million sm^3) gas at the sea surface (Apus Base Case Surface LOWC)
- A LOWC from an alternate well design at the Apus well location with the release of 8,964,764 STB (1,425,241 m^3) and 15,718 MMscf (445.01 million sm^3) gas at the seabed (Apus Alternate Subsea LOWC)
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The spill scenarios were modelled in stochastic mode with 150 replicate simulations (or realisations) to spatially define the Environment that May Be Affected (EMBA) on a probabilistic basis to inform development of the EP. Deterministic modelling was also carried out for selected worst-case realisations of the base case scenarios to further characterise impacts and to inform response planning of the OPEP. Additional deterministic modelling was applied to predict the impact of surface and subsea dispersant response strategies on mitigating oil spill impacts.

This report: has been prepared by GHD for Santos WA Energy Limited and may only be used and relied on by Santos WA Energy Limited for the purpose agreed between GHD and Santos WA Energy Limited as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Santos WA Energy Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Santos WA Energy Limited and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

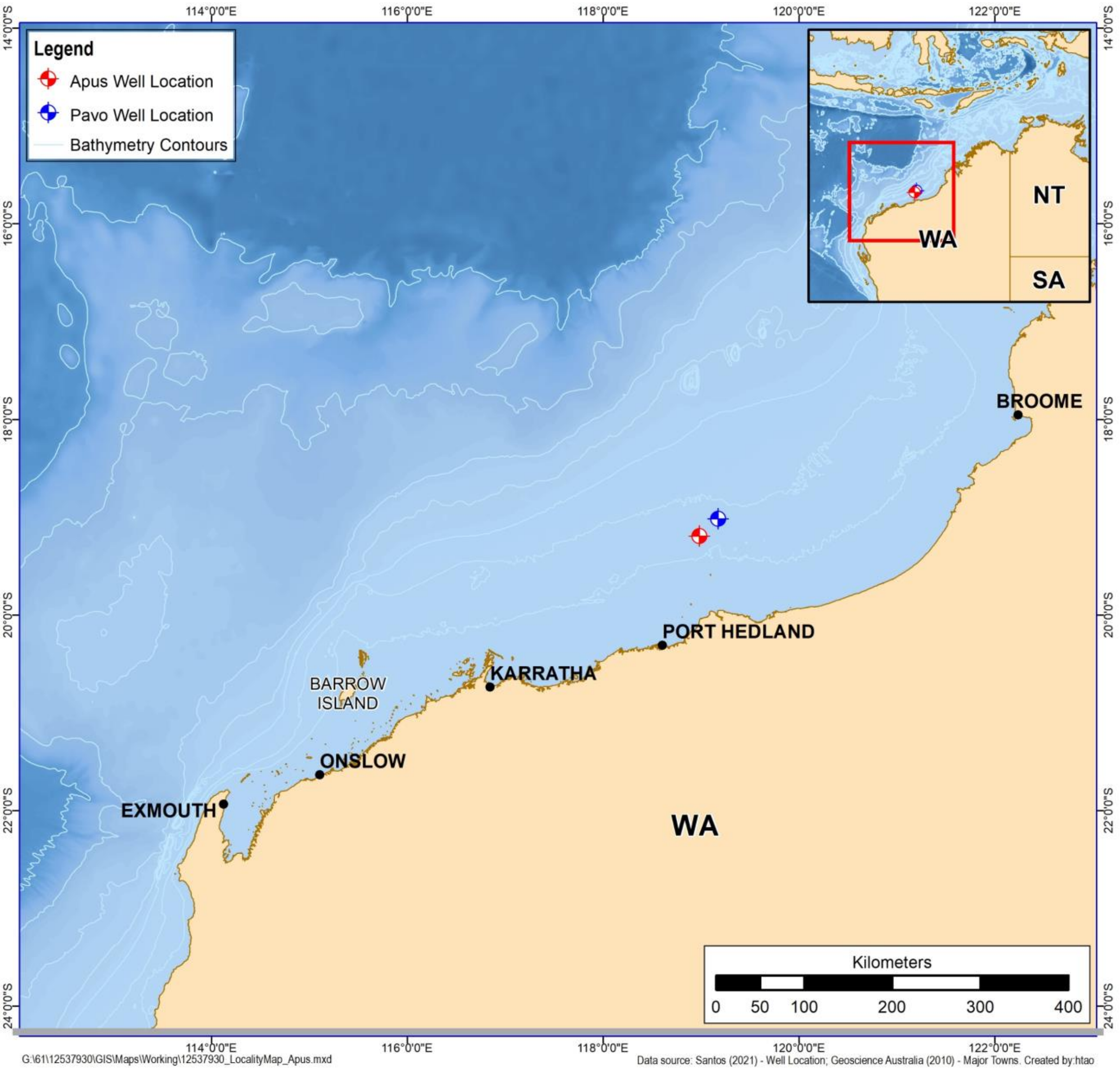


Figure 1 Locality Map

2. Data

2.1 Release Specifications

Time series of liquid condensate, gas and water release rates of the four (4) LOWC scenarios are presented in Table 1-Table 4, respectively. The general spill specifications for the LOWC scenarios are summarised in Table 5.

Table 1 Apus Base Case Subsea LOWC scenario release rates

Time	Condensate Rate (STB/d)	Gas Rate (MMscf/d)	Water Rate (STB/d) [1]
Week 1	147,517	259	-
Week 2	145,390	255	0
Week 3	144,171	253	0
Week 4	143,295	251	1
Week 5	142,607	250	3
Week 6	142,038	249	7
Week 7	141,551	248	12
Week 8	141,124	247	20
Week 9	140,741	247	31
Week 10	140,391	246	46
Week 11	140,068	246	65

Table 2 Apus Base Case Surface LOWC scenario release rates

Time	Condensate Rate (STB/d)	Gas Rate (MMscf/d)	Water Rate (STB/d) [1]
Week 1	145,791	256	-
Week 2	143,715	252	0
Week 3	142,526	250	0
Week 4	141,671	248	1
Week 5	141,000	247	3
Week 6	140,446	246	7
Week 7	139,972	245	12
Week 8	139,557	245	19
Week 9	139,186	244	30
Week 10	138,849	243	44
Week 11	138,539	243	62

[1] Note: The water release rates are a negligible proportion of the total volumetric flow (<0.05%) and were not included in the modelling

Table 3 Apus Alternate Subsea LOWC scenario release rates

Time	Condensate Rate (STB/d)	Gas Rate (MMscf/d)	Water Rate (STB/d) [1]
Week 1	119,805	210	-
Week 2	118,342	207	0
Week 3	117,501	206	0
Week 4	116,895	205	1
Week 5	116,418	204	1
Week 6	116,023	203	3
Week 7	115,684	203	5
Week 8	115,385	202	9
Week 9	115,117	202	13
Week 10	114,871	201	19
Week 11	114,642	201	27

Table 4 Apus Alternate Surface LOWC scenario release rates

Time	Condensate Rate (STB/d)	Gas Rate (MMscf/d)	Water Rate (STB/d) [1]
Week 1	111,835	196	-
Week 2	110,508	194	0
Week 3	109,746	192	0
Week 4	109,198	191	0
Week 5	108,768	191	1
Week 6	108,415	190	2
Week 7	108,116	190	4
Week 8	107,858	189	6
Week 9	107,632	189	10
Week 10	107,433	188	14
Week 11	107,256	188	20

Table 5 Summary of spill specifications for the four LOWC scenarios

Parameter	Apus Base Case Subsea LOWC	Apus Base Case Surface LOWC	Apus Alternate Subsea LOWC	Apus Alternate Surface LOWC
Location (Lat, Lon)	19° 11' 25.29" S 118° 59' 10.64" E			
Hydrocarbon type	Caley			
Depth of spill (m)	72.6	0 (Surface spill)	72.6	0 (Surface spill)
Diameter of subsea release orifice (m)	0.30	NA	0.21	NA
Liquid release volume	10,982,250 STB ($1,745,986\ m^3$)	10,858,774 STB ($1,746,355\ m^3$)	8,964,764 STB ($1,425,241\ m^3$)	8,377,354 STB ($1,331,852\ m^3$)
Gas release volume	19,255 MMscf (545.25 million sm^3)	19,039 MMscf (539.12 million sm^3)	15,718 MMscf (445.01 million sm^3)	14,688 MMscf (415.92 million sm^3)
Release duration	77 days			
Timing of release risk period	All year			

2.2 Hydrocarbon Specifications

2.2.1 LOWC Hydrocarbon– Caley

The hydrocarbon type for the LOWC scenarios was identified by Santos as Caley (named 'Caley Crude' in Intertek [2020], however Intertek [2020] also refers to the oil as a condensate and the hydrocarbon properties are representative of those of condensates). An assay report (Intertek, 2020) with information on the physical and chemical properties of the condensate were provided by Santos. Key physical/chemical properties of Caley from the assay report are shown in Table 6.

Table 6 Bulk properties of Caley from Intertek (2020)

Parameter	Caley (Intertek, 2020)
API Gravity	51.4
Specific Gravity	0.7737
Wax Content (%)	9.2
Pour Point (°C)	<-15
Asphaltene (%)	<0.5
Viscosity (cSt)	1.878 (@20°C)

2.3 Environmental Data

The environmental inputs for oil spill modelling include regional ocean currents, winds, and seawater temperatures and salinities.

2.3.1 Ocean Currents

Currents in the Indian Ocean are dominated by two rotating gyres. The larger gyre is located in the southern hemisphere, rotates counter-clockwise, and is driven by Trade Winds and Mid-Latitude Westerlies. The eastern arm of this gyre, the Western Australian Current (WAC), flows northward off the continent's west coast, bending counter-clockwise to form the South Equatorial Current (SEC), which flows toward Mozambique (Schott and McCreary 2001; Shankar *et al*., 2002).

The gyre in the Northern Indian Ocean is driven predominantly by the Indo-Australian Monsoon winds, and as such is much more seasonally variable than the subtropical gyre to the south. During the Australian Winter the gyre rotates clockwise, while in summer it rotates counter-clockwise (Shankar *et al*., 2002).

Semi-diurnal tidal currents are extremely strong. The dominant tidal components, M2 and S2, are magnified on the shelf, resulting in one of the largest tidal ranges of any open coastline in the world. Tidal ranges can be as high as 6 m off the Pilbara coast and 10 m off the Kimberley coast. This can result in currents of up to 1 m/s. During tropical cyclones surface currents may reach 4 m/s (Chang *et al*., 2016).

Large-scale oceanographic and tidal currents are sourced from the global ocean circulation model HYCOM (Chassignet *et al*., 2007) and the global tide model TPXO9 (Egbert & Erofeeva, 2002), respectively. The HYCOM and TPXO9 data span 1 January 2011 to 31 December 2015. The eight primary tidal constituents in TPXO9 were utilised in this study.

The spatial resolution of the HYCOM data is 1/12 of a degree of latitude/longitude (or approximately 9 km). The TPXO9 tidal current data were combined additively to the HYCOM data.

Monthly depth-averaged current roses generated from the HYCOM data, as well as the combined HYCOM and TPXO9 data are presented in Figure 2 and Figure 3 for the HYCOM node nearest to the simulated release location of the Apus well. Non-tidal currents are typically <5-25 cm/s and display some seasonality with:

– Westerly/south-westerly currents prevailing from April to July
– North-easterly currents prevailing from January to February

– A mixture of the regimes (south-westerly and north-westerly) during the remaining months of the year.

The inclusion of tidal currents typically results in a south-easterly/north-westerly oscillating pattern all year round with typical current speeds of 5-65 cm/s.

2.3.1.1 Adopting the Apus Well as the Worst-Case Location

Of the wells assessed by Santos for this multi-well exploration activity, the worst-case discharge rates during a LOWC incident are predicted to occur at the Pavo well (Figure 1). Despite this, Santos has defined a LOWC event at the Apus well to represent the worst-case scenario in terms of potential environmental impacts. The adoption of Apus as the worst-case location is justified as follows:

- The Apus-1 and Pavo-1 wells are 28 km apart and are in 72 m and 83 m water depths, respectively
- Apus-1 is the closest well to the nearest sensitive receptor (Bedout Island) at 46 km distance compared to Pavo-1 at 64 km distance. Further, Apus-1 is nearer to the mainland at 87 km compared to Pavo-1 at 104 km.
- The fluid for both wells is based on the same oil characteristics (Caley)
- Due to their proximity, the geometry of the Bedout Basin and gentle sloping water depth, the prevailing met-ocean conditions are likely to be very similar. Monthly currents roses at Apus (Figure 3) and Pavo (Figure 4) compare very closely.
- The size of the EMBA is primarily defined on the basis of entrained oil that is predicted to encompass a very large area (>1,500 km, see Section 4). Therefore the predicted EMBAs from LOWC incidents at these two proximal well locations would be similar as the distance between the wells is negligible relative to the overall scale potential impacts.
- Since the Pavo-1 well yields the worst case predicted discharge rates oil and gas during a LOWC incident, these flow rates serve as the model inputs at the Apus-1 well location.
- The application of worst-case discharge estimates of Pavo-1 at the Apus-1 well location is a conservative approach to characterise potential environmental risks associated with the multi-well drilling campaign.

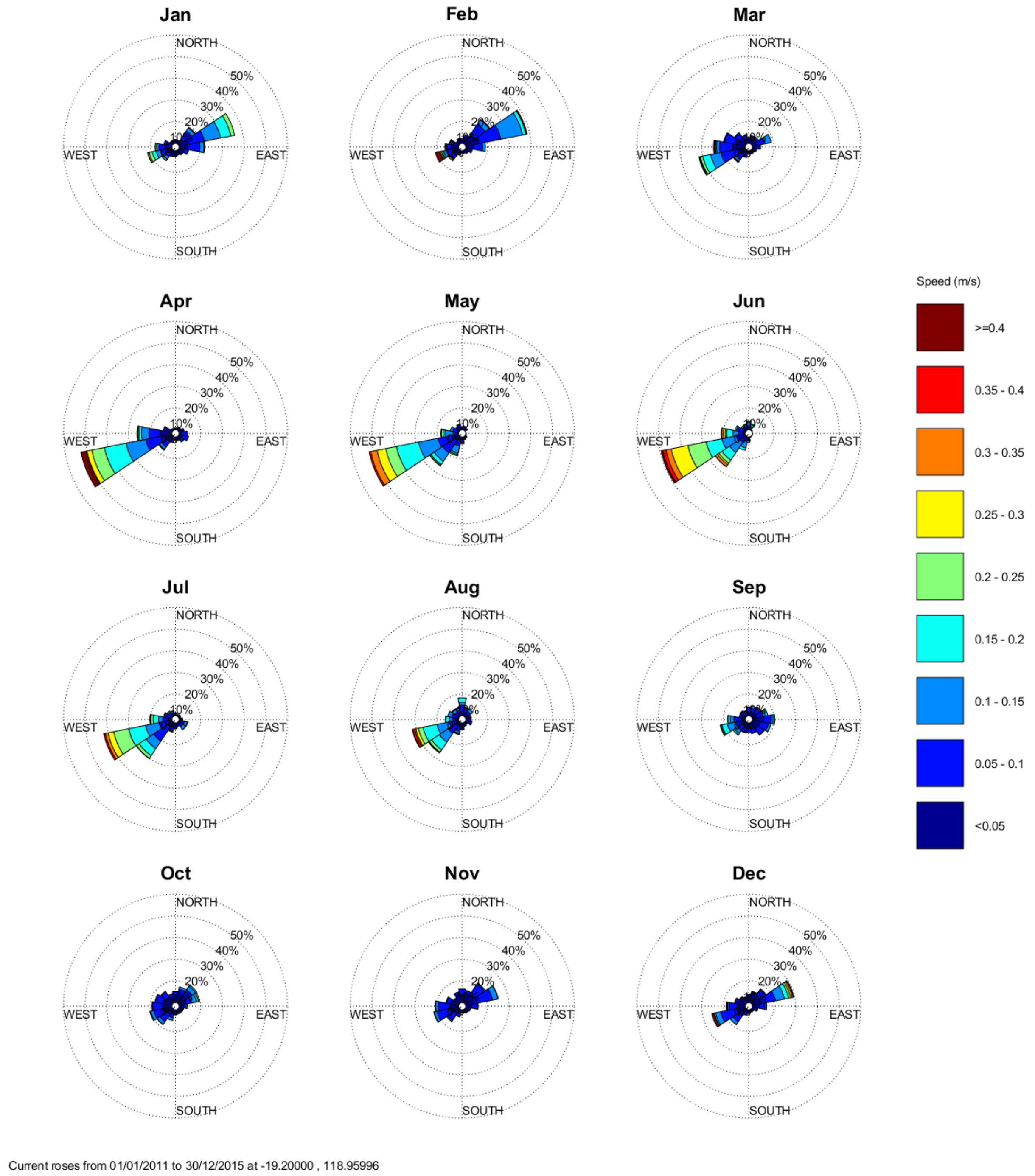


Figure 2 ***Monthly current roses (HYCOM only) at the HYCOM node nearest to the Apus release location[2]***

[2] Convention for current directions is the direction current is going *towards*

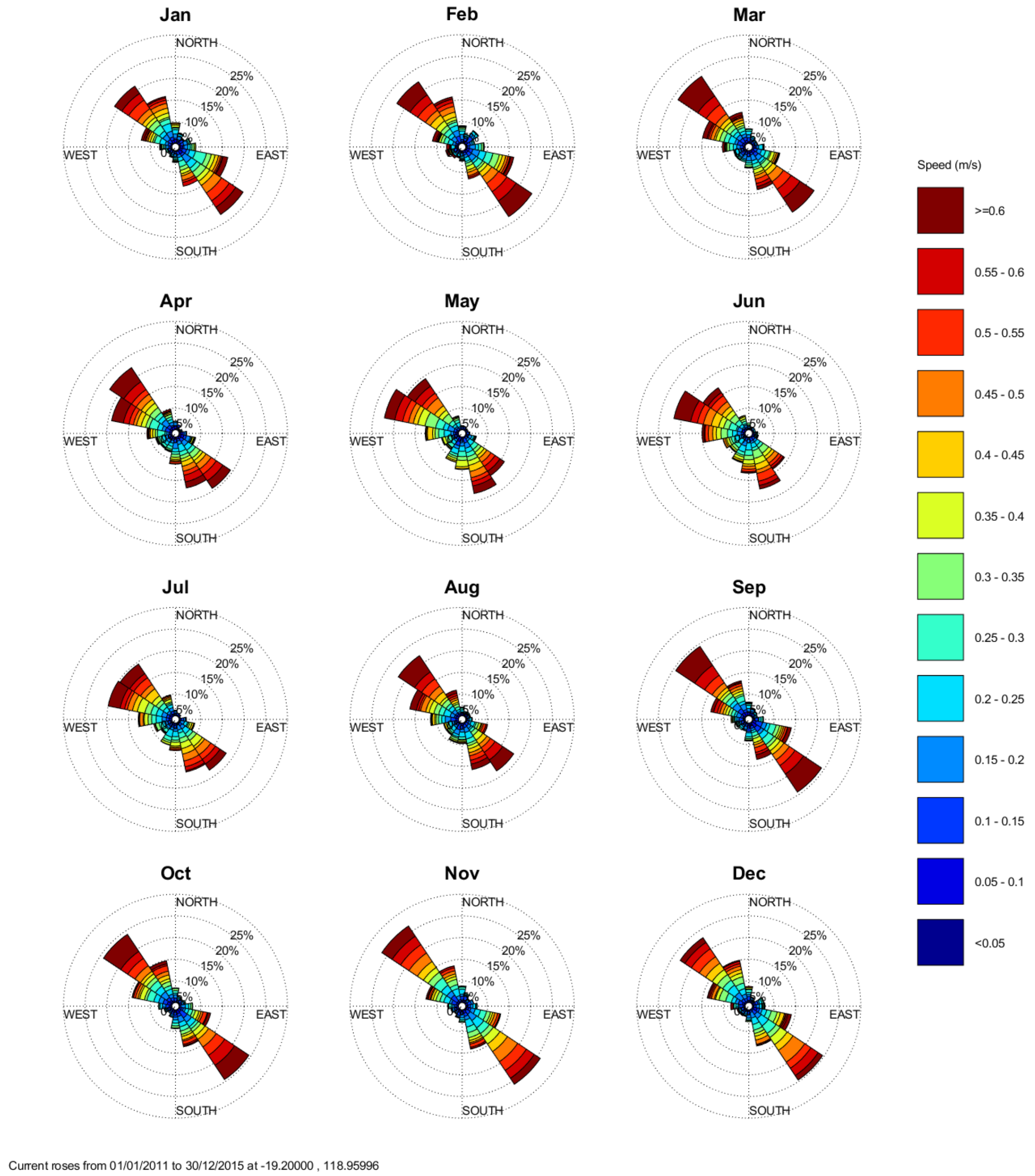


Figure 3 *As Figure 2 with tidal currents included (HYCOM + TPXO9)*[2]

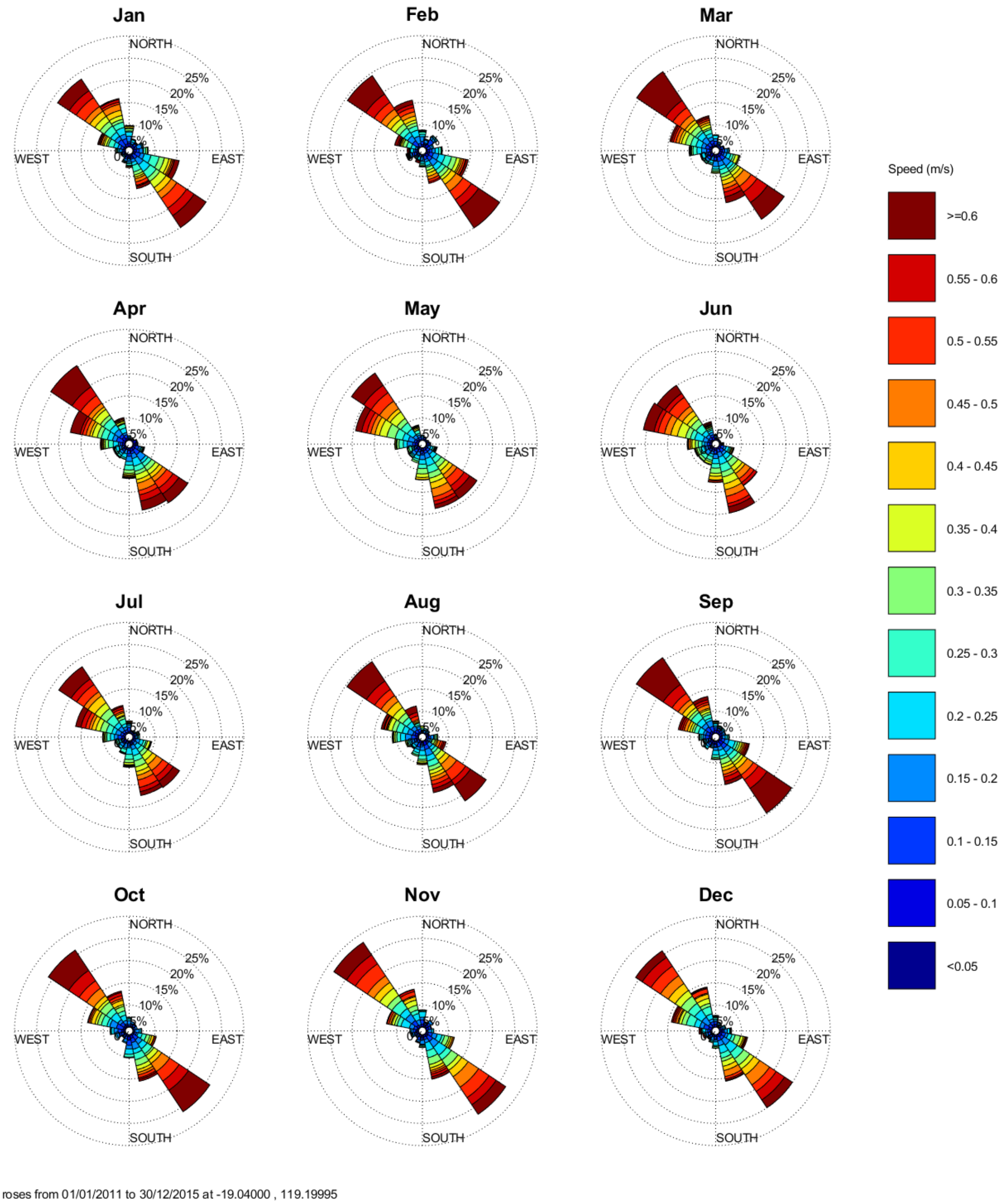


Figure 4 *As Figure 4 for the HYCOM node nearest to the Pavo well* [2]

2.3.2 Winds

Sea surface wind velocity fields were sourced from the National Centers for Environmental Prediction's (NCEP's) Climate Forecast System, version 2 (CFSv2) (Suranjana *et al.* 2014), spanning 1 January 2011 to 31 December 2015. The CFSv2 data is provided at hourly temporal resolution and 0.2 degree latitudinal/longitudinal resolution (approximately 22 km). Average monthly wind directions and wind speeds for each year of the 5-year dataset are shown in Figure 5 for the CFSv2 node nearest to the simulated release location. Monthly wind roses are presented in Figure 6. Monthly wind directions display a marked seasonal pattern with:

– April to August characterised by easterly/south-easterly winds
– South-westerly to north-westerly winds generally prevail from October to February
– March and September are transitional periods with a mixture of the two regimes.

Monthly-averaged wind speeds are typically higher (6-8 m/s) during the winter months of May to July, lower from September to March (2-5 m/s) and intermediate (2-6 m/s) at other times of year (Figure 5).

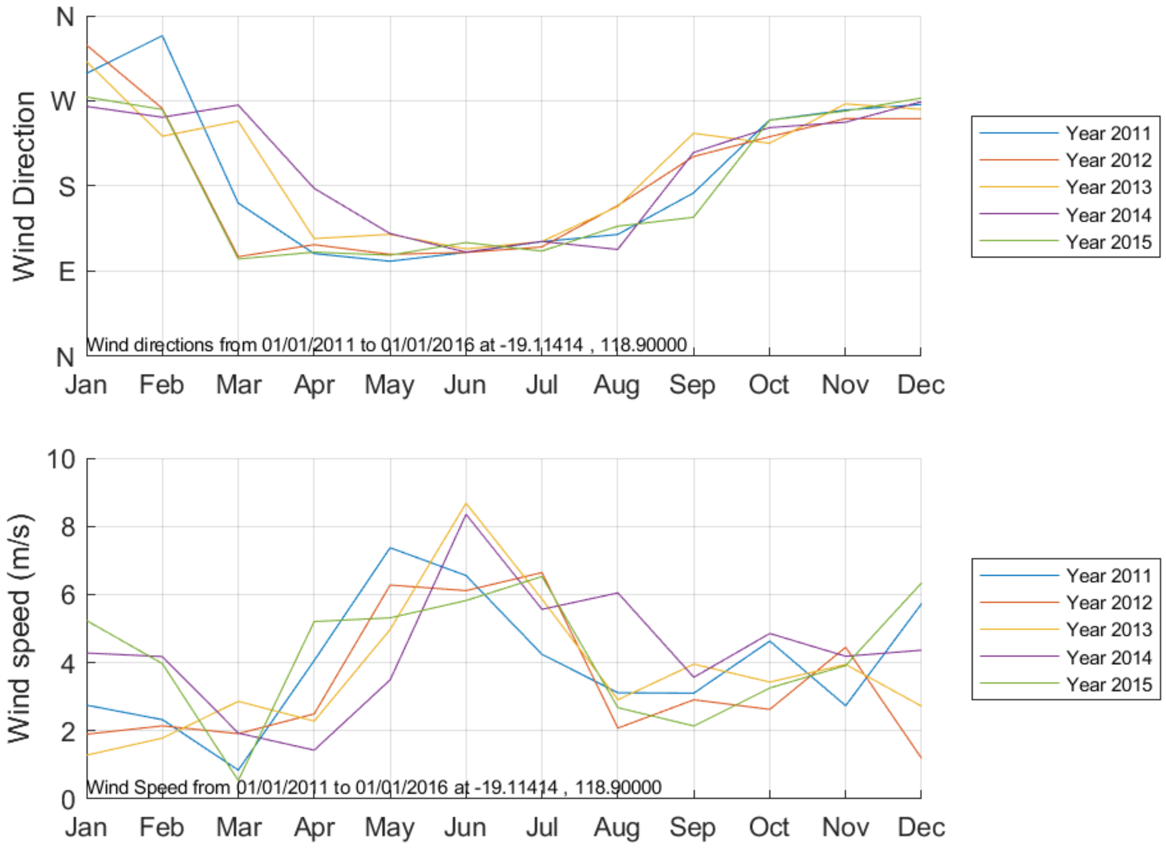
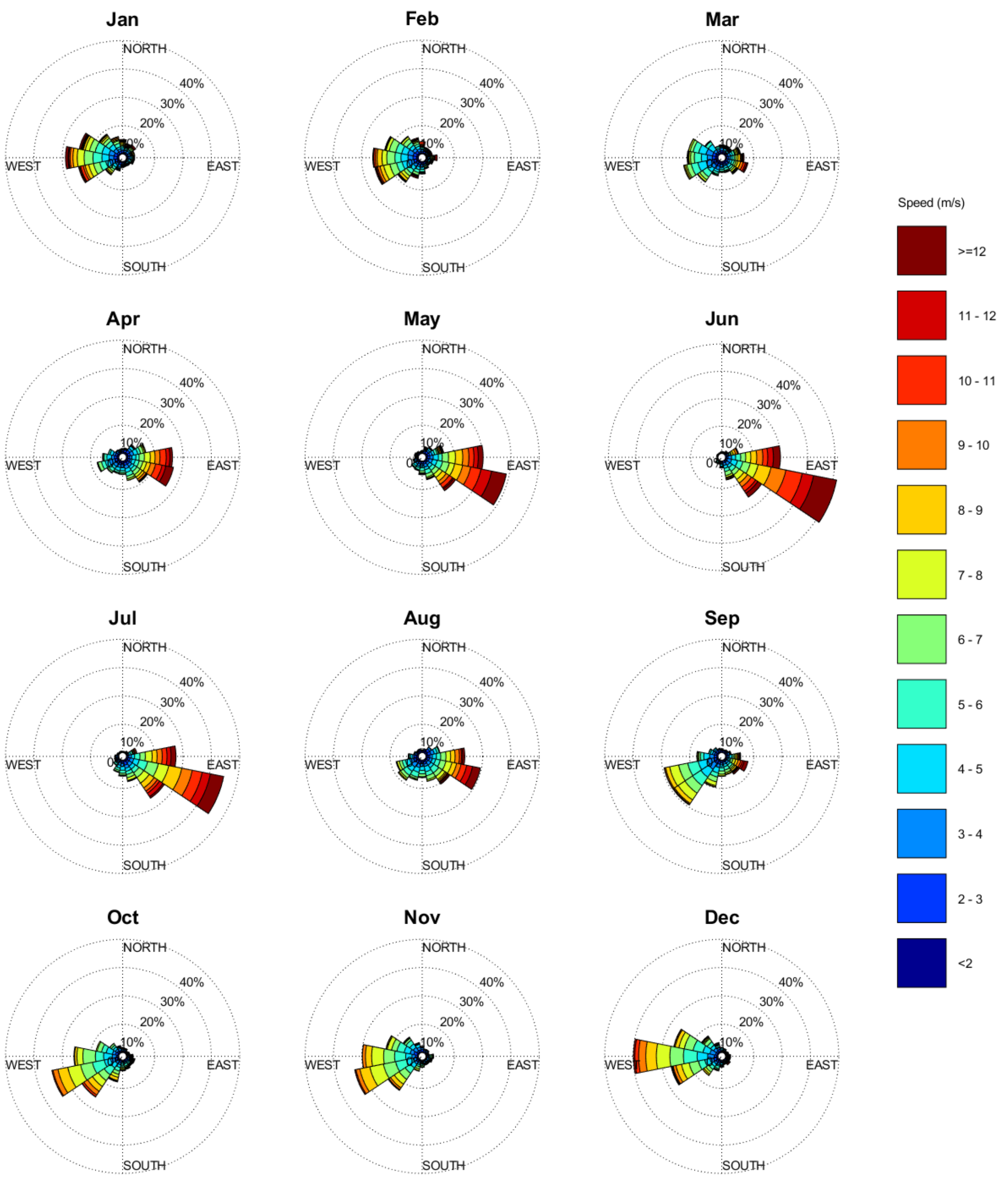


Figure 5 ***Average monthly wind direction for each year from 2011-2015 at the CFSv2 node nearest to the release location[3]***

[3] Convention for wind directions is the direction wind is coming *from*



Wind roses from 01/01/2011 to 01/01/2016 at -19.11414 , 118.90000

Figure 6 Monthly wind roses at the CFSv2 node nearest to the release location across the 2011-2015 data [3]

2.3.3 Temperature and Salinity Profiles

Temperature and salinity profiles are defined from the same five-year HYCOM dataset as the regional ocean currents (January 2011–December 2015). Vertical profiles of temperature and salinity were extracted from a HYCOM node near to the simulated release site. A single representative temperature and salinity profile of the average yearly conditions was applied across the entire model domain that provided the closest match (by least-squares regression) to the average density profile over the 5 years of HYCOM data. The selected salinity, temperature and density profile was 25 October 2011, shown on Figure 7.

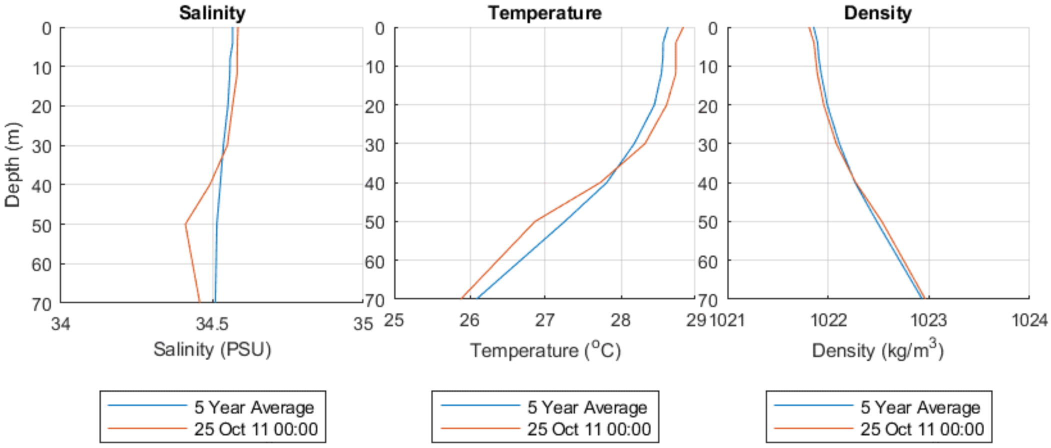


Figure 7 ***Selected salinity, temperature and density vertical profile and comparison with the yearly averages near the release site***

2.3.4 Environmental Receptors

To characterise the consequence of the simulated scenarios, discrete environmental receptors were defined by Santos, which are listed in Table 7 and displayed Figure 8 to Figure 10. The receptor regions have been allocated a sensitivity score by Santos to reflect the level of environmental value, where a higher score indicates greater sensitivity and/or value of the geographic receptor (Table 7).

Some receptors include reef systems, such as the Rowley Shoals of Clerke Reef Marine Park (Clerke Reef MP) and Imperieuse Reef MP, which are intertidal features that may only be exposed at low tides. In these instances, the large intertidal reef is classified as exposed shoreline during the model setup, which is a conservative measure to account for any potential oil stranding that might occur at these environmentally sensitive receptors. The length of 'shoreline' oiled for these receptors likely exceeds the actual length of permanently exposed shore within these receptor boundaries, as the statistic also includes the significantly larger reef in the classification of 'shoreline'.

Table 7 ***Key Santos receptors***

Name	Sensitivity Score	Priority
The Boxers Area	8 - 11	4
Margaret Harries Bank	< 8	5
Echo Shoals	< 8	5
Sahul Banks	< 8	5
JBG South Coast	8 - 11	4
Gale Bank	< 8	5
JBG West Coast	8 - 11	4
Penguin Shoal	< 8	5
Fantome Shoals	< 8	5
Eugene McDermott Shoal	< 8	5
Barracouta Shoals	< 8	5

Name	Sensitivity Score	Priority
Vulcan Shoals	< 8	5
Hibernia Reef	< 8	5
Kimberley Coast PMZ	12 - 15	3
Woodbine Bank	< 8	5
Cartier Island AMP	12 - 15	3
Ashmore Reef AMP	20 - 26	1
Heywood Shoals	< 8	5
Echuca Shoals	< 8	5
Browse Island	< 8	5
Camden Sound	12 - 15	3
Seringapatam Reef	8 - 11	4
Scott Reef North	12 - 15	3
Scott Reef South	12 - 15	3
Adele Island	< 8	5
King Sound	8 - 11	4
Lacepede Islands	8 - 11	4
Broome North Coast	8 - 11	4
Mermaid Reef AMP	16 - 19	2
Clerke Reef MP	12 - 15	3
Imperieuse Reef MP	12 - 15	3
Port Hedland-Eighty Mile Beach	< 8	5
Glomar Shoals	< 8	5
Karratha-Port Hedland	< 8	5
Dampier Archipelago	12 - 15	3
Rankin Bank	< 8	5
Northern Islands Coast	< 8	5
Montebello Islands	12 - 15	3
Lowendal Islands	12 - 15	3
Barrow Island	12 - 15	3
Barrow-Montebello Surrounds	12 - 15	3
Middle Islands Coast	< 8	5
Thevenard Islands	< 8	5
Southern Islands Coast	< 8	5
Muiron Islands	16 - 19	2
Exmouth Gulf Coast	16 - 19	2
Ningaloo Coast North	16 - 19	2
Ningaloo Coast South	12 - 15	3
Carnarvon - Inner Shark Bay	16 - 19	2
Shark Bay - Coast Outer	12 - 15	3
Zuytdorp Cliffs - Kalbarri	12 - 15	3
Kalbarri - Geraldton	12 - 15	3

Name	Sensitivity Score	Priority
Geraldton - Jurien Bay	12 - 15	3
Abrolhos - Outer Island Shoals	12 - 15	3
Abrolhos Islands Wallabi Group	16 - 19	2
Abrolhos Islands Easter Group	16 - 19	2
Abrolhos Islands Pelsaert Group	16 - 19	2
Rottnest Island	< 8	5
Perth Southern Coast	12 - 15	3
Dawesville - Bunbury	8 - 11	4
Geographe Bay - Augusta	8 - 11	4
Augusta - Walpole	8 - 11	4
Walpole - Albany	< 8	5
Albany - Esperance	< 8	5
Esperance - Cape Arid NP	< 8	5
Indonesia - East	< 8	5
Indonesia - West	< 8	5
Geographe Bay	16 - 19	2
Mandurah - Dawesville	12 - 15	3
Perth Canyon AMP	16 - 19	2
Eighty Mile Beach	16 - 19	2
Broome - Roebuck	16 - 19	2
Roebuck - Eighty Mile Beach	< 8	5
Jurien Bay - Yanchep	12 - 15	3
Perth Northern Coast	12 - 15	3
Two Rocks AMP	16 - 19	2
Kimberley AMP	12 - 15	3
Joseph Bonaparte Gulf AMP	8 - 11	4
Dampier AMP	8 - 11	4
Montebello AMP	8 - 11	4
Ningaloo - Outer Coast North	20 - 26	1
Van Cloon/Deep Shaols	8 - 11	4
Johnson Bank	12 - 15	3
Bremer AMP	8 - 11	4
Eastern Recherche AMP	8 - 11	4
Jurien AMP	16 - 19	2
Shark Bay AMP	8 - 11	4
Ashmore/Cartier - Outer	8 - 11	4
Eighty Mile Beach AMP	8 - 11	4
Rowley Shoals surrounds	8 - 11	4
Geographe - Outer	12 - 15	3
Geographe - Augusta Deep	12 - 15	3
Geographe - Offshore Augusta 1	16 - 19	2

Name	Sensitivity Score	Priority
South-west corner AMP	8 - 11	4
Geographe - Offshore Augusta 2	12 - 15	3
Abrolhos West	16 - 19	2
Ningaloo - Outer NW	12 - 15	3
Ningaloo - Offshore	8 - 11	4
Abrolhos - Offshore NW	8 - 11	4
Abrolhos - Nearshore	8 - 11	4
Abrolhos - Offshore Perth North	8 - 11	4
Perth South - Geographe - Offshore	8 - 11	4
Bedout Island	< 8	5
Christmas Island	8 - 11	4

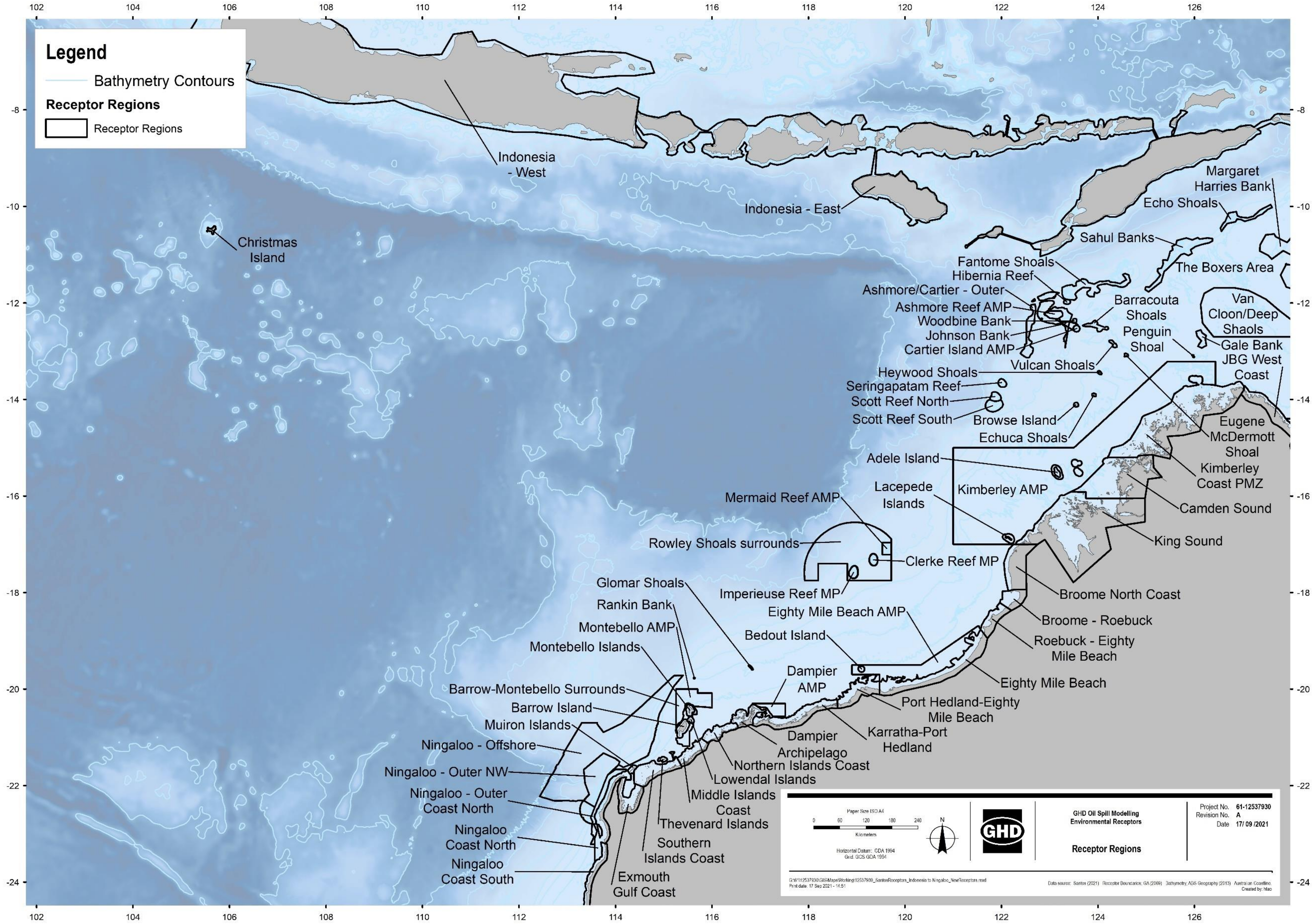


Figure 8 *Santos environmental receptors – Ningaloo to Broome*

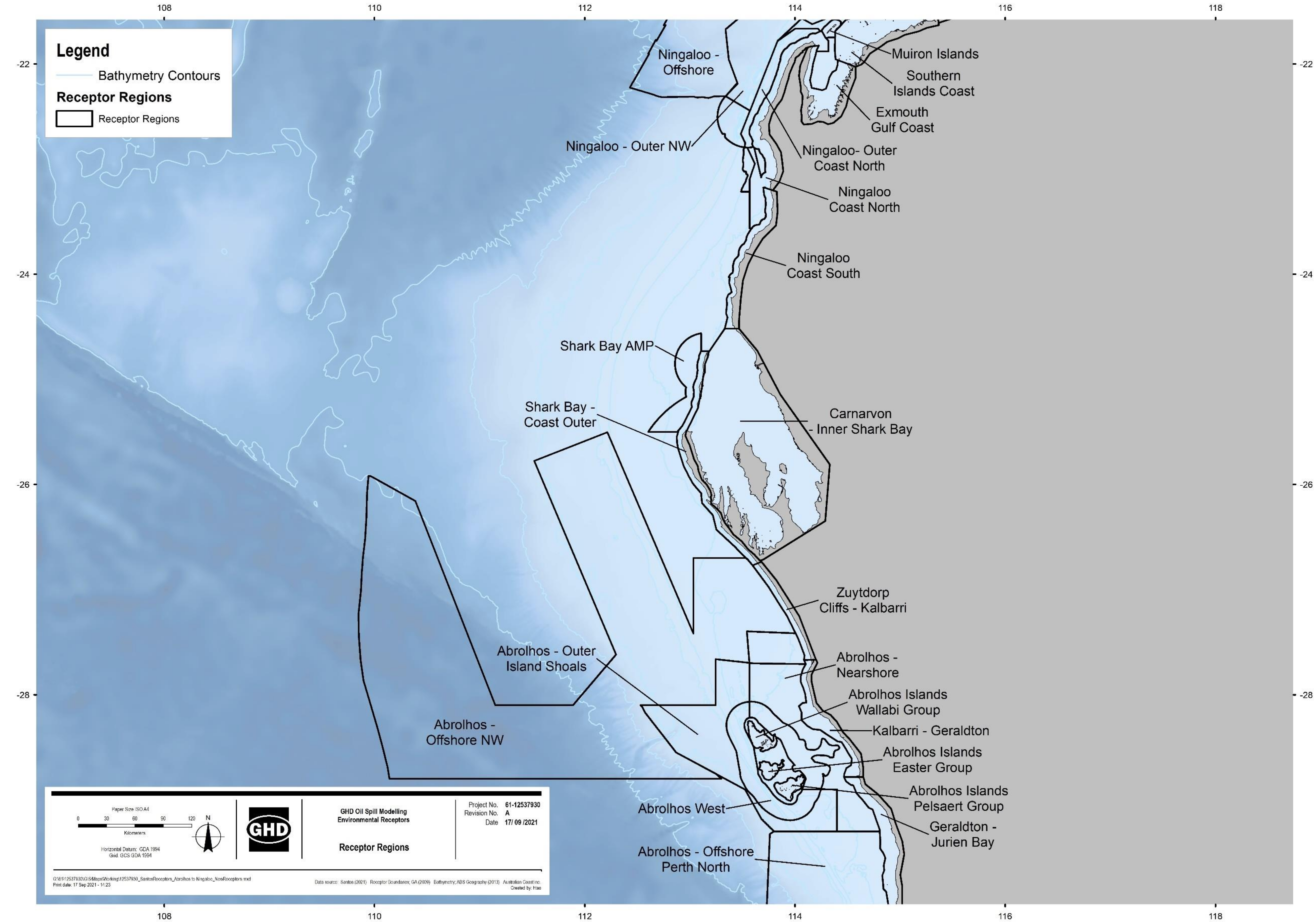


Figure 9 *Santos environmental receptors – Abrolhos to Ningaloo*

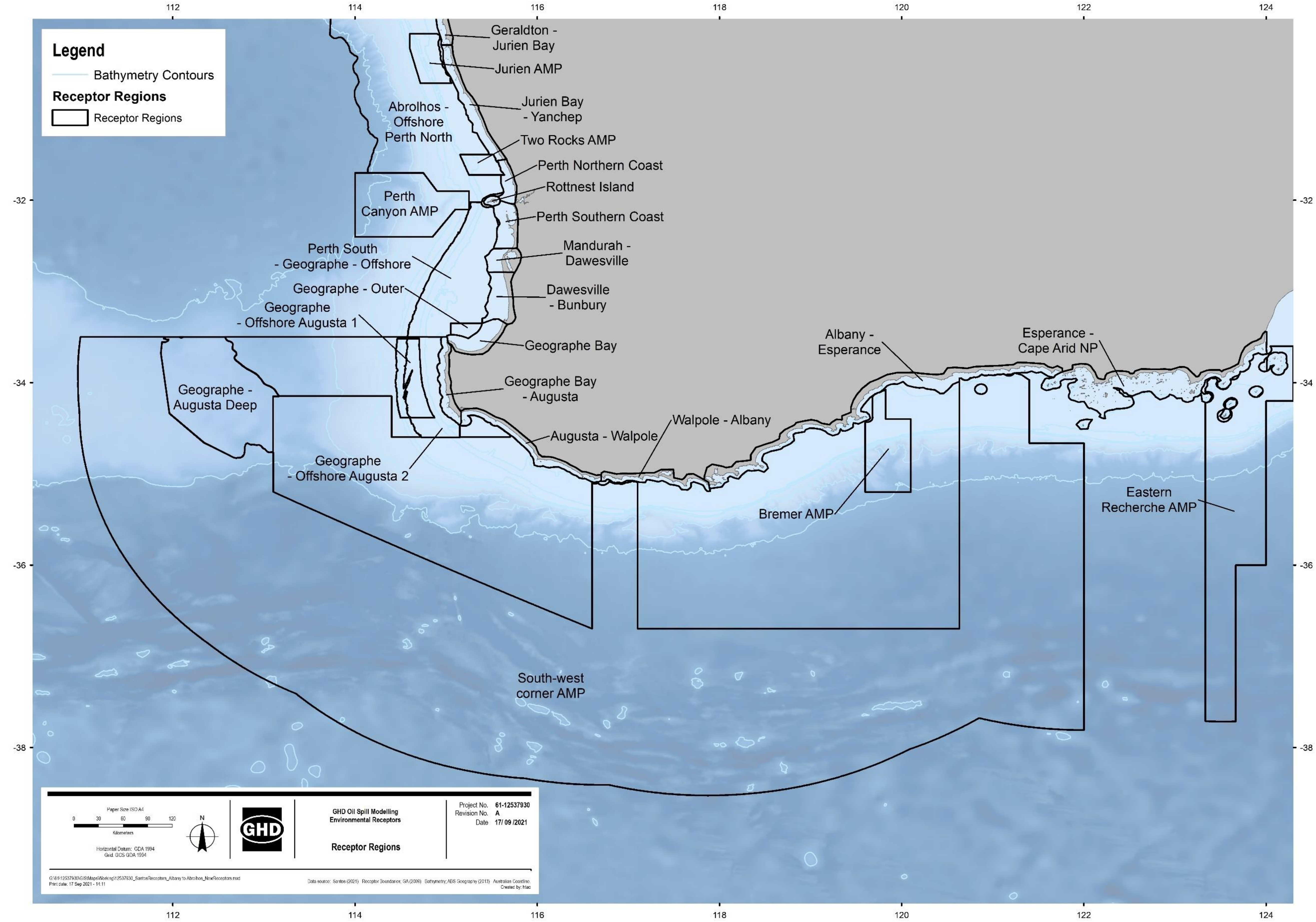


Figure 10 *Santos environmental receptors – Albany to Abrolhos*

3. Methodology

3.1 Description of the Model

Oil spill modelling was carried out with SINTEF's Oil Spill Contingency and Response (OSCAR) system (version 12.0). OSCAR is a system of integrated models that quantitatively assess the fate and transport of hydrocarbons in the marine environment, as well as evaluate the efficacy of response measures (Reed *et al*., 2001; Reed *et a*l., 2004). OSCAR provides an integrated hydrocarbon transport and weathering model that accounts for hydrocarbon advection, dispersion, surface spreading, entrainment, dissolution, biodegradation, emulsification, volatilisation and shoreline interaction. The weathering model (Daling *et al.,* 1997) is supported by an extensive oil library that contains detailed, laboratory-derived data for a wide range of hydrocarbons subjected to typical environmental conditions. OSCAR enables simulation of a hydrocarbon release scenario in deterministic mode (i.e. a scenario is simulated with one start date with spatial results available at fixed time intervals over the duration of the simulation) or stochastic mode (i.e. a scenario is simulated a number of times with varying start dates, and the results are outputted spatially in a probabilistic manner).

3.2 Selection of Hydrocarbon Modelling Analogues

Oil spill modelling in OSCAR is undertaken by selecting a hydrocarbon analogue from within the SINTEF Oil Library that provides the best match to the expected (target) hydrocarbon. The process for selecting the modelling analogue for Caley is described next.

3.2.1 Modelling Analogue for Caley

SINTEF's LAVRANS condensate was selected as the modelling analogue for Caley. A comparison of the bulk properties (Table 8) indicates the following:

– The specific gravity/API gravity of the modelling analogue LAVRANS is close to that of Caley. LAVRANS is a slightly heavier condensate (i.e. more conservative).
– The wax content (6%) of LAVRANS is lower than that of Caley (9.2%), though both oils have higher wax contents than is typical for condensates.
– The pour point of LAVRANS (-6°C) is higher than that of Caley (<-15°C).
– The LAVRANS asphaltene content (0.01%) is <0.5% reported for Caley.
– The LAVRANS viscosity of 2 cSt (measured at 20°C) is slightly higher (i.e. LAVRANS is slightly 'thicker' and more conservative) than that of Caley (1.878 cSt).

Table 8 Comparison of whole oil properties of Caley and SINTEF LAVRANS

Parameter	Caley (Intertek, 2020)	SINTEF Analogue: LAVRANS
API	51.4	47.8
Specific Gravity	0.7737	0.789
Wax Content (%)	9.2	6
Pour Point (°C)	<-15	-6
Asphaltene (%)	<0.5	0.01
Viscosity (cSt)	1.878 (@20°C)	2 (@20°C)

A comparison of the distillation curves of LAVRANS and Caley is presented in Figure 11. The distillation curve is derived from laboratory tests to determine the percentage of hydrocarbon evaporated (recovered) when heated to various temperatures (or 'cuts'). Lighter oil components evaporate under lower temperatures, whereas heavier oil components have a greater tendency to remain in liquid state, requiring higher temperatures to evaporate. This is analogous to oil weathering in the marine environment, whereby lighter components have a higher tendency to evaporate, dissolve or decay, and heavier components tend to persist as liquid hydrocarbon for extended durations. The distillation curve therefore provides a reasonable prediction of the relative proportions of hydrocarbon components that will have rapid rates of weathering and the relative proportions that will persist. The comparison of the distillation curves of LAVRANS and the Caley match very well, suggesting the hydrocarbons have similar weathering behaviour.

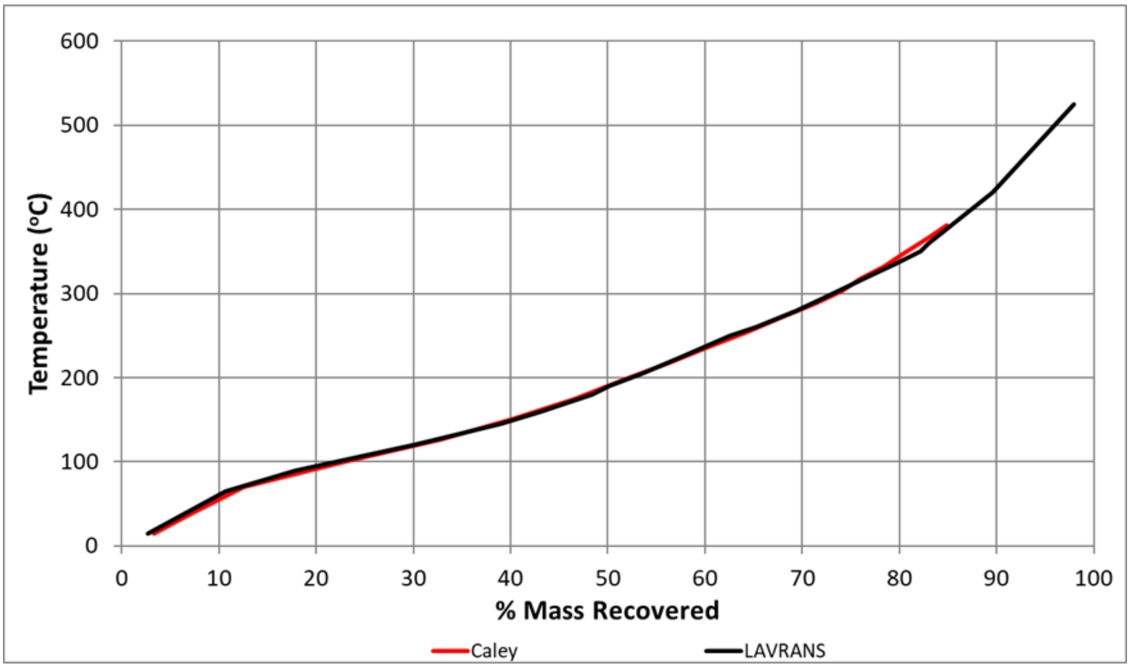


Figure 11 Comparison of distillation curves for Caley and LAVRANS

3.3 Hydrocarbon Weathering

A preliminary analysis of hydrocarbon weathering was undertaken with the SINTEF Oil Weathering Model (OWM). OWM predicts the mass balance partitioning of hydrocarbons (i.e. evaporation, surface, dispersed subsurface) and change in viscosity and pour point under steady-state met-ocean conditions. OWM simulations were run for sustained wind speeds of 1 m/s (low winds), 5 m/s (moderate winds) and 10 m/s (high winds). The simulations are based on a test case of 100 m^3 of hydrocarbon released instantaneously onto the sea surface.

3.3.1 LAVRANS

The results of the weathering analyses for the modelling analogue LAVRANS are presented in Figure 12.

Evaporation is the primary weathering mechanism for volatile condensates such as LAVRANS. Under low wind speeds of 1 m/s, approximately 65% of the surface slick is predicted to evaporate after 5 days (120 hours) while wind-driven dispersion into the water column does not occur under these relatively calm conditions. Under moderate wind speeds of 5 m/s, approximately 62% of the surface slick, which is slightly lower than the calm condition (1 m/s winds) due to wind-driven dispersion of a significant portion of the oil (35% by 48 hours and 38% after 72 hours) into the water column which reduces the amount of surface oil available for evaporation. High wind speeds of 10 m/s are predicted to rapidly (after only 12 hours) disperse (45%) and evaporate (55%) the oil with no surface slick remaining thereafter.

LAVRANS has a negligible tendency for emulsion formation (0% water content in the slick predicted under the wind conditions assessed).

The predicted changes in viscosity and pour point of the surface oil slick due to weathering are presented in Figure 13 and Figure 14, respectively. The viscosity of the surface slick was predicted to increase from ~3 cP after 0.5 hours to ~26 cP after 12 hours for the high wind (10 m/s) scenario (after which time the remaining surface slick is entirely entrained by wind activity) and up to ~36 cP after 5 days (120 hours) for the low wind (1 m/s) scenario, with additional weathering and viscosity increase anticipated to occur beyond this time. Similarly, the pour point increases as the oil weathers from ~-2-8°C after 0.5 hours, reaching 29°C after 12 hours for high winds (10 m/s) and 33°C after 5 days (120 hours) for low winds (1 m/s). These viscosity and pour point changes within the first 5 days are not likely to impact the efficacy of response measures (e.g. dispersant application) on reducing surface oil.

It is noted that the pour point of LAVRANS is predicted to reach 29-33°C (depending on wind conditions) after weathering. This exceeds typical surface water temperatures (26-29°C, section 2.3.3), which would suggest that the oil would begin to gel or solidify after weathering, however this is not reflected in the viscosity which remains relatively low. Additional information on the weathering dynamics of LAVRANS was provided by SINTEF as follows:

– In the case of this waxy condensate, the ‘gelling’ process, were it to occur, would involve the wax forming a physical network structure within the oil, which hardens it. However, this process is interrupted by wave motion continually breaking up the waxy structure. So, while it might begin to gel if left undisturbed, this doesn’t occur under the oceanic conditions simulated, nor did it occur under laboratory tests that are designed to be representative of oceanic conditions. This explains how the pour point can increase but the viscosity can remain quite low in an oceanic setting.
– The LAVRANS residue was not measured to have a high viscosity during the laboratory testing of this oil, so in this regard the weathering results agree with the laboratory testing. It was noted that the actual process of measuring viscosity can introduce shear forces into the oil which cause the wax network to break down (similar to how the waves break it down as described above).
– In conclusion, the oil would likely have the potential to form a ‘gel’ or solidified residue if left undisturbed, however this behaviour was not noted in the laboratory studies, and further is not likely to occur under oceanic conditions.

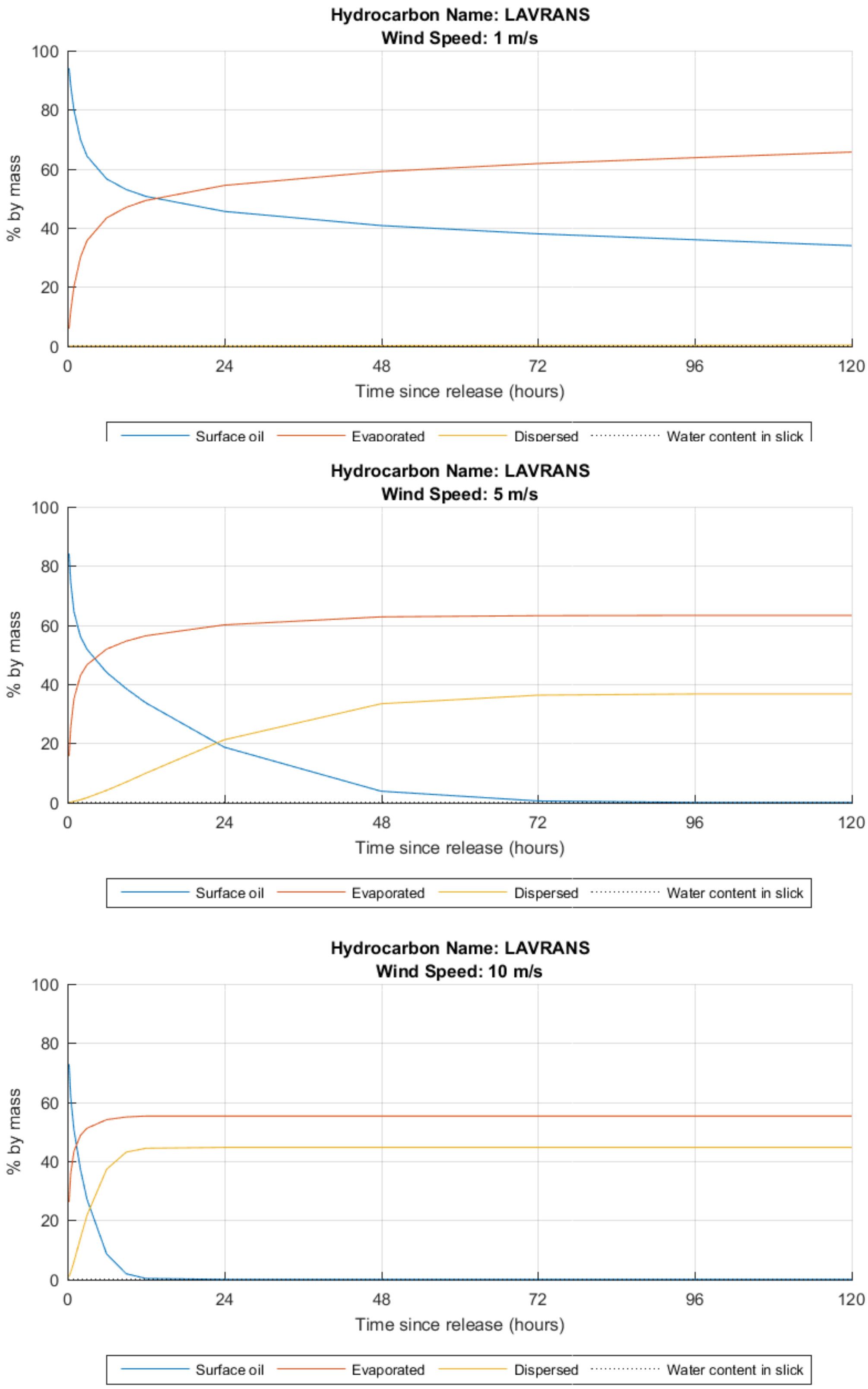


Figure 12 ***Simulated weathering of the SINTEF LAVRANS hydrocarbon for constant wind speeds of 1 m/s (top), 5 m/s (middle) and 10 m/s (bottom)***

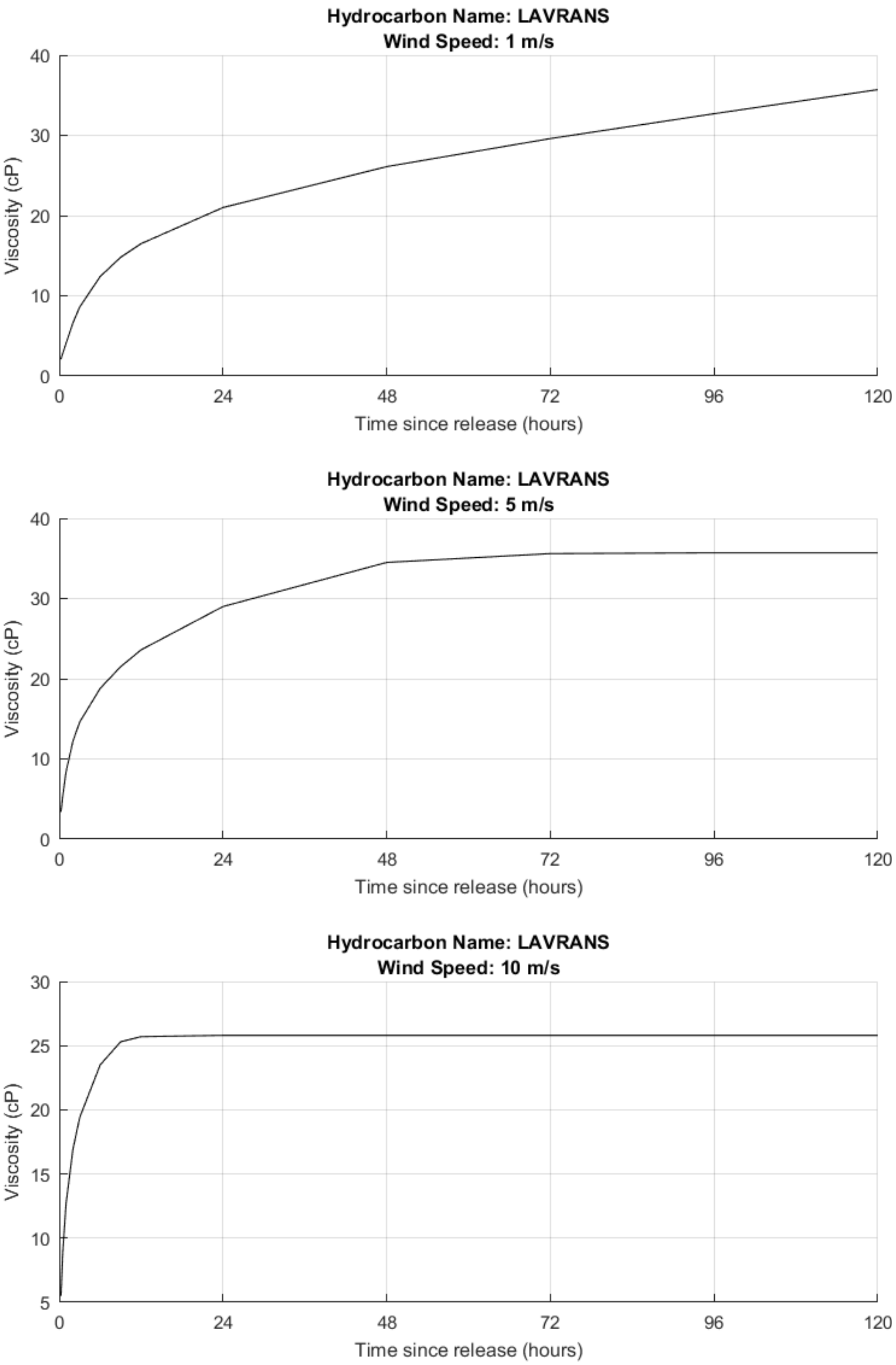


Figure 13 ***Simulated change in viscosity of the SINTEF LAVRANS hydrocarbon for constant wind speeds of 1 m/s (top), 5 m/s (middle) and 10 m/s (bottom)***

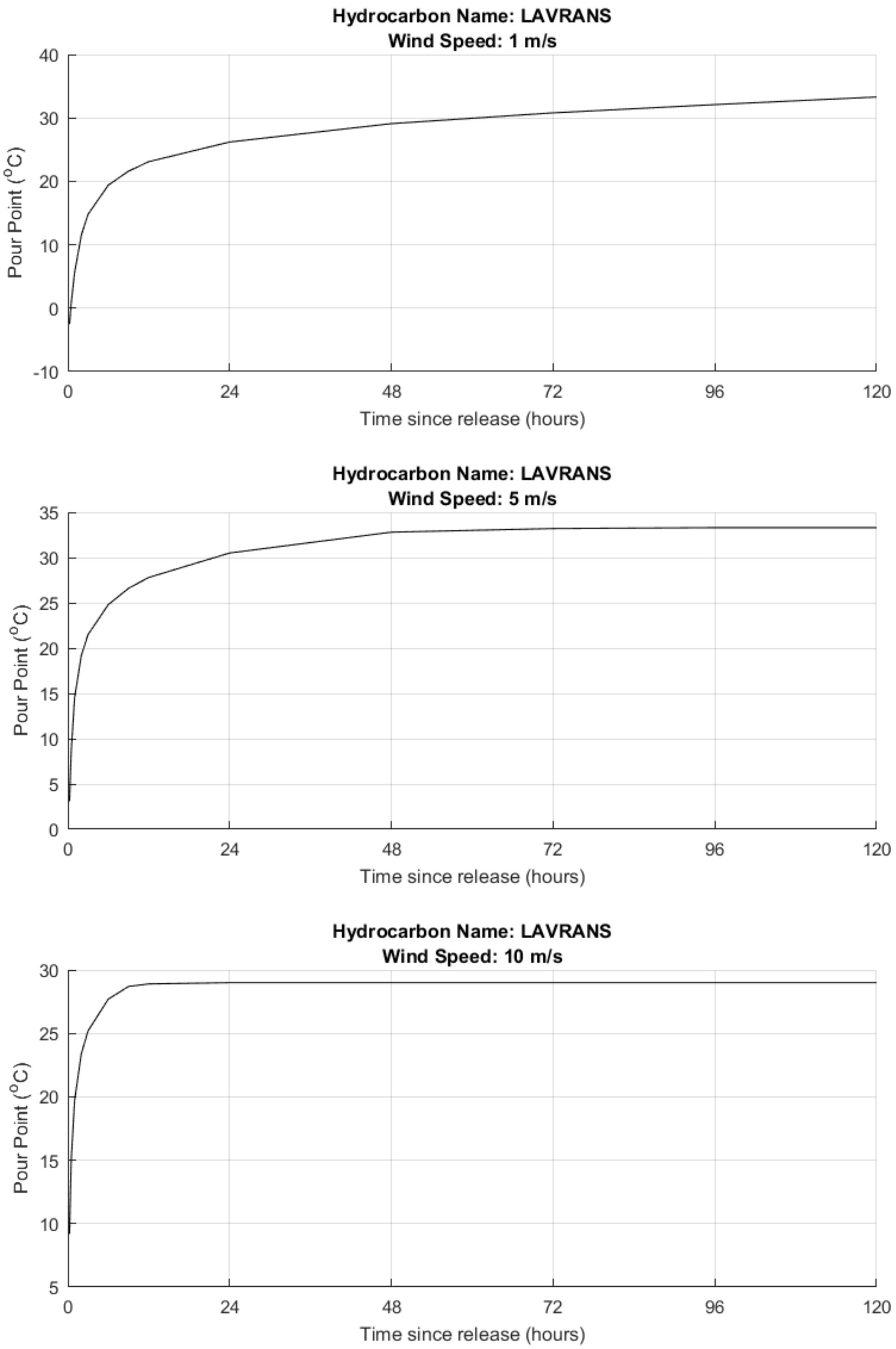


Figure 14: Simulated change in pour point of the SINTEF LAVRANS hydrocarbon for constant wind speeds of 1 m/s (top), 5 m/s (middle) and 10 m/s (bottom)

3.4 Stochastic Hydrocarbon Fate and Transport Assessment

3.4.1 Stochastic Configurations

Far-field spill modelling was carried out with OSCAR. The model was configured in stochastic mode to simulate a range of environmental conditions. The start dates for the LOWC stochastic simulations were staggered approximately fortnightly across five years of hydrodynamic and wind data. A total of 150 individual 'realisations' made up the full stochastic simulation set for each of the LOWC spill scenarios. For each set of stochastic realisations, OSCAR spatially tracked the surface oil, total submerged oil in the water column, dissolved oil and oil on shorelines. The 'total submerged oil' is comprised of dissolved oil and entrained oil (or droplets), and therefore provides a conservative (over) representation of the NOPSEMA (2019) thresholds for entrained oil.

To present this large amount of simulated data in a meaningful way, contact thresholds are applied to each of the hydrocarbon components and OSCAR generates statistical spatial outputs of the instances when and where each threshold was exceeded. For example, if a contact threshold of 100 ppb is applied to the dissolved component, the stochastic output from OSCAR will present the area of effect (potentially impacted) and associated probabilities (amongst other statistics) for which the concentration of dissolved hydrocarbons exceeded 100 ppb at any model grid cell during any of the realisations. The stochastic configurations for each spill scenario are summarised in Table 9.

3.4.2 Processing of Stochastic Results

The stochastic outputs for surface, total submerged oil, dissolved and shoreline hydrocarbons were processed in the manner described next.

Probability of Instantaneous Exposure

The *'probability of instantaneous exposure'* indicates the percentage of realisations that a threshold was exceeded at any instant at a particular location. The thresholds may be an instantaneous concentration (ppb), a time-integrated concentration (ppb.hr) or a mass per unit area (g/m^2).[4]

Arrival Time

The *'arrival time'* indicates the amount of time from the start of a realisation (i.e. the start of the release) until an adopted threshold is first exceeded. For stochastic simulations, the *'minimum arrival time'* is the shortest arrival time from any single realisation. This statistic is evaluated for individual cells in the model grid. When reported for receptor regions consisting of multiple cells, the minimum value anywhere within the receptor region is reported.

Concentration

The *'concentration'* indicates the mass of oil per unit volume (i.e. submerged in seawater) or per unit area (i.e. on seawater surface or on shoreline) of the receiving environment. For stochastic simulations, the *'maximum concentration'* is the highest concentration from any single point in time, in any single realisation, and if applicable at any water depth. This statistic is evaluated for individual cells in the model grid. When reported for receptor regions consisting of multiple cells, the maximum value anywhere within the receptor region boundary is reported.

Time-Averaged Outputs

'*Time-averaged'* data (e.g. time-averaged concentration) are reported for a number of parameters. For stochastic realisations, time averaging is calculated over the times at which a parameter exceeds the specified threshold. For example, when considering dissolved hydrocarbons concentration above a threshold of 100 ppb, the '*time-averaged concentration'* for a model cell will be the average concentration in that cell when the concentration was above 100 ppb (i.e. the average is not reduced by the periods in which no dissolved hydrocarbons were present, or dissolved hydrocarbons were below the threshold value).

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[4] Toxicity thresholds should account for intensity, duration and frequency. The instantaneous approach (ppb) does not account for exposure duration.

Table 9 Summary of stochastic simulation configuration

Parameter	Apus Base Case Subsea LOWC	Apus Base Case Surface LOWC	Apus Alternate Subsea LOWC	Apus Alternate Surface LOWC	Source/Justification
Location	19° 11' 25.29" S 118° 59' 10.64" E				Apus-1 well location (advised by Santos, selected as the worst-case location as described in section 2.3.1.1)
Hydrocarbon Modelling Analogue	LAVRANS				*LAVRANS* selected as the modelling analogue for Caley (Section 3.2.1) in the SINTEF oil library
Release Depth	72 m	0 m (sea surface)	72 m	0 m (sea surface)	Advised by Santos
Diameter of subsea release orifice (m)	0.30	NA	0.21	NA	Advised by Santos. Surface spills do not use the diameter as an input as the hydrocarbon is initialised as floating oil on the sea surface.
Simulation Period	All months of the year				Advised by Santos
Liquid Release Volume	10,982,250 STB (1,745,986 m^3)	10,858,774 STB (1,746,355 m^3)	8,964,764 STB (1,425,241 m^3)	8,377,354 STB (1,331,852 m^3)	Advised by Santos
Gas Release Volume	19,255 MMscf (545.25 million sm^3)	NA	15,718 MMscf (445.01 million sm^3)	NA	Advised by Santos. Surface spills do not require a gas input as gas discharged is lost directly to the atmosphere.
Release Duration	77 days				Advised by Santos
Simulation Duration	112 days (16 weeks)				Sufficient duration following cessation of the release to allow environmental concentrations to reduce below the selected thresholds
Approximate interval between sequential stochastic realisation start dates	2 weeks				Sufficiently small interval to characterise stochastic range of oil spill effects
Threshold for Shoreline Hydrocarbons	10 g/m^2, 100 g/m^2 and 1,000 g/m^2				On the basis of NOPSEMA Bulletin #1 (NOPSEMA, 2019)
Thresholds for Surface Hydrocarbons	1 g/m^2, 10 g/m^2, and 50 g/m^2				On the basis of NOPSEMA Bulletin #1 (NOPSEMA, 2019)
Threshold for Total Submerged Oil	10 ppb and 100 ppb				On the basis of NOPSEMA Bulletin #1 (NOPSEMA, 2019)[5]
Threshold for Dissolved Hydrocarbons	10 ppb, 50 ppb and 400 ppb				On the basis of NOPSEMA Bulletin #1 (NOPSEMA, 2019)

[5] Note: the NOPSEMA thresholds refer to an entrained concentration only (not total submerged oil, which is entrained + dissolved oil). OSCAR outputs are provided as total submerged oil values. The entrained thresholds specified by NOPSEMA are applied directly as total submerged oil thresholds in this assessment, which is a conservative approach given that entrained oil contributes only partially to the calculation of total submerged oil.

Accumulated Oil Ashore

Oil on shorelines is tracked by OSCAR as an accumulated value for the stochastic simulations. The calculation for accumulated oil is the sum of all oil that has arrived at a shoreline cell over the duration of the simulation. In this manner, it does not consider weathering losses due to evaporation or washing of the shoreline by waves. The accumulated value will therefore be a conservative over-estimate of the peak oil mass at a shoreline when compared to the deterministic prediction, which does consider these loss mechanisms. In contrast, the accumulated oil ashore for deterministic simulations in OSCAR accounts for weathering losses on the shoreline due to evaporation and degradation, as well as washing of the shoreline by waves.

Scaling Analysis of Shoreline Loading of Small Islands

Three small Australian islands (Cartier Island, Ashmore Reef and Bedout Island) have smaller characteristic length scales (l_{Island}) than the minimum model shoreline length (~5.7 km [l_{Grid}] which is the diagonal length of the ~4 km model cells). A scaling analysis to reduce the simulated shoreline loading onto the larger modelled islands (L_{Grid}) was used to estimate a more realistic loading onto the actual small island dimensions (L_{Island}) on the basis of the model output where:

$$L_{Island} = \frac{l_{Island}}{l_{Grid}} L_{Grid}$$

The shoreline scaling factors (l_{island}/l_{grid}) used for the small islands are presented in Table 10.

Table 10 Small island scaling factors

Receptor Name	l_{Island} (km)	l_{Grid} (km)	Scaling Factor (l_{island}/l_{grid})
Cartier Island	0.6	5.7	11%
Ashmore Reef	5.0	39.8	13%
Bedout Island	1.1	5.7	19%

3.5 Deterministic Assessment

The stochastic simulation output provides a probabilistic temporal and spatial representation of potential impacts from an oil spill incident. To further inform the OPEP, individual stochastic realisations were selected to run in OSCAR's deterministic mode to characterise shoreline loading (i.e. loads) and the mass balance of the released oil in the marine environment (e.g. proportion of released oil lost to decay or volatilisation, proportion remaining as droplets).

The deterministic simulations were run only for the base case scenarios (worst-case flow rates) and were selected based on the following criteria:

– Highest accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for the surface and subsea LOWC scenarios
– Highest surface oil mass >50 g/m^2 for whichever is higher of the surface/subsea LOWC scenarios
– Minimum arrival time of accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for whichever is shorter of the surface/subsea LOWC
– Maximum length of accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for whichever is longer of the surface/subsea LOWC.

Further, the deterministic simulations of the highest accumulated shoreline loading were run with and without the inclusion of a dispersant application plan. The following dispersant response strategies were evaluated via deterministic simulations of the selected realisations of the surface and subsurface LOWC scenarios:

– For the selected surface LOWC realisation, deterministic simulations only evaluated surface dispersant application (SDA) via vessels and aircraft, with dispersant only being applied outside of an exclusion zone of 25 km radius around the Apus-1 well location.

– For the above scenario, an additional SDA response was simulated which allowed dispersant application in the immediate vicinity of the well site, rather than outside of a 25 km radius exclusion zone. The purpose was to evaluate the benefit of the exclusion zone in allowing evaporation of oil from the surface slick prior to chemically dispersing the oil into the water column. This simulation was compared to the simulation with the dispersant application exclusion zone to estimate differences between the two strategies.
– For the selected subsea LOWC realisation, deterministic simulations were carried out of subsea dispersant injection (SSDI) and a combined SSDI and SDA (i.e. the two responses occurring concurrently) to evaluate the relative benefit of each approach.

The configurations of the SDA and SSDI response plans are described next.

3.5.1 Surface Dispersant Application Plan

Surface Dispersant Application (SDA) was simulated with the OSCAR response module that included the use of vessels, Fixed Wing Aerial Dispersant Capability (FWADC) aircraft and Hercules aircraft as summarised in Table 11. Further, varying mobilisation and operation times for each individual vessel and aircraft were included in the response strategy as summarised in Figure 15, including up to 8 vessels, up to 8 FWADC and 1 Hercules.

Table 11: Summary of surface dispersant application mitigation strategy[6]

Strategy Element	Vessel/s	Aircraft (FWADC)	Aircraft (Hercules)
Base of operations (location)	Port Hedland	Port Hedland	Port Hedland
Downtime at base (refuelling etc.)	0.5 hrs	1.5 hrs	2.7 hrs
Daily operation hours	12 (daylight only)	12 (daylight only)	12 (daylight only)
Cruise speed	13 knots	160 knots	300 knots
Operational speed (when applying dispersants)	5 knots	90 knots	150 knots
Dispersant tank size	10 m^3	3 m^3	13 m^3
Dispersant application rate	1:25		
Dispersant efficacy	40%		
Oil searching strategy	Thickest Oil		
Minimum thickness threshold	>50 µm		
Maximum viscosity threshold	<10,000 cSt		
Exclusion zones	Australian Marine Parks (Multiple Use Zones allowed), State Marine Parks, State Waters Within 10 km of water depths <10 m Within exclusion zones of offshore facilities Not applied within 25 km of the well site[7]		

[6] Strategy inputs provided by Santos.
[7] The 25 km exclusion zone allows for natural evaporation from the surface slick prior to chemically dispersing the oil (and preventing further evaporation until resurfacing). 25 km allows for ~24 hours of evaporation to occur, assuming a typical current speed of 0.25 m/s (section 2.3.1), which will yield evaporation of ~60% of the oil under moderate winds of 5 m/s (section 3.3.1).

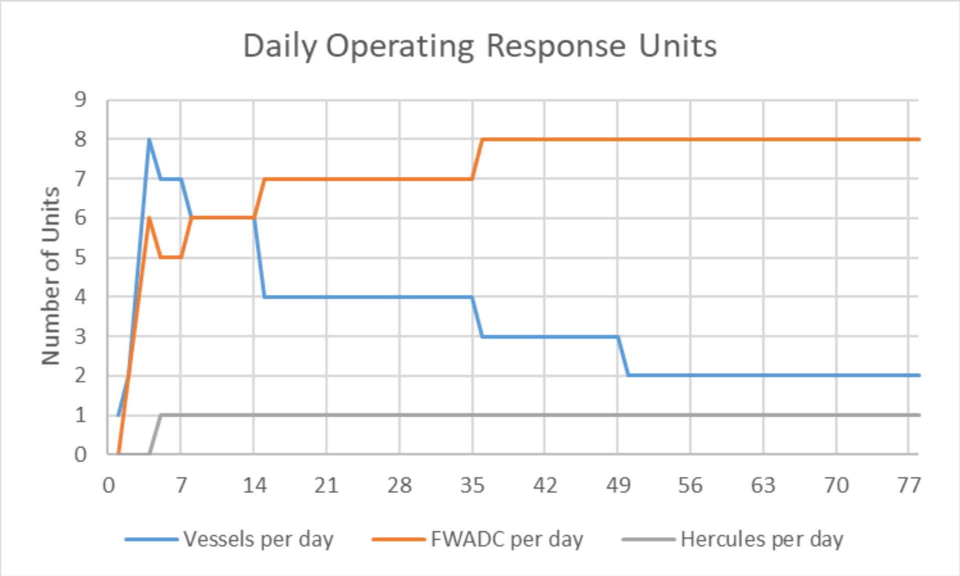


Figure 15 *Summary of response asset availability for the SDA plan*

3.5.2 Subsea Dispersant Injection Plan

Subsea Dispersant Injection (SSDI) involves injecting dispersant into the subsea plume at the release orifice. The response plan provided by Santos specified SSDI beginning 9 days after the start of the release, with an application rate of 1:100 (1 part dispersant to 100 parts liquid condensate) and a dispersant efficacy of 75%. For the subsea LOWC scenario, this application rate results in the use of 15,587 m^3 of dispersant applied to the subsea plume after day 9.

SSDI is configured in OSCAR by specifying the start and end days of SSDI injection and the dispersant efficacy (i.e. mixing efficiency). For the portion of the volume treated by SSDI, the simulated droplets in the subsea plume are assigned a reduced oil-water interfacial tension (reduced to half that of untreated oil). This has the effect of causing the liquid droplets (of the treated oil component) to break up into smaller droplets during release.

4. Results

4.1 Stochastic Modelling

Stochastic modelling outputs were evaluated for the following thresholds (also refer to Table 9 of section 3.4.1):

– Accumulated shoreline oiling above 10 g/m^2, 100 g/m^2 and 1,000 g/m^2.
– Instantaneous surface hydrocarbons above 1 g/m^2, 10 g/m^2 and 50 g/m^2.
– Instantaneous total submerged oil above 10 ppb and 100 ppb.
– Instantaneous dissolved hydrocarbons above 10 ppb, 50 ppb and 400 ppb.

The spatial extent of each threshold is described in the following sections with greater emphasis on the moderate thresholds (those underlined in bullet list above), which represent the lower limits for environmental impacts.

Further, the simulated shoreline oiling lengths of Cartier Island AMP, Ashmore Reef AMP and Bedout Island are an artefact of the relatively large model grid size of ~5.7 km compared to the smaller lengths of exposed shoreline at these locations (as described in section 3.4.2). Similarly, the maximum shoreline accumulations on the emergent shorelines would be less, as the total accumulation occurs on the larger modelled island length. Scaled shoreline accumulation and maximum oiled shoreline lengths are shown in parentheses for these receptors within the summary tables. Only the scaled values are referred to in the descriptions of the predicted shoreline oiling impacts, while the unscaled results can be seen in the summary tables.

4.1.1 Apus Base Case Subsea LOWC Scenario

4.1.1.1 Subsea Dynamics

The subsea dynamics of the Apus Base Case Subsea LOWC are highly energetic due to the gas volume that accompanies the release of liquid for this scenario. Whereas a surface release scenario will result in the gas being immediately lost to the atmosphere, the gas in a subsea discharge scenario contributes to the velocity and momentum of the subsea plume as it exits the release orifice.

At standard temperature and pressure (STP, which is 15°C and atmospheric pressure), the gas flow rate varies between 84.8 sm^3/s during the first week, decreasing to 80.5 sm^3/s by week 11 (Table 12). However, at the release depth of 72 m for the subsea scenario, the hydrostatic pressure compresses the gas, reducing the volumetric flow rate to 12.3-13.0 m^3/s.

Simulated momentum and buoyancy-scaled exit velocities range between 27.2-28.5 m/s that yield small median droplet sizes of 407-432 µm.

Table 12 Summary of near-field subsea plume dynamics

Week	Gas Flow Rate at STP[8] (sm^3/s)	Gas Flow Rate at Release Depth (m^3/s)	Liquid Oil Flow Rate (m^3/s)	Momentum and Buoyancy Scaled Effective Outlet Velocity (m/s)	Median Droplet Size (µm)
Week 1	84.8	13.0	0.27	28.5	407
Week 2	83.5	12.8	0.27	28.2	413
Week 3	82.8	12.7	0.27	27.9	417
Week 4	82.3	12.6	0.26	27.8	420
Week 5	81.9	12.6	0.26	27.7	422
Week 6	81.6	12.5	0.26	27.6	424
Week 7	81.3	12.5	0.26	27.5	426
Week 8	81.1	12.4	0.26	27.4	427
Week 9	80.9	12.4	0.26	27.3	429
Week 10	80.7	12.4	0.26	27.3	430
Week 11	80.5	12.3	0.26	27.2	432

4.1.1.2 Accumulated Shoreline Oil

Shoreline oiling is assessed at three thresholds that represent low (10 g/m^2, visual/aesthetic threshold), moderate (100 g/m^2, impact threshold that may require clean-up effort), and high (1,000 g/m^2, requires intensive clean-up effort) accumulated shoreline loadings. A summary of the shoreline loading predictions is presented in Table 13, and loading probabilities and maximum accumulated shoreline loadings are mapped spatially in Figure 17 and Figure 18, respectively, for the three thresholds.

Shoreline loading above the low (10 g/m^2) threshold was predicted to occur up to ~1,300 km from the release site to the southwest (at Jurien Bay – Yanchep) and ~1,000 km to the north-northeast (at Indonesia – East) (Figure 17). At the moderate (100 g/m^2) and high (1,000 g/m^2) thresholds, the spatial extent of shoreline accumulation to the southwest was reduced to ~1,100 km and ~900 km, for each threshold respectively, while accumulation to the north-northeast remained at ~1,000 km distance (at Indonesia – East).

Shoreline accumulation above the moderate threshold (100 g/m^2) is summarised as follows:

– Across all shorelines, a 100% contact probability is predicted with a maximum accumulated shoreline load of 2,054 tonnes, a minimum arrival time of 3.5 days and a maximum length of oiled shoreline of 433 km.

– A very high contact probability of 81% was predicted for the proximal island receptor of Bedout Island. This receptor was predicted to receive a maximum shoreline accumulation of 63 tonnes, with a minimum arrival time of 3.5 days and maximum oiled shoreline length of 1 km (the island length).

– Moderately high contact probabilities of 30-57% were predicted at Clerke Reef MP, Imperieuse Reef MP, Dampier Archipelago, Montebello Islands, Barrow Island, Thevenard Islands, Southern Islands Coast, Muiron Islands and Ningaloo Coast North. Maximum accumulated shoreline loads at these locations were 1,014 tonnes at Imperieuse Reef MP, 919 tonnes at Clerke Reef MP, 849 tonnes at Dampier Archipelago and 102-420 tonnes at the other receptors. Minimum arrival times of shoreline loading at these locations ranged between 13.5 days to 30.5 days. Maximum predicted lengths of shoreline accumulation were between 11 km to 85 km, with the exception of Ningaloo Coast North (188 km).

– Moderate contact probabilities of 12-29% were predicted at Scott Reef South, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Lowendal Islands, Ningaloo Coast South, Eighty Mile

[8] Standard Temperature and Pressure – The volume of gas is calculated assuming a temperature of 15°C and a pressure of 1 atm

Beach, and Roebuck – Eighty Mile Beach. Maximum accumulated shoreline loads at these receptors were between 52 tonnes and 642 tonnes. Minimum arrival times of shoreline loading at these locations ranged between 5.1 days and 53.9 days, while maximum predicted lengths of shoreline accumulation were between 6 km and 85 km.

– Low probabilities of contact (<10%) were predicted at Cartier Island AMP, Ashmore Reef AMP, Scott Reef North, King Sound, Broome North Coast, Middle Islands Coast, Shark Bay – Coast Outer, Abrolhos Islands Wallabi Group, Abrolhos Islands Pelsaert Group, Indonesia – East, Broome – Roebuck and Jurien Bay - Yanchep. Contact probabilities, accumulated shoreline loads, minimum arrival times and maximum oiled shoreline lengths for these receptors are summarised in Table 13.

A histogram of total shoreline loading above the moderate threshold (100 g/m^2) across the 150 stochastic realisations is presented in Figure 16 and a spatial summary of maximum accumulated shoreline oil is shown on Figure 18. Shoreline accumulation at the moderate threshold was predicted to occur for 100% of the realisations. No clear seasonal trend is evident in the shoreline loading predictions. Approximately half of the realisations resulted in shoreline accumulation greater than 500 tonnes (up to a maximum of 2,054 tonnes).

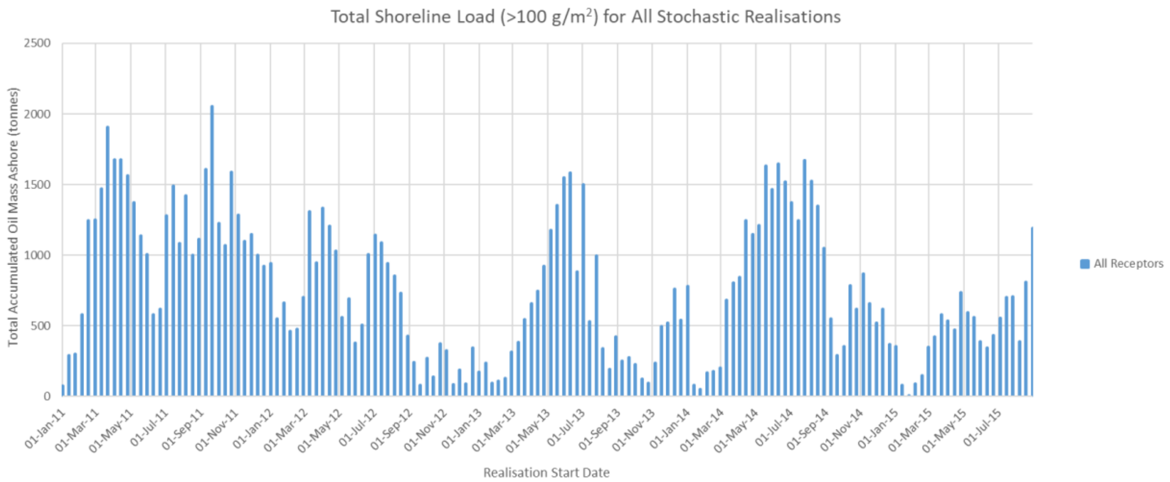


Figure 16 *Apus Base Case Subsea LOWC Scenario – Summary of total accumulated shoreline load for all stochastic realisations for the 100 g/m^2 threshold*

4.1.1.3 Surface Oil

Surface oiling is evaluated at three instantaneous contact thresholds representing low (1 g/m^2, visual/aesthetic threshold), moderate (10 g/m^2, lower limit for potential ecological impacts), and high (50 g/m^2, approximating concentrations that can be targeted during spill response) concentrations. A summary of the surface oil predictions are presented in Table 14, and contact probabilities and maximum surface oil concentrations are mapped spatially in Figure 19 and Figure 20 for the three thresholds, respectively.

Surface oil above the low threshold (1 g/m^2) was predicted to occur at distances up to ~1,100 km from the release location (Figure 19). Significant reductions in the spatial extent of surface oil are predicted for the moderate threshold (10 g/m^2) which extends up to ~550 km from the release location, while the high threshold (50 g/m^2) is further reduced in spatial extent to within ~225 km of the release location.

Surface oil impacts at the moderate threshold (10 g/m^2) include:

– A moderately high contact probability of 54% was predicted for the Eighty Mile Beach AMP, with a maximum time-averaged surface oil concentration of 43 g/m^2 and a minimum arrival time of 1.8 days.

– A moderate contact probability of 23% was predicted at Bedout Island, with a maximum time-averaged surface oil concentration of 42 g/m^2 and a minimum arrival time of 3.3 days.

– Low contact probabilities (<6%) were predicted at Mermaid Reef AMP, Port Hedland-Eighty Mile Beach, Glomar Shoals, Eighty Mile Beach, Rowley Shoals surrounds and Ningaloo - Offshore, with maximum time-averaged concentrations of 12-17 g/m^2 and minimum arrival times of 13.7 to 45.8 days.

4.1.1.4 Total Submerged Oil

Total submerged oil (entrained plus dissolved oil) is evaluated at low (10 ppb, potential exceedance of water quality triggers) and moderate (100 ppb, potential impacts) instantaneous contact thresholds. Total submerged oil predictions are summarised in Table 15 and contact probabilities are mapped spatially in Figure 21 for the two thresholds.

Total submerged oil at the low threshold (10 ppb) was predicted to occur up to ~1,800 km from the release location. At the moderate threshold (100 ppb), predicted contact reduced in spatial to within ~1,100 km from the release location.

Total submerged oil impacts at the moderate threshold (100 ppb) include:

– Very high contact probabilities were predicted at Eighty Mile Beach AMP (99%) and Bedout Island (73%), with maximum time-averaged concentrations at these receptors of 1,936 ppb and 1,037 ppb, respectively, and with minimum arrival times of 2.1 and 3.8 days, respectively.

– Moderately high contact probabilities of 30-58% were predicted at Glomar Shoals, Dampier Archipelago, Eighty Mile Beach, Kimberley AMP, Dampier AMP, Montebello AMP, Rowley Shoals surrounds and Ningaloo - Offshore. Maximum time-averaged concentrations at these locations ranged between 315 ppb and 1,987 ppb, with minimum arrival times of 10.4 to 24.3 days.

– Moderate contact probabilities of 12-28% were predicted at Mermaid Reef AMP, Clerke Reef MP, Imperieuse Reef MP, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Rankin Bank, Montebello Islands, Barrow-Montebello Surrounds, Roebuck - Eighty Mile Beach, Ningaloo – Outer Coast North and Ningaloo – Outer NW. Maximum time-averaged concentrations at these locations ranged between 231 ppb and 1,823 ppb, with minimum arrival times of 5.2 to 25.9 days.

– Very low contact probabilities (<8%) occurred at several other receptor locations with contact probabilities, maximum time-averaged oil concentrations and minimum arrival times summarised in Table 15.

4.1.1.5 Dissolved Hydrocarbons

Dissolved hydrocarbons were evaluated at the low (10 ppb, potential exceedance of water quality triggers), moderate (50 ppb, potential sub-lethal toxic effects) and high (400 ppb, potential toxic lethal effects) instantaneous contact thresholds. A summary of the dissolved hydrocarbon predictions is presented in Table 16 and contact probabilities are mapped spatially in Figure 22 for the three thresholds.

Dissolved hydrocarbons at the low threshold (10 ppb) were predicted to extend a maximum distance of ~350 km from the release location. At the moderate threshold (50 ppb), the spatial extent was reduced to within ~150 km, while exceedance of the high threshold (400 ppb) was limited to within ~100 km of the release site.

Eighty Mile Beach AMP was the only receptor predicted to be contacted at the moderate threshold (50 ppb) with a very low contact probability of 5%, a maximum time-averaged concentration of 94 ppb and minimum arrival time of 4.8 days.

Table 13 Apus Base Case Subsea LOWC Scenario – Summary of shoreline oiling

Receptor Name	Total Contact Probability (%)			Maximum Accumulated Oil Concentration (g/m^2)			Maximum Accumulated Oil Ashore (tonnes)			Minimum Arrival Time (days)			Maximum Length of Oiled Shoreline (km)		
	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2
Cartier Island AMP	2.7	2.7	2.0	2,299	2,299	2,299	26.1 (2.7)	26.1 (2.7)	26.1 (2.7)	73.1	73.1	73.1	5.7 (0.6)	5.7 (0.6)	5.7 (0.6)
Ashmore Reef AMP	4.7	4.7	4.0	7,080	7,080	7,080	227.4 (28.6)	227.4 (28.6)	227.4 (28.6)	64.3	64.3	71.3	39.8 (5.0)	39.8 (5.0)	39.8 (5.0)
Scott Reef North	8.7	8.7	6.0	4,048	4,048	4,048	200.8	200.8	178.4	51.8	51.8	61.7	45.5	45.5	34.1
Scott Reef South	12.0	12.0	8.7	12,772	12,772	12,772	595.4	595.4	595.4	53.9	53.9	55.9	56.9	56.9	56.9
King Sound	2.0	2.0	2.0	4,963	4,963	4,963	56.4	56.4	56.4	56.3	56.3	56.3	5.7	5.7	5.7
Broome North Coast	7.3	6.0	4.7	5,053	5,053	5,053	108.0	108.0	108.0	26.1	26.1	26.1	22.7	22.7	11.4
Clerke Reef MP	45.3	44.7	38.7	21,768	21,768	21,768	919.1	919.1	911.0	15.9	15.9	15.9	51.2	51.2	51.2
Imperieuse Reef MP	58.0	57.3	45.3	27,259	27,259	27,259	1,014	1,014	1,008	13.5	13.5	13.5	56.9	56.9	56.9
Port Hedland-Eighty Mile Beach	22.7	21.3	13.3	18,322	18,322	18,322	641.8	641.8	641.8	5.1	5.1	5.1	51.2	45.5	34.1
Karratha-Port Hedland	22.0	20.0	6.7	6,533	6,533	6,533	138.5	138.5	138.5	7.6	7.6	7.6	39.8	34.1	11.4
Dampier Archipelago	55.3	54.7	51.3	21,712	21,712	21,712	848.9	848.9	833.2	15.2	15.2	15.2	91.0	85.3	68.2
Northern Islands Coast	16.7	14.7	5.3	3,671	3,671	3,671	61.3	61.2	61.2	28.2	28.2	31.3	22.7	17.1	17.1
Montebello Islands	49.3	46.7	38.0	17,238	17,238	17,238	419.9	419.9	417.0	19.5	19.5	22.5	22.7	22.7	22.7
Lowendal Islands	21.3	17.3	9.3	7,726	7,726	7,726	87.8	87.8	87.8	20.4	20.4	29.4	5.7	5.7	5.7
Barrow Island	44.0	42.7	33.3	12,989	12,989	12,989	337.3	337.3	331.3	24.1	24.1	24.1	73.9	68.2	51.2
Middle Islands Coast	0.7	0.7	0.7	1,487	1,487	1,487	16.9	16.9	16.9	106.8	106.8	106.8	5.7	5.7	5.7
Thevenard Islands	34.0	30.0	18.7	5,842	5,842	5,842	101.6	101.6	101.6	25.4	25.4	31.0	11.4	11.4	11.4
Southern Islands Coast	41.3	39.3	31.3	17,788	17,788	17,788	315.6	315.6	311.5	26.7	26.7	28.7	22.7	17.1	17.1
Muiron Islands	42.0	40.0	24.7	17,542	17,542	17,542	287.8	287.8	287.8	28.2	28.2	29.5	17.1	17.1	17.1
Ningaloo Coast North	41.3	40.7	26.0	7,498	7,498	7,498	400.4	397.9	307.1	30.5	30.5	30.5	210.4	187.6	68.2
Ningaloo Coast South	16.0	14.0	2.7	1,700	1,700	1,700	54.1	51.8	19.3	52.8	52.8	71.3	102.3	85.3	5.7
Shark Bay - Coast Outer	6.0	4.7	NC	920	920	NC	16.2	14.6	NC	80.7	80.7	NC	39.8	22.7	NC
Abrolhos Islands Wallabi Group	1.3	NC	NC	68	NC	NC	0.8	NC	NC	91.2	NC	NC	5.7	NC	NC
Abrolhos Islands Pelsaert Group	0.7	NC	NC	77	NC	NC	0.9	NC	NC	93.3	NC	NC	5.7	NC	NC
Indonesia - East	0.7	0.7	0.7	1,061	1,061	1,061	21.4	21.2	12.1	102.9	102.9	108.6	17.1	11.4	5.7
Eighty Mile Beach	28.7	28.7	28.7	13,899	13,899	13,899	482.0	481.5	481.5	13.9	13.9	13.9	51.2	45.5	39.8
Broome - Roebuck	5.3	5.3	4.7	5,096	5,096	5,096	57.9	57.9	57.9	30.8	30.8	30.8	5.7	5.7	5.7
Roebuck - Eighty Mile Beach	26.7	24.7	23.3	10,806	10,806	10,806	340.3	340.3	340.3	17.9	17.9	17.9	34.1	34.1	34.1
Jurien Bay - Yanchep	0.7	NC	NC	12	NC	NC	0.1	NC	NC	111.9	NC	NC	5.7	NC	NC
Bedout Island	82.0	81.3	70.0	28,497	28,497	28,497	324.0 (62.5)	324.0 (62.5)	324.0 (62.5)	3.5	3.5	3.5	5.7 (1.1)	5.7 (1.1)	5.7 (1.1)
All Shorelines	**100**	**100**	**99**	**28,497**	**28,497**	**28,497**	**2,100 (2,054)**	**2,100 (2,054)**	**2,086 (2,040)**	**3.5**	**3.5**	**3.5**	**477.6 (473.0)**	**437.8 (433.2)**	**199.0 (194.4)**

Table 14 Apus Base Case Subsea LOWC Scenario – Summary of surface oil

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Oil Concentration (g/m^2)			Minimum Arrival Time (days)		
	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2
Barracouta Shoals	0.7	NC	NC	2.4	NC	NC	100.9	NC	NC
Browse Island	0.7	NC	NC	2.6	NC	NC	110.2	NC	NC
Seringapatam Reef	0.7	NC	NC	2.5	NC	NC	109.2	NC	NC
Scott Reef North	1.3	NC	NC	2.9	NC	NC	99.2	NC	NC
Scott Reef South	1.3	NC	NC	3.0	NC	NC	72.8	NC	NC
King Sound	2.7	NC	NC	3.6	NC	NC	53.0	NC	NC
Broome North Coast	4.7	NC	NC	3.6	NC	NC	24.7	NC	NC
Mermaid Reef AMP	16.0	0.7	NC	8.8	11.8	NC	17.4	17.5	NC
Clerke Reef MP	12.7	NC	NC	4.9	NC	NC	16.1	NC	NC
Imperieuse Reef MP	24.7	NC	NC	6.8	NC	NC	12.6	NC	NC
Port Hedland-Eighty Mile Beach	22.0	2.7	NC	6.3	14.1	NC	5.1	18.6	NC
Glomar Shoals	34.7	4.0	NC	6.0	16.0	NC	9.5	23.2	NC
Karratha-Port Hedland	7.3	NC	NC	4.7	NC	NC	6.7	NC	NC
Dampier Archipelago	5.3	NC	NC	3.3	NC	NC	18.3	NC	NC
Rankin Bank	8.7	NC	NC	6.6	NC	NC	21.9	NC	NC
Northern Islands Coast	0.7	NC	NC	1.8	NC	NC	58.1	NC	NC
Montebello Islands	3.3	NC	NC	3.5	NC	NC	27.7	NC	NC
Barrow-Montebello Surrounds	2.7	NC	NC	3.5	NC	NC	27.8	NC	NC
Southern Islands Coast	2.0	NC	NC	2.7	NC	NC	68.2	NC	NC
Muiron Islands	0.7	NC	NC	1.4	NC	NC	88.0	NC	NC
Ningaloo Coast North	0.7	NC	NC	1.4	NC	NC	88.8	NC	NC
Eighty Mile Beach	36.7	4.0	NC	8.7	16.8	NC	7.7	13.7	NC
Broome - Roebuck	10.7	NC	NC	3.9	NC	NC	20.1	NC	NC
Roebuck - Eighty Mile Beach	27.3	NC	NC	4.2	NC	NC	16.1	NC	NC
Kimberley AMP	23.3	NC	NC	5.1	NC	NC	24.8	NC	NC
Dampier AMP	25.3	NC	NC	3.8	NC	NC	14.0	NC	NC
Montebello AMP	23.3	NC	NC	4.1	NC	NC	21.0	NC	NC
Ashmore/Cartier - Outer	0.7	NC	NC	3.0	NC	NC	76.8	NC	NC
Eighty Mile Beach AMP	90.7	54.0	7.3	35.8	42.5	68.3	1.8	1.8	3.8
Rowley Shoals surrounds	44.7	5.3	NC	8.2	11.7	NC	12.2	18.2	NC
Ningaloo - Outer NW	2.0	NC	NC	3.6	NC	NC	26.7	NC	NC
Ningaloo - Offshore	18.7	2.0	NC	9.5	11.7	NC	16.0	45.8	NC
Bedout Island	63.3	23.3	3.3	40.3	42.4	71.6	3.3	3.3	13.6
All Ocean	**100**	**100**	**100**	**84.8**	**135.9**	**221.3**	**0.1**	**0.1**	**0.1**

Table 15 Apus Base Case Subsea LOWC Scenario – Summary of total submerged oil

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Sahul Banks	0.7	NC	11.8	NC	107.7	NC
Fantome Shoals	1.3	NC	60.7	NC	111.3	NC
Barracouta Shoals	1.3	0.7	195.5	202.8	99.8	99.8
Vulcan Shoals	0.7	NC	10.6	NC	101.4	NC
Woodbine Bank	0.7	NC	32.1	NC	97.2	NC
Cartier Island AMP	2.0	NC	39.2	NC	86.4	NC
Ashmore Reef AMP	4.7	NC	52.8	NC	63.4	NC
Seringapatam Reef	6.7	NC	48.4	NC	54.3	NC
Scott Reef North	7.3	NC	34.6	NC	51.9	NC
Scott Reef South	10.7	NC	57.3	NC	51.6	NC
King Sound	1.3	1.3	264.0	264.0	75.6	75.6
Broome North Coast	8.0	6.0	267.7	310.0	38.4	38.4
Mermaid Reef AMP	48.0	20.0	351.1	1,729	18.8	18.8
Clerke Reef MP	44.0	17.3	197.3	1,146	21.4	21.4
Imperieuse Reef MP	56.7	28.0	343.3	937.9	15.7	15.7
Port Hedland-Eighty Mile Beach	64.7	23.3	1,258	1,823	5.2	5.2
Glomar Shoals	93.3	58.0	128.4	872.2	9.3	10.9
Karratha-Port Hedland	55.3	14.7	273.6	301.7	10.8	15.3
Dampier Archipelago	56.7	30.7	155.0	315.2	11.5	18.7
Rankin Bank	70.0	18.7	95.8	387.9	15.5	24.1
Northern Islands Coast	36.0	2.0	90.7	152.4	18.8	32.3
Montebello Islands	50.7	12.7	55.1	291.1	15.6	24.5
Lowendal Islands	29.3	2.0	66.7	118.1	19.6	65.3
Barrow Island	45.3	7.3	77.4	131.9	21.0	33.7
Barrow-Montebello Surrounds	54.0	16.0	101.5	519.3	15.4	24.8
Middle Islands Coast	2.7	0.7	90.5	112.8	43.6	107.4
Thevenard Islands	34.7	NC	53.1	NC	25.8	NC
Southern Islands Coast	44.0	4.7	96.0	272.1	26.1	47.7
Muiron Islands	42.7	2.0	62.6	121.3	26.5	41.2
Exmouth Gulf Coast	3.3	NC	46.9	NC	48.0	NC
Ningaloo Coast North	46.0	6.7	77.5	182.8	30.7	50.1
Ningaloo Coast South	11.3	NC	63.8	NC	50.9	NC
Carnarvon - Inner Shark Bay	0.7	NC	21.6	NC	105.1	NC
Shark Bay - Coast Outer	2.7	NC	49.4	NC	68.9	NC
Abrolhos - Outer Island Shoals	3.3	NC	57.8	NC	79.1	NC
Abrolhos Islands Easter Group	0.7	NC	40.0	NC	88.3	NC
Abrolhos Islands Pelsaert Group	0.7	NC	10.1	NC	103.3	NC
Indonesia - East	1.3	NC	41.1	NC	105.8	NC

Perth Canyon AMP	0.7	NC	33.9	NC	101.8	NC
Eighty Mile Beach	44.7	36.7	1,697	1,697	12.3	12.3
Broome - Roebuck	9.3	6.7	510.2	510.2	20.3	20.3
Roebuck - Eighty Mile Beach	24.7	20.0	843.0	843.0	19.3	19.3
Kimberley AMP	51.3	30.0	1,789	1,789	24.3	24.3
Dampier AMP	63.3	54.7	251.0	768.7	10.4	10.4
Montebello AMP	78.7	47.3	201.6	658.5	12.4	12.8
Ningaloo - Outer Coast North	50.7	14.0	64.7	231.6	27.0	31.3
Johnson Bank	5.3	NC	52.8	NC	63.4	NC
Shark Bay AMP	10.0	NC	57.7	NC	56.6	NC
Ashmore/Cartier - Outer	11.3	2.7	291.3	291.3	54.3	64.1
Eighty Mile Beach AMP	99.3	98.7	1,936	1,936	2.1	2.1
Rowley Shoals surrounds	80.7	58.0	1,783	1,987	12.0	12.0
Abrolhos West	4.0	NC	52.7	NC	79.1	NC
Ningaloo - Outer NW	54.0	14.0	298.9	320.5	24.8	25.9
Ningaloo - Offshore	84.0	34.0	515.7	858.7	15.1	16.4
Abrolhos - Offshore NW	16.7	NC	58.4	NC	61.8	NC
Abrolhos - Offshore Perth North	4.0	NC	78.8	NC	97.3	NC
Bedout Island	95.3	73.3	320.4	1,037	3.8	3.8
All Ocean	**100**	**100**	**5,617**	**5,617**	**0.1**	**0.1**

Table 16 Apus Base Case Subsea LOWC Scenario – Summary of dissolved hydrocarbons

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Concentration (ppb)			Minimum Arrival Time (days)		
	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb
Eighty Mile Beach AMP	47.3	5.3	NC	35.6	93.8	NC	2.3	4.8	NC
Bedout Island	1.3	NC	NC	20.4	NC	NC	48.1	NC	NC
All Ocean	**100**	**100**	**100**	**4,776**	**4,818**	**6,823**	**0.1**	**0.1**	**0.1**

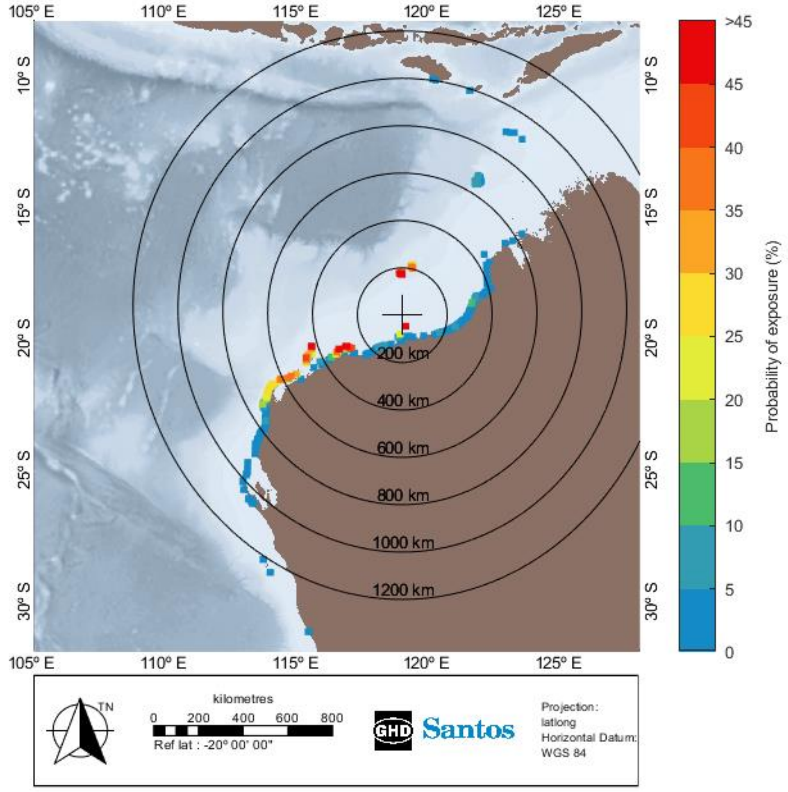
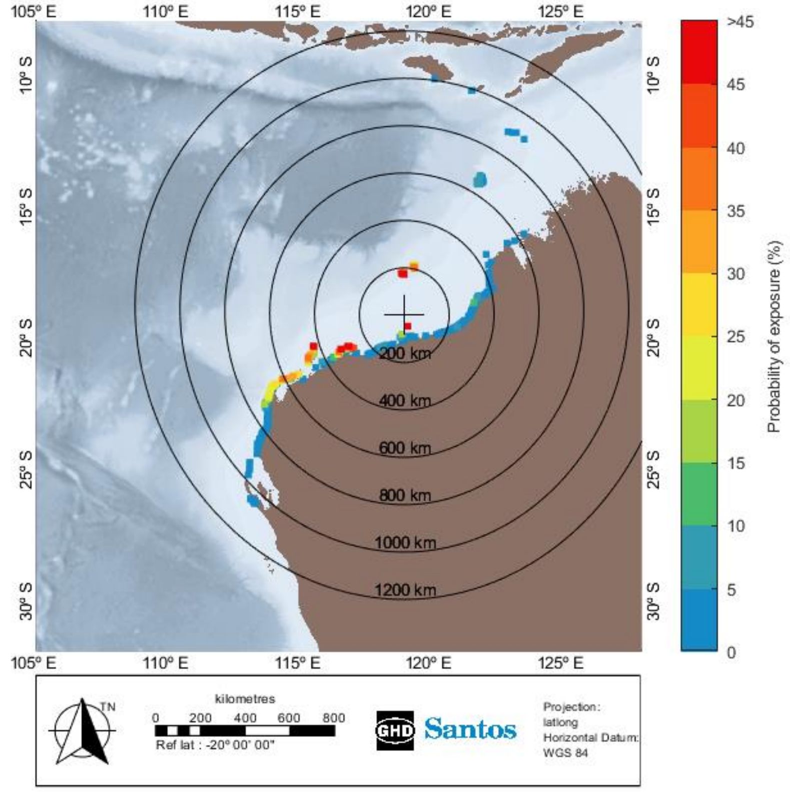
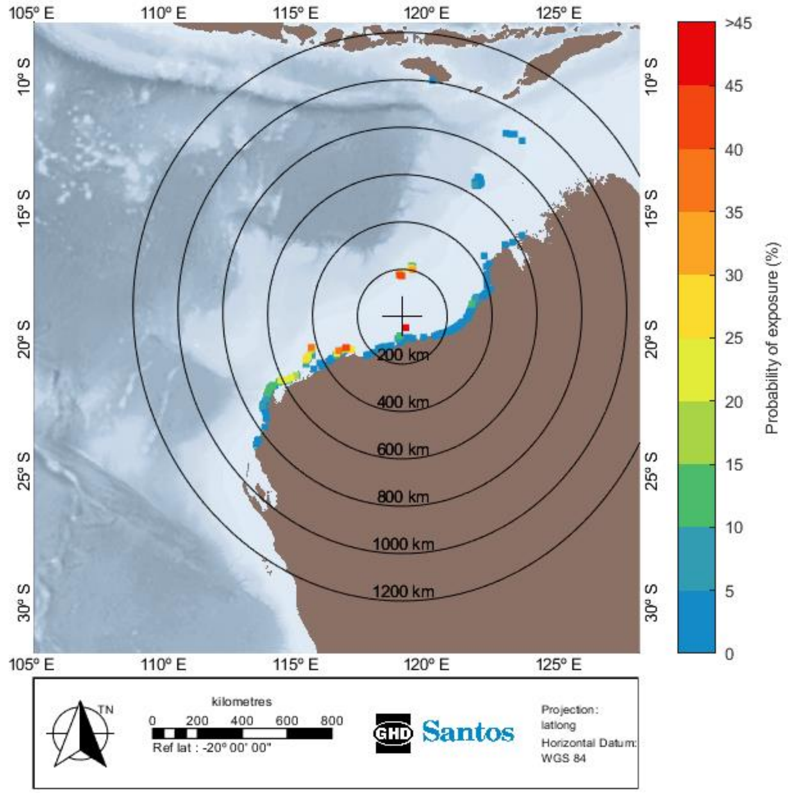
Shoreline Contact	> 10 g/m²	> 100 g/m²
Probability		
Shoreline Contact	**> 1,000 g/m²**	
Probability		

Figure 17 Apus Base Case Subsea LOWC Scenario – Summary of probability of shoreline oiling

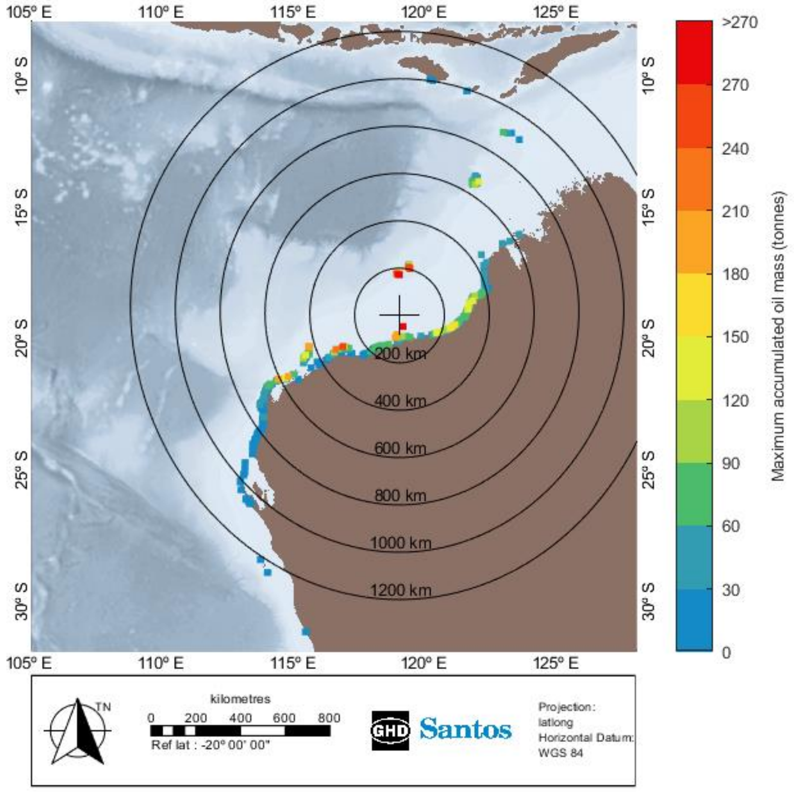
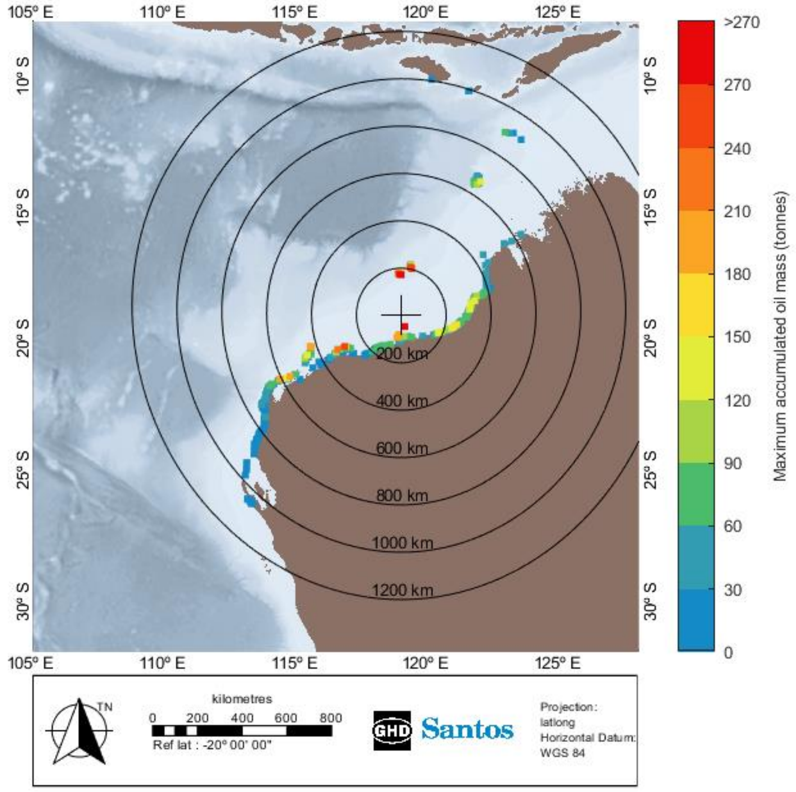
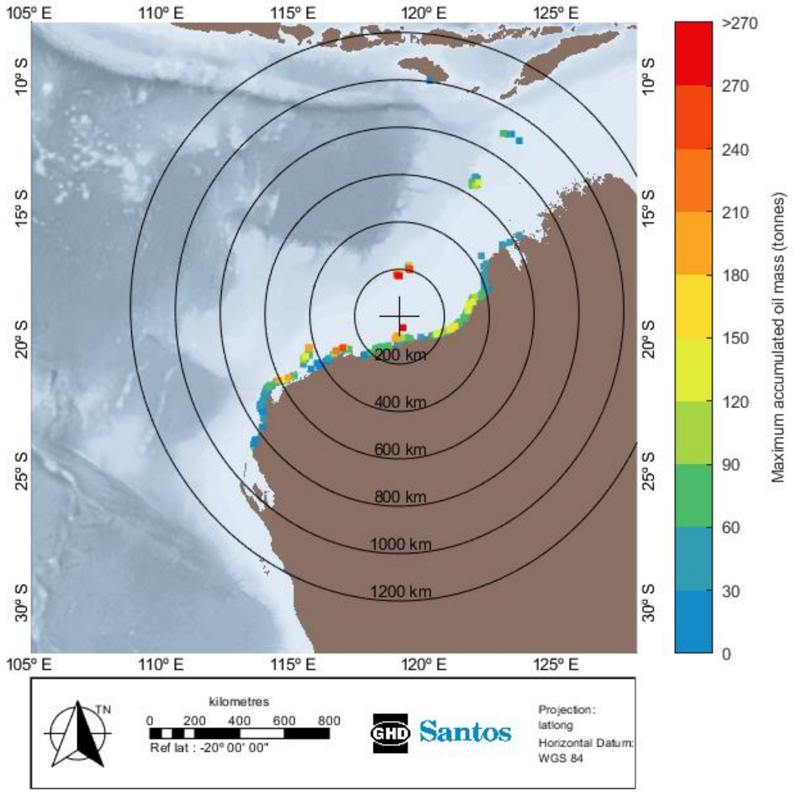
<table>
<tr><th>Shoreline Contact</th><th>> 10 g/m²</th><th>> 100 g/m²</th></tr>
<tr><td>Mass</td><td>
</td><td>
</td></tr>
<tr><th>Shoreline Contact</th><th>> 1,000 g/m²</th><th></th></tr>
<tr><td>Mass</td><td>
</td><td></td></tr>
</table>

Figure 18 Apus Base Case Subsea LOWC Scenario – Summary of maximum accumulated oil mass (tonnes) on shorelines

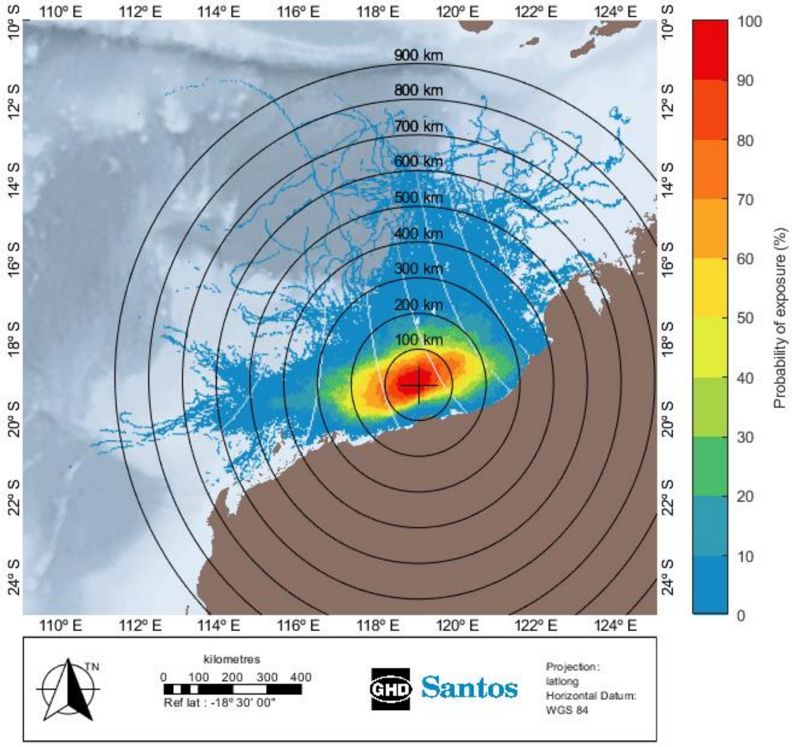
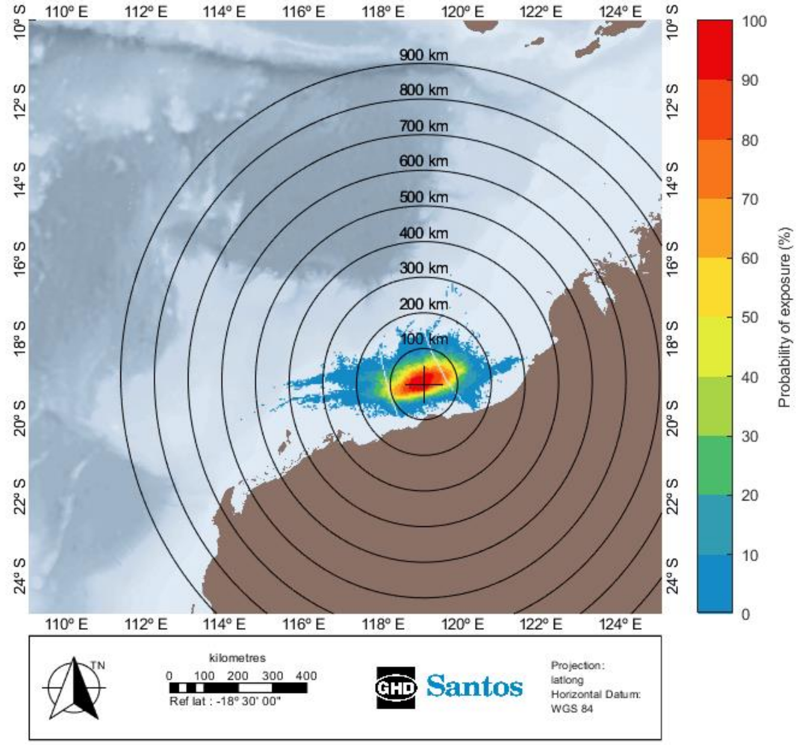
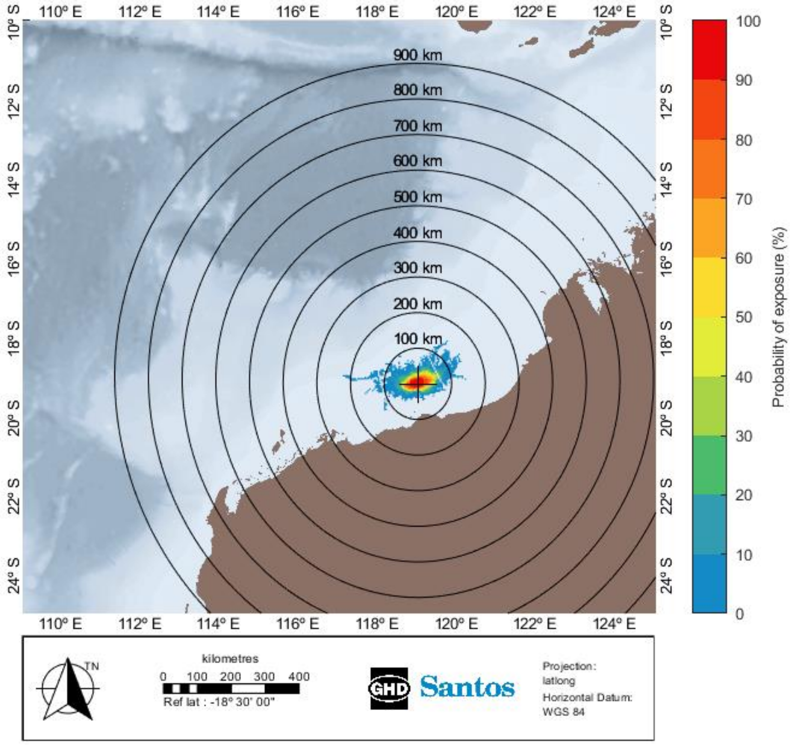
Surface Oil	> 1 g/m²	> 10 g/m²	> 50 g/m²
Probability			

Figure 19 Apus Base Case Subsea LOWC Scenario – Summary of probability of surface oil [9]

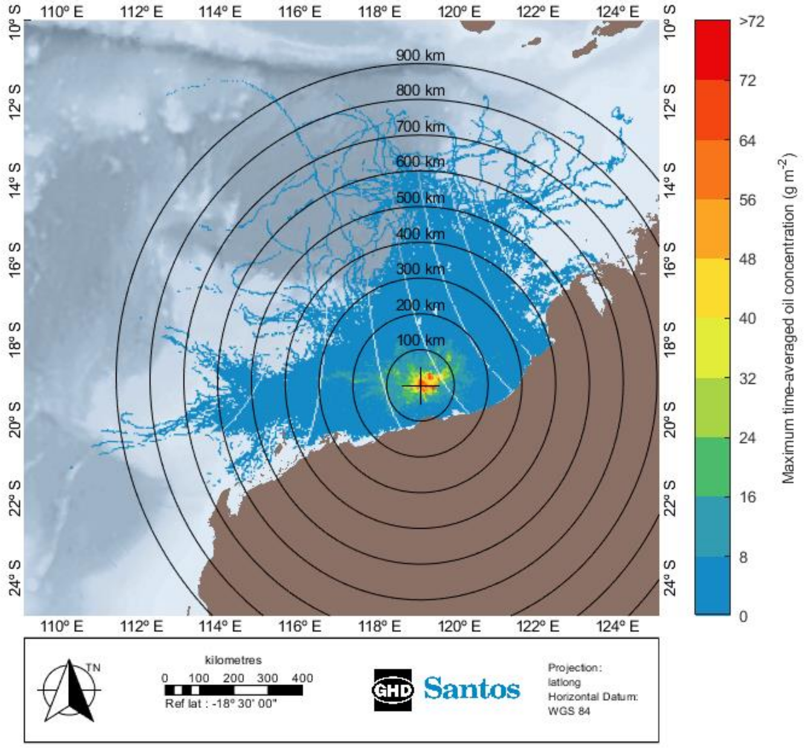
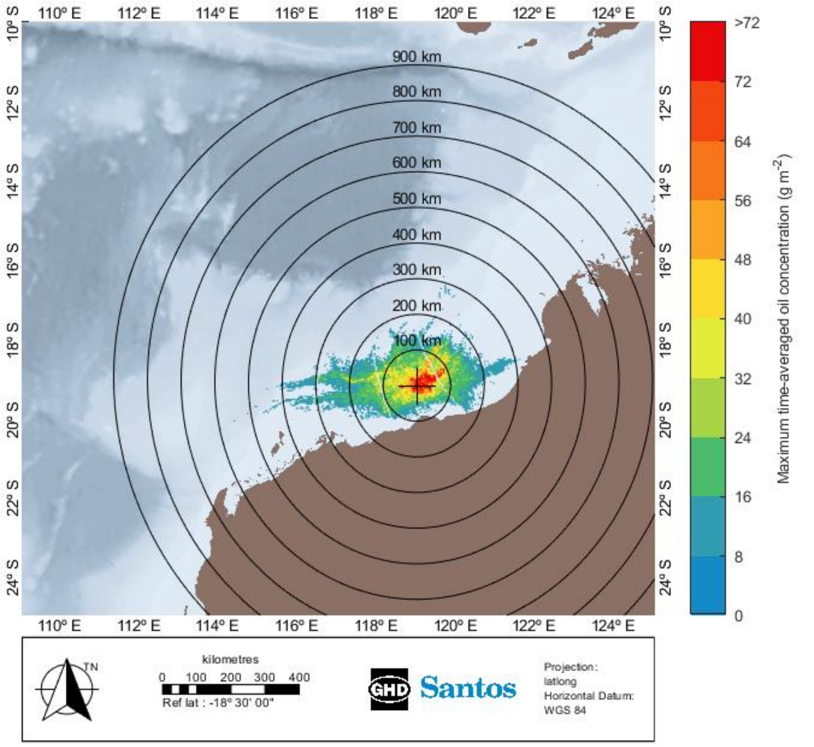
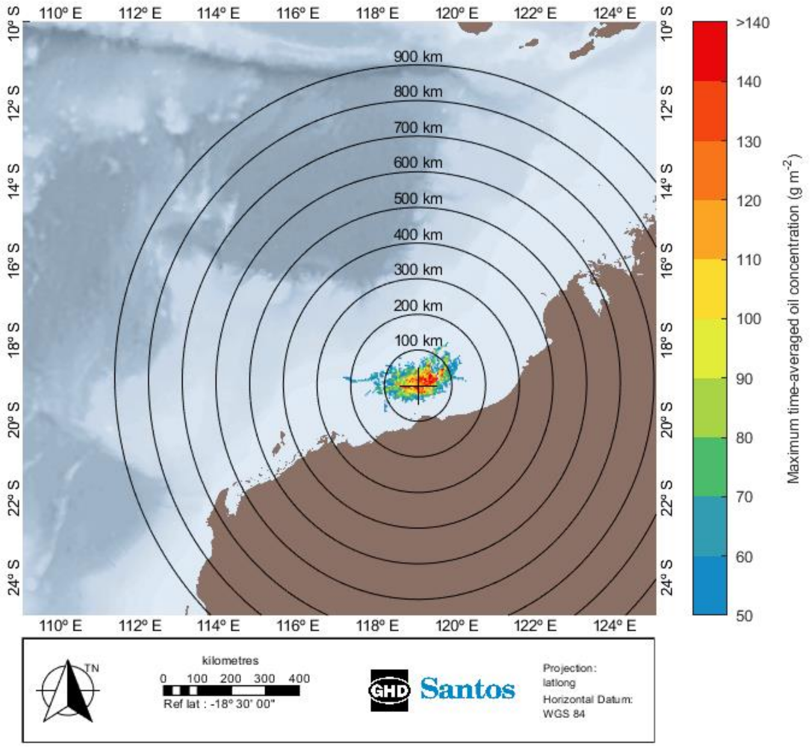
Surface Oil	> 1 g/m²	> 10 g/m²	> 50 g/m²
Concentration			

Figure 20 Apus Base Case Subsea LOWC Scenario – Summary of maximum time-averaged surface oil concentration [9]

[9] Note: The curved lines of 'gaps' in the data are an artefact of the OSCAR software projecting the model outputs from the native model projection (Lat/Lon) onto a Universal Transverse Mercator (UTM) grid during the export process. No data is deleted during this process. The gaps do not have a material impact on the data reported in the results tables, only an aesthetic impact on these figures.

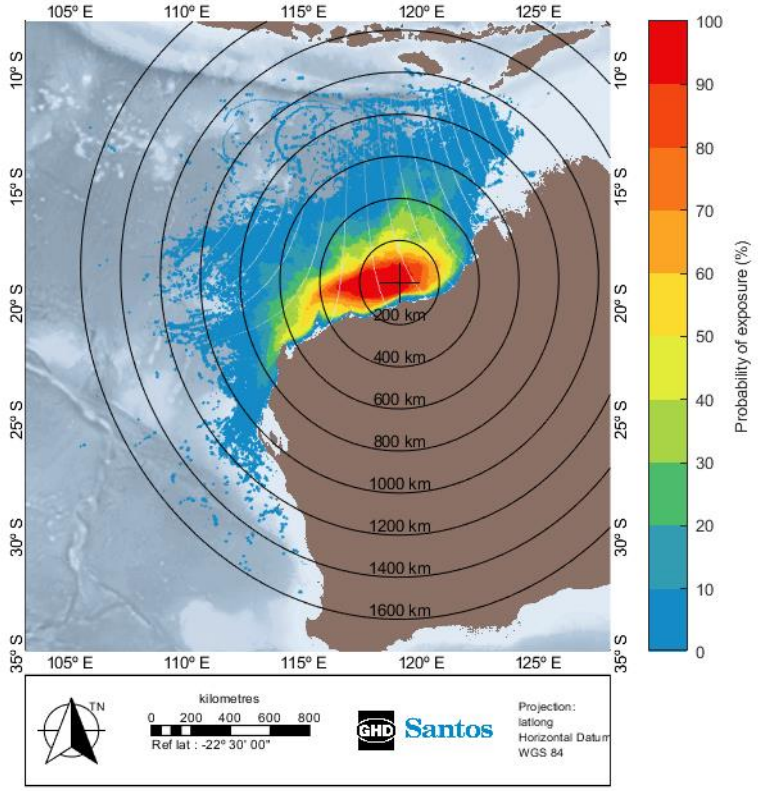
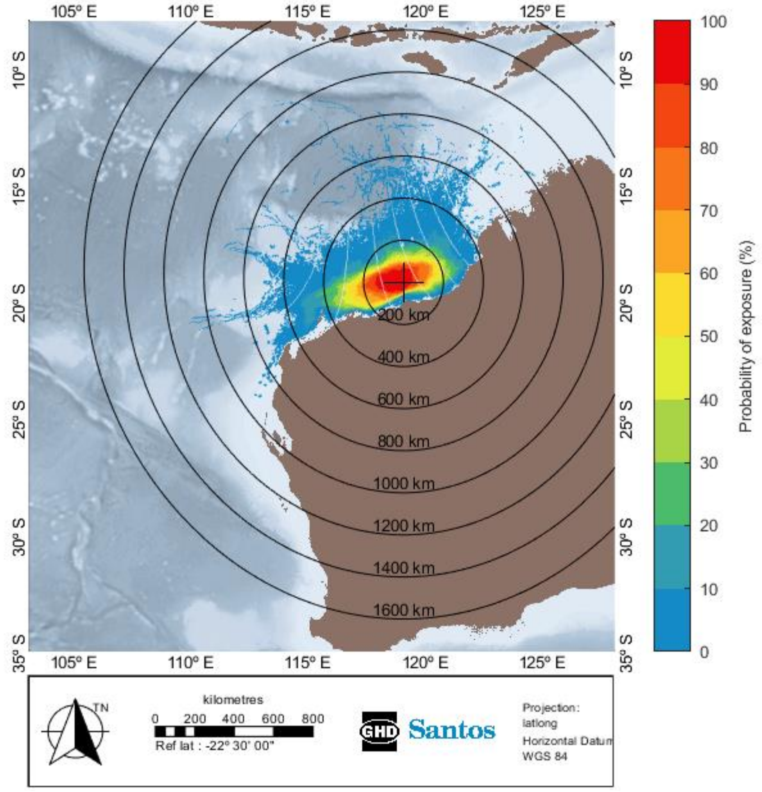
<table>
<tr><th>Total Submerged Oil</th><th>> 10 ppb</th><th>> 100 ppb</th></tr>
<tr><td>Probability</td><td>
</td><td>
</td></tr>
</table>

Figure 21 Apus Base Case Subsea LOWC Scenario – Summary of probability of total submerged oil [9]

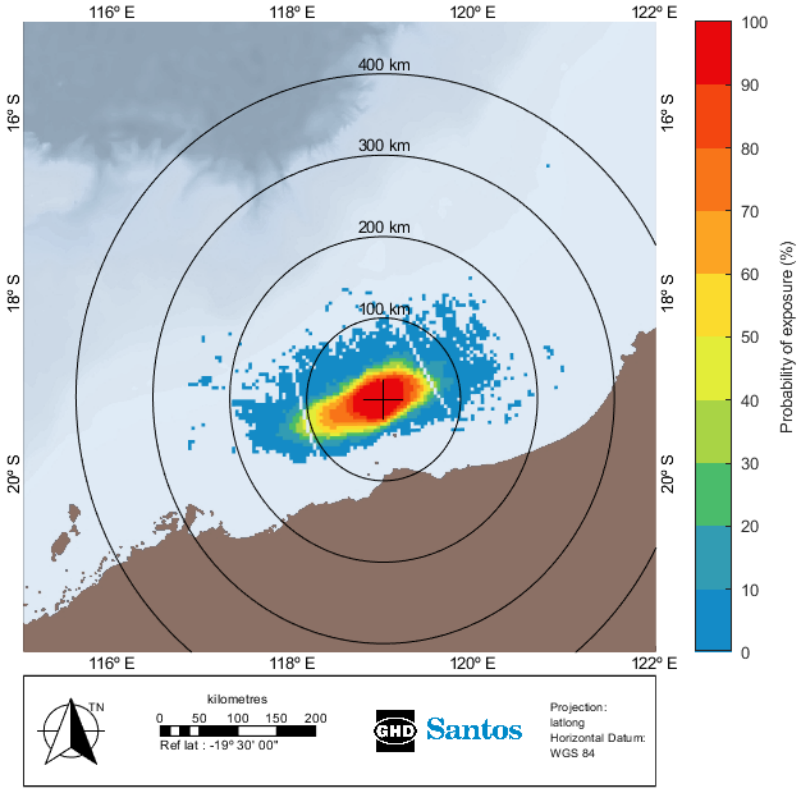
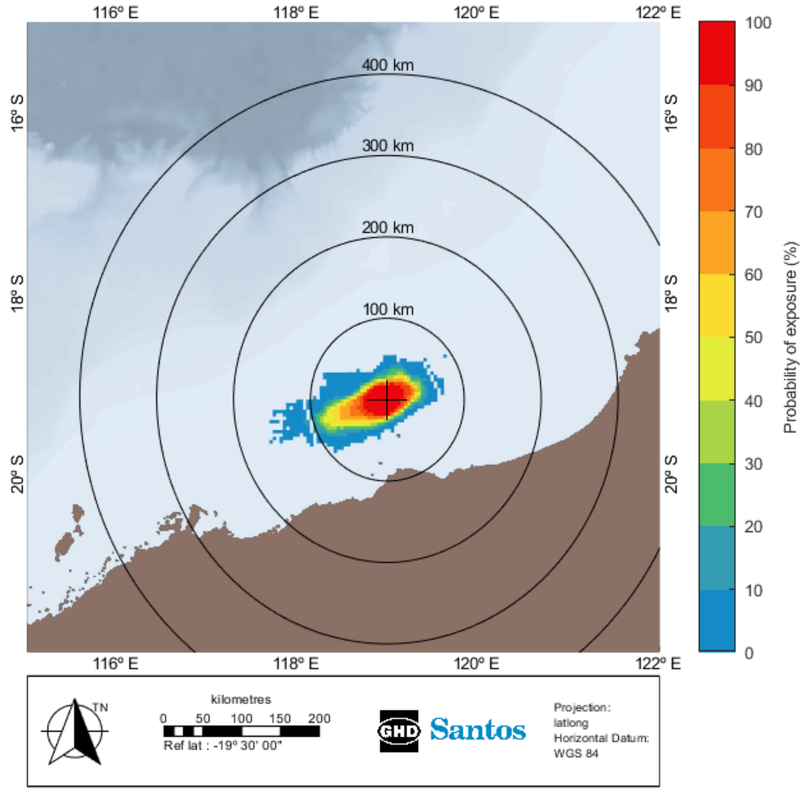
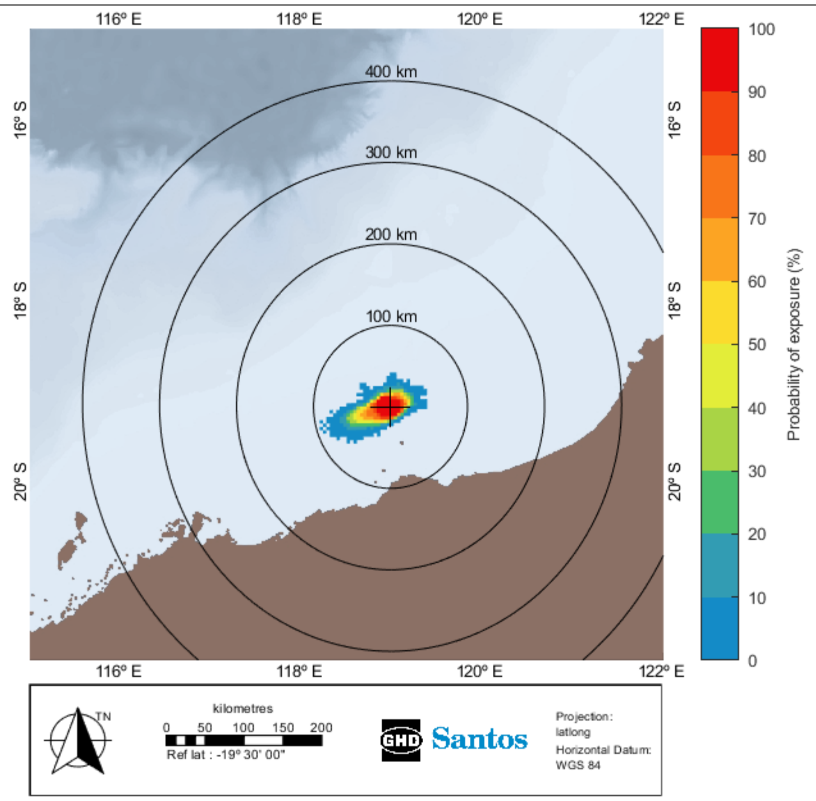
Dissolved Hydrocarbons	> 10 ppb	> 50 ppb
Probability		
Dissolved Hydrocarbons	> 400 ppb	
Probability		

Figure 22 Apus Base Case Subsea LOWC Scenario – Summary of probability of dissolved hydrocarbons [9]

4.1.2 Apus Base Case Surface LOWC Scenario

4.1.2.1 Accumulated Shoreline Oil

Shoreline oiling is assessed at three thresholds that represent low (10 g/m^2, visual/aesthetic threshold), moderate (100 g/m^2, impact threshold that may require clean-up effort), and high (1,000 g/m^2, requires intensive clean-up effort) accumulated shoreline loadings. A summary of the shoreline loading predictions is presented in Table 17, and loading probabilities and maximum accumulated shoreline loadings are mapped spatially in Figure 24 and Figure 25 for the three thresholds, respectively.

Shoreline loading above the low (>10 g/m^2) and moderate (100 g/m^2) thresholds was predicted to occur up to ~1,300 km northwest (at Indonesia – East) and south-west (at Abrolhos Islands Pelsaert Group) from the release site. At the high (1,000 g/m^2) threshold, the spatial extent of shoreline accumulation was reduced to ~900 km north-east (at Ashmore Reef AMP and Cartier Island AMP) and ~1,050 km southwest (at Shark Bay – Coast Outer).

Shoreline accumulation above the moderate threshold (100 g/m^2) is summarised as follows:

- Across all shorelines, a 100% contact probability is predicted with a maximum accumulated shoreline load of 5,125 tonnes, a minimum arrival time of 2.0 days and a maximum length of oiled shoreline of 500 km.
- A very high contact probability of 77% was predicted for the proximal island receptor of Bedout Island. This receptor was predicted to receive a maximum shoreline accumulation of 58 tonnes, with a minimum arrival time of 2 days and maximum oiled shoreline length of 1 km (the island length).
- Moderately high contact probabilities of 33-59% were predicted at Clerke Reef MP, Imperieuse Reef MP, Dampier Archipelago, Montebello Islands, Barrow Island, Thevenard Islands, Southern Islands Coast, Muiron Islands, Ningaloo Coast North, Eighty Mile Beach and Roebuck – Eighty Mile Beach. Maximum accumulated shoreline loads at these locations were 2,301 tonnes at Eighty Mile Beach, 2,040 tonnes at Imperieuse Reef MP, 1,455 tonnes at Clerke Reef MP and 178-865 tonnes at the other receptors. Minimum arrival times of shoreline loading at these locations ranged between 11.4 days to 30.6 days. Maximum predicted lengths of shoreline accumulation were between 11 km to 97 km, with the exception of Ningaloo Coast North (227 km) and Eighty Mile Beach (136 km).
- Moderate contact probabilities of 10-27% were predicted at Scott Reef North, Scott Reef South, Broome North Coast, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Northern Islands Coast, Lowendal Islands, Ningaloo Coast South and Broome - Roebuck. Maximum accumulated shoreline loads at these receptors were 2,035 tonnes at Port Hedland-Eighty Mile Beach, 972 tonnes at Karratha-Port Hedland, 625 tonnes at Scott Reef South and between 44 tonnes and 198 tonnes at the other locations. Minimum arrival times of shoreline loading at these locations ranged between 2.9 days and 52.3 days, while maximum predicted lengths of shoreline accumulation were between 6 km and 91 km.
- Low probabilities of contact (<10%) were predicted at Cartier Island AMP, Ashmore Reef AMP, King Sound, Exmouth Gulf Coast, Shark Bay – Coast Outer, Zuytdorp Cliffs – Kalbarri, Kalbarri – Geraldton, Abrolhos Islands Easter Group, Abrolhos Islands Pelsaert Group and Indonesia – East. Contact probabilities, accumulated shoreline loads, minimum arrival times and maximum oiled shoreline lengths for these receptors are summarised in Table 17.

A histogram of total shoreline loading above the moderate threshold (100 g/m^2) across the 150 stochastic realisations is presented in Figure 23. Shoreline accumulation at the moderate threshold was predicted to occur for 100% of the realisations. No clear seasonal trend is evident in the shoreline loading predictions. Approximately half of the realisations resulted in shoreline accumulation greater than 1,000 tonnes (up to a maximum of 5,125 tonnes).

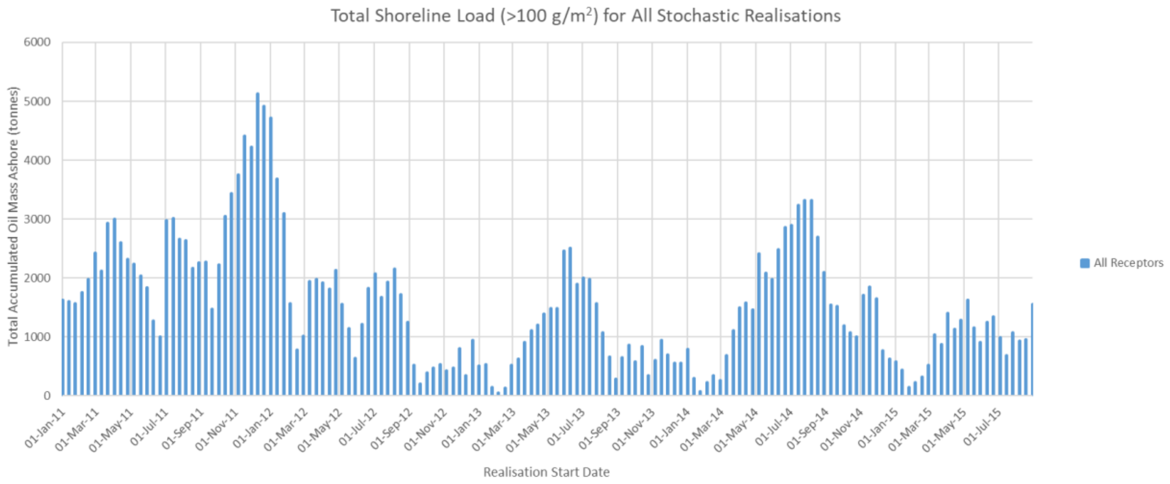


Figure 23 *Apus Base Case Surface LOWC Scenario – Summary of total accumulated shoreline load for all stochastic realisations for the 100 g/m^2 threshold*

4.1.2.2 Surface Oil

Surface oiling is evaluated at three instantaneous contact thresholds representing low (1 g/m^2, visual/aesthetic threshold), moderate (10 g/m^2, lower limit for potential ecological impacts), and high (50 g/m^2, approximating concentrations that can be targeted during spill response) concentrations. A summary of the surface oil predictions are presented in Table 18, with contact probabilities and maximum surface oil concentrations mapped spatially in Figure 26 and Figure 27 for the three thresholds, respectively.

Surface oil above the low threshold (1 g/m^2) was predicted to occur at distances up to ~1,100 km from the release location. The spatial extent of surface oil predicted for the moderate threshold (10 g/m^2) reduced to ~600 km, and the high threshold (50 g/m^2) spatial extent was restricted to within ~300 km of the release location.

Surface oil impacts at the moderate threshold (10 g/m^2) include:

– A high contact probability of 70% was predicted for the Eighty Mile Beach AMP, with a maximum time-averaged surface oil concentration of 150 g/m^2 and a minimum arrival time of 0.8 days.

– A moderately high contact probability of 47% was predicted at Bedout Island, with a maximum time-averaged surface oil concentration of 145 g/m^2 and a minimum arrival time of 1.5 days.

– Moderately low contact probabilities of 13-18% were predicted at Port Hedland-Eighty Mile Beach, Glomar Shoals, Eighty Mile Beach and Rowley Shoals surrounds, with maximum time-averaged surface oil concentrations of 15-30 g/m^2 and minimum arrival times of 2-16 days.

– Low contact probabilities (<6%) were predicted at Mermaid Reef AMP, Imperieuse Reef MP, Karratha-Port Hedland and Ningaloo - Offshore, with maximum time-averaged concentrations of 10-18 g/m^2 and minimum arrival times of 17.9 to 48.3 days.

4.1.2.3 Total Submerged Oil

Total submerged oil (entrained plus dissolved oil) is evaluated at low (10 ppb, potential exceedance of water quality triggers) and moderate (100 ppb, potential impacts) instantaneous contact thresholds. Total submerged oil predictions are summarised in Table 19 and contact probabilities are mapped spatially in Figure 28 for the two thresholds.

Total submerged oil at the low threshold (10 ppb) was predicted to occur up to ~1,800 km from the release location. At the moderate threshold (100 ppb), predicted contact was reduced in spatial extent to within 1,200 km from the release location.

Total submerged oil impacts at the moderate threshold (100 ppb) include:

– A very high contact probability of 94% was predicted at Eighty Mile Beach AMP, with a maximum time-averaged concentration of 2,611 ppb and minimum arrival time of 0.8 days.

- Moderate to high contact probabilities of 32-69% were predicted at Imperieuse Reef MP, Glomar Shoals, Dampier Archipelago, Rankin Bank, Eighty Mile Beach, Roebuck – Eighty Mile Beach, Kimberley AMP, Dmapier AMP, Montebello AMP, Rowley Shoals surrounds, Ningaloo – Offshore and Bedout Island. Maximum time-averaged concentrations at these locations ranged between 295 ppb and 1,866 ppb, with minimum arrival times of 1.9 to 21.3 days.
- Moderate contact probabilities of 11-29% were predicted at Mermaid Reef AMP, Clerke Reef MP, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Montebello Islands, Barrow Island, Barrow-Montebello Surrounds, Ningaloo Coast North, Broome - Roebuck, Ningaloo – Outer Coast North and Ningaloo – Outer NW. Maximum time-averaged concentrations at these locations ranged between 190 ppb and 3,755 ppb, with minimum arrival times of 2 to 32.7 days.
- Low contact probabilities (<10%) occurred at several other receptor locations with contact probabilities, maximum time-averaged oil concentrations and minimum arrival times summarised in Table 19.

4.1.2.4 Dissolved Hydrocarbons

Dissolved hydrocarbons were evaluated at the low (10 ppb, potential exceedance of water quality triggers), moderate (50 ppb, potential sub-lethal toxic effects) and high (400 ppb, potential toxic lethal effects) instantaneous contact thresholds. A summary of the dissolved hydrocarbon predictions is presented in Table 20 and contact probabilities are mapped spatially in Figure 29 for the three thresholds.

Dissolved hydrocarbons at the low threshold (10 ppb) were predicted to extend a maximum distance of ~500 km from the release location. At the moderate threshold (50 ppb), the spatial extent was generally reduced in extent to within ~250 km, though a localised exceedance was predicted in one model cell at a distance of ~450 km from the release location. Exceedance of the high threshold (400 ppb) was limited to within ~150 km of the release site.

Dissolved hydrocarbon impacts at the moderate threshold (50 ppb) include:

- A moderately high contact probability of 60% was predicted at Eighty Mile Beach AMP, with a maximum time-averaged concentration of 346 ppb and a minimum arrival time of 0.8 days.
- A moderate contact probability of 28% was predicted at Bedout Island, with a maximum time-averaged concentration of 304 ppb and a minimum arrival time of 2 days.
- Very low contact probabilities (<5%) were predicted at Imperieuse Reef MP, Port Hedland-Eighty Mile Beach, Eighty Mile Beach and Rowley Shoals Surrounds. Maximum time-averaged concentrations at these receptors were 100-261 ppb with minimum arrival times of 3.7-28.4 days.

Table 17 Apus Base Case Surface LOWC Scenario – Summary of shoreline oiling

Receptor Name	Total Contact Probability (%)			Maximum Accumulated Oil Concentration (g/m^2)			Maximum Accumulated Oil Ashore (tonnes)			Minimum Arrival Time (days)			Maximum Length of Oiled Shoreline (km)		
	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2
Cartier Island AMP	3.3	2.7	1.3	3,157	3,157	3,157	35.9 (3.8)	35.9 (3.8)	35.9 (3.8)	84.6	84.6	84.6	5.7 (0.6)	5.7 (0.6)	5.7 (0.6)
Ashmore Reef AMP	7.3	6.7	4.0	13,498	13,498	13,498	229.7 (28.9)	229.7 (28.9)	219.1 (27.5)	62.3	62.3	62.3	39.8 (5.0)	39.8 (5.0)	22.7 (5.0)
Scott Reef North	10.7	10.7	4.7	3,189	3,189	3,189	136.5	136.5	119.8	46.4	46.4	46.4	51.2	51.2	39.8
Scott Reef South	16.0	16.0	8.7	10,631	10,631	10,631	625.2	625.2	625.2	39.0	39.0	39.0	56.9	56.9	56.9
King Sound	2.0	2.0	1.3	4,608	4,608	4,608	52.4	52.4	52.4	62.9	62.9	62.9	11.4	5.7	5.7
Broome North Coast	13.3	11.3	8.7	9,841	9,841	9,841	197.6	197.6	197.6	35.9	35.9	35.9	34.1	34.1	22.7
Clerke Reef MP	52.7	52.7	42.7	23,606	23,606	23,606	1,455	1,455	1,455	16.3	16.3	16.3	51.2	51.2	51.2
Imperieuse Reef MP	58.7	58.7	48.7	29,886	29,886	29,886	2,040	2,040	2,040	11.4	11.4	11.4	56.9	56.9	56.9
Port Hedland-Eighty Mile Beach	23.3	22.7	14.7	23,422	23,422	23,422	2,035	2,035	2,035	2.9	2.9	2.9	102.3	91.0	91.0
Karratha-Port Hedland	18.7	16.0	6.7	15,156	15,156	15,156	972.1	972.1	972.1	6.6	6.6	6.6	51.2	51.2	51.2
Dampier Archipelago	58.0	57.3	50.0	21,248	21,248	21,248	864.7	864.7	844.9	12.1	12.1	12.1	96.6	96.6	62.5
Northern Islands Coast	23.3	22.7	9.3	3,419	3,419	3,419	54.7	54.7	53.2	26.3	26.3	26.3	22.7	22.7	11.4
Montebello Islands	48.0	46.0	40.7	25,077	25,077	25,077	663.1	663.1	663.1	16.8	16.8	16.8	22.7	22.7	22.7
Lowendal Islands	30.0	27.3	16.0	9,696	9,696	9,696	110.2	110.2	110.2	27.9	27.9	27.9	5.7	5.7	5.7
Barrow Island	47.3	46.0	39.3	13,827	13,827	13,827	628.3	628.3	628.3	19.3	19.3	19.3	79.6	68.2	56.9
Thevenard Islands	40.0	40.0	30.0	10,264	10,264	10,264	178.0	178.0	178.0	23.9	23.9	23.9	11.4	11.4	11.4
Southern Islands Coast	46.0	44.7	39.3	19,942	19,942	19,942	441.0	441.0	439.5	24.9	24.9	24.9	22.7	22.7	17.1
Muiron Islands	44.7	42.7	34.7	20,143	20,143	20,143	350.3	350.3	350.3	26.6	26.6	28.3	17.1	17.1	17.1
Exmouth Gulf Coast	0.7	NC	NC	28	NC	NC	0.3	NC	NC	109.8	NC	NC	5.7	NC	NC
Ningaloo Coast North	41.3	41.3	32.0	10,938	10,938	10,938	698.5	698.5	573.3	30.6	30.6	30.6	233.1	227.4	96.6
Ningaloo Coast South	15.3	14.7	3.3	2,887	2,887	2,887	45.3	44.2	32.8	52.3	52.3	59.4	73.9	68.2	11.4
Shark Bay - Coast Outer	8.0	4.7	1.3	1,034	1,034	1,034	22.4	22.4	11.8	59.0	59.0	69.2	34.1	34.1	5.7
Zuytdorp Cliffs - Kalbarri	2.0	2.0	NC	604	604	NC	13.7	13.7	NC	92.8	92.8	NC	17.1	17.1	NC
Kalbarri - Geraldton	0.7	0.7	NC	236	236	NC	2.7	2.7	NC	108.6	108.6	NC	5.7	5.7	NC
Abrolhos Islands Easter Group	0.7	0.7	NC	536	536	NC	6.1	6.1	NC	104.6	104.6	NC	5.7	5.7	NC
Abrolhos Islands Pelsaert Group	0.7	0.7	NC	134	134	NC	1.5	1.5	NC	105.9	105.9	NC	5.7	5.7	NC
Indonesia - East	0.7	0.7	NC	356	356	NC	6.0	6.0	NC	102.6	102.6	NC	11.4	11.4	NC
Eighty Mile Beach	34.7	34.7	33.3	15,945	15,945	15,945	2,303	2,301	2,294	11.4	11.4	11.4	147.8	136.4	125.1
Broome - Roebuck	13.3	10.0	9.3	7,112	7,112	7,112	180.2	180.2	180.2	27.8	31.8	31.8	17.1	17.1	17.1
Roebuck - Eighty Mile Beach	34.7	33.3	32.0	17,261	17,261	17,261	811.2	811.2	805.4	14.8	14.8	14.8	56.9	56.9	51.2
Bedout Island	76.7	76.7	72.0	26,295	26,295	26,295	299.0 (57.7)	299.0 (57.7)	299.0 (57.7)	2.0	2.0	2.0	5.7 (1.1)	5.7 (1.1)	5.7 (1.1)
All Shorelines	**100**	**100**	**100**	**29,886**	**29,886**	**29,886**	**5,361 (5,127)**	**5,359 (5,125)**	**5,333 (5,099)**	**2.0**	**2.0**	**2.0**	**523.0**	**500.3**	**267.2 (262.6)**

Table 18 Apus LOWC Surface Scenario – Summary of surface oil

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Oil Concentration (g/m²)			Minimum Arrival Time (days)		
	>1 g/m²	>10 g/m²	>50 g/m²	>1 g/m²	>10 g/m²	>50 g/m²	>1 g/m²	>10 g/m²	>50 g/m²
Scott Reef South	0.7	NC	NC	2.6	NC	NC	38.5	NC	NC
King Sound	0.7	NC	NC	3.3	NC	NC	102.4	NC	NC
Lacepede Islands	0.7	NC	NC	3.0	NC	NC	60.3	NC	NC
Broome North Coast	10.7	NC	NC	4.5	NC	NC	34.6	NC	NC
Mermaid Reef AMP	16.0	0.7	NC	10.3	10.3	NC	17.4	17.9	NC
Clerke Reef MP	22.7	NC	NC	6.3	NC	NC	18.8	NC	NC
Imperieuse Reef MP	34.0	0.7	NC	8.3	10.3	NC	10.9	48.3	NC
Port Hedland-Eighty Mile Beach	26.7	14.0	0.7	17.8	30.3	56.2	1.9	2.0	71.5
Glomar Shoals	58.0	13.3	NC	9.1	24.8	NC	9.5	12.0	NC
Karratha-Port Hedland	10.0	2.7	NC	10.4	16.0	NC	5.8	29.0	NC
Dampier Archipelago	10.0	NC	NC	3.9	NC	NC	19.8	NC	NC
Rankin Bank	21.3	NC	NC	5.0	NC	NC	17.6	NC	NC
Northern Islands Coast	1.3	NC	NC	2.4	NC	NC	55.5	NC	NC
Montebello Islands	4.0	NC	NC	2.8	NC	NC	26.5	NC	NC
Barrow-Montebello Surrounds	10.0	NC	NC	4.0	NC	NC	26.2	NC	NC
Southern Islands Coast	0.7	NC	NC	1.4	NC	NC	96.2	NC	NC
Muiron Islands	0.7	NC	NC	1.7	NC	NC	94.2	NC	NC
Ningaloo Coast North	0.7	NC	NC	1.0	NC	NC	42.5	NC	NC
Eighty Mile Beach	44.7	14.7	NC	27.8	28.3	NC	4.1	4.6	NC
Broome - Roebuck	19.3	NC	NC	4.1	NC	NC	26.1	NC	NC
Roebuck - Eighty Mile Beach	34.0	NC	NC	5.5	NC	NC	14.3	NC	NC
Kimberley AMP	32.7	NC	NC	5.3	NC	NC	20.8	NC	NC
Dampier AMP	30.0	NC	NC	4.4	NC	NC	12.2	NC	NC
Montebello AMP	41.3	NC	NC	6.5	NC	NC	11.3	NC	NC
Ningaloo - Outer Coast North	6.0	NC	NC	3.5	NC	NC	30.7	NC	NC
Ashmore/Cartier - Outer	1.3	NC	NC	2.4	NC	NC	47.8	NC	NC
Eighty Mile Beach AMP	84.7	70.0	49.3	80.1	149.8	180.8	0.8	0.8	1.8
Rowley Shoals surrounds	50.0	18.0	NC	11.6	15.4	NC	9.4	16.0	NC
Ningaloo - Outer NW	7.3	NC	NC	3.6	NC	NC	32.7	NC	NC
Ningaloo - Offshore	31.3	5.3	NC	7.1	18.2	NC	13.6	18.2	NC
Bedout Island	59.3	46.7	29.3	145.3	145.3	173.4	1.1	1.5	2.0
All Ocean	**100**	**100**	**100**	**153.5**	**240.2**	**467.0**	**0.1**	**0.1**	**0.1**

Table 19 Apus Base Case Surface LOWC Scenario – Summary of total submerged oil

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Fantome Shoals	2.0	NC	52.7	NC	89.4	NC
Barracouta Shoals	1.3	NC	44.9	NC	83.3	NC
Vulcan Shoals	0.7	NC	45.9	NC	107.3	NC
Hibernia Reef	1.3	NC	29.3	NC	97.3	NC
Woodbine Bank	1.3	NC	48.8	NC	102.4	NC
Cartier Island AMP	2.7	NC	46.5	NC	81.3	NC
Ashmore Reef AMP	4.7	NC	53.2	NC	64.9	NC
Browse Island	0.7	NC	44.1	NC	84.0	NC
Seringapatam Reef	10.0	NC	54.0	NC	51.9	NC
Scott Reef North	10.7	NC	55.1	NC	51.0	NC
Scott Reef South	16.0	1.3	109.2	122.7	43.7	43.8
King Sound	0.7	NC	13.3	NC	77.8	NC
Broome North Coast	16.7	8.7	669.7	669.7	25.4	35.4
Mermaid Reef AMP	50.0	20.7	607.0	752.1	18.3	18.6
Clerke Reef MP	50.7	27.3	232.6	715.9	15.3	15.3
Imperieuse Reef MP	59.3	34.7	265.9	958.7	10.7	11.3
Port Hedland-Eighty Mile Beach	56.0	29.3	3,755	3,755	2.0	2.0
Glomar Shoals	94.0	62.7	215.3	446.7	6.7	6.7
Karratha-Port Hedland	54.0	16.7	969.8	1,030.7	7.3	7.3
Dampier Archipelago	58.7	34.7	178.0	585.9	12.1	16.2
Rankin Bank	70.7	36.0	141.1	294.5	14.3	14.3
Northern Islands Coast	38.7	4.0	248.1	398.2	18.2	26.4
Montebello Islands	51.3	18.7	60.7	521.2	16.2	19.0
Lowendal Islands	34.7	5.3	75.4	208.4	19.5	41.8
Barrow Island	47.3	18.0	85.3	236.3	19.8	21.3
Barrow-Montebello Surrounds	54.0	29.3	138.3	570.5	15.8	18.4
Middle Islands Coast	2.0	NC	26.9	NC	52.6	NC
Thevenard Islands	42.0	1.3	51.4	105.6	24.0	56.4
Southern Islands Coast	46.0	8.7	94.2	203.8	24.1	32.3
Muiron Islands	44.7	9.3	72.4	232.0	25.7	25.8
Exmouth Gulf Coast	10.0	NC	49.2	NC	33.5	NC
Ningaloo Coast North	44.7	10.7	61.4	190.4	28.4	32.7
Ningaloo Coast South	18.0	NC	51.0	NC	52.6	NC
Shark Bay - Coast Outer	4.7	NC	47.4	NC	89.3	NC
Zuytdorp Cliffs - Kalbarri	0.7	NC	43.0	NC	92.9	NC
Kalbarri - Geraldton	0.7	NC	43.4	NC	108.3	NC
Abrolhos - Outer Island Shoals	8.7	NC	56.7	NC	68.9	NC
Abrolhos Islands Pelsaert Group	0.7	NC	12.2	NC	106.2	NC
Perth Canyon AMP	2.7	NC	14.8	NC	78.3	NC
Eighty Mile Beach	54.0	46.0	1,355	1,419	5.0	5.0
Broome - Roebuck	21.3	19.3	1,488	1,488	18.8	18.8

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Roebuck - Eighty Mile Beach	34.7	32.0	1,537	1,537	16.5	16.5
Kimberley AMP	54.0	40.0	1,579	1,579	21.3	21.3
Dampier AMP	61.3	51.3	295.8	773.1	11.0	11.4
Montebello AMP	75.3	52.0	177.9	1,556	11.1	11.1
Ningaloo - Outer Coast North	50.0	19.3	94.8	390.4	25.8	28.9
Johnson Bank	6.0	NC	50.0	NC	64.0	NC
Bremer AMP	0.7	NC	16.4	NC	99.3	NC
Jurien AMP	2.0	NC	31.3	NC	90.9	NC
Shark Bay AMP	13.3	NC	60.6	NC	51.6	NC
Ashmore/Cartier - Outer	16.0	3.3	405.2	587.3	40.5	47.8
Eighty Mile Beach AMP	98.0	94.0	2,611	2,611	0.8	0.8
Rowley Shoals surrounds	82.7	62.0	1,707	1,866	10.5	10.6
Abrolhos West	2.7	NC	12.4	NC	80.8	NC
Ningaloo - Outer NW	56.0	24.0	332.3	1,257	24.3	25.8
Ningaloo - Offshore	84.7	48.0	396.8	1,437	13.3	13.3
Abrolhos - Offshore NW	21.3	0.7	96.7	103.1	48.8	106.8
Abrolhos - Offshore Perth North	6.0	NC	44.2	NC	68.4	NC
Bedout Island	88.7	68.7	457.1	1,292	1.9	1.9
All Ocean	**100**	**100**	**4,416**	**4,416**	**0.1**	**0.1**

Table 20 Apus Base Case Surface LOWC Scenario – Summary of dissolved hydrocarbons

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Concentration (ppb)			Minimum Arrival Time (days)		
	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb
Imperieuse Reef MP	6.0	1.3	NC	51.6	79.4	NC	10.7	10.7	NC
Port Hedland-Eighty Mile Beach	8.0	4.0	NC	79.4	260.9	NC	2.7	3.7	NC
Glomar Shoals	2.7	NC	NC	44.4	NC	NC	49.5	NC	NC
Eighty Mile Beach	5.3	1.3	NC	57.9	199.6	NC	5.0	28.4	NC
Eighty Mile Beach AMP	67.3	60.0	8.7	346.0	346.0	653.7	0.8	0.8	3.1
Rowley Shoals surrounds	12.7	2.0	NC	60.9	99.9	NC	10.5	22.1	NC
Bedout Island	38.0	28.0	NC	163.8	304.1	NC	1.9	2.0	NC
All Ocean	**100**	**100**	**100**	**790.2**	**1,347**	**2,396**	**0.1**	**0.1**	**0.2**

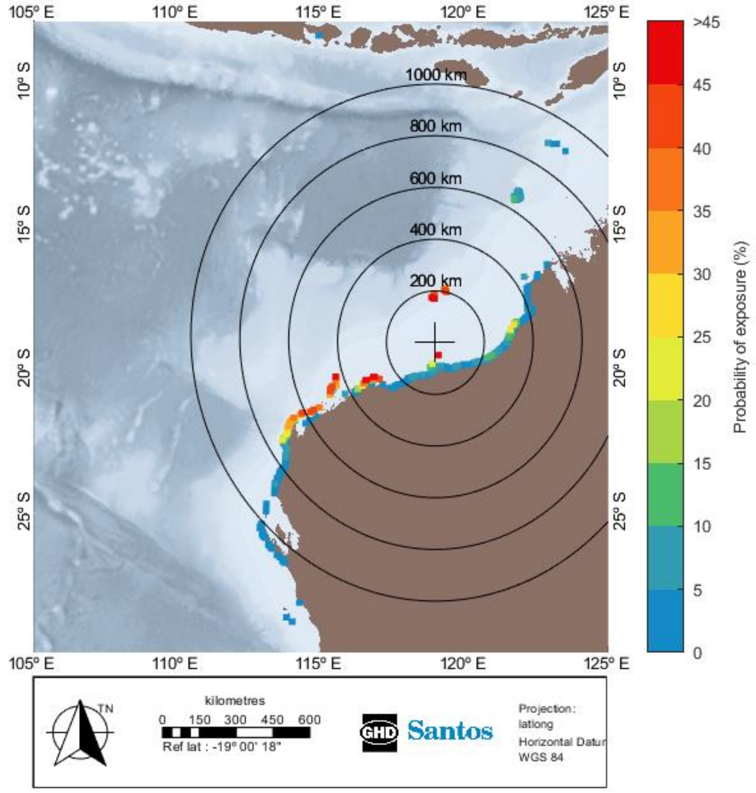
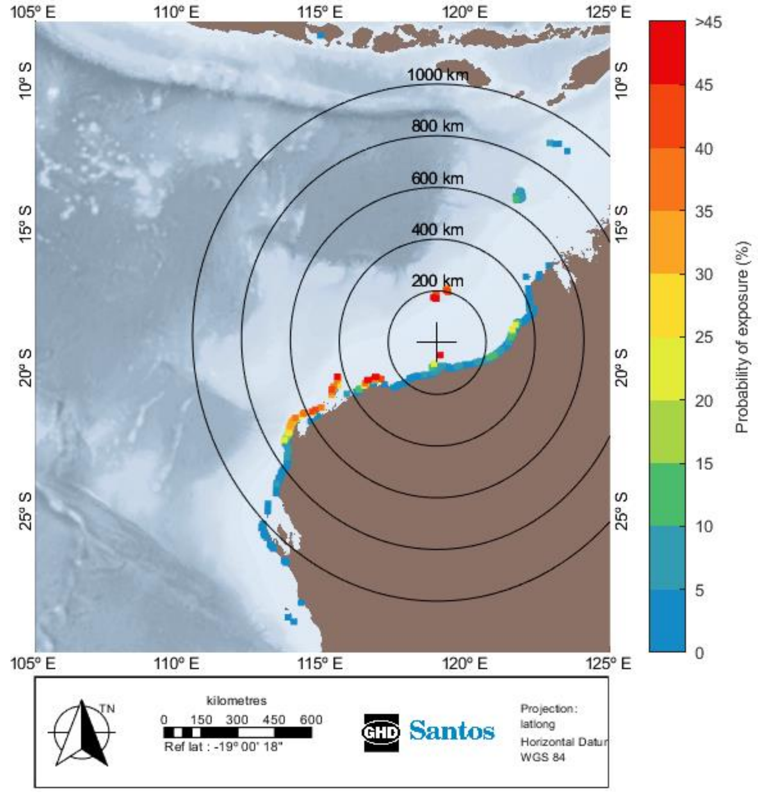
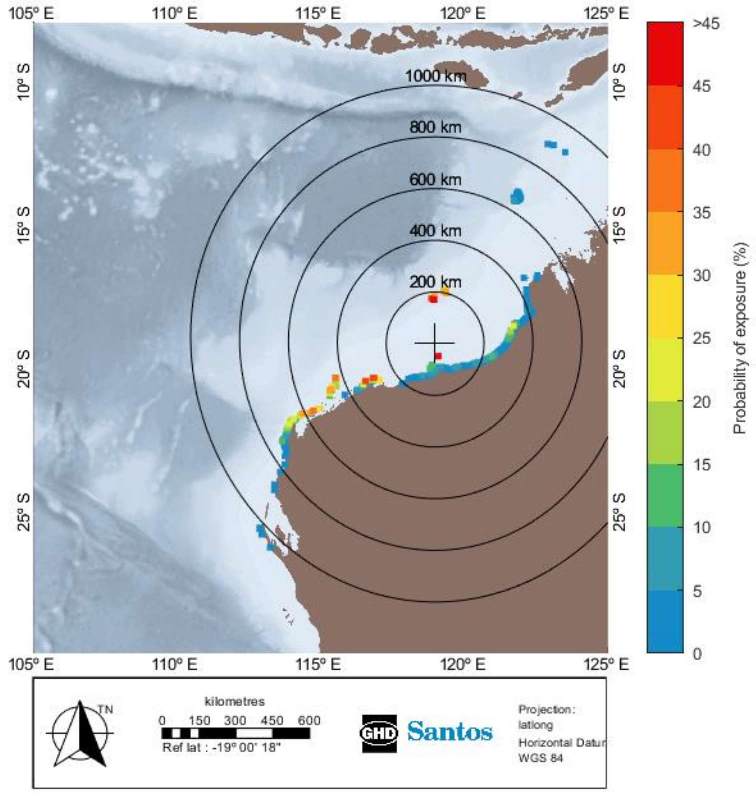
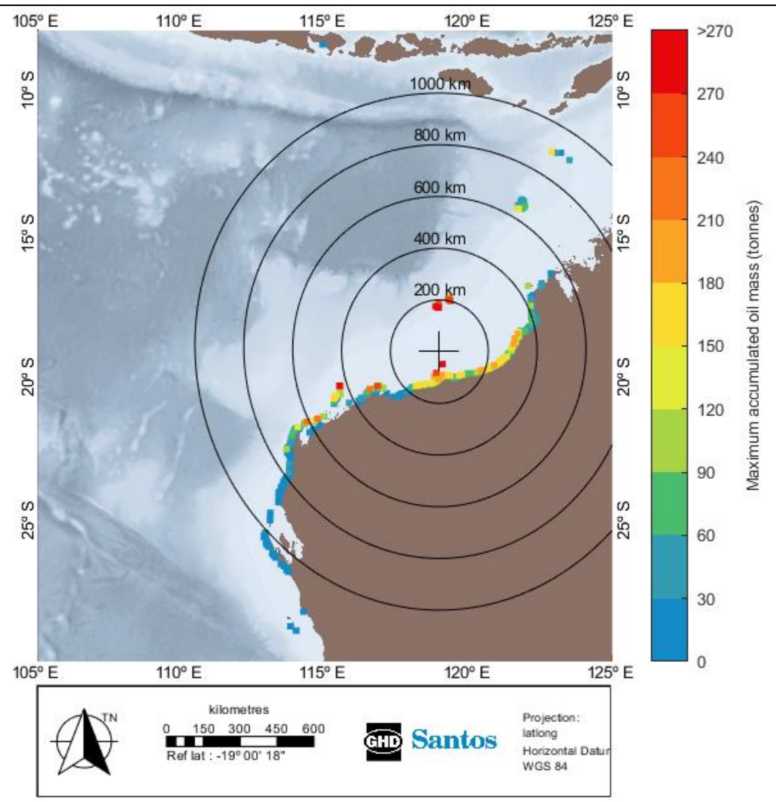
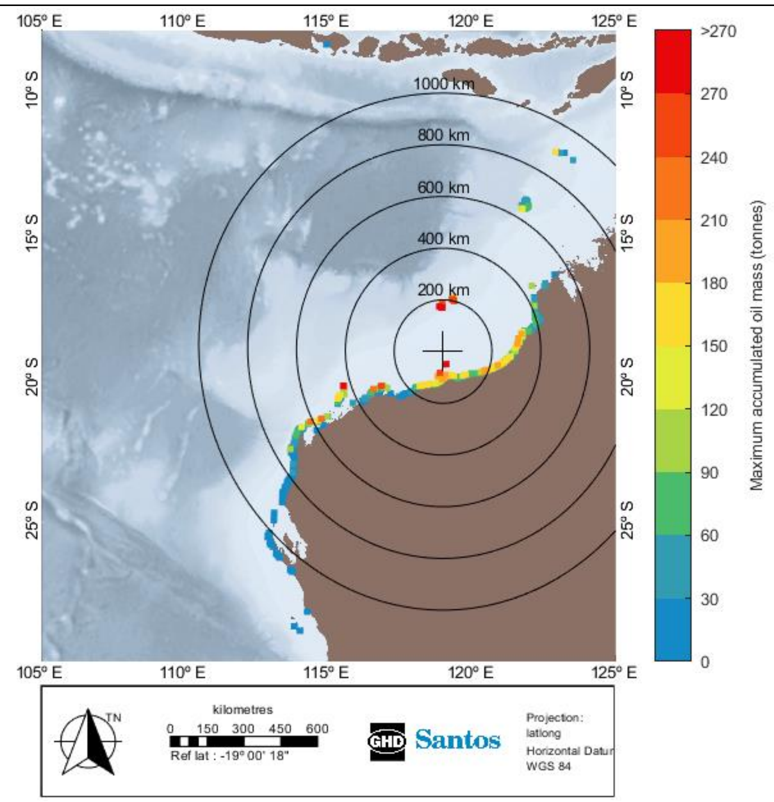
Shoreline Contact	> 10 g/m^2	> 100 g/m^2
Probability		
Shoreline Contact	**> 1,000 g/m^2**	
Probability		

Figure 24 Apus Base Case Surface LOWC Scenario – Summary of probability of shoreline oiling

<table>
<tr><th>Shoreline Contact</th><th>> 10 g/m²</th><th>> 100 g/m²</th></tr>
<tr><td>Mass</td><td>
</td><td>
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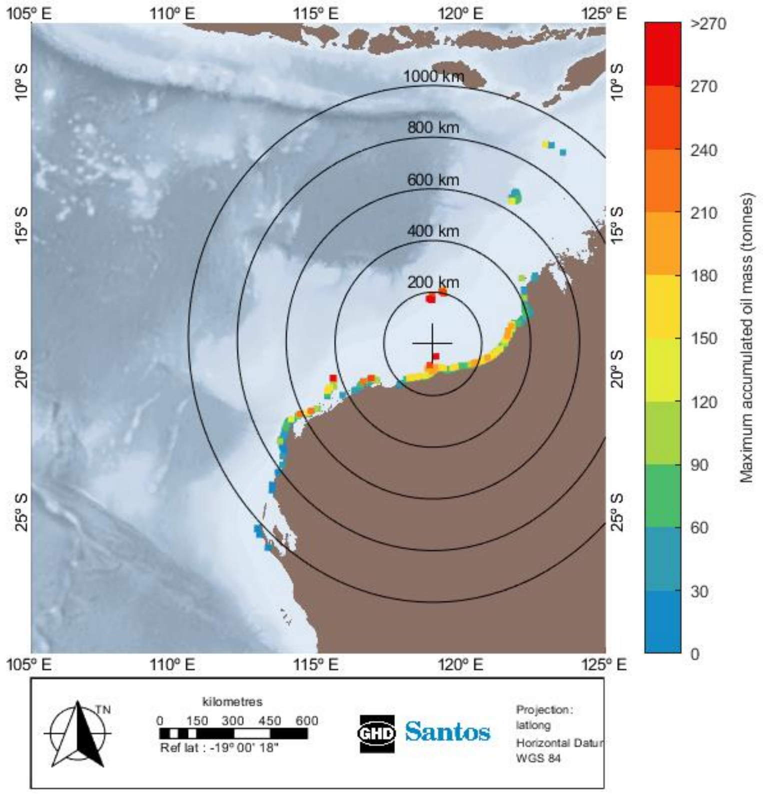
<tr><th>Shoreline Contact</th><th>> 1,000 g/m²</th><th></th></tr>
<tr><td>Mass</td><td>
</td><td></td></tr>
</table>

Figure 25 Apus Base Case Surface LOWC Scenario – Summary of maximum accumulated oil mass (tonnes) on shorelines

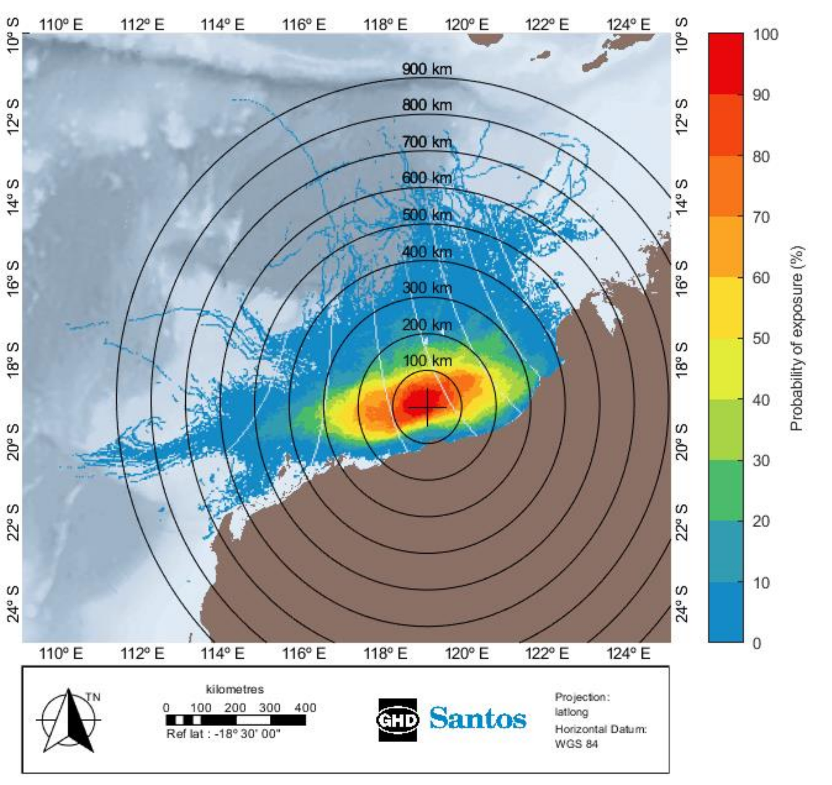
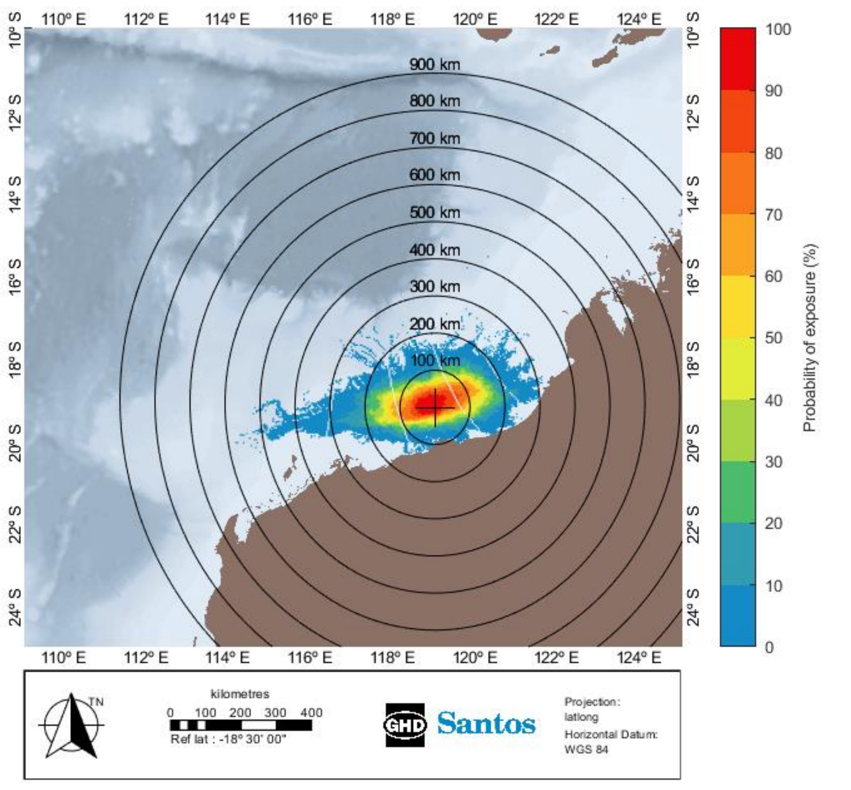
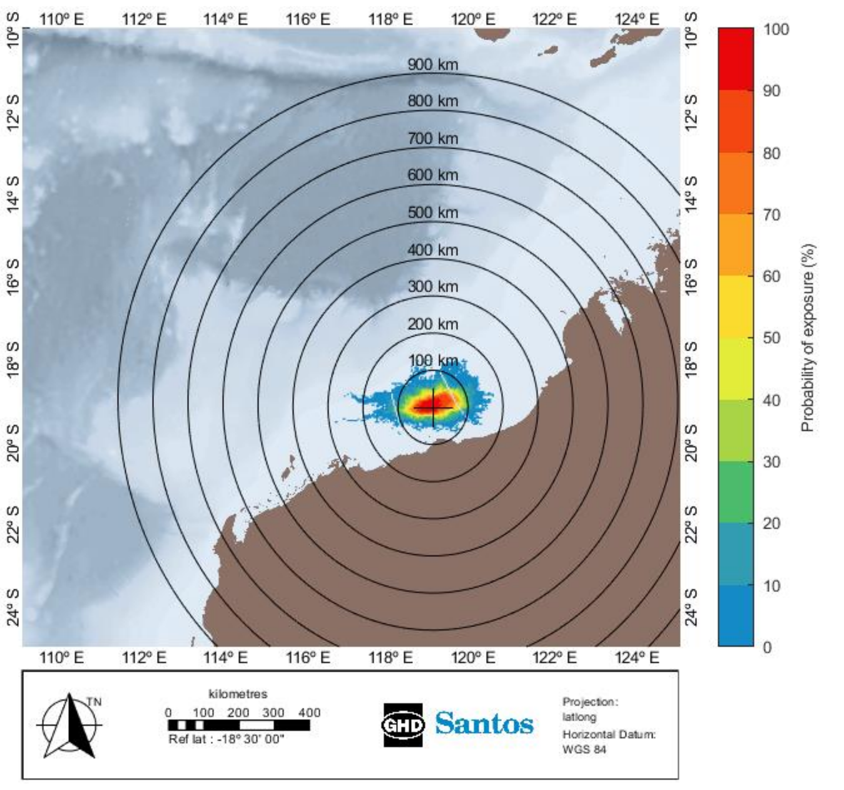
Surface Oil	> 1 g/m^2	> 10 g/m^2	> 50 g/m^2
Probability			

Figure 26 Apus Base Case Surface LOWC Scenario – Summary of probability of surface oil [9]

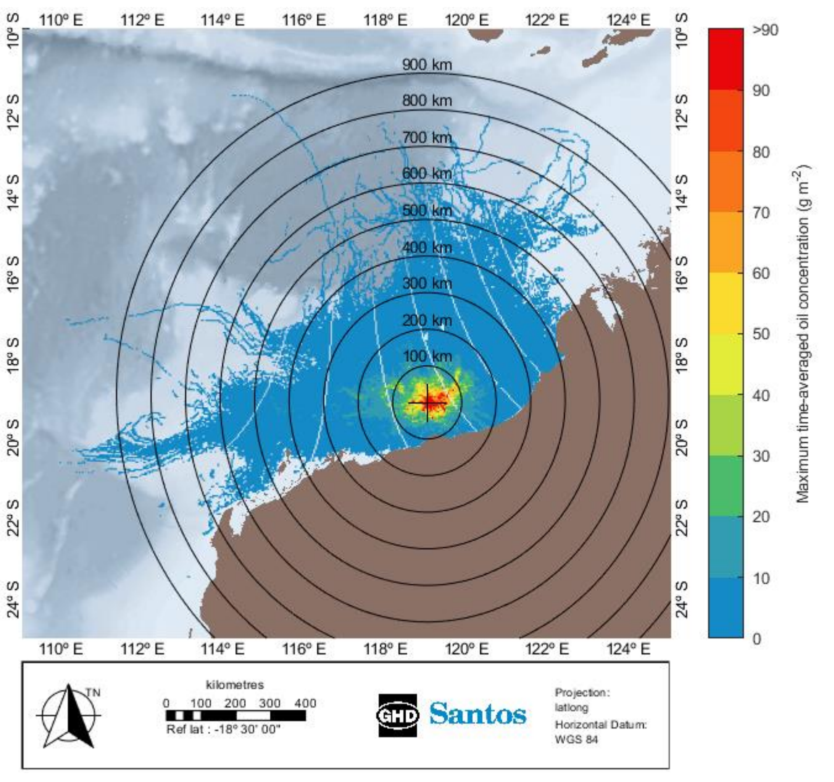
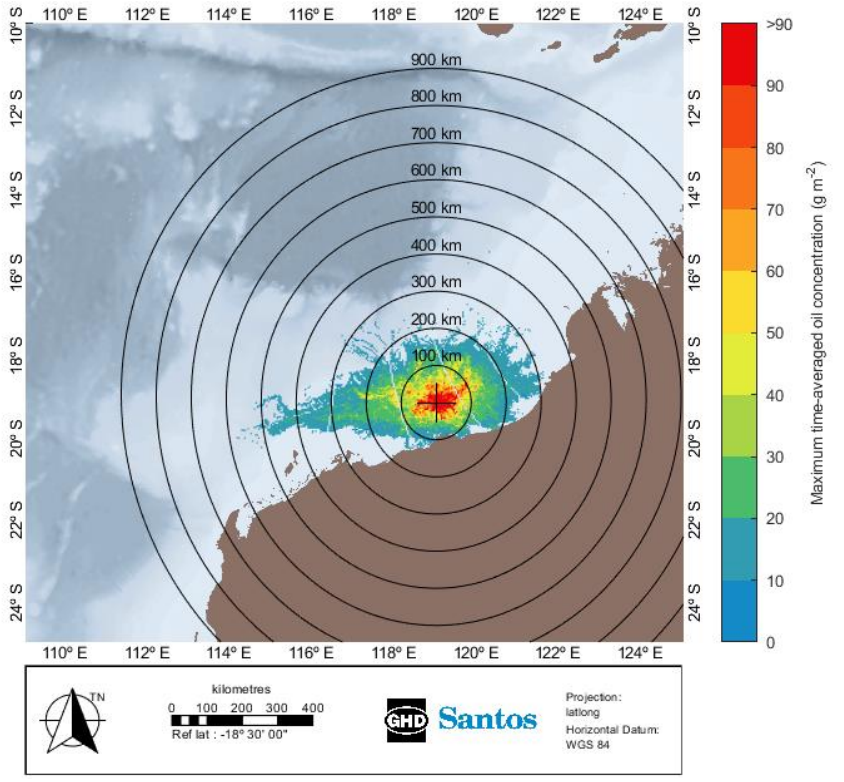
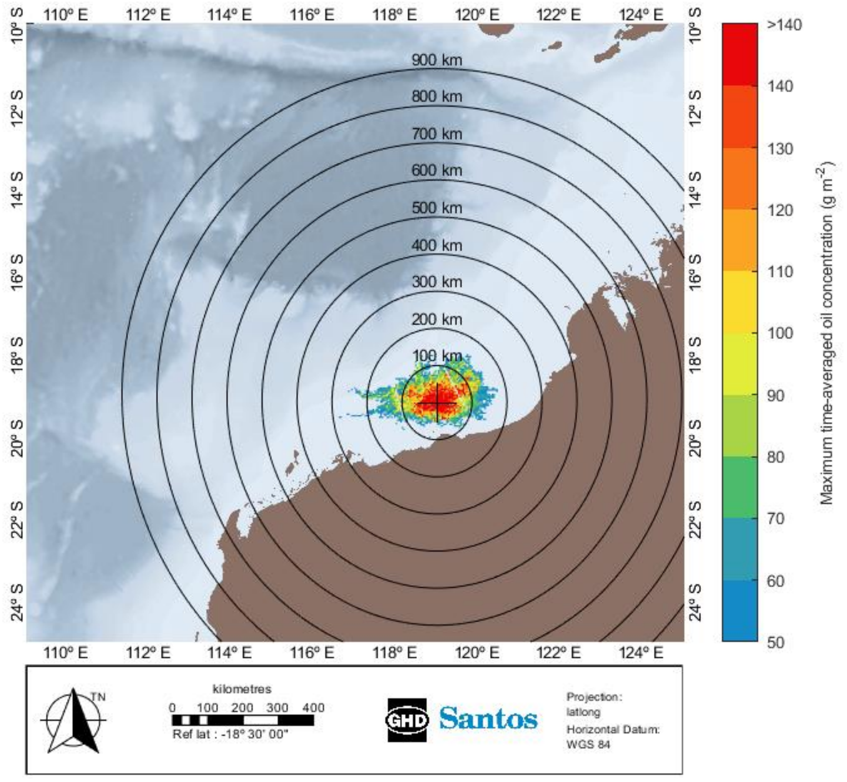
Surface Oil	> 1 g/m^2	> 10 g/m^2	> 50 g/m^2
Concentration			

Figure 27 Apus Base Case Surface LOWC Scenario – Summary of maximum time-averaged surface oil concentration [9]

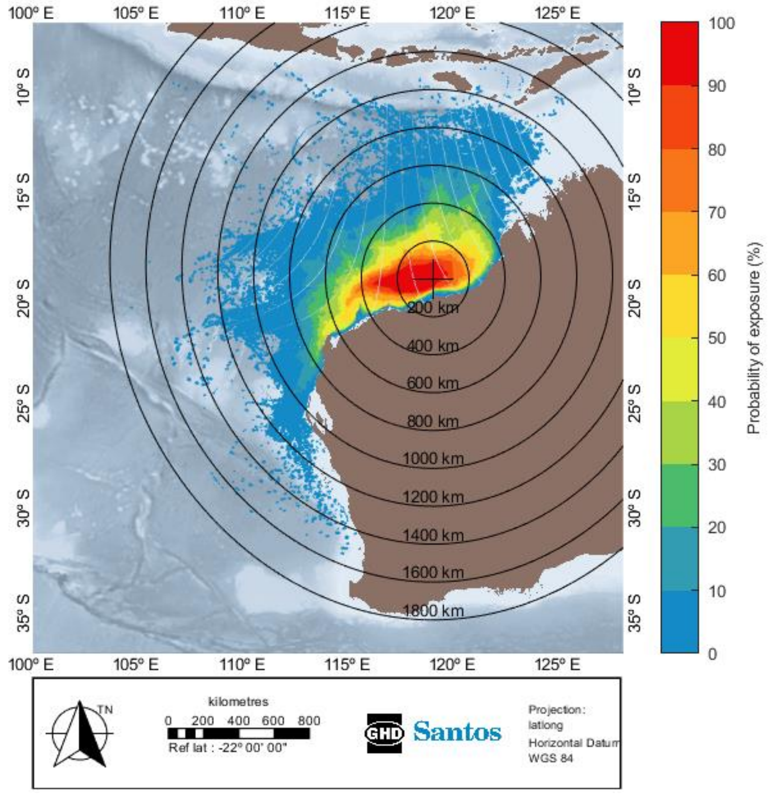
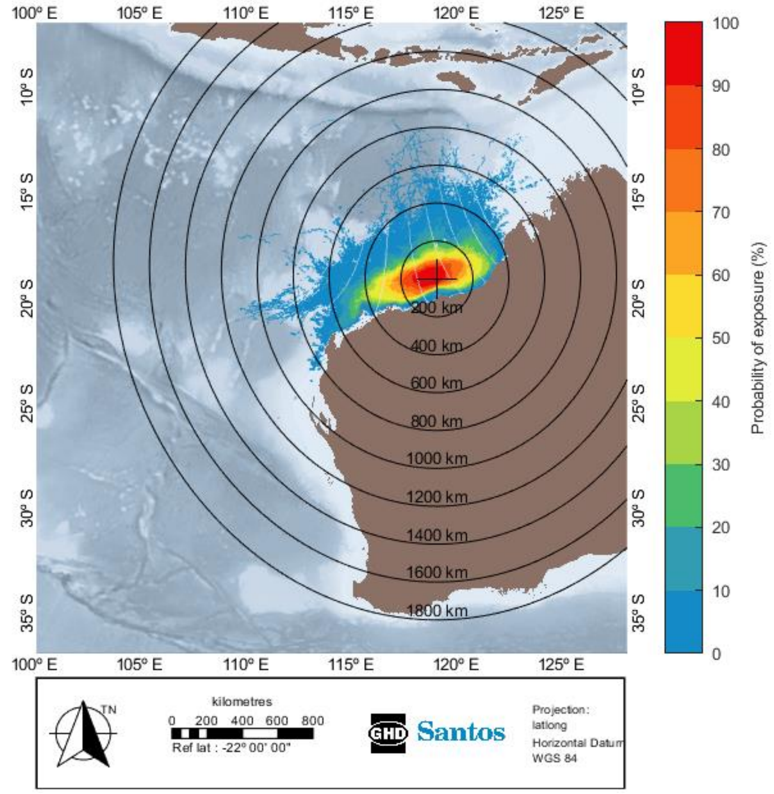
Total Submerged Oil	> 10 ppb	> 100 ppb
Probability		

Figure 28 Apus Base Case Surface LOWC Scenario – Summary of probability of total submerged oil [9]

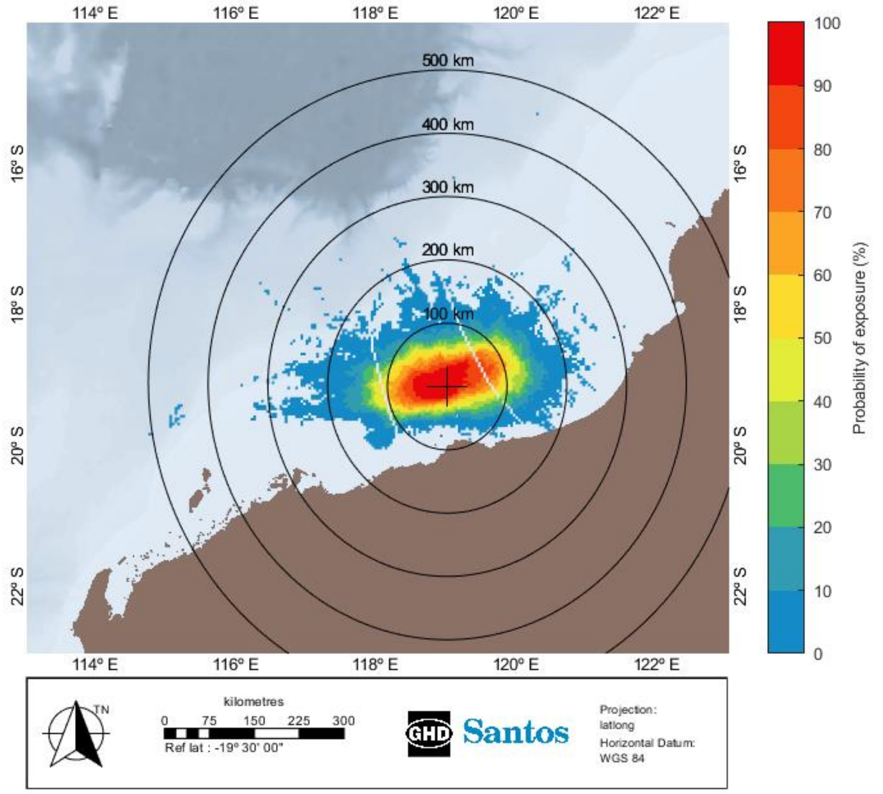
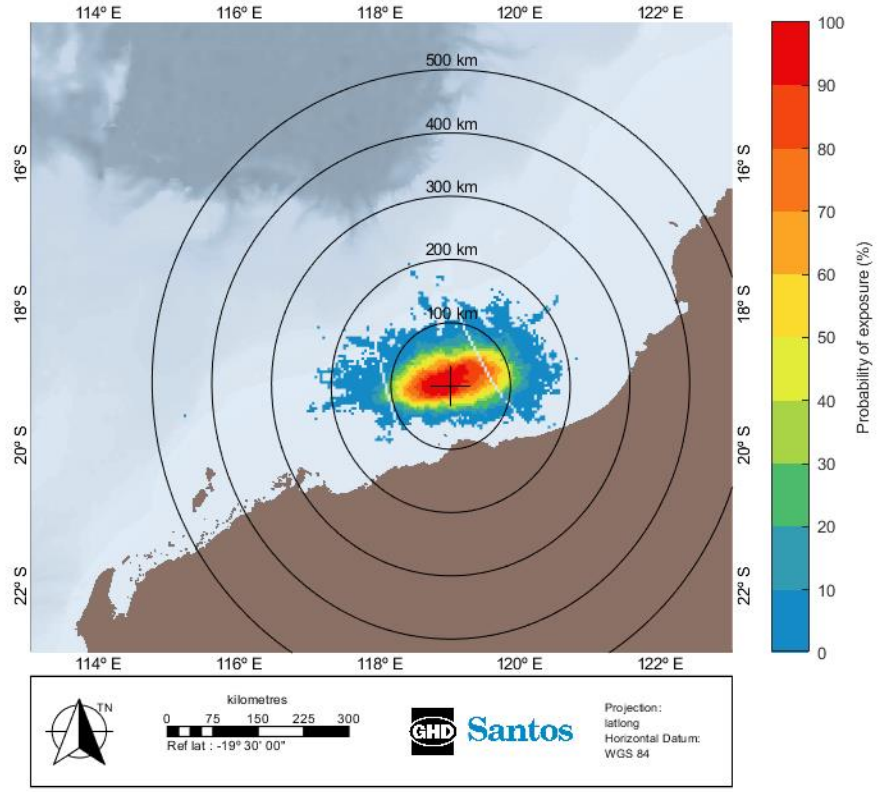
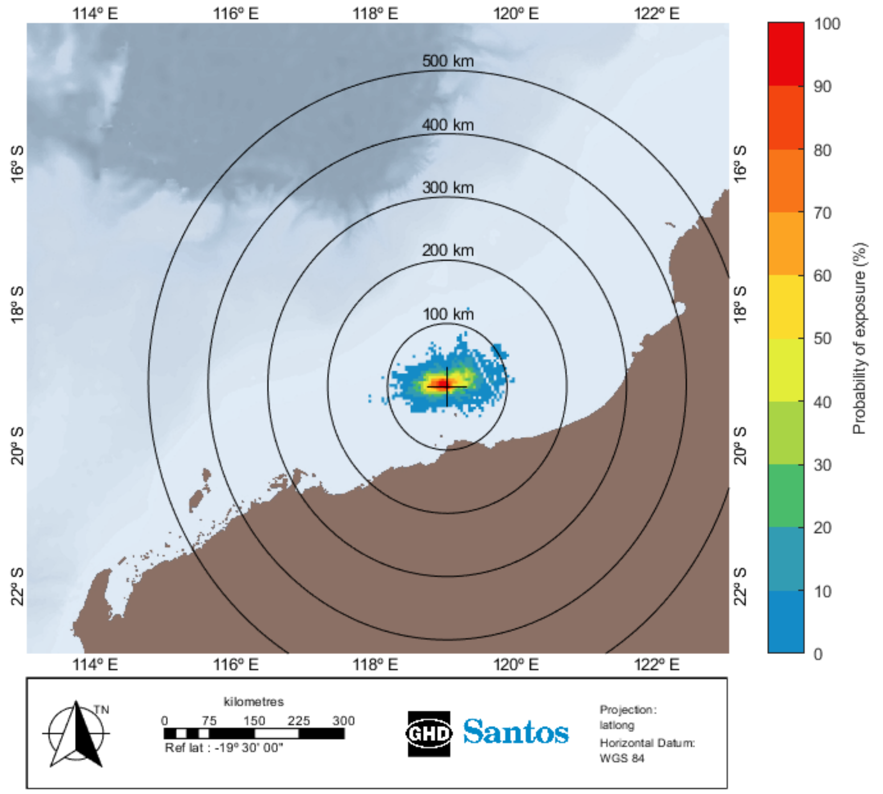
<table>
<tr><th>Dissolved Hydrocarbons</th><th>> 10 ppb</th><th>> 50 ppb</th></tr>
<tr><td>Probability</td><td>
</td><td>
</td></tr>
<tr><th>Dissolved Hydrocarbons</th><th>> 400 ppb</th><th></th></tr>
<tr><td>Probability</td><td>
</td><td></td></tr>
</table>

Figure 29 *Apus Base Case Surface LOWC Scenario – Summary of probability of dissolved hydrocarbons* [9]

4.1.3 Apus Alternate Subsea LOWC Scenario

4.1.3.1 Subsea Dynamics

The subsea dynamics of the Apus Alternate Subsea LOWC are highly energetic due to the gas volume that accompanies the release of liquid for this scenario. Whereas a surface release scenario will result in the gas being immediately lost to the atmosphere, the gas in a subsea discharge scenario contributes to the velocity and momentum of the subsea plume as it exits the release orifice.

At standard temperature and pressure (STP, which is 15°C and atmospheric pressure), the gas flow rate varies between 68.8 sm^3/s during the first week, decreasing to 65.9 sm^3/s by week 11 (Table 21). However, at the release depth of 72 m for the subsea scenario, the hydrostatic pressure compresses the gas, reducing the volumetric flow rate to 10.7-10.2 m^3/s.

Simulated momentum and buoyancy-scaled exit velocities range between 46.1-44.1 m/s that yield very small median droplet sizes of 199-210 µm.

While the discharge rates of liquid condensate and gas are reduced compared to the Apus Base Case scenario, outlet velocities increase for the alternate well design due to the reduction in the orifice diameter (from 0.30 m base case to 0.21 m alternate). This yields a reduced droplet sizes relative to the base case subsea scenario, which results in longer durations of oil entrainment prior to surfacing.

Table 21 Summary of near-field subsea plume dynamics

Week	Gas Flow Rate at STP[10] (sm^3/s)	Gas Flow Rate at Release Depth (m^3/s)	Liquid Oil Flow Rate (m^3/s)	Momentum and Buoyancy Scaled Effective Outlet Velocity (m/s)	Median Droplet Size (µm)
Week 1	68.8	10.7	0.22	46.1	199
Week 2	68.0	10.5	0.22	45.6	202
Week 3	67.5	10.4	0.22	45.3	204
Week 4	67.2	10.4	0.22	45.0	205
Week 5	66.9	10.4	0.21	44.8	206
Week 6	66.7	10.3	0.21	44.7	207
Week 7	66.5	10.3	0.21	44.6	208
Week 8	66.3	10.3	0.21	44.5	208
Week 9	66.2	10.2	0.21	44.4	209
Week 10	66.0	10.2	0.21	44.3	209
Week 11	65.9	10.2	0.21	44.1	210

4.1.3.2 Accumulated Shoreline Oil

Shoreline oiling is assessed at three thresholds that represent low (10 g/m^2, visual/aesthetic threshold), moderate (100 g/m^2, impact threshold that may require clean-up effort), and high (1,000 g/m^2, requires intensive clean-up effort) accumulated shoreline loadings. A summary of the shoreline loading predictions is presented in Table 22, and loading probabilities and maximum accumulated shoreline loadings are mapped spatially in Figure 31 and Figure 32, respectively, for the three thresholds.

Shoreline loading above the low (10 g/m^2) and moderate (100 g/m^2) thresholds was predicted to occur up to ~1,200 km from the release site to the southwest at Abrolhos Islands Pelsaert Group and ~1,000 km to the northeast at Indonesia East (Figure 31). At the high threshold (1,000 g/m^2) the spatial extent of shoreline accumulation was reduced to within ~950 km of the release site.

[10] Standard Temperature and Pressure – The volume of gas is calculated assuming a temperature of 15°C and a pressure of 1 atm

Shoreline accumulation above the moderate threshold (100 g/m^2) is summarised as follows:

– Across all shorelines, a 100% contact probability is predicted with a maximum accumulated shoreline load of 984 tonnes, a minimum arrival time of 5.8 days and a maximum length of oiled shoreline of 312 km.
– A very high contact probability of 77% was predicted for the proximal island receptor of Bedout Island. This receptor was predicted to receive a maximum shoreline accumulation of 64 tonnes, with a minimum arrival time of 5.8 days and maximum oiled shoreline length of 1 km (the island length).
– Moderately high contact probabilities of 30-54% were predicted at Clerke Reef MP, Imperieuse Reef MP, Dampier Archipelago, Montebello Islands, Barrow Island, Southern Islands Coast, Muiron Islands and Ningaloo Coast North. Maximum accumulated shoreline loads at these locations were 539 tonnes at Dampier Archipelago, 508 tonnes at Imperieuse Reef MP, 432 tonnes at Clerke Reef MP and 122-253 tonnes at the other receptors. Minimum arrival times of shoreline loading at these locations ranged between 14.7 days to 30.8 days. Maximum predicted lengths of shoreline accumulation were between 17 km to 85 km, except for Ningaloo Coast North (136 km).
– Moderate contact probabilities of 10-23% were predicted at Scott Reef South, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Lowendal Islands, Thevenard Islands, Eighty Mile Beach, and Roebuck – Eighty Mile Beach. Maximum accumulated shoreline loads at these receptors were between 34 tonnes and 183 tonnes, apart from Scott Reef South (490 tonnes) and Port Hedland-Eighty Mile Beach (405 tonnes). Minimum arrival times of shoreline loading at these locations ranged between 12.6 days and 48.2 days, while maximum predicted lengths of shoreline accumulation were between 6 km and 57 km.
– Low probabilities of contact (<10%) were predicted at Kimberley Coast PMZ, Cartier Island AMP, Ashmore Reef AMP, Camden Sound, Scott Reef North, King Sound, Broome North Coast, Northern Islands Coast, Ningaloo Coast South, Shark Bay – Coast Outer, Abrolhos Islands Pelsaert Group, Indonesia – East and Broome – Roebuck. Contact probabilities, accumulated shoreline loads, minimum arrival times and maximum oiled shoreline lengths for these receptors are summarised in Table 22.

A histogram of total shoreline loading above the moderate threshold (100 g/m^2) across the 150 stochastic realisations is presented in Figure 30 and a spatial summary of maximum accumulated shoreline oil is shown on Figure 32. Shoreline accumulation at the moderate threshold was predicted to occur for 100% of the realisations. No clear seasonal trend is evident in the shoreline loading predictions. Approximately half of the realisations resulted in shoreline accumulation greater than 300 tonnes (up to a maximum of 984 tonnes).

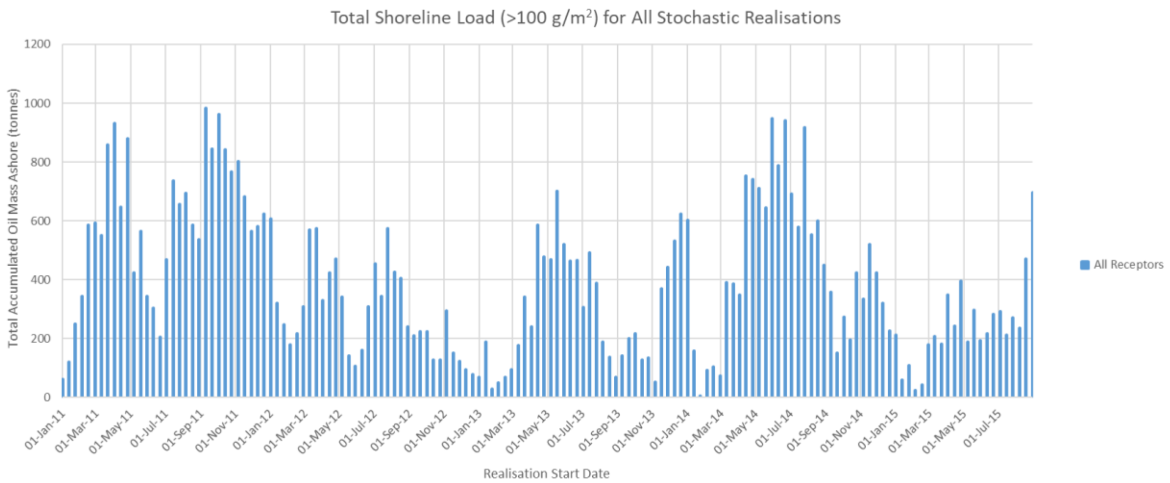


Figure 30 ***Apus Alternate Subsea LOWC Scenario – Summary of total accumulated shoreline load for all stochastic realisations for the 100 g/m^2 threshold***

4.1.3.3 Surface Oil

Surface oiling is evaluated at three instantaneous contact thresholds representing low (1 g/m^2, visual/aesthetic threshold), moderate (10 g/m^2, lower limit for potential ecological impacts), and high (50 g/m^2, approximating concentrations that can be targeted during spill response) concentrations. A summary of the surface oil predictions are presented in Table 23, and contact probabilities and maximum surface oil concentrations are mapped spatially in Figure 33 and Figure 34 for the three thresholds, respectively.

Surface oil above the low threshold (1 g/m^2) was predicted to occur at distances up to ~1,000 km from the release location (Figure 33). Significant reductions in the spatial extent of surface oil are predicted for the moderate threshold (10 g/m^2) which extends up to ~350 km from the release location, while the high threshold (50 g/m^2) is further reduced in spatial extent to primarily within ~100 km of the release location, though some isolated patches were predicted to occur up to ~200 km away.

Surface oil impacts at the moderate threshold (10 g/m^2) include:

– A moderately high contact probability of 43% was predicted for the Eighty Mile Beach AMP, with a maximum time-averaged surface oil concentration of 29 g/m^2 and a minimum arrival time of 3.2 days.
– A low contact probability of 7% was predicted at Bedout Island, with a maximum time-averaged surface oil concentration of 22 g/m^2 and a minimum arrival time of 13.1 days.

4.1.3.4 Total Submerged Oil

Total submerged oil (entrained plus dissolved oil) is evaluated at low (10 ppb, potential exceedance of water quality triggers) and moderate (100 ppb, potential impacts) instantaneous contact thresholds. Total submerged oil predictions are summarised in Table 24 and contact probabilities are mapped spatially in Figure 35 for the two thresholds.

Total submerged oil at the low threshold (10 ppb) was predicted to occur up to ~1,800 km from the release location. At the moderate threshold (100 ppb), predicted contact reduced in spatial to within ~1,100 km from the release location.

Total submerged oil impacts at the moderate threshold (100 ppb) include:

– Very high contact probabilities were predicted at Eighty Mile Beach AMP (98%) and Bedout Island (75%), with maximum time-averaged concentrations at these receptors of 1,673 ppb and 1,147 ppb, respectively, and with minimum arrival times of 1.8 and 3.7 days, respectively.
– Moderately high contact probabilities of 30-54% were predicted at Glomar Shoals, Eighty Mile Beach, Dampier AMP, Montebello AMP and Rowley Shoals surrounds. Maximum time-averaged concentrations at these locations ranged between 335 ppb and 1,545 ppb, with minimum arrival times of 11.2 to 13.6 days.
– Moderate contact probabilities of 11-25% were predicted at Imperieuse Reef MP, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Dampier Archipelago, Rankin Bank, Roebuck - Eighty Mile Beach, Kimberley AMP, and Ningaloo – Offshore. Maximum time-averaged concentrations at these locations ranged between 195 ppb and 1,399 ppb, with minimum arrival times of 14.4 to 31.9 days.
– Very low contact probabilities (<9%) occurred at several other receptor locations with contact probabilities, maximum time-averaged oil concentrations and minimum arrival times summarised in Table 24.

4.1.3.5 Dissolved Hydrocarbons

Dissolved hydrocarbons were evaluated at the low (10 ppb, potential exceedance of water quality triggers), moderate (50 ppb, potential sub-lethal toxic effects) and high (400 ppb, potential toxic lethal effects) instantaneous contact thresholds. A summary of the dissolved hydrocarbon predictions is presented in Table 25 and contact probabilities are mapped spatially in Figure 36 for the three thresholds.

Dissolved hydrocarbons at the low threshold (10 ppb) were predicted to extend a maximum distance of ~250 km from the release location. At the moderate threshold (50 ppb), the spatial extent was reduced to within ~150 km, while exceedance of the high threshold (400 ppb) was limited to within ~100 km of the release site.

Eighty Mile Beach AMP was the only receptor predicted to be contacted at the moderate threshold (50 ppb) with a moderately low contact probability of 14%, a maximum time-averaged concentration of 133 ppb and minimum arrival time of 5.8 days.

Table 22 Apus Alternate Subsea LOWC Scenario – Summary of shoreline oiling

Receptor Name	Total Contact Probability (%)			Maximum Accumulated Oil Concentration (g/m^2)			Maximum Accumulated Oil Ashore (tonnes)			Minimum Arrival Time (days)			Maximum Length of Oiled Shoreline (km)		
	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2
Kimberley Coast PMZ	0.7	0.7	0.7	3,288	3,288	3,288	37.4	37.4	37.4	88.9	88.9	88.9	5.7	5.7	5.7
Cartier Island AMP	1.3	1.3	0.7	1,066	1,066	1,066	12.1 (1.3)	12.1 (1.3)	12.1 (1.3)	72.0	72.0	72.0	5.7 (0.6)	5.7 (0.6)	5.7 (0.6)
Ashmore Reef AMP	6.0	6.0	4.7	6,093	6,093	6,093	166.8 (21.0)	165.7 (20.8)	156.5 (19.7)	70.9	70.9	70.9	39.8 (5.0)	39.8 (5.0)	28.4 (5.0)
Camden Sound	1.3	1.3	1.3	2,742	2,742	2,742	31.6	31.2	31.2	80.4	80.4	80.4	11.4	5.7	5.7
Scott Reef North	7.3	7.3	3.3	3,332	3,332	3,332	111.8	111.8	79.5	59.2	59.2	59.2	51.2	51.2	17.1
Scott Reef South	10.0	10.0	5.3	7,475	7,475	7,475	489.6	489.6	475.2	48.2	48.2	48.2	56.9	56.9	56.9
King Sound	0.7	0.7	0.7	3,716	3,716	3,716	42.3	42.3	42.3	62.6	62.6	62.6	5.7	5.7	5.7
Broome North Coast	5.3	4.0	4.0	3,970	3,970	3,970	45.1	45.1	45.1	36.0	36.0	36.0	11.4	11.4	5.7
Clerke Reef MP	41.3	40.0	32.7	15,256	15,256	15,256	432.2	432.2	406.5	18.6	18.6	18.6	51.2	51.2	45.5
Imperieuse Reef MP	53.3	52.0	41.3	17,008	17,008	17,008	508.0	508.0	498.6	14.7	14.7	14.7	56.9	56.9	56.9
Port Hedland-Eighty Mile Beach	15.3	14.7	10.0	21,020	21,020	21,020	405.2	405.2	405.2	13.1	13.1	13.9	22.7	17.1	17.1
Karratha-Port Hedland	18.0	16.0	2.7	4,944	4,944	4,944	107.5	107.5	107.5	15.8	15.8	30.1	34.1	28.4	11.4
Dampier Archipelago	54.7	54.0	46.7	12,766	12,766	12,766	538.8	538.8	518.4	16.0	16.0	16.0	85.3	85.3	56.9
Northern Islands Coast	12.0	8.0	1.3	1,729	1,729	1,729	21.0	21.0	19.7	31.8	31.8	53.7	17.1	17.1	5.7
Montebello Islands	46.0	44.0	32.7	17,349	17,349	17,349	253.3	253.3	243.8	18.9	18.9	18.9	22.7	22.7	22.7
Lowendal Islands	18.7	15.3	5.3	3,010	3,010	3,010	34.2	34.2	34.2	33.8	33.8	33.8	5.7	5.7	5.7
Barrow Island	42.7	42.0	23.3	4,704	4,704	4,704	154.2	152.3	140.5	24.2	24.2	24.4	62.5	62.5	34.1
Thevenard Islands	24.7	20.0	4.7	3,287	3,287	3,287	44.6	44.6	37.4	27.6	27.6	27.6	11.4	11.4	5.7
Southern Islands Coast	40.7	38.7	22.7	7,319	7,319	7,319	150.9	150.9	149.4	28.7	28.7	28.7	22.7	22.7	17.1
Muiron Islands	36.0	32.0	16.7	7,172	7,172	7,172	122.1	122.1	122.1	29.6	29.6	29.6	17.1	17.1	17.1
Ningaloo Coast North	38.0	34.7	15.3	4,404	4,404	4,404	189.8	187.9	125.2	30.8	30.8	40.9	136.4	136.4	39.8
Ningaloo Coast South	12.7	9.3	1.3	1,293	1,293	1,293	17.4	17.4	14.7	55.0	55.0	55.0	28.4	28.4	5.7
Shark Bay - Coast Outer	2.7	2.7	NC	684	684	NC	8.9	7.8	NC	77.0	77.0	NC	34.1	11.4	NC
Abrolhos Islands Pelsaert Group	0.7	0.7	NC	133	133	NC	1.5	1.5	NC	108.9	108.9	NC	5.7	5.7	NC
Indonesia - East	1.3	1.3	NC	860	860	NC	9.8	9.8	NC	91.4	91.4	NC	5.7	5.7	NC
Eighty Mile Beach	23.3	22.7	21.3	14,373	14,373	14,373	201.2	201.0	201.0	12.6	12.6	12.6	34.1	28.4	28.4
Broome - Roebuck	6.0	5.3	4.7	4,336	4,336	4,336	49.3	49.3	49.3	36.8	36.8	36.8	11.4	5.7	5.7
Roebuck - Eighty Mile Beach	23.3	22.7	22.0	10,435	10,435	10,435	182.6	182.6	182.6	18.5	18.5	18.5	28.4	22.7	22.7
Bedout Island	78.0	77.3	67.3	29,081	29,081	29,081	330.7 (63.8)	330.7 (63.8)	330.7 (63.8)	5.8	5.8	5.8	5.7 (1.1)	5.7 (1.1)	5.7 (1.1)
All Shorelines	**100**	**100**	**99.3**	**29,081**	**29,081**	**29,081**	**1,035 (984)**	**1,035 (984)**	**998.5 (947.0)**	**5.8**	**5.8**	**5.8**	**329.7**	**318.4**	**142.1**

Table 23 Apus Alternate Subsea LOWC Scenario – Summary of surface oil

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Oil Concentration (g/m^2)			Minimum Arrival Time (days)		
	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2
Kimberley Coast PMZ	0.7	NC	NC	2.4	NC	NC	83.3	NC	NC
Camden Sound	0.7	NC	NC	1.1	NC	NC	80.4	NC	NC
Seringapatam Reef	0.7	NC	NC	2.3	NC	NC	109.4	NC	NC
Broome North Coast	4.0	NC	NC	2.9	NC	NC	35.4	NC	NC
Mermaid Reef AMP	6.0	NC	NC	5.7	NC	NC	18.1	NC	NC
Clerke Reef MP	8.0	NC	NC	3.3	NC	NC	31.7	NC	NC
Imperieuse Reef MP	14.7	NC	NC	3.4	NC	NC	14.7	NC	NC
Port Hedland-Eighty Mile Beach	13.3	NC	NC	5.3	NC	NC	13.1	NC	NC
Glomar Shoals	22.7	NC	NC	3.9	NC	NC	11.9	NC	NC
Karratha-Port Hedland	2.7	NC	NC	3.5	NC	NC	29.3	NC	NC
Dampier Archipelago	1.3	NC	NC	1.4	NC	NC	22.3	NC	NC
Rankin Bank	8.7	NC	NC	3.1	NC	NC	22.2	NC	NC
Barrow-Montebello Surrounds	0.7	NC	NC	2.5	NC	NC	23.2	NC	NC
Eighty Mile Beach	30.0	NC	NC	4.4	NC	NC	12.0	NC	NC
Broome - Roebuck	9.3	NC	NC	3.1	NC	NC	30.0	NC	NC
Roebuck - Eighty Mile Beach	24.0	NC	NC	3.4	NC	NC	18.1	NC	NC
Kimberley AMP	13.3	NC	NC	4.0	NC	NC	31.0	NC	NC
Dampier AMP	13.3	NC	NC	3.1	NC	NC	16.3	NC	NC
Montebello AMP	10.7	NC	NC	2.9	NC	NC	21.9	NC	NC
Eighty Mile Beach AMP	87.3	42.7	NC	20.4	28.5	NC	2.1	3.2	NC
Rowley Shoals surrounds	40.7	NC	NC	6.0	NC	NC	13.9	NC	NC
Ningaloo - Offshore	16.7	NC	NC	5.5	NC	NC	18.2	NC	NC
Bedout Island	49.3	6.7	NC	15.1	21.6	NC	3.6	13.1	NC
All Ocean	**100**	**100**	**100**	**60.5**	**102.1**	**165.3**	**0.1**	**0.1**	**0.2**

Table 24 Apus Alternate Subsea LOWC Scenario – Summary of total submerged oil

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Fantome Shoals	0.7	NC	34.6	NC	108.2	NC
Barracouta Shoals	1.3	NC	10.6	NC	110.9	NC
Vulcan Shoals	0.7	NC	50.3	NC	108.8	NC
Hibernia Reef	0.7	NC	42.4	NC	107.9	NC
Woodbine Bank	1.3	NC	48.2	NC	86.4	NC
Cartier Island AMP	3.3	NC	40.9	NC	76.2	NC
Ashmore Reef AMP	6.0	NC	56.7	NC	73.2	NC
Camden Sound	1.3	0.7	98.6	118.7	75.0	75.5
Seringapatam Reef	4.7	0.7	56.0	110.0	61.1	104.1
Scott Reef North	7.3	NC	82.3	NC	59.1	NC
Scott Reef South	9.3	2.7	79.0	159.3	48.4	68.9
Adele Island	1.3	NC	15.7	NC	82.3	NC
King Sound	0.7	NC	14.6	NC	87.0	NC
Broome North Coast	6.0	3.3	277.3	277.3	37.8	51.3
Mermaid Reef AMP	39.3	6.0	748.4	1,461	18.2	18.2
Clerke Reef MP	44.0	8.7	252.7	295.2	21.6	21.9
Imperieuse Reef MP	56.0	18.0	222.4	279.0	20.1	32.8
Port Hedland-Eighty Mile Beach	57.3	18.0	1,241	1,399	13.3	14.4
Glomar Shoals	91.3	51.3	101.9	335.0	11.2	11.2
Karratha-Port Hedland	52.7	13.3	171.6	390.1	10.3	16.5
Dampier Archipelago	57.3	19.3	78.5	194.7	13.6	17.7
Rankin Bank	65.3	15.3	69.6	257.4	17.5	19.6
Northern Islands Coast	34.0	1.3	71.3	229.8	19.8	77.3
Montebello Islands	46.0	4.0	67.5	205.7	18.3	37.4
Lowendal Islands	30.0	1.3	58.6	154.6	22.5	42.9
Barrow Island	47.3	1.3	58.1	161.5	22.6	78.7
Barrow-Montebello Surrounds	50.0	7.3	72.5	163.3	18.0	32.4
Middle Islands Coast	1.3	NC	24.6	NC	55.1	NC
Thevenard Islands	24.0	NC	58.6	NC	27.5	NC
Southern Islands Coast	43.3	0.7	50.9	104.3	28.2	68.3
Muiron Islands	39.3	2.7	79.0	136.4	29.3	54.6
Exmouth Gulf Coast	4.0	NC	36.5	NC	48.0	NC
Ningaloo Coast North	41.3	NC	55.1	NC	28.8	NC
Ningaloo Coast South	9.3	NC	43.5	NC	68.8	NC
Shark Bay - Coast Outer	2.0	NC	28.6	NC	76.8	NC
Abrolhos - Outer Island Shoals	5.3	NC	40.2	NC	89.3	NC
Indonesia - East	1.3	NC	48.0	NC	91.3	NC
Perth Canyon AMP	1.3	NC	37.2	NC	88.3	NC

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Eighty Mile Beach	40.0	30.0	1,545	1,545	11.8	11.8
Broome - Roebuck	8.0	7.3	1,297	1,297	37.2	48.3
Roebuck - Eighty Mile Beach	13.3	11.3	262.5	262.5	27.7	27.7
Kimberley AMP	43.3	21.3	731.9	731.9	26.4	31.9
Dampier AMP	60.0	46.0	188.1	1,143.1	11.0	11.8
Montebello AMP	75.3	41.3	210.6	532.8	12.2	12.7
Ningaloo - Outer Coast North	46.7	1.3	68.7	203.4	26.8	60.3
Johnson Bank	5.3	0.7	172.4	172.4	70.6	106.3
Shark Bay AMP	6.7	NC	70.8	NC	67.9	NC
Ashmore/Cartier - Outer	14.0	2.0	174.1	191.3	58.5	70.6
Eighty Mile Beach AMP	99.3	98.0	1,051	1,673	1.8	1.8
Rowley Shoals surrounds	76.7	54.0	1,463	1,472	13.6	13.6
Abrolhos West	1.3	NC	10.1	NC	101.3	NC
Ningaloo - Outer NW	55.3	6.7	110.1	239.2	25.3	47.5
Ningaloo - Offshore	80.7	25.3	398.8	1,176	16.5	17.5
Abrolhos - Offshore NW	12.0	NC	84.1	NC	61.3	NC
Abrolhos - Offshore Perth North	2.0	NC	46.4	NC	74.8	NC
Perth South - Geographe - Offshore	0.7	NC	13.2	NC	97.5	NC
Bedout Island	96.0	74.7	290.3	1,147	3.7	3.7
All Ocean	**100**	**100**	**5,502**	**6,180**	**0.1**	**0.1**

Table 25 Apus Alternate Subsea LOWC Scenario – Summary of dissolved hydrocarbons

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Concentration (ppb)			Minimum Arrival Time (days)		
	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb
Eighty Mile Beach AMP	51.3	14.0	NC	66.1	133.1	NC	2.3	5.8	NC
Bedout Island	4.0	NC	NC	19.6	NC	NC	15.3	NC	NC
All Ocean	**100**	**100**	**100**	**2,698**	**4,773**	**7,765**	**0.1**	**0.1**	**0.1**

<table>
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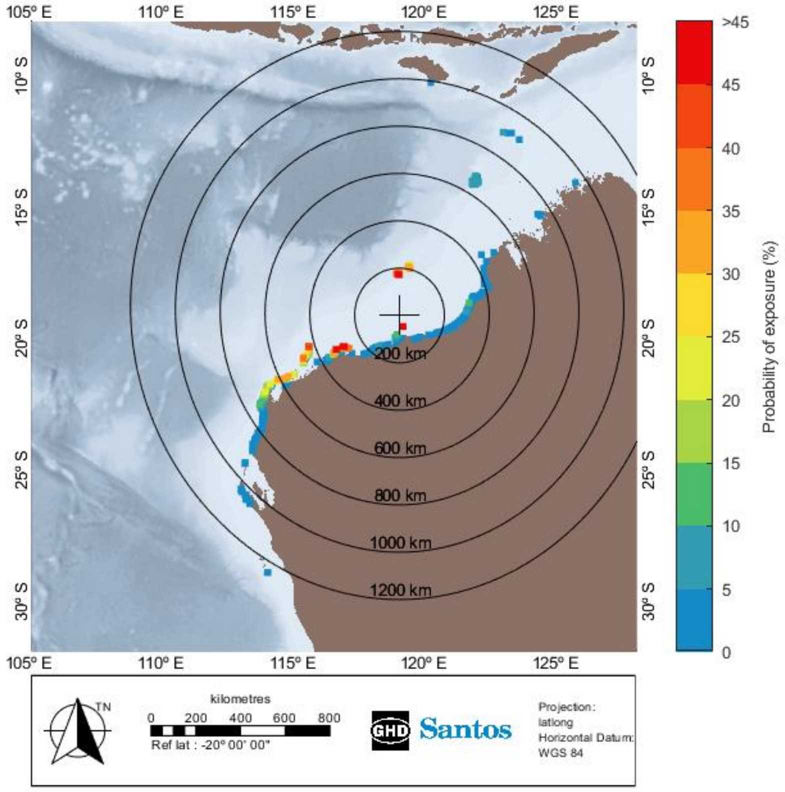
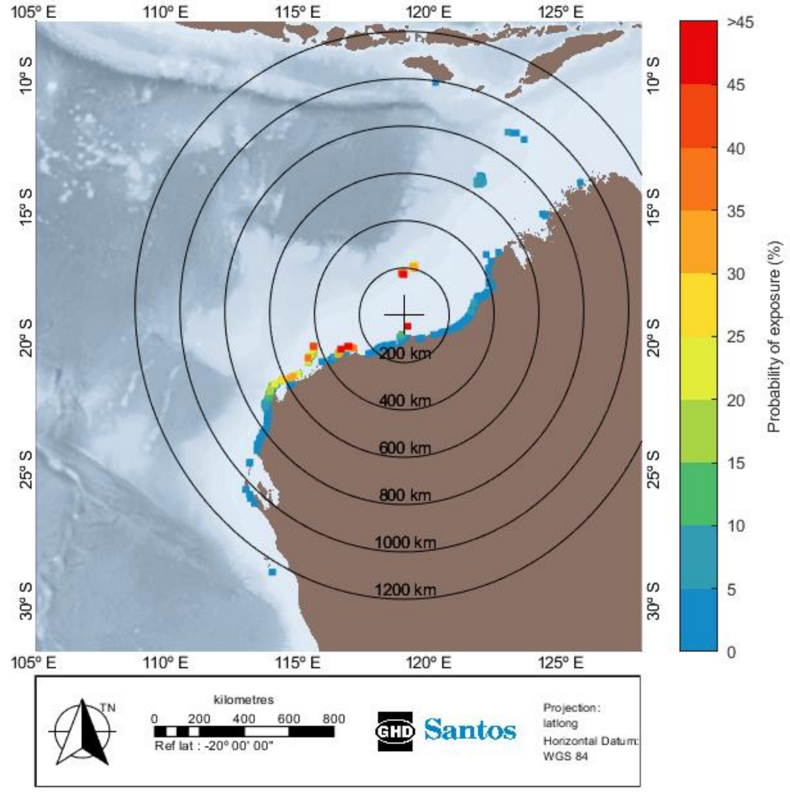
<tr><td>Probability</td><td>
</td><td>
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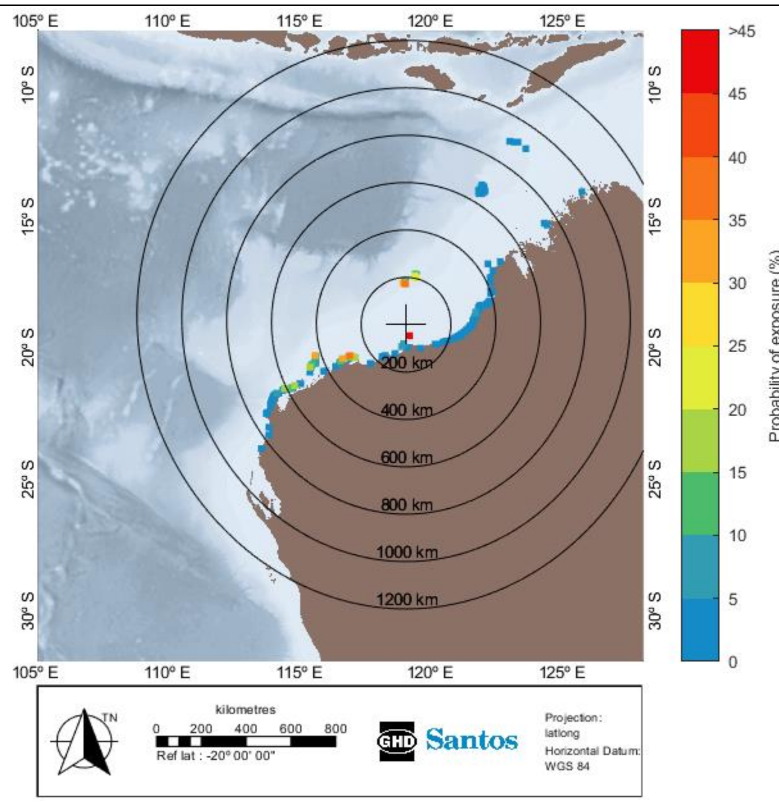
<tr><td>Probability</td><td>
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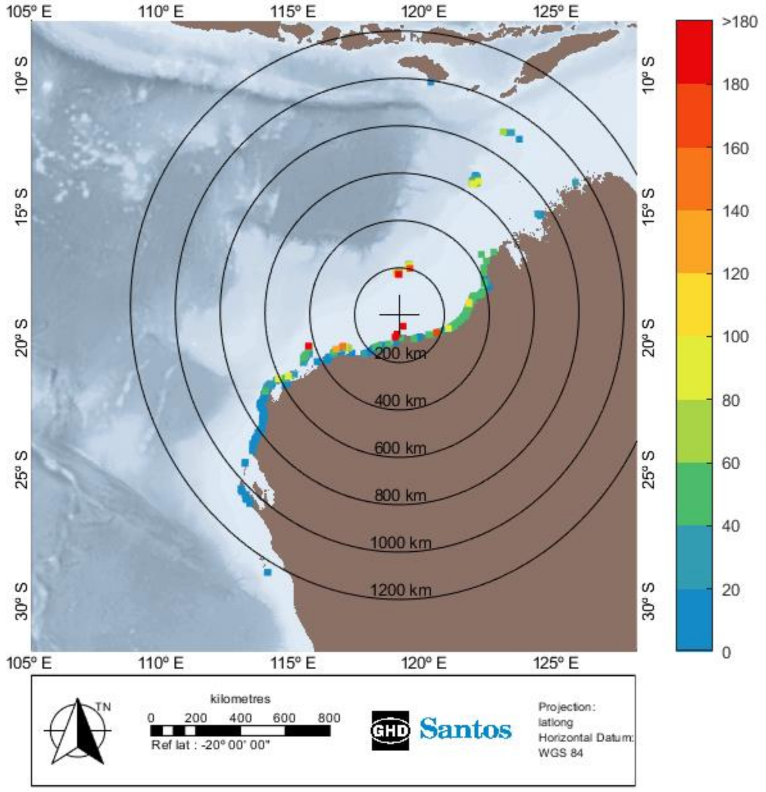
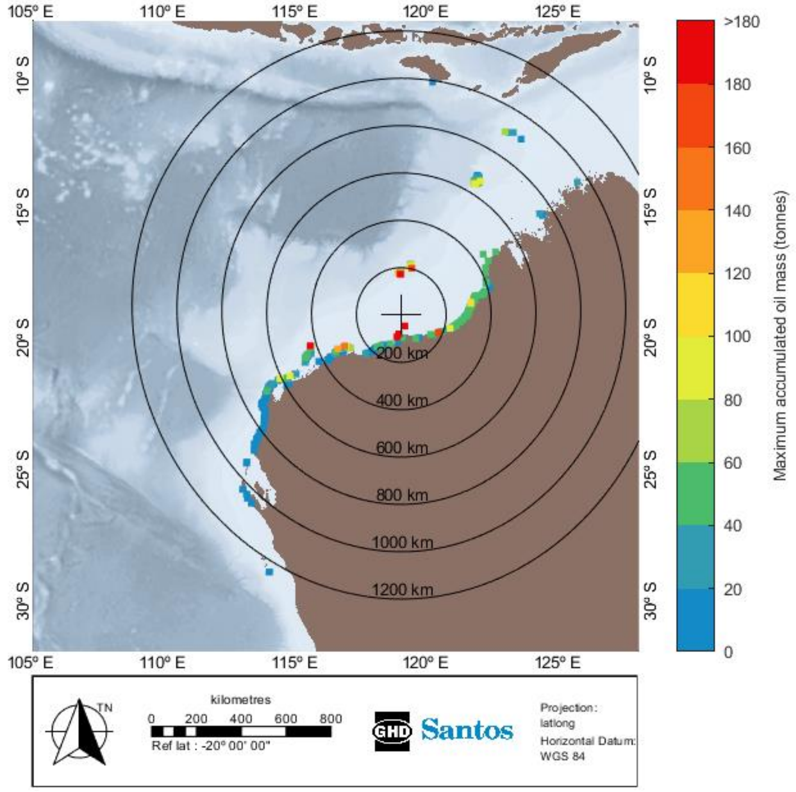
Figure 31 Apus Alternate Subsea LOWC Scenario – Summary of probability of shoreline oiling

Shoreline Contact	> 10 g/m²	> 100 g/m²
Mass		
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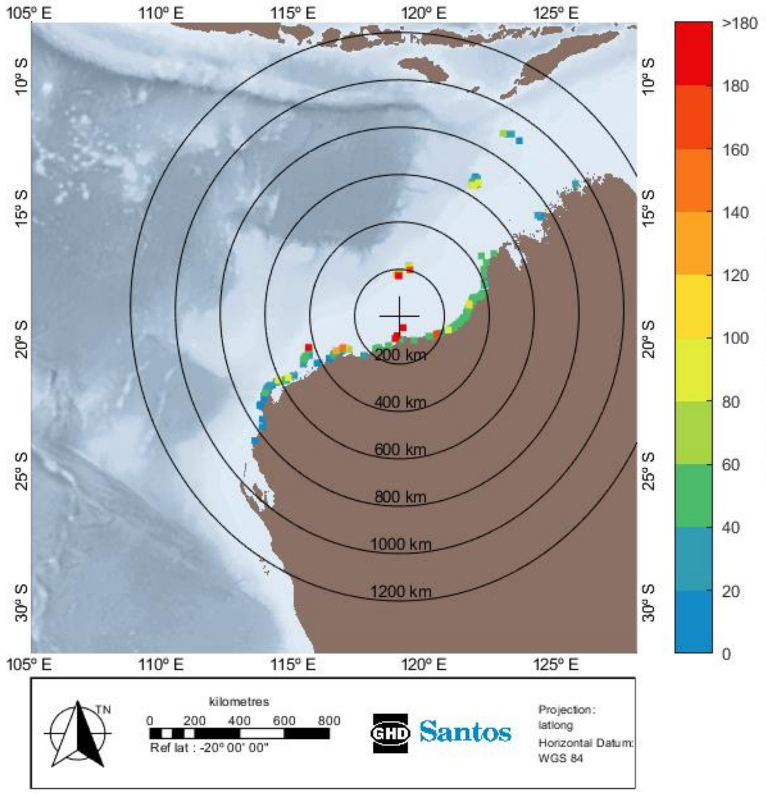
Mass		

Figure 32 Apus Alternate Subsea LOWC Scenario – Summary of maximum accumulated oil mass (tonnes) on shorelines

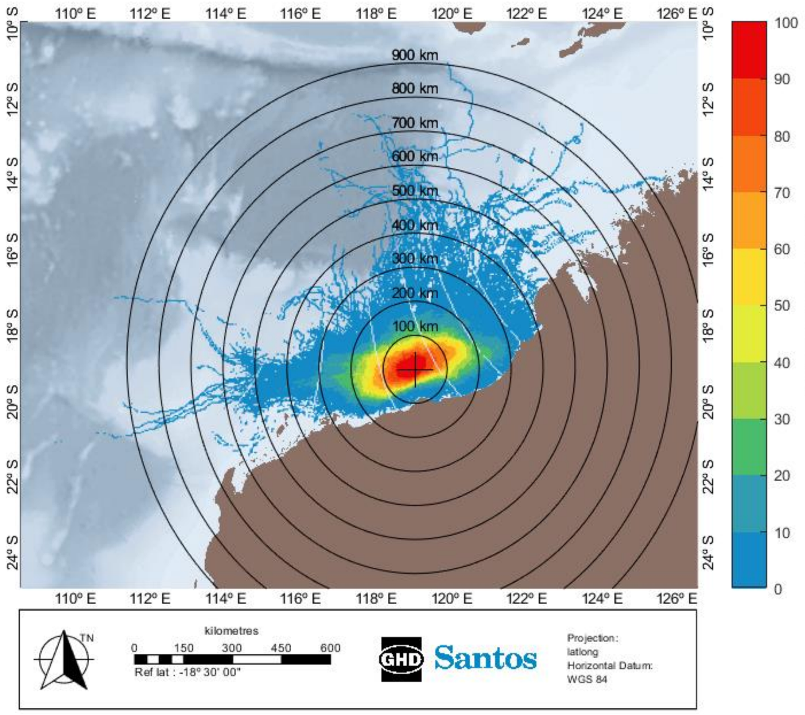
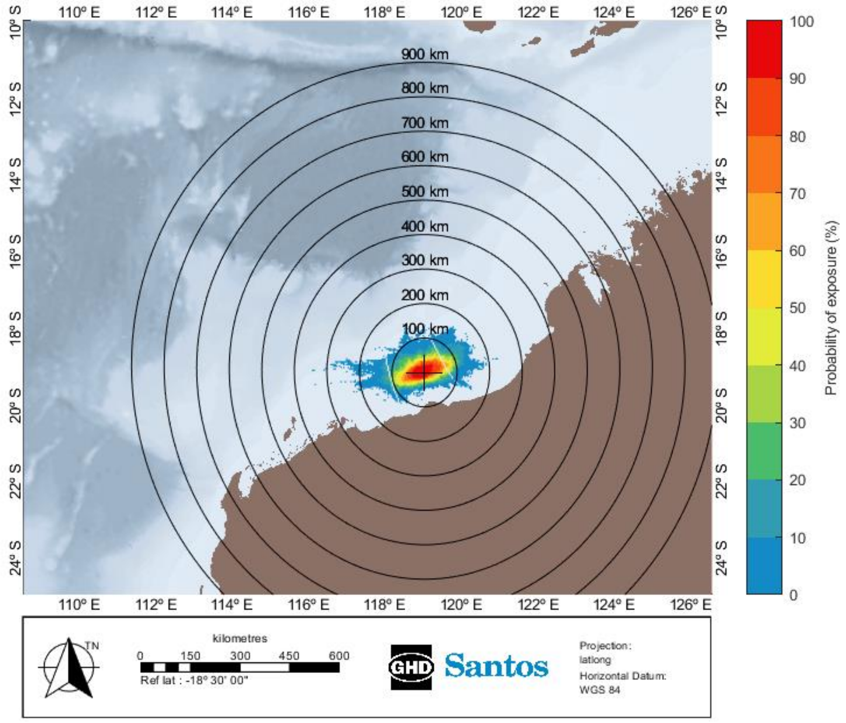
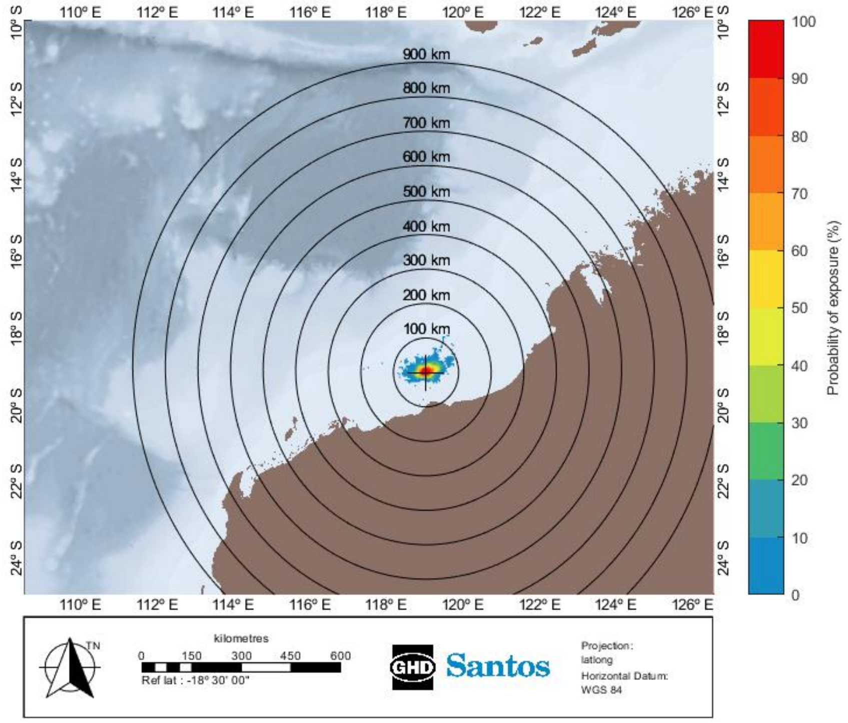
Surface Oil	> 1 g/m²	> 10 g/m²	> 50 g/m²
Probability			

Figure 33 Apus Alternate Subsea LOWC Scenario – Summary of probability of surface oil [11]

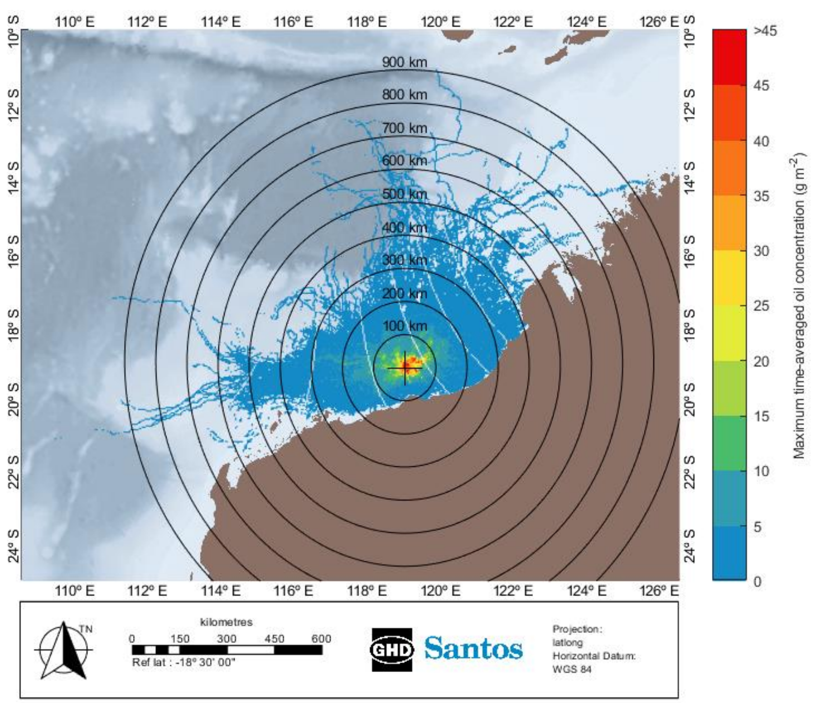
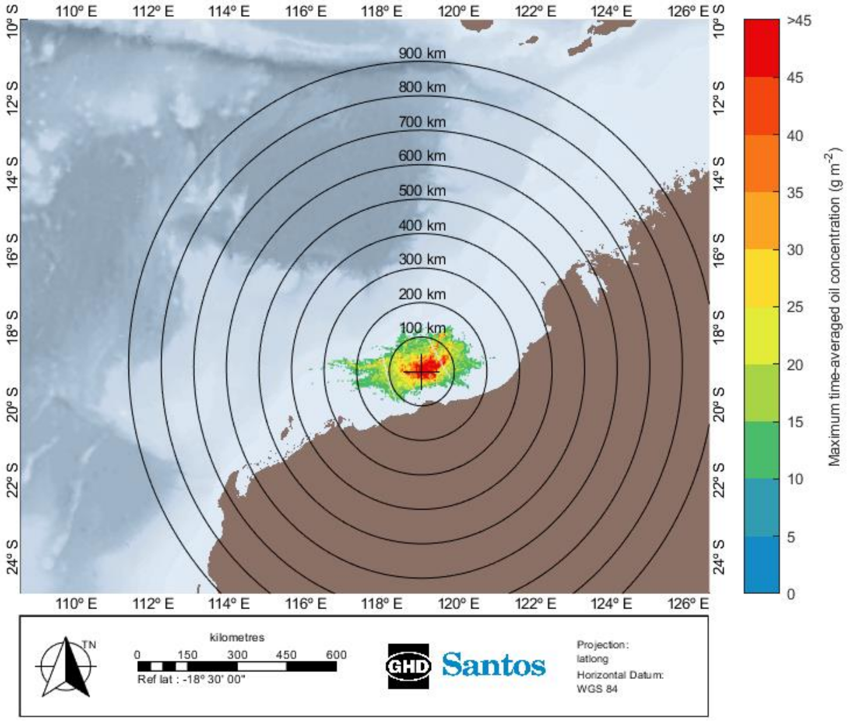
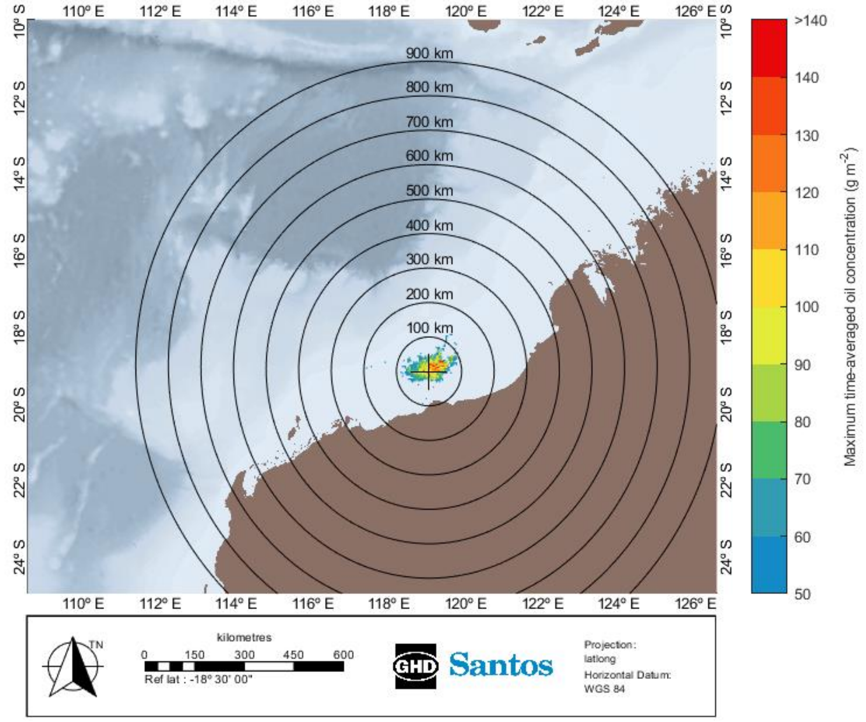
Surface Oil	> 1 g/m²	> 10 g/m²	> 50 g/m²
Concentration			

Figure 34 Apus Alternate Subsea LOWC Scenario – Summary of maximum time-averaged surface oil concentration [9]

[11] Note: The curved lines of 'gaps' in the data are an artefact of the OSCAR software projecting the model outputs from the native model projection (Lat/Lon) onto a Universal Transverse Mercator (UTM) grid during the export process. No data is deleted during this process. The gaps do not have a material impact on the data reported in the results tables, only an aesthetic impact on these figures.

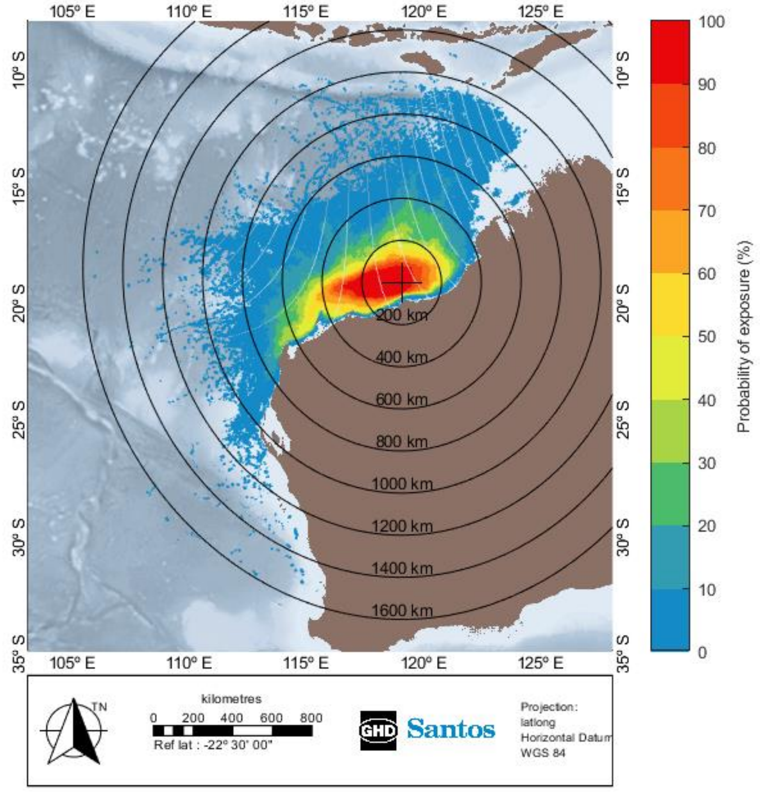
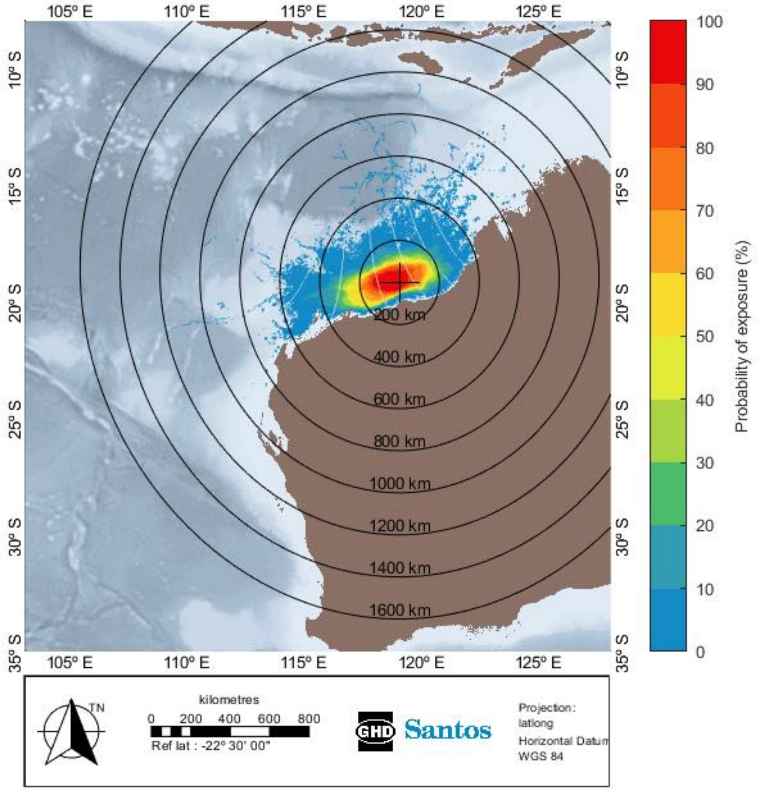
Total Submerged Oil	> 10 ppb	> 100 ppb
Probability		

Figure 35 ***Apus Alternate Subsea LOWC Scenario – Summary of probability of total submerged oil [9]***

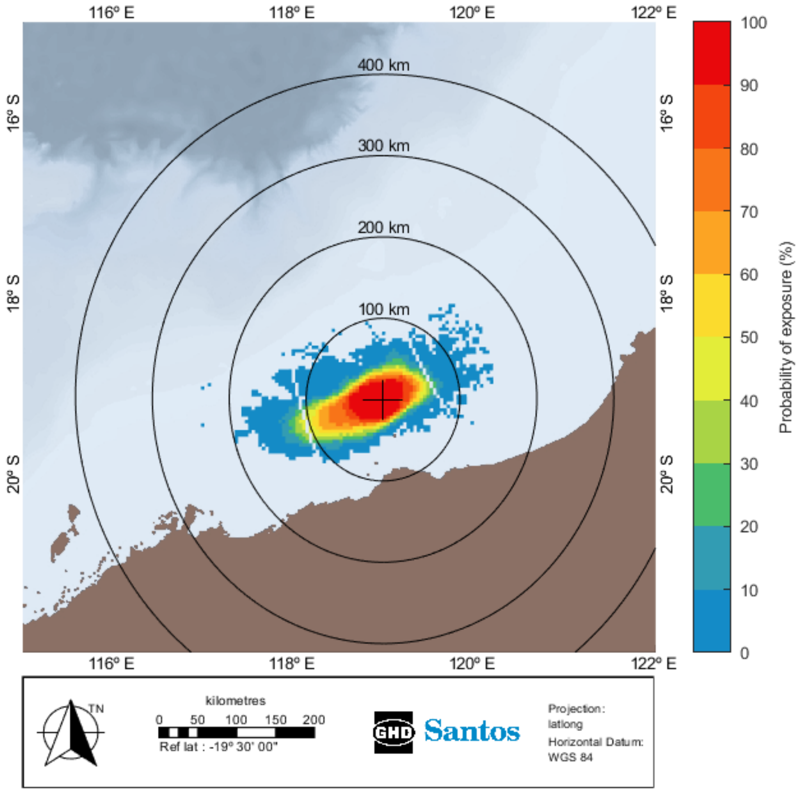
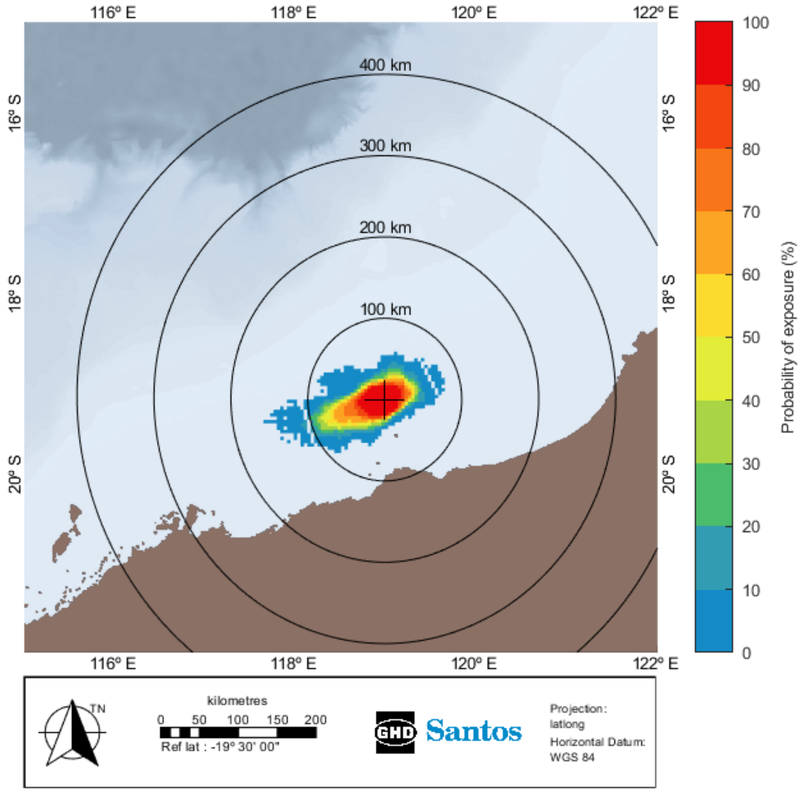
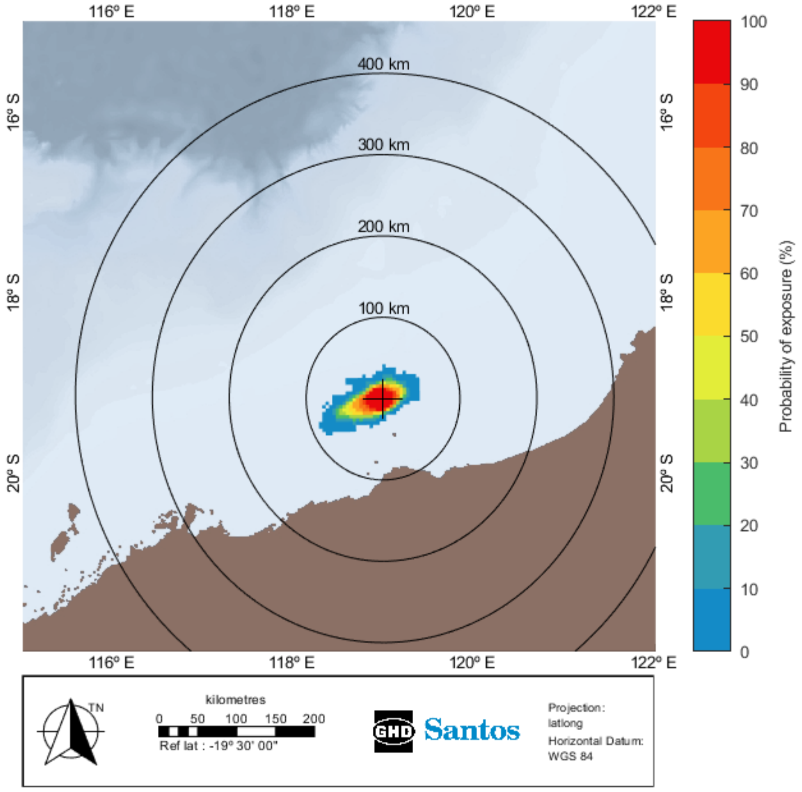
<table>
<tr><th>Dissolved Hydrocarbons</th><th>> 10 ppb</th><th>> 50 ppb</th></tr>
<tr><td>Probability</td><td>
</td><td>
</td></tr>
<tr><th>Dissolved Hydrocarbons</th><th>> 400 ppb</th><th></th></tr>
<tr><td>Probability</td><td>
</td><td></td></tr>
</table>

Figure 36 Apus Alternate Subsea LOWC Scenario – Summary of probability of dissolved hydrocarbons [9]

4.1.4 Apus Alternate Surface LOWC Scenario

4.1.4.1 Accumulated Shoreline Oil

Shoreline oiling is assessed at three thresholds that represent low (10 g/m^2, visual/aesthetic threshold), moderate (100 g/m^2, impact threshold that may require clean-up effort), and high (1,000 g/m^2, requires intensive clean-up effort) accumulated shoreline loadings. A summary of the shoreline loading predictions is presented in Table 26, and loading probabilities and maximum accumulated shoreline loadings are mapped spatially in Figure 38 and Figure 39 for the three thresholds, respectively.

Shoreline loading above the low (10 g/m^2) threshold was predicted to occur up to ~1,100 km northwest (at Indonesia – East) and ~1,400 km south-west (at Jurien Bay - Yanchep) from the release site. At the moderate (100 g/m^2) threshold, the spatial extent of shoreline accumulation was reduced to ~1,100 km north-east and 1,200 km south-west, while at the high (1,000 g/m^2) threshold, the maximum spatial extent of shoreline accumulation up to ~900 km from the release site.

Shoreline accumulation above the moderate threshold (100 g/m^2) is summarised as follows:

- Across all shorelines, a 100% contact probability is predicted with a maximum accumulated shoreline load of 3,573 tonnes, a minimum arrival time of 2.0 days and a maximum length of oiled shoreline of 404 km.
- A very high contact probability of 76% was predicted for the proximal island receptor of Bedout Island. This receptor was predicted to receive a maximum shoreline accumulation of 57 tonnes, with a minimum arrival time of 2 days and maximum oiled shoreline length of 1 km (the island length).
- Moderately high contact probabilities of 31-57% were predicted at Clerke Reef MP, Imperieuse Reef MP, Dampier Archipelago, Montebello Islands, Barrow Island, Thevenard Islands, Southern Islands Coast, Muiron Islands, Ningaloo Coast North and Roebuck – Eighty Mile Beach. Maximum accumulated shoreline loads at these locations were 1,474 tonnes at Imperieuse Reef MP, 1,186 tonnes at Clerke Reef MP and 98-548 tonnes at the other receptors. Minimum arrival times of shoreline loading at these locations ranged between 12.4 days to 31.2 days. Maximum predicted lengths of shoreline accumulation were between 11 km to 85 km, with the exception of Ningaloo Coast North (193 km).
- Moderate contact probabilities of 10-29% were predicted at Scott Reef South, Broome North Coast, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Northern Islands Coast, Lowendal Islands, Ningaloo Coast South and Eighty Mile Beach. Maximum accumulated shoreline loads at these receptors were 1,558 tonnes at Port Hedland-Eighty Mile Beach, 1,465 tonnes at Eighty Mile Beach and between 32 tonnes and 392 tonnes at the other locations. Minimum arrival times of shoreline loading at these locations ranged between 2.9 days and 56.0 days, while maximum predicted lengths of shoreline accumulation were between 6 km and 102 km.
- Low probabilities of contact (<10%) were predicted at Cartier Island AMP, Ashmore Reef AMP, Scott Reef North, Middle Islands Coast, Shark Bay – Coast Outer, Zuytdorp Cliffs – Kalbarri, Abrolhos Islands Wallabi Group, Abrolhos Islands Pelsaert Group, Indonesia – East and Broome - Roebuck. Contact probabilities, accumulated shoreline loads, minimum arrival times and maximum oiled shoreline lengths for these receptors are summarised in Table 26.

A histogram of total shoreline loading above the moderate threshold (100 g/m^2) across the 150 stochastic realisations is presented in Figure 37. Shoreline accumulation at the moderate threshold was predicted to occur for 100% of the realisations. No clear seasonal trend is evident in the shoreline loading predictions. Approximately half of the realisations resulted in shoreline accumulation greater than 800 tonnes (up to a maximum of 5,125 tonnes).

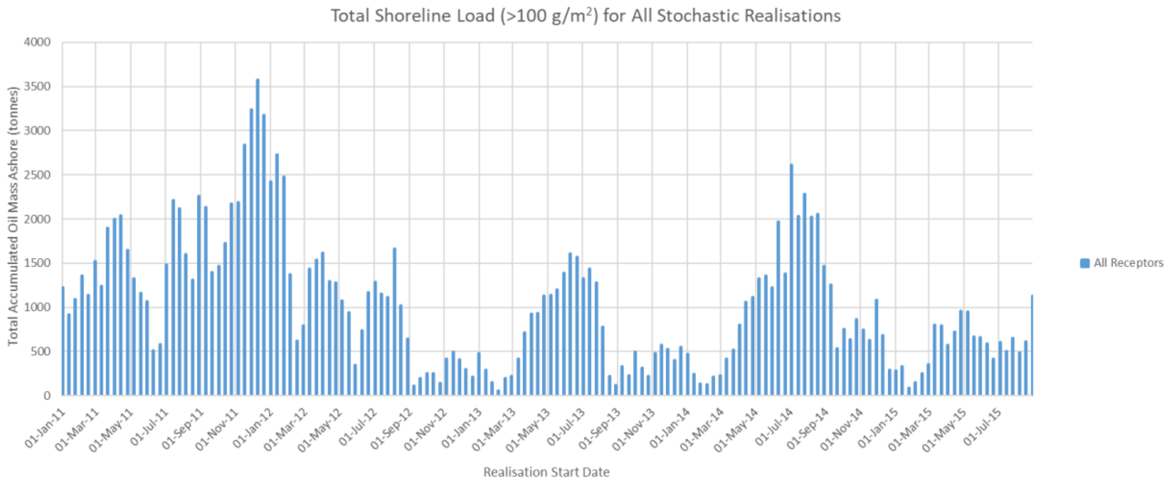


Figure 37 ***Apus Alternate Surface LOWC Scenario – Summary of total accumulated shoreline load for all stochastic realisations for the 100 g/m² threshold***

4.1.4.2 Surface Oil

Surface oiling is evaluated at three instantaneous contact thresholds representing low (1 g/m², visual/aesthetic threshold), moderate (10 g/m², lower limit for potential ecological impacts), and high (50 g/m², approximating concentrations that can be targeted during spill response) concentrations. A summary of the surface oil predictions are presented in Table 27, with contact probabilities and maximum surface oil concentrations mapped spatially in Figure 40 and Figure 41 for the three thresholds, respectively.

Surface oil above the low threshold (1 g/m²) was predicted to occur at distances up to ~1,000 km from the release location. The spatial extent of surface oil predicted for the moderate threshold (10 g/m²) reduced to ~525 km, and the high threshold (50 g/m²) spatial extent was restricted to within ~225 km of the release location.

Surface oil impacts at the moderate threshold (10 g/m²) include:

– A high contact probability of 66% was predicted for the Eighty Mile Beach AMP, with a maximum time-averaged surface oil concentration of 106 g/m² and a minimum arrival time of 1.2 days.

– A moderately high contact probability of 43% was predicted at Bedout Island, with a maximum time-averaged surface oil concentration of 104 g/m² and a minimum arrival time of 1.8 days.

– Moderately low contact probabilities of 11-13% were predicted at Port Hedland-Eighty Mile Beach, Glomar Shoals and Eighty Mile Beach, with maximum time-averaged surface oil concentrations of 19-26 g/m² and minimum arrival times of 2-12 days.

– Low contact probabilities (<5%) were predicted at Rowley Shoals surrounds and Ningaloo - Offshore, with maximum time-averaged concentrations of 15 g/m² and minimum arrival times of 30 to 33.9 days.

4.1.4.3 Total Submerged Oil

Total submerged oil (entrained plus dissolved oil) is evaluated at low (10 ppb, potential exceedance of water quality triggers) and moderate (100 ppb, potential impacts) instantaneous contact thresholds. Total submerged oil predictions are summarised in Table 28 and contact probabilities are mapped spatially in Figure 42 for the two thresholds.

Total submerged oil at the low threshold (10 ppb) was predicted to occur up to ~1,800 km from the release location. At the moderate threshold (100 ppb), predicted contact was reduced in spatial extent to within 1,200 km from the release location.

Total submerged oil impacts at the moderate threshold (100 ppb) include:

– A very high contact probability of 92% was predicted at Eighty Mile Beach AMP, with a maximum time-averaged concentration of 1,356 ppb and minimum arrival time of 0.9 days.

- Moderate to high contact probabilities of 30-63% were predicted at Imperieuse Reef MP, Glomar Shoals, Eighty Mile Beach, Roebuck – Eighty Mile Beach, Kimberley AMP, Dampier AMP, Montebello AMP, Rowley Shoals surrounds, Ningaloo – Offshore and Bedout Island. Maximum time-averaged concentrations at these locations ranged between 542 ppb and 1,888 ppb, with minimum arrival times of 2.0 to 23.1 days.
- Moderate contact probabilities of 11-29% were predicted at Mermaid Reef AMP, Clerke Reef MP, Port Hedland-Eighty Mile Beach, Karratha-Port Hedland, Dampier Archipelago, Rankin Bank, Montebello Islands, Barrow Island, Barrow-Montebello Surrounds, Broome - Roebuck, Ningaloo – Outer Coast North and Ningaloo – Outer NW. Maximum time-averaged concentrations at these locations ranged between 164 ppb and 1,581 ppb, with minimum arrival times of 2.0 to 31.3 days.
- Low contact probabilities (<10%) occurred at several other receptor locations with contact probabilities, maximum time-averaged oil concentrations and minimum arrival times summarised in Table 28.

4.1.4.4 Dissolved Hydrocarbons

Dissolved hydrocarbons were evaluated at the low (10 ppb, potential exceedance of water quality triggers), moderate (50 ppb, potential sub-lethal toxic effects) and high (400 ppb, potential toxic lethal effects) instantaneous contact thresholds. A summary of the dissolved hydrocarbon predictions is presented in Table 29 and contact probabilities are mapped spatially in Figure 43 for the three thresholds.

Dissolved hydrocarbons at the low threshold (10 ppb) were predicted to extend a maximum distance of ~450 km from the release location. At the moderate threshold (50 ppb), the spatial extent was reduced to within ~250 km, while exceedances of the high threshold (400 ppb) were limited to within ~100 km of the release site.

Dissolved hydrocarbon impacts at the moderate threshold (50 ppb) include:

- A moderately high contact probability of 56% was predicted at Eighty Mile Beach AMP, with a maximum time-averaged concentration of 312 ppb and a minimum arrival time of 0.9 days.
- A moderate contact probability of 25% was predicted at Bedout Island, with a maximum time-averaged concentration of 169 ppb and a minimum arrival time of 2.2 days.
- A very low contact probability of 3% was predicted at Port Hedland – Eighty Mile Beach, with a maximum concentration of 87 ppb and minimum arrival time of 4.6 days.

Table 26 Apus Alternate Surface LOWC Scenario – Summary of shoreline oiling

Receptor Name	Total Contact Probability (%)			Maximum Accumulated Oil Concentration (g/m^2)			Maximum Accumulated Oil Ashore (tonnes)			Minimum Arrival Time (days)			Maximum Length of Oiled Shoreline (km)		
	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2
Cartier Island AMP	2.7	2.7	NC	757	757	NC	8.6 (0.9)	8.6 (0.9)	NC	77.1	77.1	NC	5.7 (0.6)	5.7 (0.6)	NC
Ashmore Reef AMP	6.7	6.0	3.3	6,418	6,418	6,418	132.6 (16.7)	132.6 (16.7)	101.8 (12.8)	61.3	61.3	61.3	39.8 (5.0)	39.8 (5.0)	17.1 (5.0)
Scott Reef North	9.3	9.3	2.7	2,779	2,779	2,779	103.1	103.1	80.7	49.1	49.1	49.1	45.5	45.5	22.7
Scott Reef South	16.7	16.0	6.7	6,382	6,382	6,382	391.9	391.9	385.0	44.6	44.6	50.9	56.9	56.9	56.9
King Sound	0.7	NC	NC	11	NC	NC	0.1	NC	NC	52.8	NC	NC	5.7	NC	NC
Broome North Coast	14.0	10.0	6.7	4,131	4,131	4,131	73.7	73.5	73.5	29.5	29.5	29.5	28.4	28.4	11.4
Clerke Reef MP	49.3	49.3	40.0	23,486	23,486	23,486	1,186	1,186	1,186	16.2	16.2	16.2	51.2	51.2	51.2
Imperieuse Reef MP	57.3	56.7	48.7	27,767	27,767	27,767	1,474	1,474	1,474	12.4	12.4	12.4	56.9	56.9	56.9
Port Hedland-Eighty Mile Beach	17.3	17.3	14.7	17,936	17,936	17,936	1,563	1,562	1,558	2.9	2.9	2.9	102.3	96.6	85.3
Karratha-Port Hedland	16.0	14.0	7.3	15,514	15,514	15,514	392.2	392.2	392.2	7.1	7.1	7.1	28.4	28.4	28.4
Dampier Archipelago	56.0	55.3	50.0	13,649	13,649	13,649	547.9	547.9	533.2	13.2	13.2	13.2	85.3	85.3	56.9
Northern Islands Coast	14.7	13.3	4.0	2,859	2,859	2,859	32.9	32.5	32.5	30.2	30.2	31.0	34.1	28.4	5.7
Montebello Islands	49.3	48.7	38.7	20,760	20,760	20,760	518.2	518.2	518.2	18.9	18.9	18.9	22.7	22.7	22.7
Lowendal Islands	25.3	22.0	13.3	7,418	7,418	7,418	84.3	84.3	84.3	25.1	25.1	28.8	5.7	5.7	5.7
Barrow Island	45.3	44.7	34.0	11,722	11,722	11,722	416.4	415.2	392.8	18.4	18.4	18.4	79.6	73.9	45.5
Middle Islands Coast	2.0	0.7	NC	131	131	NC	1.5	1.5	NC	60.0	75.8	NC	5.7	5.7	NC
Thevenard Islands	38.0	35.3	21.3	6,964	6,964	6,964	97.7	97.7	97.7	24.5	24.5	24.7	11.4	11.4	11.4
Southern Islands Coast	44.7	44.0	37.3	20,649	20,649	20,649	409.5	409.5	400.7	22.6	22.6	22.6	22.7	22.7	17.1
Muiron Islands	46.7	44.0	37.3	18,096	18,096	18,096	334.7	334.7	334.7	21.3	21.3	21.3	17.1	17.1	17.1
Ningaloo Coast North	42.7	41.3	30.7	9,592	9,592	9,592	462.0	461.2	353.0	31.2	31.2	31.2	204.7	193.3	79.6
Ningaloo Coast South	15.3	12.0	4.0	2,213	2,213	2,213	47.3	47.3	25.2	56.0	56.0	70.2	51.2	39.8	11.4
Shark Bay - Coast Outer	10.7	8.0	0.7	1,310	1,310	1,310	36.7	36.2	31.2	61.9	61.9	77.3	39.8	28.4	17.1
Zuytdorp Cliffs - Kalbarri	1.3	0.7	NC	134	134	NC	1.5	1.5	NC	94.3	112.0	NC	5.7	5.7	NC
Abrolhos Islands Wallabi Group	0.7	0.7	NC	100	100	NC	1.1	1.1	NC	101.2	101.2	NC	5.7	5.7	NC
Abrolhos Islands Pelsaert Group	0.7	NC	NC	13	NC	NC	0.1	NC	NC	108.4	NC	NC	5.7	NC	NC
Indonesia - East	2.0	2.0	NC	525	525	NC	22.7	22.7	NC	69.2	69.2	NC	34.1	34.1	NC
Eighty Mile Beach	30.0	28.7	26.7	15,804	15,804	15,804	1,477	1,477	1,465	13.0	13.0	13.0	108.0	102.3	79.6
Broome - Roebuck	8.0	8.0	6.0	4,072	4,072	4,072	78.9	78.9	78.9	30.9	30.9	34.7	17.1	11.4	11.4
Roebuck - Eighty Mile Beach	31.3	31.3	30.7	12,583	12,583	12,583	306.7	306.7	305.2	20.8	20.8	20.8	39.8	39.8	39.8
Jurien Bay - Yanchep	0.7	NC	NC	28	NC	NC	0.3	NC	NC	95.8	NC	NC	5.7	NC	NC
Bedout Island	76.7	76.0	64.7	25,916	25,916	25,916	294.7 (56.9)	294.7 (56.9)	294.7 (56.9)	2.0	2.0	2.0	5.7 (1.1)	5.7 (1.1)	5.7 (1.1)
All Shorelines	**100**	**100**	**100**	**27,767**	**27,767**	**27,767**	**3,804 (3,574)**	**3,804 (3,573)**	**3,785 (3,554)**	**2.0**	**2.0**	**2.0**	**460.5**	**403.7**	**233.1 (228.5)**

Table 27 Apus Alternate Surface LOWC Scenario – Summary of surface oil

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Oil Concentration (g/m^2)			Minimum Arrival Time (days)		
	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2	>1 g/m^2	>10 g/m^2	>50 g/m^2
Broome North Coast	6.7	NC	NC	2.9	NC	NC	26.1	NC	NC
Mermaid Reef AMP	14.0	NC	NC	5.0	NC	NC	17.5	NC	NC
Clerke Reef MP	14.7	NC	NC	5.8	NC	NC	16.3	NC	NC
Imperieuse Reef MP	32.0	NC	NC	7.0	NC	NC	13.6	NC	NC
Port Hedland-Eighty Mile Beach	25.3	13.3	NC	15.2	23.0	NC	1.9	2.0	NC
Glomar Shoals	48.7	12.7	NC	7.0	18.6	NC	10.0	12.0	NC
Karratha-Port Hedland	8.7	NC	NC	5.7	NC	NC	6.3	NC	NC
Dampier Archipelago	6.0	NC	NC	2.5	NC	NC	25.5	NC	NC
Rankin Bank	11.3	NC	NC	4.3	NC	NC	17.3	NC	NC
Northern Islands Coast	0.7	NC	NC	2.0	NC	NC	30.3	NC	NC
Montebello Islands	2.7	NC	NC	1.8	NC	NC	44.0	NC	NC
Lowendal Islands	1.3	NC	NC	1.4	NC	NC	43.3	NC	NC
Barrow Island	2.0	NC	NC	1.7	NC	NC	40.2	NC	NC
Barrow-Montebello Surrounds	3.3	NC	NC	2.3	NC	NC	32.4	NC	NC
Southern Islands Coast	2.0	NC	NC	1.9	NC	NC	26.4	NC	NC
Muiron Islands	0.7	NC	NC	1.1	NC	NC	55.6	NC	NC
Eighty Mile Beach	43.3	11.3	NC	14.6	26.4	NC	4.1	7.7	NC
Broome - Roebuck	14.7	NC	NC	3.0	NC	NC	22.3	NC	NC
Roebuck - Eighty Mile Beach	33.3	NC	NC	4.9	NC	NC	18.7	NC	NC
Kimberley AMP	23.3	NC	NC	4.5	NC	NC	21.4	NC	NC
Dampier AMP	32.0	NC	NC	5.2	NC	NC	11.9	NC	NC
Montebello AMP	39.3	NC	NC	4.6	NC	NC	11.3	NC	NC
Ningaloo - Outer Coast North	4.7	NC	NC	2.5	NC	NC	32.3	NC	NC
Ashmore/Cartier - Outer	0.7	NC	NC	2.0	NC	NC	88.4	NC	NC
Eighty Mile Beach AMP	82.7	66.0	42.0	77.5	106.0	140.2	0.8	1.2	1.8
Rowley Shoals surrounds	46.7	2.7	NC	10.2	15.3	NC	9.4	30.0	NC
Ningaloo - Outer NW	4.7	NC	NC	2.7	NC	NC	27.8	NC	NC
Ningaloo - Offshore	28.0	4.0	NC	6.2	15.1	NC	15.4	33.9	NC
Bedout Island	57.3	43.3	20.7	103.8	103.8	123.3	1.6	1.8	5.9
All Ocean	**100**	**100**	**100**	**114.2**	**176.7**	**354.6**	**0.1**	**0.1**	**0.1**

Table 28 Apus Alternate Surface LOWC Scenario – Summary of total submerged oil

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Fantome Shoals	1.3	NC	38.6	NC	89.6	NC
Barracouta Shoals	0.7	NC	11.7	NC	100.8	NC
Hibernia Reef	1.3	NC	52.1	NC	67.8	NC
Woodbine Bank	2.0	NC	58.5	NC	90.2	NC
Cartier Island AMP	1.3	NC	66.6	NC	88.9	NC
Ashmore Reef AMP	6.0	NC	57.8	NC	63.4	NC
Browse Island	0.7	NC	48.5	NC	107.8	NC
Seringapatam Reef	11.3	NC	57.8	NC	44.8	NC
Scott Reef North	8.0	NC	48.6	NC	51.7	NC
Scott Reef South	12.7	0.7	136.2	166.3	47.0	105.8
Broome North Coast	14.7	6.0	882.9	882.9	26.2	26.2
Mermaid Reef AMP	47.3	19.3	352.5	1,432	17.8	18.3
Clerke Reef MP	51.3	22.0	216.3	572.4	19.6	19.6
Imperieuse Reef MP	58.7	35.3	301.6	1,314	11.5	11.8
Port Hedland-Eighty Mile Beach	51.3	26.7	1,251	1,251	2.0	2.0
Glomar Shoals	92.0	62.0	147.0	542.2	7.7	8.5
Karratha-Port Hedland	51.3	14.7	1,581	1,581	7.0	7.0
Dampier Archipelago	58.0	28.7	114.6	295.9	13.1	13.3
Rankin Bank	68.7	26.7	113.3	315.9	14.7	16.3
Northern Islands Coast	34.0	2.0	227.2	299.5	18.3	27.7
Montebello Islands	52.0	11.3	79.1	303.0	16.4	16.8
Lowendal Islands	29.3	4.0	63.3	302.9	25.7	28.2
Barrow Island	47.3	10.7	54.7	164.4	19.3	24.0
Barrow-Montebello Surrounds	54.0	20.0	77.9	212.1	15.3	16.8
Middle Islands Coast	1.3	NC	33.6	NC	55.0	NC
Thevenard Islands	35.3	NC	50.3	NC	24.4	NC
Southern Islands Coast	45.3	9.3	108.0	292.2	20.8	34.4
Muiron Islands	44.0	6.0	59.7	216.8	21.2	45.8
Exmouth Gulf Coast	9.3	NC	46.0	NC	33.3	NC
Ningaloo Coast North	47.3	8.7	87.8	714.8	27.8	33.0
Ningaloo Coast South	19.3	NC	71.0	NC	48.5	NC
Carnarvon - Inner Shark Bay	1.3	NC	54.8	NC	76.8	NC
Shark Bay - Coast Outer	4.0	NC	50.1	NC	60.8	NC
Zuytdorp Cliffs - Kalbarri	0.7	NC	39.7	NC	111.4	NC
Abrolhos - Outer Island Shoals	7.3	NC	78.9	NC	69.2	NC
Indonesia - East	1.3	NC	14.9	NC	69.9	NC
Perth Canyon AMP	1.3	NC	41.3	NC	100.7	NC
Eighty Mile Beach	55.3	45.3	1,446	1,532	4.9	4.9
Broome - Roebuck	18.0	15.3	1,243	1,243	23.0	23.0
Roebuck - Eighty Mile Beach	34.0	31.3	1,484	1,484	15.4	15.4
Kimberley AMP	56.0	30.0	1,150	1,214	22.0	23.1

Receptor Name	Total Contact Probability (%)		Maximum Time-averaged Concentration (ppb)		Minimum Arrival Time (days)	
	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >100 ppb	Total Submerged Oil >10 ppb	Total Submerged Oil >10 ppb
Dampier AMP	62.0	52.0	166.0	1,063	11.1	11.7
Montebello AMP	76.0	50.7	177.4	1,212	10.8	10.8
Ningaloo - Outer Coast North	48.0	18.7	66.6	450.5	25.6	31.3
Johnson Bank	5.3	0.7	53.9	105.6	62.7	95.8
Jurien AMP	0.7	NC	10.2	NC	99.3	NC
Shark Bay AMP	9.3	NC	63.5	NC	62.1	NC
Ashmore/Cartier - Outer	18.0	1.3	101.0	134.1	50.2	57.9
Eighty Mile Beach AMP	97.3	91.3	949.3	1,356	0.9	0.9
Rowley Shoals surrounds	82.7	56.7	1,326	1,543	10.4	10.4
Abrolhos West	2.7	NC	70.8	NC	80.7	NC
Ningaloo - Outer NW	56.0	18.7	193.1	1,187.2	24.6	24.8
Ningaloo - Offshore	82.0	40.7	452.1	1,110.6	14.0	14.0
Abrolhos - Offshore NW	18.0	0.7	72.0	104.8	47.3	85.3
Abrolhos - Offshore Perth North	7.3	NC	51.1	NC	63.4	NC
Perth South - Geographe - Offshore	0.7	NC	18.9	NC	110.5	NC
Bedout Island	88.7	63.3	576.8	1,888	2.0	2.0
All Ocean	**100**	**100**	**2,671**	**3,060**	**0.1**	**0.1**

Table 29 Apus Alternate Surface LOWC Scenario – Summary of dissolved hydrocarbons

Receptor Name	Total Contact Probability (%)			Maximum Time-averaged Concentration (ppb)			Minimum Arrival Time (days)		
	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb	Dissolved Hydrocarbons >10 ppb	Dissolved Hydrocarbons >50 ppb	Dissolved Hydrocarbons >400 ppb
Imperieuse Reef MP	4.7	NC	NC	35.5	NC	NC	11.5	NC	NC
Port Hedland-Eighty Mile Beach	6.0	2.7	NC	57.2	87.0	NC	3.8	4.6	NC
Glomar Shoals	0.7	NC	NC	11.2	NC	NC	34.8	NC	NC
Eighty Mile Beach	5.3	NC	NC	59.5	NC	NC	5.1	NC	NC
Eighty Mile Beach AMP	64.7	56.0	2.7	257.8	311.6	652.7	0.9	0.9	14.3
Rowley Shoals surrounds	5.3	NC	NC	47.9	NC	NC	10.6	NC	NC
Bedout Island	32.7	25.3	NC	169.0	169.0	NC	2.2	2.2	NC
All Ocean	**100**	**100**	**100**	**811.3**	**1,169**	**2,382**	**0.1**	**0.1**	**0.2**

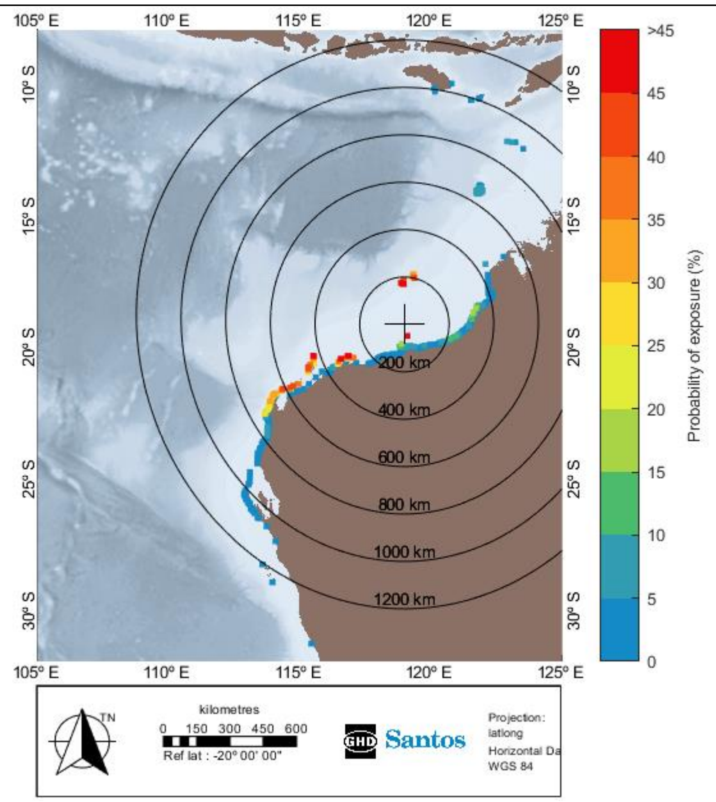
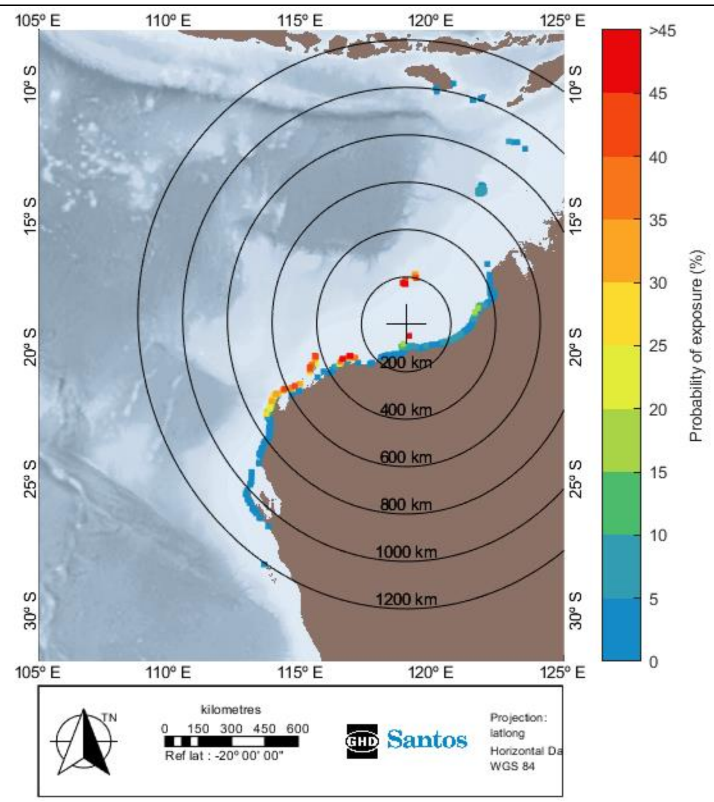
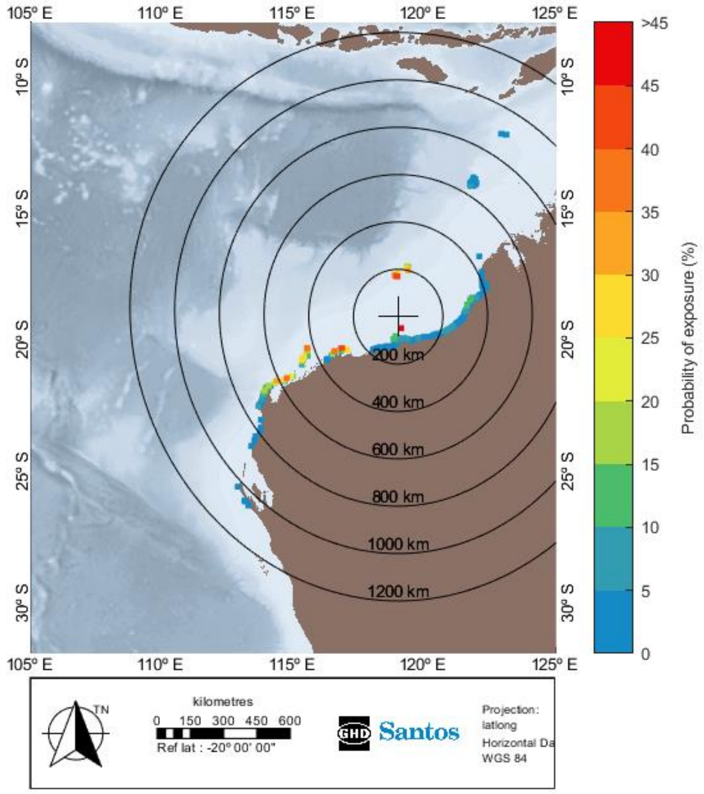
Shoreline Contact	> 10 g/m²	> 100 g/m²
Probability		
Shoreline Contact	**> 1,000 g/m²**	
Probability		

Figure 38 Apus Alternate Surface LOWC Scenario – Summary of probability of shoreline oiling

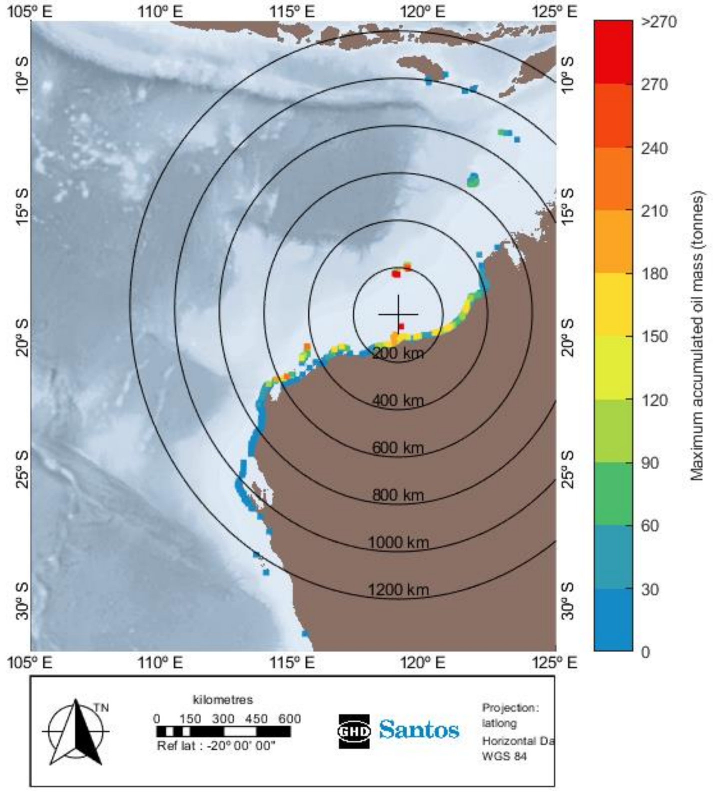
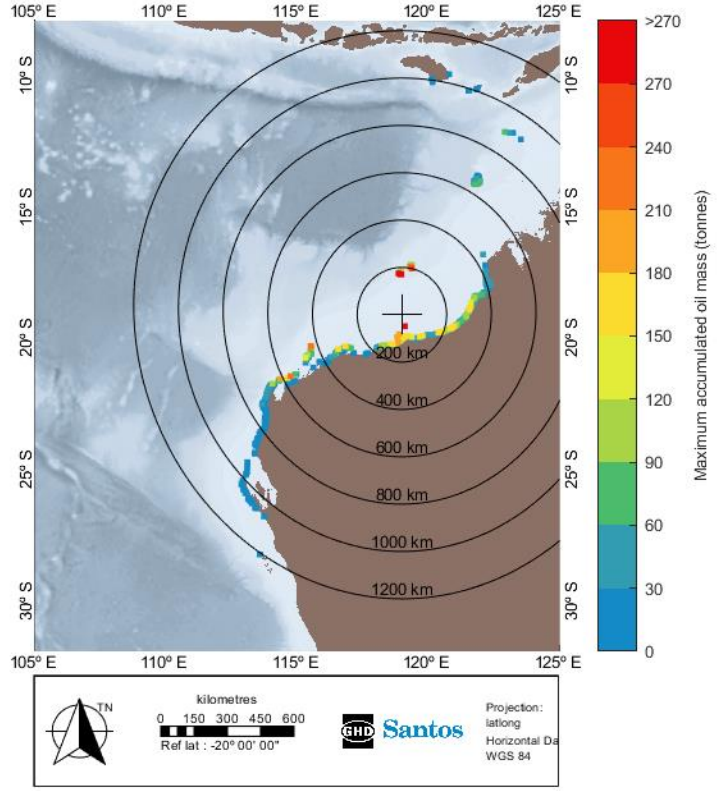
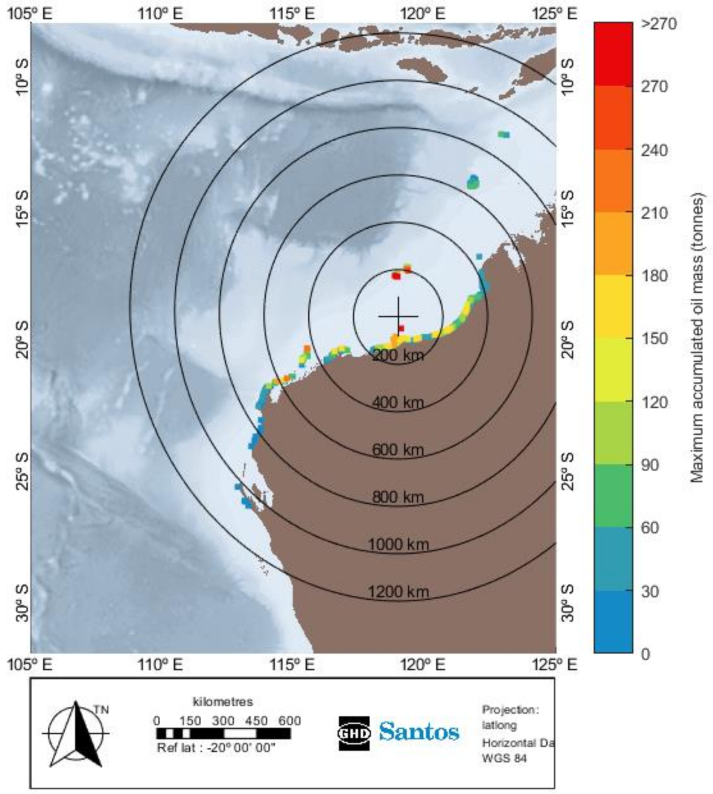
Shoreline Contact	> 10 g/m^2	> 100 g/m^2
Mass		
Shoreline Contact	**> 1,000 g/m^2**	
Mass		

Figure 39 Apus Alternate Surface LOWC Scenario – Summary of maximum accumulated oil mass (tonnes) on shorelines

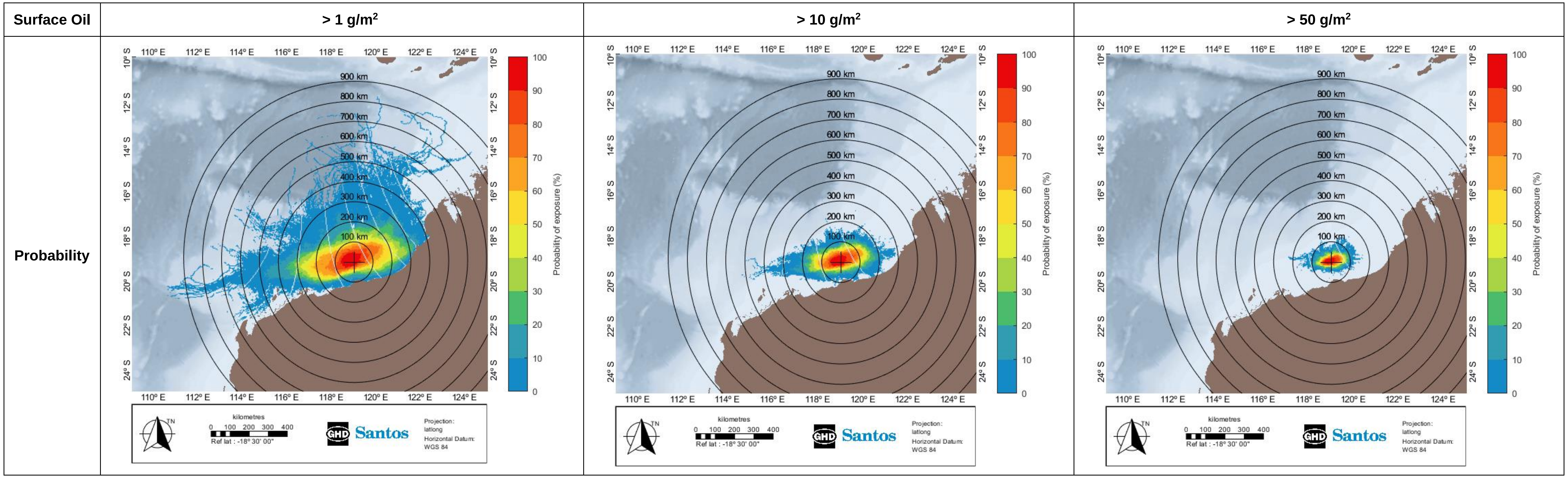


Figure 40 *Apus Alternate Surface LOWC Scenario – Summary of probability of surface oil [9]*

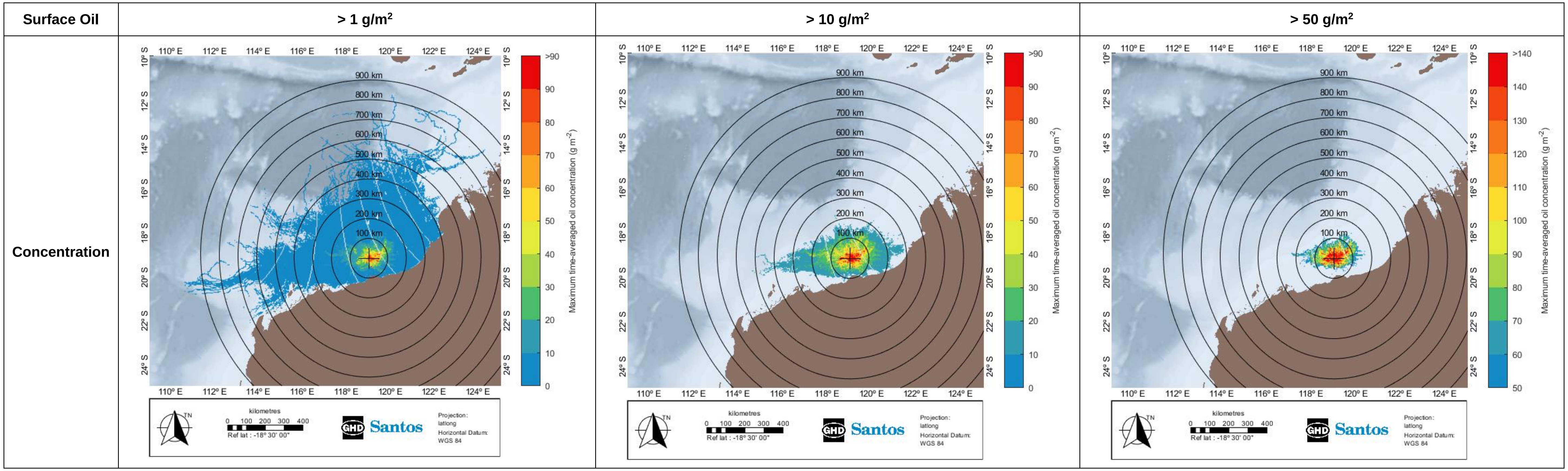


Figure 41 *Apus Alternate Surface LOWC Scenario – Summary of maximum time-averaged surface oil concentration [9]*

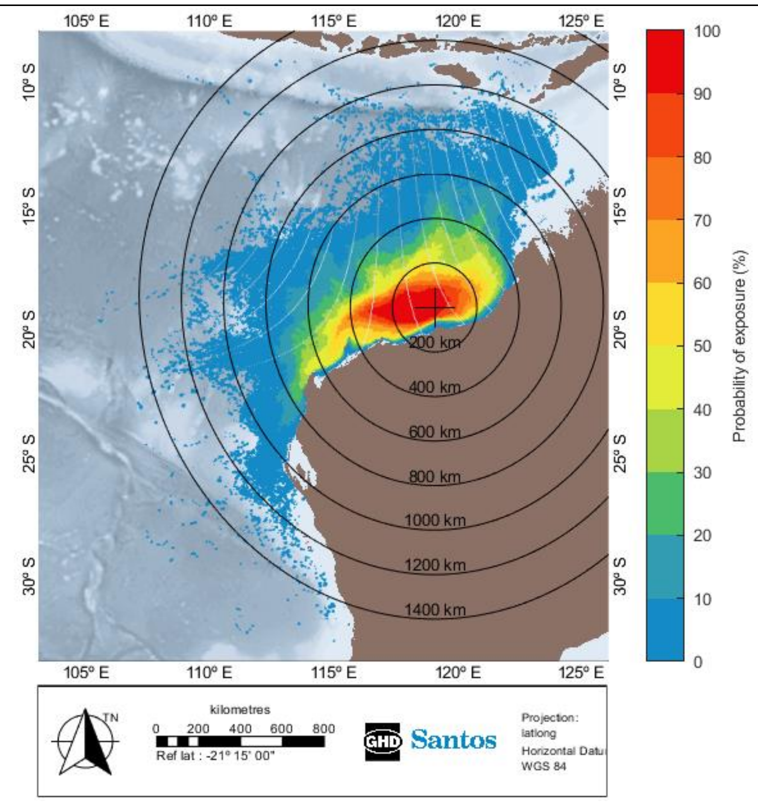
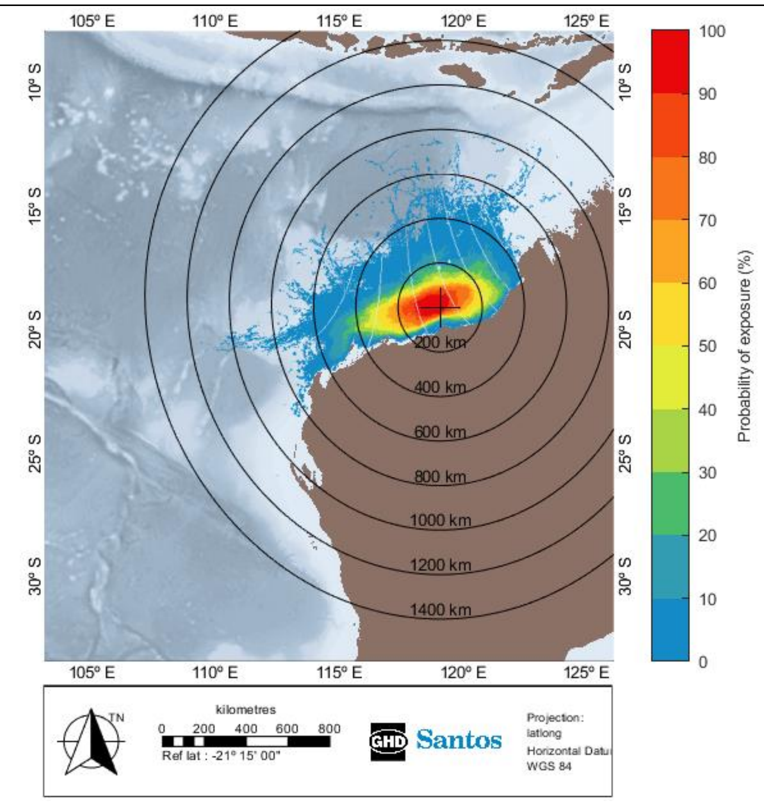
Total Submerged Oil	> 10 ppb	> 100 ppb
Probability		

Figure 42 Apus Alternate Surface LOWC Scenario – Summary of probability of total submerged oil [9]

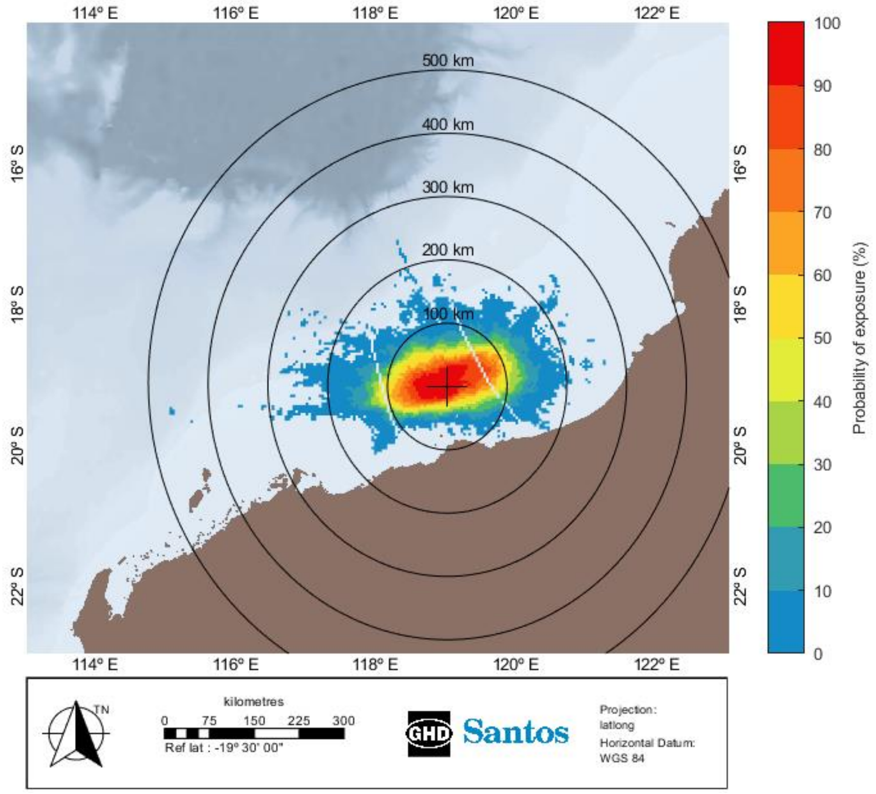
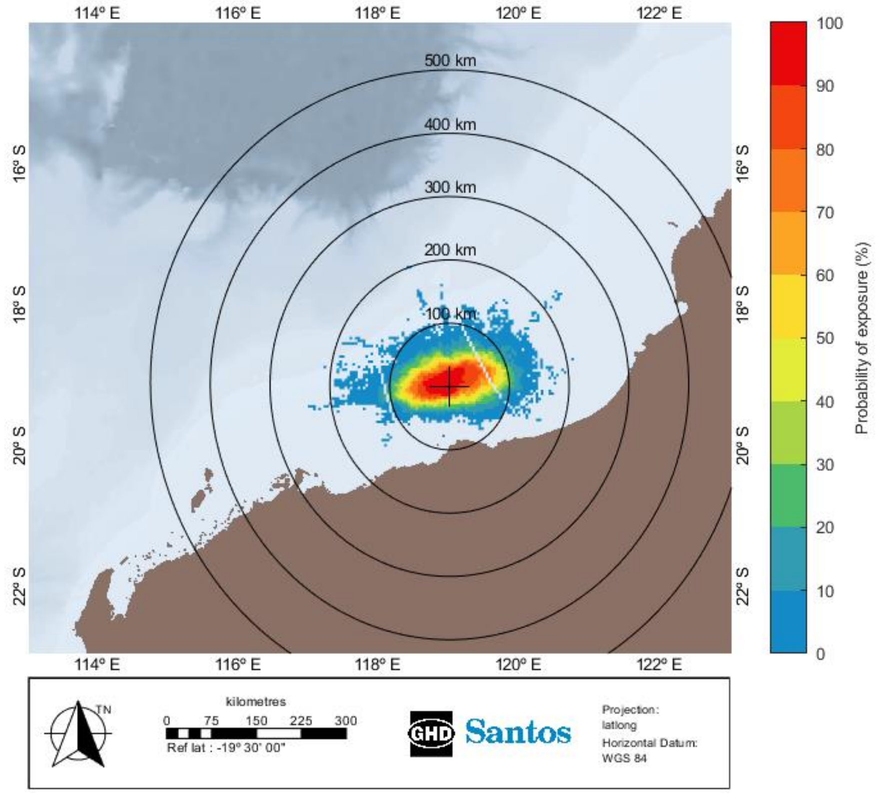
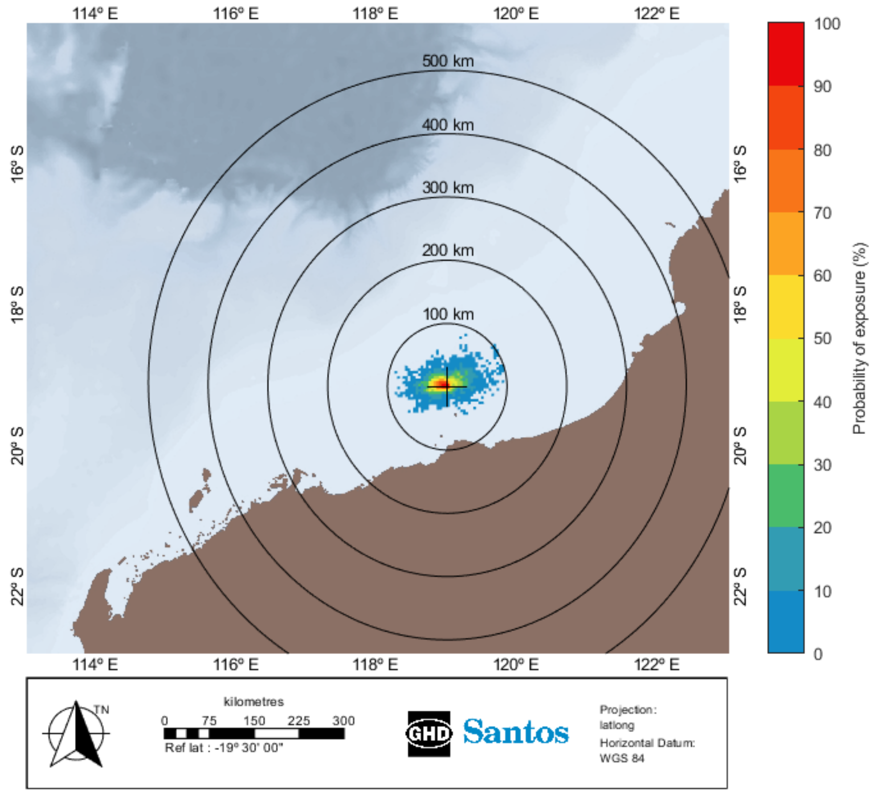
<table>
<tr><th>Dissolved Hydrocarbons</th><th>> 10 ppb</th><th>> 50 ppb</th></tr>
<tr><td>Probability</td><td>
</td><td>
</td></tr>
<tr><th>Dissolved Hydrocarbons</th><th>> 400 ppb</th><th></th></tr>
<tr><td>Probability</td><td>
</td><td></td></tr>
</table>

Figure 43 Apus Alternate Surface LOWC Scenario – Summary of probability of dissolved hydrocarbons [9]

4.2 Deterministic Modelling

4.2.1 Selection of Realisations for Deterministic Simulations

As described in section 3.5, several realisations from the base case LOWC scenarios were selected to be run in OSCAR's deterministic mode to further inform development of the OPEP. The deterministic simulations were selected based on the following criteria:

- Highest accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for the surface and subsea LOWC scenarios
- Minimum arrival time of accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for whichever is shorter of the surface/subsea LOWC
- Maximum length of accumulated shoreline loading >10 g/m^2 and >100 g/m^2 for whichever is longer of the surface/subsea LOWC
- Highest surface oil mass >50 g/m^2 for whichever is higher of the surface/subsea LOWC scenarios.

A summary of the selected deterministic realisations is presented in Table 30 including the realisation numbers, start dates and a summary of predicted stochastic impacts relevant to the above selection criteria. Two LOWC realisations were also simulated with dispersant application response strategies (as detailed in section 3.5 and summarised in Table 30) to predict the potential reduction (benefit) in shoreline loading.

Table 30 Selected stochastic realisations for deterministic simulations

LOWC Scenario	Sim Number	Start of Release	Description of Impact	Mitigation Options Simulated
Apus Base Case Subsea	24	20-Sep-11	The highest accumulated shoreline mass above the low threshold (10 g/m^2) of 2,054 tonnes across all shorelines, including the following key outcomes: – 738 tonnes at Imperieuse Reef MP – 430 tonnes at Eighty Mile Beach – 390 tonnes at Clerke Reef MP – 319 tonnes at Roe - Eighty Mile Beach – 108 tonnes at Broome North Coast This is also the highest accumulated shoreline mass above the moderate threshold (100 g/m^2), with the same accumulated loads as listed above.	– Unmitigated – SSDI mitigated – SSDI+SDA mitigated
Apus Base Case Surface	31	9-Dec-11	The highest accumulated shoreline mass above the low threshold (10 g/m^2) of 5,127 tonnes across all shorelines, including the following key outcomes: – 2,303 tonnes at Eighty Mile Beach – 1,826 tonnes at Port Hedland-Eighty Mile Beach – 518 tonnes at Karratha-Port Hedland – 417 tonnes at Roebuck - Eighty Mile Beach This is also the highest accumulated shoreline mass above moderate threshold (100 g/m^2), with the same accumulated loads as listed above (for the 10 g/m^2 threshold) with the exception of a reduction of 2 tonnes at Eighty Mile Beach (i.e. accumulated load at Eighty Mile Beach above 100 g/m^2 was 2,301 tonnes)	– Unmitigated – SDA mitigated – SDA mitigated without the 25 km dispersant exclusion zone

LOWC Scenario	Sim Number	Start of Release	Description of Impact	Mitigation Options Simulated
Apus Base Case Surface	5	15-Feb-11	The earliest shoreline arrival time above the low threshold (10 g/m^2) including: – 2 days at Bedout Island – 2.9 days at Port Hedland-Eighty Mile Beach – Dampier Archipelago, Montebello Islands, Lowendal Islands, Barrow Islands, Thevenard Islands, Ningaloo Coast North and Shark Bay - Coast Outer after 62 days This is also the earliest shoreline arrival time above the moderate threshold (100 g/m^2), with generally similar arrival times as described above for the 10 g/m^2 threshold, with the exception of Lowendal Islands which was not contacted by accumualted oil above 100 g/m^2.	– Unmitigated
Apus Base Case Surface	9	2-Apr-11	The maximum length of shoreline oiled above the moderate threshold (10 g/m^2) of 523 km length across all shorelines, including the following key outcomes: – 210 km at Ningaloo Coast North – 80 km at Dampier Archipelago – 63 km at Ningaloo Coast South – 57 km at Barrow Island This is also the maximum length of accumulated shoreline mass above moderate threshold (100 g/m^2) of , including the following key outcomes: – 210 km at Ningaloo Coast North – 63 km at Dampier Archipelago – 57 km at Barrow Island – 51 km at Ningaloo Coast South	– Unmitigated
Apus Base Case Surface	101	15-Feb-14	The maximum surface oil mass above 50 g/m^2	– Unmitigated

4.2.2 Note on Deterministic Shoreline Predictions

As described in section 3.4.2, shoreline loading predictions for deterministic simulations account for weathering of oil on the shoreline (evaporation, decay and shoreline washing by wave action), whereas the accumulated shoreline load statistic reported for the stochastic simulations only considers total oil arrival and therefore ignores weathering processes that occur after each portion of oil is stranded ashore. The shoreline loading predictions presented in the following sections will therefore differ slightly to the stochastic results reported in Table 30. The deterministic peak oil loads are generally lower than the stochastic accumulated oil, while in some instances the minimum arrival times are also marginally increased and the oiled shoreline lengths are marginally reduced compared to the stochastic predictions. The differences in all cases are the result of the mitigative effect of the weathering processes on the oil stranded ashore, which delays and reduces impacts.

Another difference between the stochastic simulations and deterministic simulations is the inclusion of shoreline washing in the deterministic simulations, which is not incorporated in the stochastic predictions. Shoreline washing involves remobilisation of oil stranded ashore back into the water column by waves and tides. The shoreline washing mechanism can contribute to reductions in the deterministic oiled shoreline length when compared to the stochastic accumulated length in the same manner as the weathering (described above). However, it can also have the opposite effect and may in some cases yield increased oiled shoreline lengths for the deterministic simulations. This can occur because the remobilisation of portions of stranded oil introduces additional oil to the near-shore sea surface, which may then re-strike the shoreline in a different model cell that was otherwise uncontacted, thereby increasing the total oiled shoreline length. As such, while shoreline loading predictions are generally broadly similar between stochastic and deterministic simulations, some subtle variations may arise in some instances.

4.2.3 Apus Base Case Subsea LOWC Scenario #24

4.2.3.1 Unmitigated results

Stochastic realisation 24 of the Apus Base Case Subsea LOWC scenario resulted in the highest accumulated shoreline load (for that scenario) of 2,054 tonnes (of which the entire accumulated load exceeded 10 g/m^2 and 100 g/m^2).

The unmitigated simulation of this realisation resulted in a surface slick exceeding 10 µm thickness that extended up to ~180 km from the release location (Figure 45). Shoreline loading greater than 10 and 100 g/m^2 extended up to ~350 km of the release site (Figure 46). Total submerged oil exceeding 100 ppb extended up to ~700 km in sparse patches that travelled to the north-east of the release site, while the majority of exceedances were confined to within ~300 km of the release site (Figure 47). Dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~50 km from the release location (Figure 47).

Shoreline accumulation for this realisation above both thresholds (10 g/m^2 and 100 g/m^2) began during day 32 at Roebuck – Eighty Mile Beach, with significant shoreline loading events continuing at a range of shoreline receptors until day 111. A time-series of shoreline accumulation impacts during this realisation is presented in Figure 48 (for 10 g/m^2) and Figure 49 (for 100 g/m^2), while summarised shoreline loading predictions are displayed in Table 32 and Table 33 for 10 and 100 g/m^2, respectively. The following key shoreline impacts are predicted at the moderate threshold (100 g/m^2):

– Imperieuse Reef MP received an instantaneous peak shoreline load of 616 tonnes, with shoreline accumulation beginning on day 81, and reaching the peak load on day 107, with a maximum oiled shoreline length of 57 km.
– Lower, but significant peak shoreline loads were also predicted at Clerke Reef MP (195 tonnes on day 110), Eighty Mile Beach (102 tonnes on day 61), Roebuck – Eighty Mile Beach (131 tonnes on day 51) and Bedout Island (17 tonnes on day 68).
– Across all shorelines combined, a peak oil loading of 853 tonnes occurred during day 103, with a maximum oiled shoreline length of 138 km.

The predicted hydrocarbon weathering (i.e. mass balance partitioning) for the specific met-ocean conditions encountered during the deterministic simulation is presented in Figure 50, and summarised as follows:

– Evaporation is the primary weathering mechanism with evaporated oil accounting for ~60% of the total oil mass by day 80.
– Oil decay (i.e. biodegradation) accounts for an additional ~30% of the oil by the end of the simulation (day 112).
– Several large wind-driven entrainment events occurred throughout the simulation resulting in increases in the mass of entrained droplets that were concomitant with decreases in the mass of surface oil. For this subsea discharge, entrained droplets typically accounted for ~15-30% of the total oil mass throughout the duration of the discharge (i.e. the first 77 days), while surface oil was proportionally lower (typically 1-10% of all oil) during this period.

4.2.3.2 Assessment of dispersant efficacy

The dispersant responses simulated for this scenario included SSDI and a combined SSDI and SDA response. A summary of the total dispersant applied by each response unit type (vessels and aircraft) for the SDA component of the combined SSDI and SDA response is presented in Table 31.

The effect of each response on the mass of surface oil and entrained droplets throughout the simulation is displayed in Figure 44, with spatial maps presented in Figure 45-Figure 47, comparisons of shoreline loading presented in Figure 48 (10 g/m^2) and Figure 49 (100 g/m^2), with summarised shoreline loading predictions displayed in Table 32 and Table 33 for 10 and 100 g/m^2, respectively .

4.2.3.2.1 SSDI response

Undertaking SSDI at an application ratio of 1:100 (dispersant:oil) from day 9 onwards results in the use of 15,587 m^3 of chemical dispersant.

This highly energetic subsea discharge with high exit velocities is predicted to generate small droplets, so the relative effect of further reductions in droplet diameters via SSDI to enhance dispersion is low. The median droplet size of oil treated by SSDI (75%) is predicted to be 270 µm in diameter relative to untreated median diameters of 413-432 µm (see Table 12 in the stochastic results for untreated droplet diameters). Negligible reductions to the surface slick mass were predicted from solely the SSDI response, with concomitant negligible increases in entrained oil mass (Figure 44).

In general, SSDI alone was not predicted to yield significant benefits to shoreline loading (Table 32-Table 34, Figure 48-Figure 49). At the moderate threshold (100 g/m^2) some increases in peak shoreline loads were predicted at various receptors, while a reduction was predicted at Imperieuse Reef MP. The increases in shoreline loading are likely from delayed surfacing of oil and less evaporative losses (which are the dominant weathering mechanism for this oil) and greater mass of surface oil in proximity to shoreline receptors at some locations. Overall, the accumulated shoreline load (i.e. the sum of oil arrival ignoring weathering) increased from 2,054 tonnes (unmitigated) to 2,439 tonnes (SSDI mitigated), though the altered timing of loading events for the SSDI scenario compared to the unmitigated scenario resulted in a slightly reduced instantaneous peak oil load of 811 tonnes on day 111 (SSDI mitigated) compared to 853 tonnes on day 103 (unmitigated).

4.2.3.2.2 Combined SSDI+SDA Response

For the SDA component of the combined SSDI+SDA response, the total daily dispersant application capacity for each response unit is 15 m^3 for FWADC (5 sorties per day, 3 m^3 dispersant tank), 40 m^3 for the Hercules (4 sorties, 10 m^3 dispersant tank) and 10 m^3 for vessels (1 sortie, 10 m^3 dispersant tank). Given the operational constraints (Section 3.5), the simulated dispersant application rates for the response aircraft (Hercules and FWADC) were ~80% of the daily capacity, with average daily application rates of 31.1 m^3 for the Hercules and 12.4 m^3 for the FWADC. The vessels applied on average 5.3 m^3 per day (53% of the daily capacity of 10 m^3 per day), with reduced efficiencies primarily being the result of long times required to cruise from Port Hedland to the response site that reduced the amount of daylight hours available for dispersant application. All response units were also limited by reduced availability of surface oil meeting the treatment threshold (>50 µm thickness) due to the initiation of SSDI from day 9. The total volume of dispersant applied throughout the combined SSDI+SDA response was 10,866 m^3 for the SDA component, and 15,587 m^3 for the SSDI component (total of 26,453 m^3).

In contrast to the solely SSDI response simulation, the combined SSDI+SDA response yields significant reductions in instantaneous surface oil loads of up to ~20,000 tonnes that were concomitant with approximately equal increases in the entrained oil mass (Figure 44). The SDA component of the response has therefore contributed significantly to reducing surface oil loads compared to the relatively ineffective SSDI response. The accumulated shoreline load reduces from 2,054 tonnes for the unmitigated simulation to 939 tonnes for the combined SSDI+SDA simulation (Table 34), indicating that 1,115 tonnes of oil were prevented from arriving at shorelines as a result of the response. At the moderate threshold (100 g/m^2), significant reductions in peak oil loads were also predicted at all contacted receptors, a total peak loading of 424 tonnes (reduced from 853 tonnes unmitigated) with Eighty Mile Beach and Roebuck – Eighty Mile Beach no longer receiving any oil loading above the threshold.

Table 31 Apus Base Case Subsea LOWC Scenario #24 – Summary of surface dispersant response (as part of combined SSDI+SDA response)

Response item	Amount of		
	Oil handled (tonnes)	Dispersant used (m^3)	Average dispersant applied each day per response unit (m^3)
FWADCs	74,483	7,448	12.4
Hercules	23,039	2,304	31.1
Vessels	11,136	1,114	5.3
Total amount of oil treated with dispersants (tonnes):	108,658		
Total amount of dispersant used (m^3):	10,866		

Table 32 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated, SSDI mitigated and Combined SSDI and SDA mitigated shoreline loading exceeding the moderate threshold (10 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)			Minimum Arrival Time (days)			Peak Loading Time (days)			Maximum Length of Oiled Shoreline (km)		
	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated
Clerke Reef MP	195.3	232.1	174.3	35.8	89.8	34.1	110.8	112.0	111.3	51.2	51.2	51.2
Imperieuse Reef MP	616.2	428.7	265.7	81.2	42.8	84.1	107.2	108.2	107.5	56.9	56.9	56.9
Eighty Mile Beach	102.6	382.7	NC	35.1	40.2	NC	61.1	62.0	NC	51.2	85.3	NC
Roebuck - Eighty Mile Beach	131.2	239.6	NC	32.9	31.8	NC	51.1	36.3	NC	51.2	62.5	NC
Bedout Island	17.3	19.6	8.0	42.8	32.8	31.7	68.3	68.2	43.8	1.1	1.1	1.1
All Shorelines	**856.0**	**816.5**	**424.1**	**32.9**	**31.8**	**31.7**	**103.8**	**111.1**	**111.1**	**200.1**	**245.6**	**109.1**

Table 33 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated, SSDI mitigated and Combined SSDI and SDA mitigated shoreline loading exceeding the moderate threshold (100 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)			Minimum Arrival Time (days)			Peak Loading Time (days)			Maximum Length of Oiled Shoreline (km)		
	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated
Clerke Reef MP	195.3	232.1	174.3	35.8	89.8	34.1	110.8	112.0	111.3	51.2	51.2	51.2
Imperieuse Reef MP	616.2	428.7	265.7	81.2	42.8	84.1	107.2	108.2	107.5	56.9	56.9	56.9
Eighty Mile Beach	102.2	382.2	NC	36.0	40.2	NC	61.1	62.0	NC	22.7	45.5	NC
Roebuck - Eighty Mile Beach	130.5	239.2	NC	32.9	31.8	NC	51.1	36.3	NC	17.1	22.7	NC
Bedout Island	17.3	19.6	8.0	42.8	32.8	31.7	68.3	68.2	43.8	1.1	1.1	1.1
All Shorelines	**853.2**	**811.1**	**424.1**	**32.9**	**31.8**	**31.7**	**103.8**	**111.1**	**111.1**	**137.5**	**171.6**	**109.1**

Table 34 Apus Base Case Subsea LOWC Scenario #24 – Comparison of total accumulated shoreline load for unmitigated, SSDI mitigated and Combined SSDI and SDA mitigated cases

	Unmitigated	SSDI Mitigated	SSDI+SDA Mitigated
Total Accumulated Shoreline Load (tonnes)	2,054	2,439	939

Figure 44 ***Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (blue), SSDI mitigated (orange) and Combined SSDI and SDA mitigated (green) surface oil mass (top panel), entrained droplets (middle panel) and combined surface and entrained mass (bottom panel)***

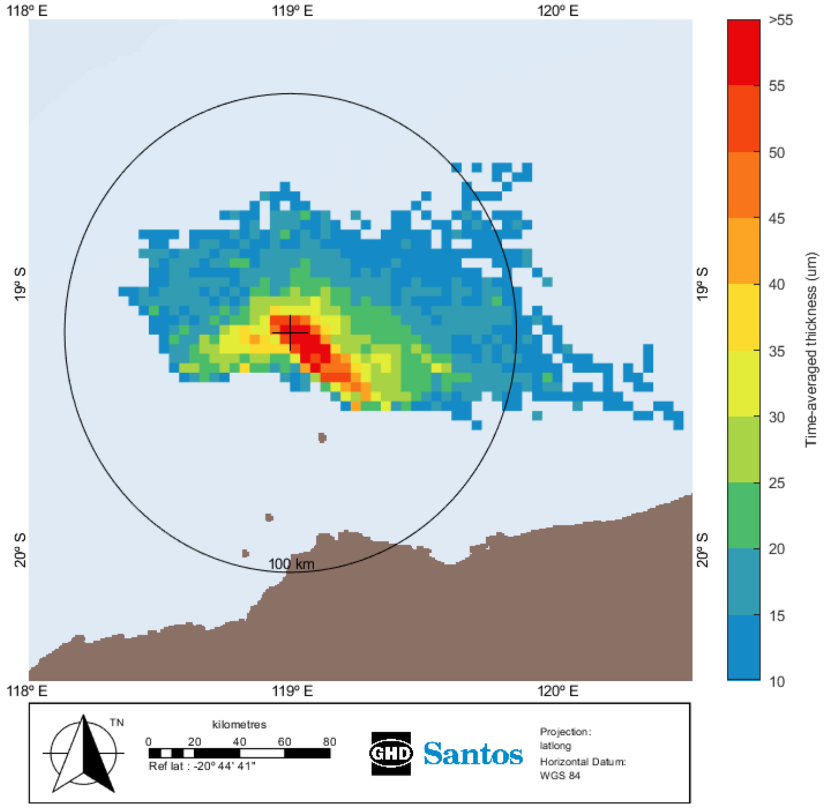
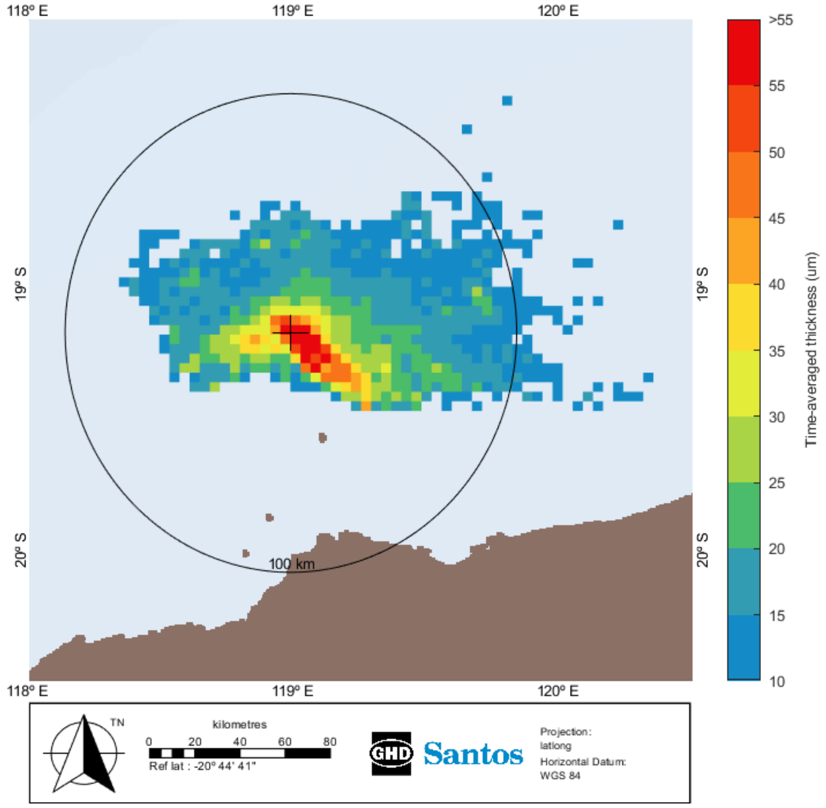
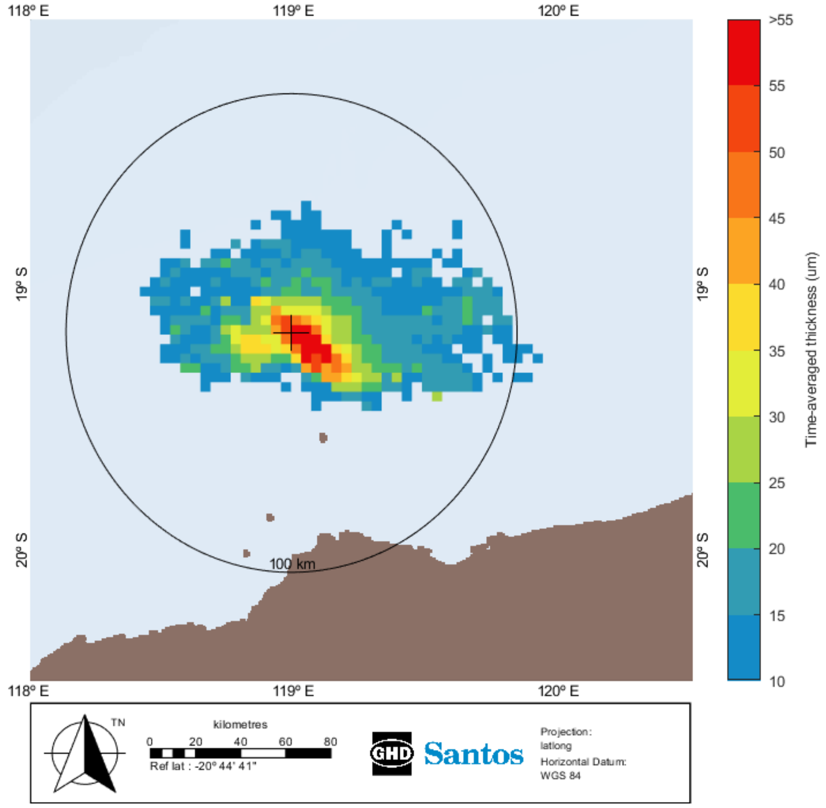
	Unmitigated	SSDI	SSDI+SDA
Surface Thickness > 10 µm			

Figure 45 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) surface thicknesses of oil greater than 10 µm

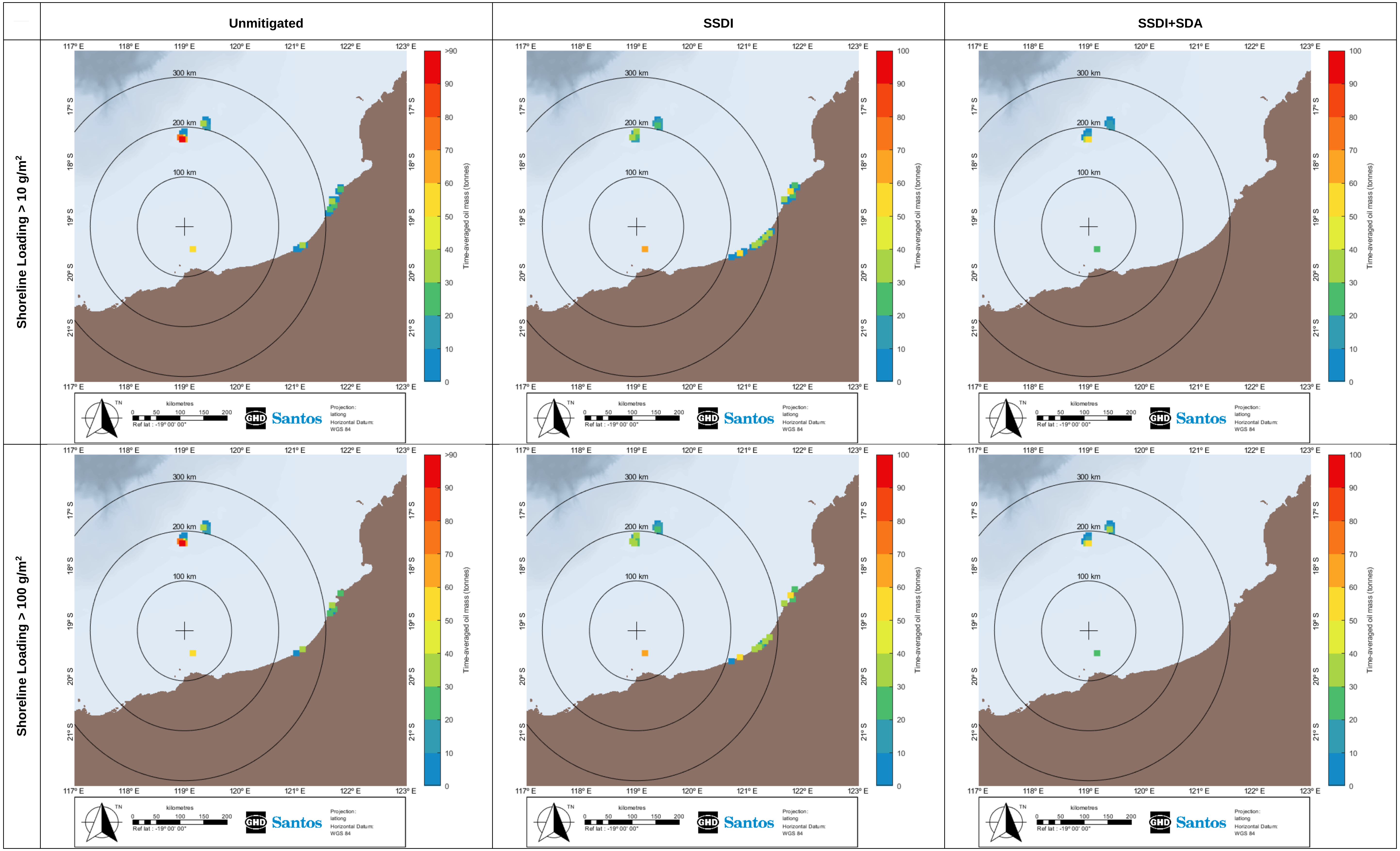


Figure 46 *Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) shoreline loading above 10 g/m² (top) and shoreline loading above 100 g/m² (bottom)*

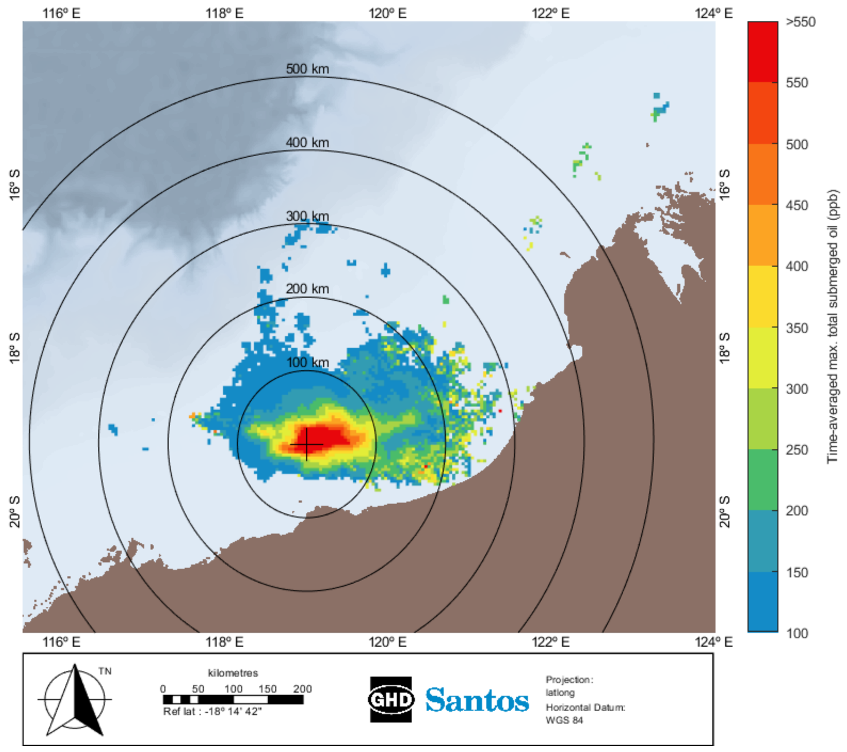
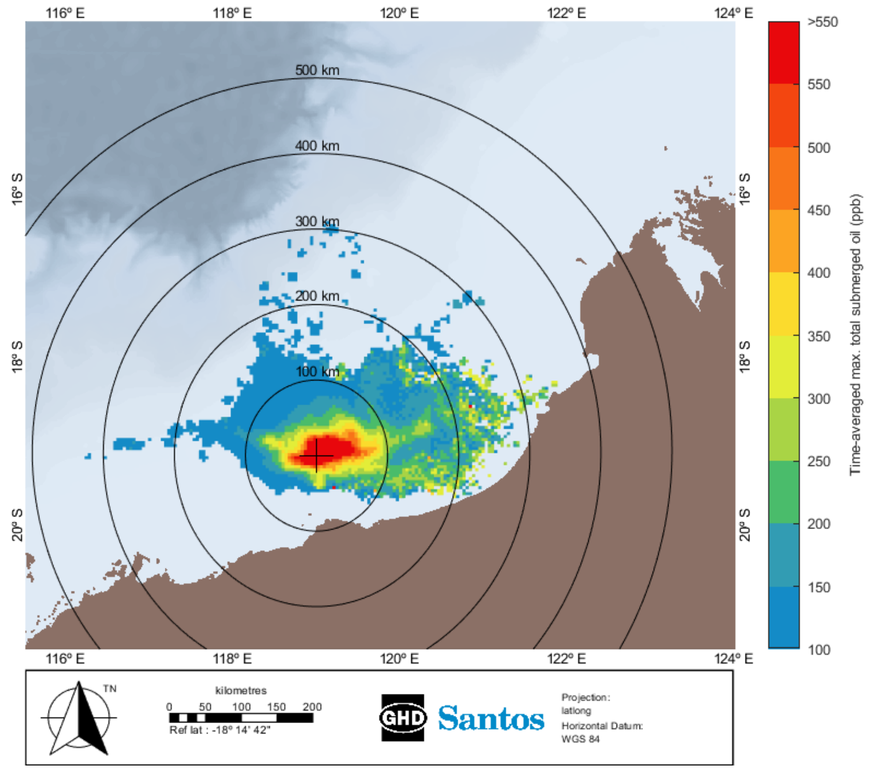
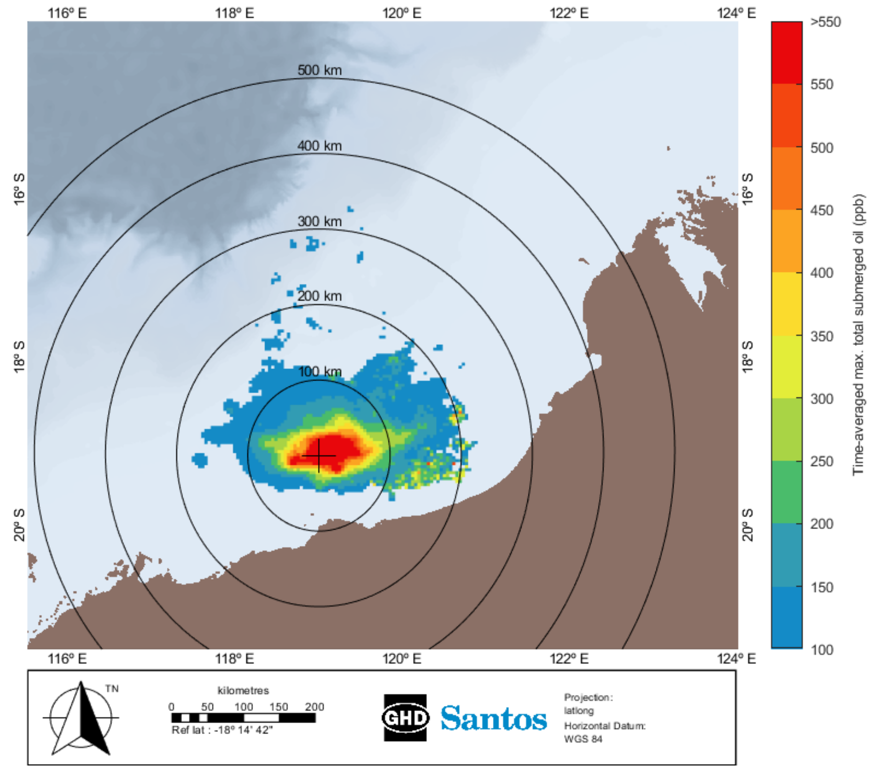
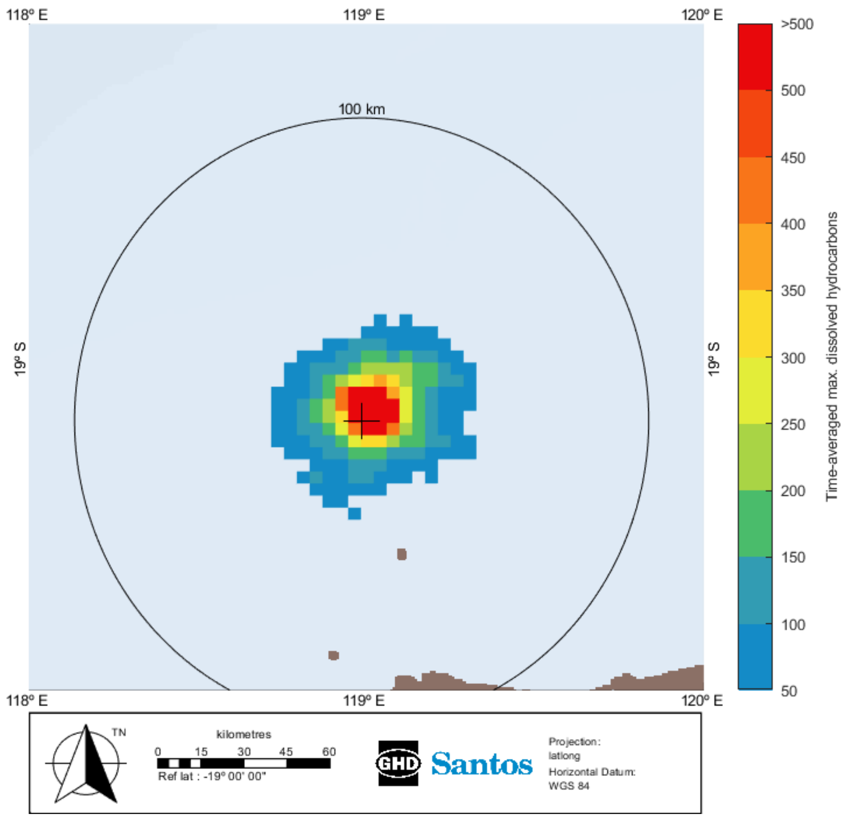
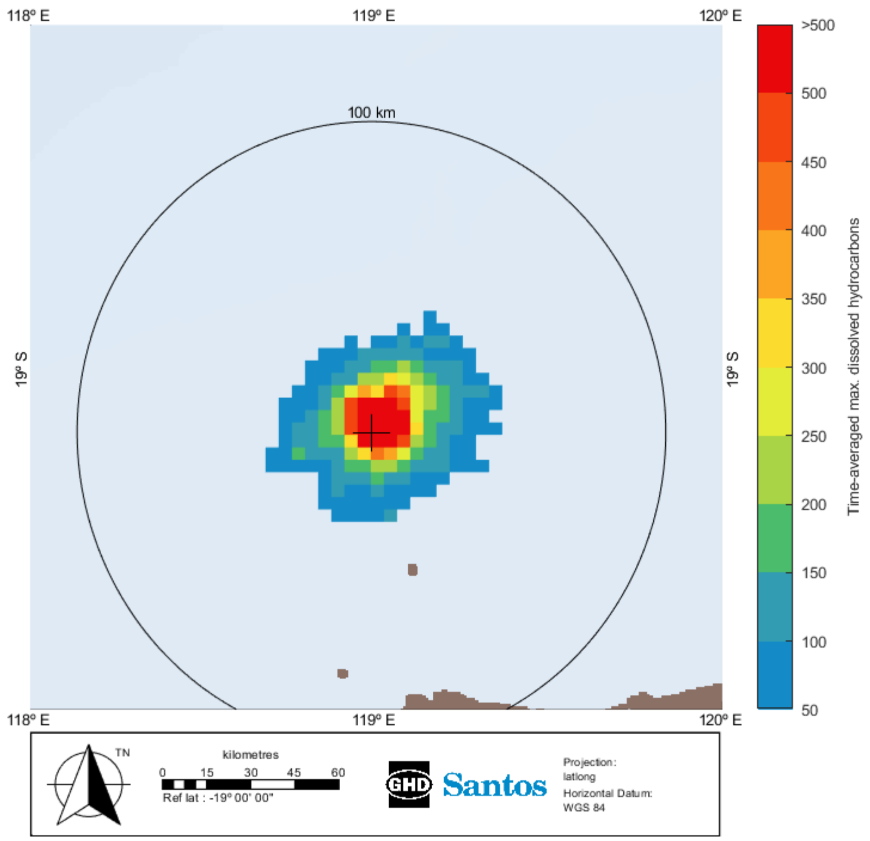
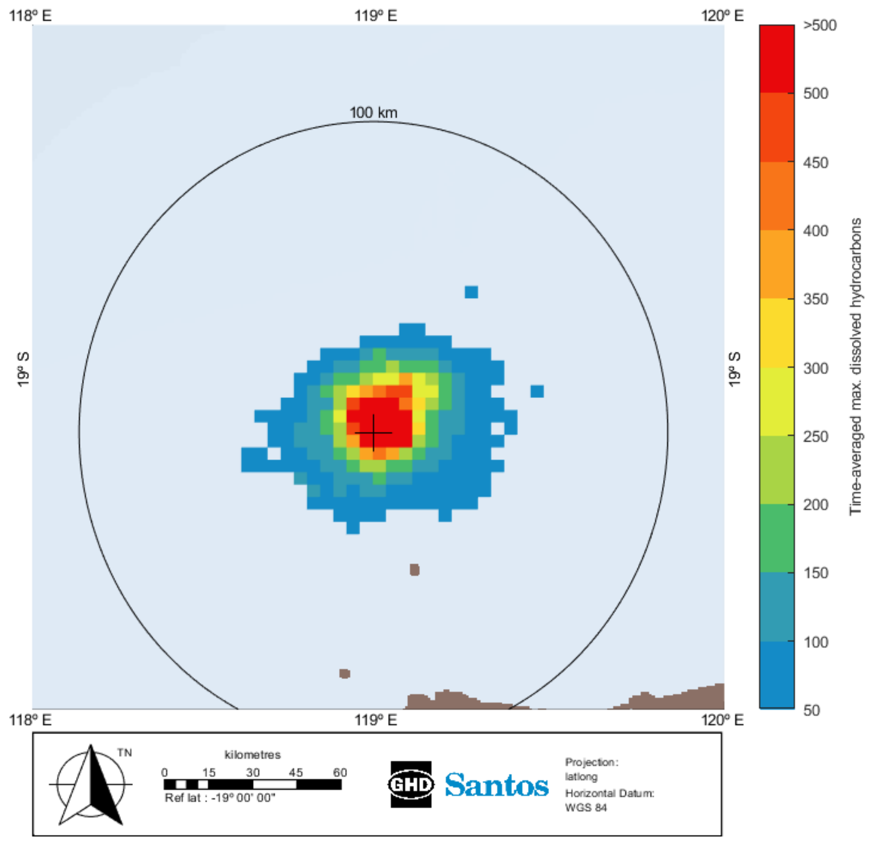
	Unmitigated	SSDI	SSDI+SDA
Maximum Total Submerged Oil > 100 ppb			
Maximum Dissolved Hydrocarbon > 50 ppb			

Figure 47 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) maximum total submerged oil greater than 10 ppb (top) and maximum dissolved hydrocarbon above 10 ppb (bottom)

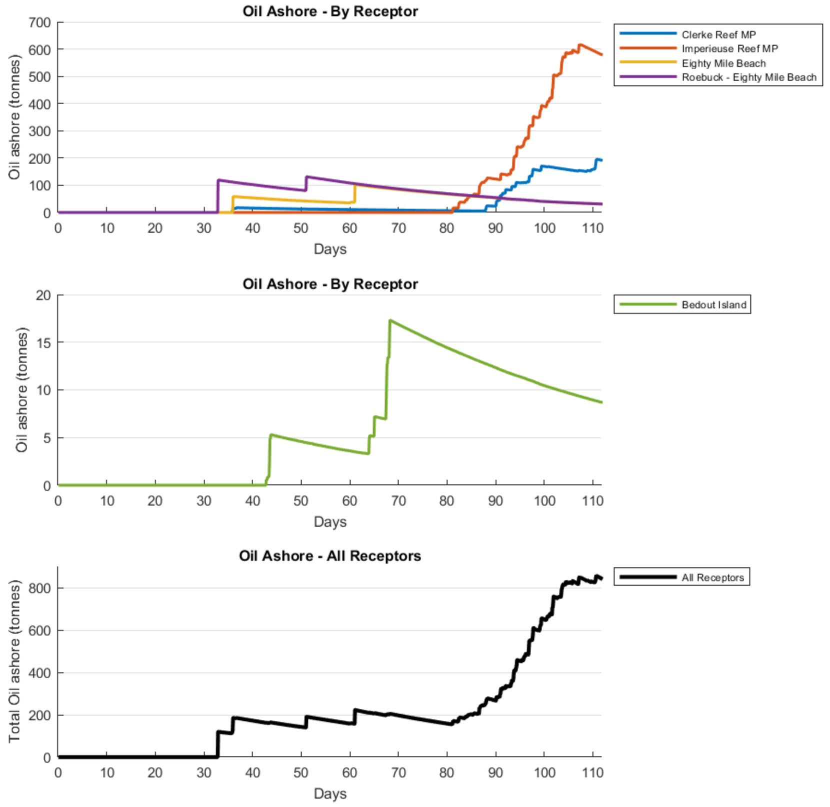
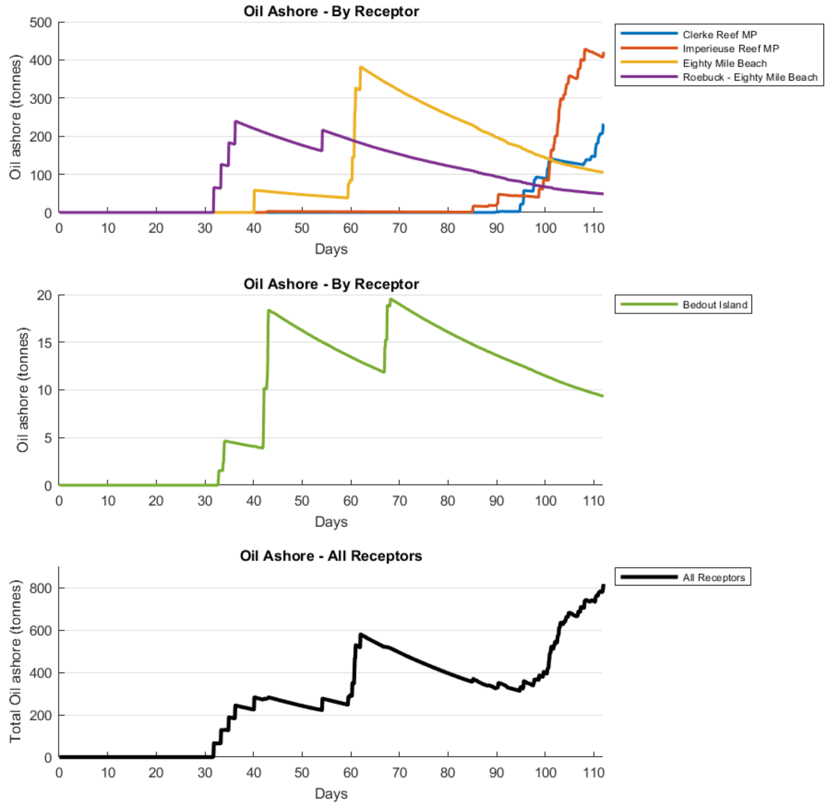
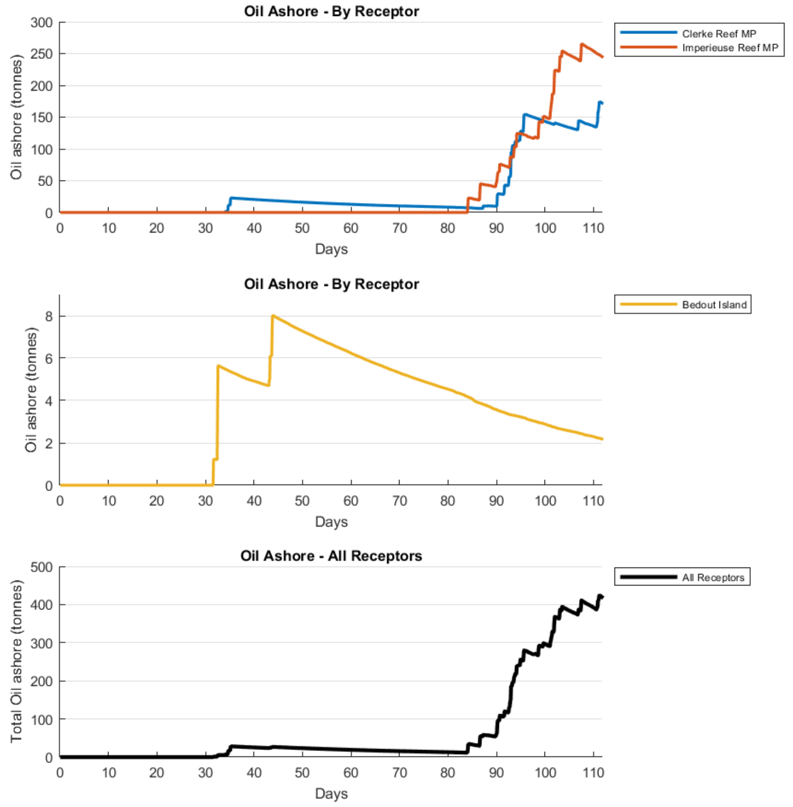
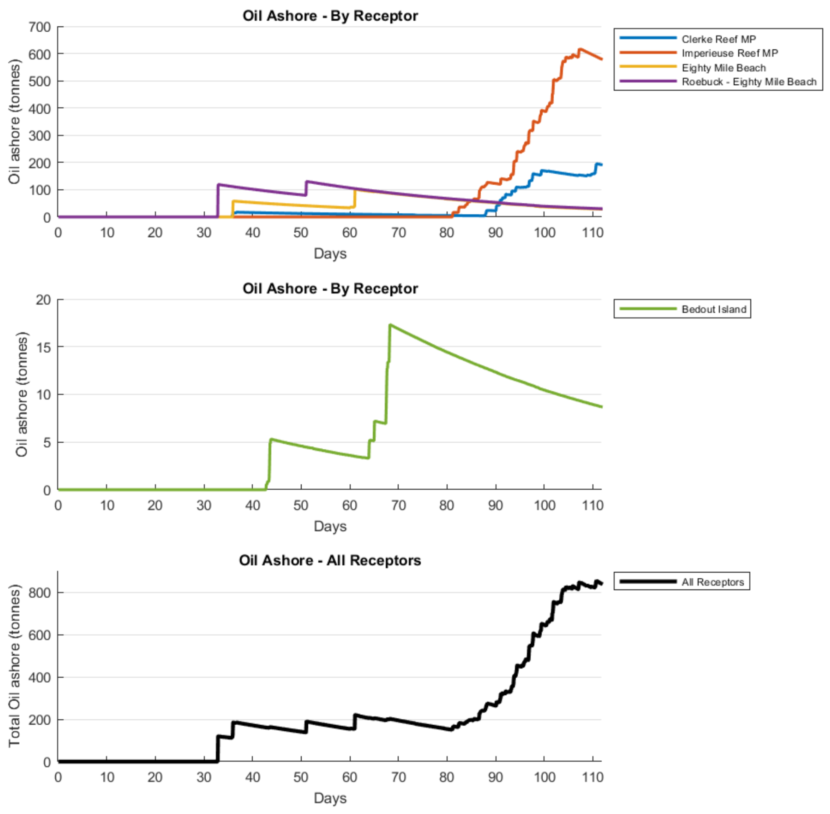
	Unmitigated	SSDI	SSDI+SDA
Shoreline Loading Time-series			

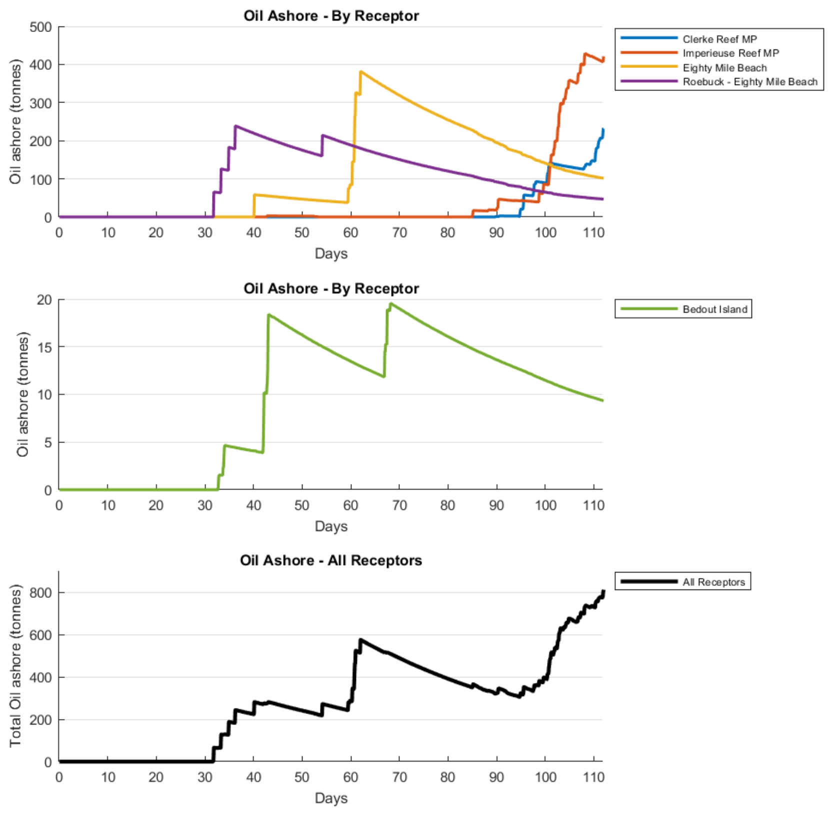
Figure 48 *Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) mitigated (right) time series of shoreline loading above 10 g/m²*

Shoreline Loading Time-series

Unmitigated



SSDI



SSDI+SDA

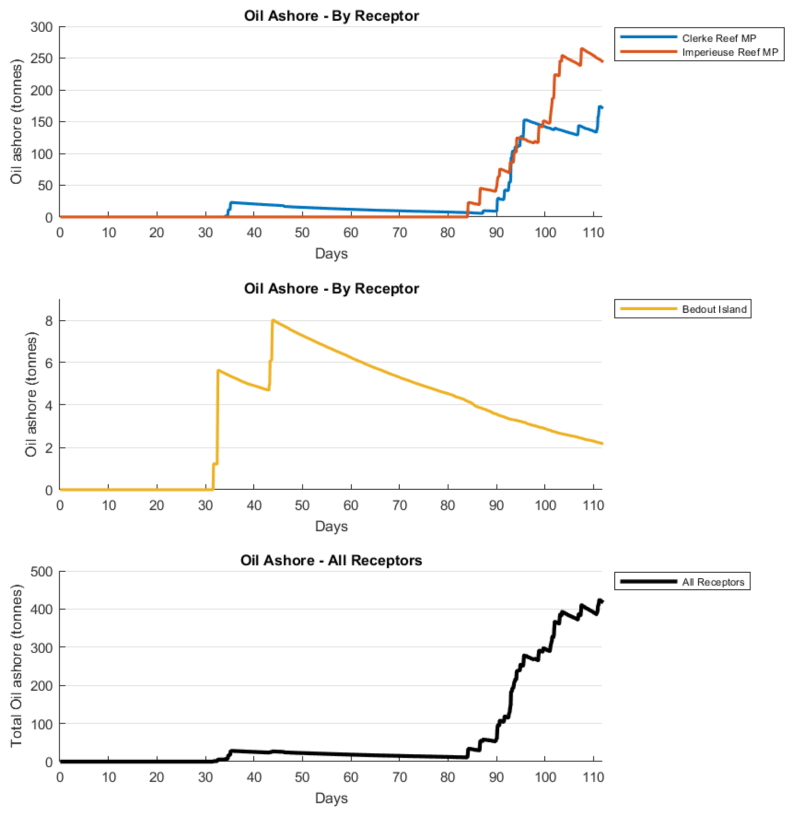


Figure 49 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) mitigated (right) time series of shoreline loading above 100 g/m²

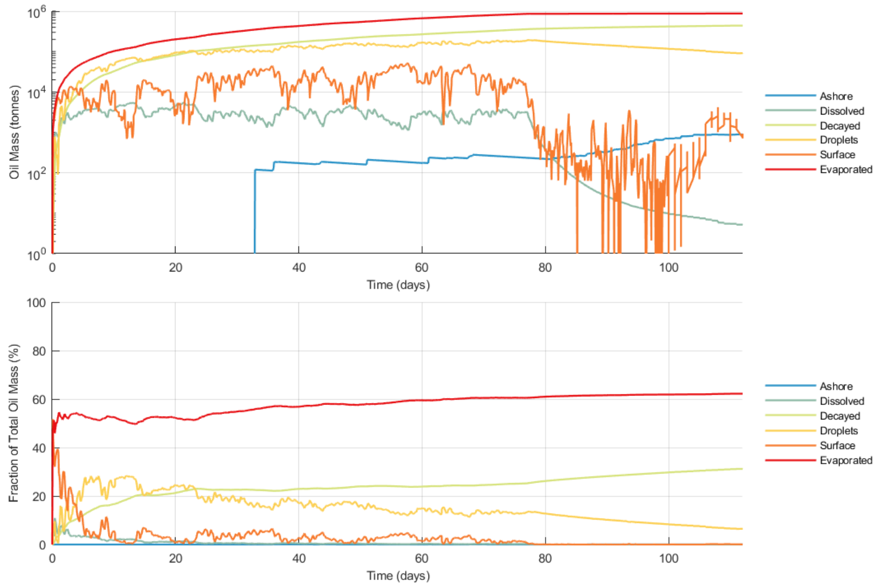
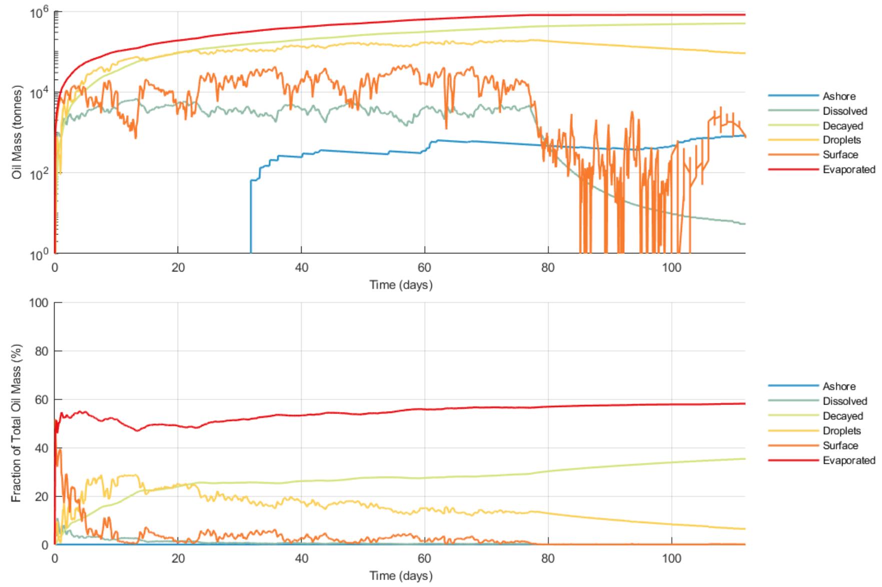
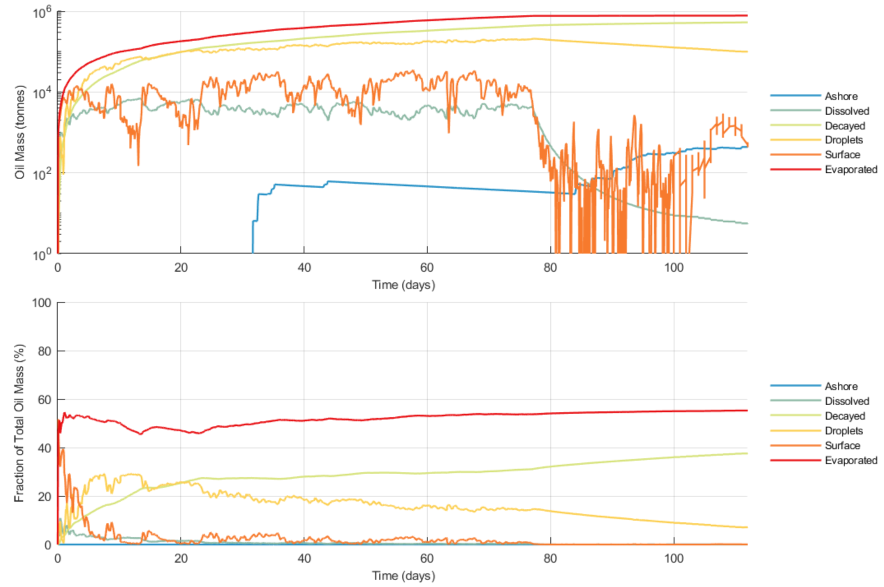
	Unmitigated	SSDI	SSDI+SDA
Hydrocarbon Mass Balance Time-series			

Figure 50 Apus Base Case Subsea LOWC Scenario #24 – Comparison of unmitigated (left), SSDI mitigated (middle) and Combined SSDI and SDA mitigated (right) hydrocarbon mass balance time series

4.2.4 Apus Base Case Surface LOWC Scenario #31

4.2.4.1 Unmitigated results

Stochastic realisation 31 of the Apus Base Case Surface LOWC scenario resulted in the highest accumulated shoreline load (of all LOWC scenarios simulated) of 5,127 tonnes above 10 g/m^2 and 5,125 tonnes above 100 g/m^2.

The unmitigated simulation of this realisation resulted in a surface slick exceeding 10 µm thickness that extended up to ~300 km from the release location (Figure 52). Shoreline loading greater than 10 and 100 g/m^2 extended up to ~350 km of the release site (Figure 53). Total submerged oil exceeding 100 ppb extended up to ~400 km, while dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~150 km from the release location (Figure 54).

Shoreline accumulation for this realisation above both thresholds (10 g/m^2 and 100 g/m^2) began during day 14 at Roebuck – Eighty Mile Beach, with significant shoreline loading events continuing at a range of shoreline receptors until day 80. A time-series of shoreline accumulation impacts during this realisation is presented in Figure 55 (for 10 g/m^2) and Figure 56 (for 100 g/m^2), while summarised shoreline loading predictions are displayed in Table 36 and Table 37 for 10 and 100 g/m^2, respectively. The following key shoreline impacts are predicted at the moderate threshold (100 g/m^2):

– Eighty Mile Beach received an instantaneous peak shoreline load of 1,504 tonnes, with shoreline accumulation beginning on day 28 and reaching the peak load on day 81, with a maximum oiled shoreline length of 119 km.
– Port Hedland-Eighty Mile Beach received an instantaneous peak shoreline load of 1,329 tonnes, with shoreline accumulation beginning on day 37 and reaching the peak load on day 54, with a maximum oiled shoreline length of 85 km.
– Lower, but significant peak shoreline loads were also predicted at Karratha-Port Hedland (657 tonnes on day 53), Roebuck – Eighty Mile Beach (606 tonnes on day 45) and Bedout Island (32 tonnes on day 34).
– Across all shorelines combined, a peak oil loading of 2,940 tonnes occurred during day 53, with a maximum oiled shoreline length of 302 km.

The predicted hydrocarbon weathering (i.e. mass balance partitioning) for the specific met-ocean conditions encountered during the deterministic simulation is presented in Figure 57, and summarised as follows:

– Evaporation is the primary weathering mechanism with evaporated oil accounting for ~80% of the total oil mass by day 100.
– Oil decay (i.e. biodegradation) accounts for the remaining ~20% of the oil by day 100.
– Several large wind-driven entrainment events occurred throughout the simulation resulting in increases in the mass of entrained droplets that were concomitant with decreases in the mass of surface oil. For this surface discharge, entrained droplets typically accounted for ~10-20% of the total oil mass throughout the duration of the discharge (i.e. the first 77 days), while surface oil was generally lower (typically 1-20% of all oil) during this period.

4.2.4.2 Assessment of dispersant efficacy

The dispersant responses simulated for this scenario included the standard SDA response, along with a modified SDA response that did not have the 25 km exclusion zone implemented (i.e. dispersant could be applied in close proximity to the well). A summary of the total dispersant applied by each response unit type (vessels and aircraft) for two SDA responses is presented in Table 35.

The effect of each response on the mass of surface oil and entrained droplets throughout the simulation is displayed in Figure 51, with spatial maps presented in Figure 52-Figure 54, comparisons of shoreline loading presented Figure 55 (10 g/m^2) and Figure 56 (100 g/m^2), with summarised shoreline loading predictions displayed in Table 36 and Table 37 for 10 and 100 g/m^2, respectively .

4.2.4.2.1 SDA Response

For the SDA response, the total daily dispersant application capacity for each response unit is 15 m^3 for FWADC (5 sorties per day, 3 m^3 dispersant tank), 40 m^3 for the Hercules (4 sorties, 10 m^3 dispersant tank) and 10 m^3 for vessels (1 sortie, 10 m^3 dispersant tank). Given the operational constraints (Section 3.5), the simulated dispersant application rates for the response aircraft (Hercules and FWADC) were near the daily capacity, with average daily application rates of 38.8 m^3 for the Hercules and 14.8 m^3 for the FWADC. The vessels applied on average 6.3 m^3 per day (63% of the daily capacity of 10 m^3 per day), with reduced efficiencies primarily being the result of long times required to cruise from Port Hedland to the response site that reduced the amount of daylight hours available for dispersant application. The total volume of dispersant applied throughout the SDA response was 13,861 m^3.

The SDA response yields significant reductions in instantaneous surface oil loads of up to ~15,000 tonnes that were concomitant with approximately equal increases in the entrained oil mass (Figure 51).

The reduction in surface oil loads yields significant benefits to the shoreline loading. The accumulated shoreline load reduces from 5,127 tonnes for the unmitigated simulation to 3,830 tonnes for the SDA simulation (Table 38), indicating that 1,297 tonnes of oil were prevented from arriving at shorelines as a result of the response. At the moderate threshold (100 g/m^2), significant reductions in peak oil loads were also predicted at all contacted receptors (with the exception of Bedout Island which had a negligible change in peak oil load). A total peak loading of 2,091 tonnes was predicted across all shorelines, which was reduced from 2,940 tonnes for the unmitigated simulation.

4.2.4.2.2 SDA Response without the 25 km exclusion zone

For the SDA response that did not incorporate the 25 km exclusion zone, the total daily dispersant application capacity for each response unit is 15 m^3 for FWADC (5 sorties per day, 3 m^3 dispersant tank), 40 m^3 for the Hercules (4 sorties, 10 m^3 dispersant tank) and 10 m^3 for vessels (1 sortie, 10 m^3 dispersant tank). Given the operational constraints (Section 3.5), the simulated dispersant application rates for the response aircraft (Hercules and FWADC) were near the daily capacity, with average daily application rates of 39.9 m^3 for the Hercules and 14.9 m^3 for the FWADC. The vessels applied on average 7.4 m^3 per day (74% of the daily capacity of 10 m^3 per day), with reduced efficiencies primarily being the result of long times required to cruise from Port Hedland to the response site that reduced the amount of daylight hours available for dispersant application. The total volume of dispersant applied throughout the SDA response was 14,322 m^3. The higher dispersant volumes applied for the scenario compared to the SDA scenario that incorporated the 25 km exclusion zone are the result of greater availability of surface oil in close proximity to the well that meets the response thresholds (>50 um thickness).

In general, the SDA without the exclusion zone yields similar surface oil and entrained oil masses to the SDA response that incorporated the exclusion zone (Figure 51), though in some instances the maintenance of the exclusion zone yielded greater reductions in surface oil by an additional ~5,000 tonnes. Further, a higher volume of chemical dispersant is required without the exclusion zone to achieve a similar (and slightly less effective) outcome.

The shoreline load reductions predicted for the SDA response without the exclusion zone were significant, but less than those with the exclusion zone. Accumulated shoreline load was predicted to decrease from 5,127 tonnes for the unmitigated simulation to 4,051 tonnes for SDA without the exclusion zone (Table 38) (i.e. prevention of 1,076 tonnes of oil shoreline arrival in comparison with 1,297 tonnes with the exclusion zone). At the moderate threshold (100 g/m^2) a total peak loading of 2,323 tonnes was predicted across all shorelines, which was lower than the 2,940 tonnes for the unmitigated simulation, but higher than the 2,091 tonnes for the exclusion zone scenario.

Overall, these results indicate that incorporating an exclusion zone around the well for the SDA response strategy is effective to allow evaporation to occur prior to application of chemical dispersants onto the surface slick. This also reduces the amount of dispersant required and provides environmental benefits in the form of reduced shoreline loads.

Table 35 Apus Base Case Surface LOWC Scenario Realisation #31 – Summary of surface dispersant response for SDA mitigated and SDA mitigated without 25km exlusion zone

Response item	SDA Mitigated			SDA Mitigated w/o 25 km Exclusion Zone		
	Amount of oil handled (tonnes)	Amount of dispersant used (m^3)	Amount of average dispersant applied each day (m^3)	Amount of oil handled (tonnes)	Amount of dispersant used (m^3)	Amount of average dispersant applied each day (m^3)
FWADCs	92,988	9,299	14.8	94,473	9,447	14.9
Hercules	28,713	2,871	38.8	29,563	2,956	39.9
Vessels	16,913	1,691	6.3	19,187	1,919	7.4
Total amount of oil treated with dispersants (tonnes):	138,614			143,223		
Total amount of dispersant used (m^3):	13,861			14,322		

Table 36 Apus Base Case Subsea LOWC Scenario #31 – Comparison of unmitigated, SDA mitigated and SDA mitigated without 25km exlusion zone shoreline loading exceeding the moderate threshold (10 g/m^2)

Receptor Name	Peak Mass of Oil Ashore (tonnes)			Minimum Arrival Time (days)			Peak Loading Time (days)			Maximum Length of Oiled Shoreline (km)		
	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone
Port Hedland-Eighty Mile Beach	1,330	806	1,208	37.9	36.4	36.8	54.9	55.3	54.3	130.8	85.3	113.7
Karratha-Port Hedland	656.5	532.5	402.6	52.3	52.3	52.4	53.2	54.4	53.9	91.0	79.6	73.9
Eighty Mile Beach	1,508	1,196	1,274	15.7	27.8	19.8	81.3	80.9	81.0	216.0	164.9	176.2
Roebuck - Eighty Mile Beach	607.9	234.6	182.7	14.8	21.8	25.6	29.4	27.5	29.1	96.6	73.9	45.5
Bedout Island	32.4	32.4	32.6	33.3	33.7	33.3	34.8	35.3	87.3	1.1	1.1	1.1
All Shorelines	**2,951**	**2,101**	**2,334**	**14.8**	**21.8**	**19.8**	**53.9**	**54.8**	**54.0**	**518.4**	**393.4**	**399.1**

Table 37 Apus Base Case Subsea LOWC Scenario #31 – Comparison of unmitigated, SDA mitigated and SDA mitigated without 25km exlusion zone shoreline loading exceeding the moderate threshold (100 g/m^2)

Receptor Name	Peak Mass of Oil Ashore (tonnes)			Minimum Arrival Time (days)			Peak Loading Time (days)			Maximum Length of Oiled Shoreline (km)		
	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone	Unmitigated	SDA Mitigated	SDA Mitigated w/o exclusion zone
Port Hedland-Eighty Mile Beach	1,329	806	1,206	37.9	36.4	36.8	54.9	55.3	54.3	85.3	68.2	96.6
Karratha-Port Hedland	656.5	532.5	402.6	52.3	52.3	52.4	53.2	54.4	53.9	62.5	28.4	28.4
Eighty Mile Beach	1,504	1,192	1,272	28.1	27.8	20.8	81.3	80.9	81.0	119.4	102.3	119.4
Roebuck - Eighty Mile Beach	606.2	234.6	182.7	14.8	21.8	25.6	29.4	27.5	29.1	45.5	28.4	28.4
Bedout Island	32.4	32.4	32.6	33.3	33.7	33.3	34.8	35.3	87.3	1.1	1.1	1.1
All Shorelines	**2,940**	**2,091**	**2,323**	**14.8**	**21.8**	**20.8**	**53.9**	**54.8**	**54.0**	**302.4**	**217.1**	**256.9**

Table 38 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of total accumulated shoreline load for unmitigated,SDA mitigated and SDA mitigated without 25km exclusion zone cases

	Unmitigated	**SDA Mitigated**	**SDA Mitigated w/o exclusion zone**
Total Accumulated Shoreline Load (tonnes)	5,127	3,830	4,051

Figure 51 ***Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (blue), SDA mitigated (orange) and SDA mitigated without 25km exclusion zone (green) surface oil mass (top panel), entrained droplets (middle panel) and combined surface and entrained mass (bottom panel)***

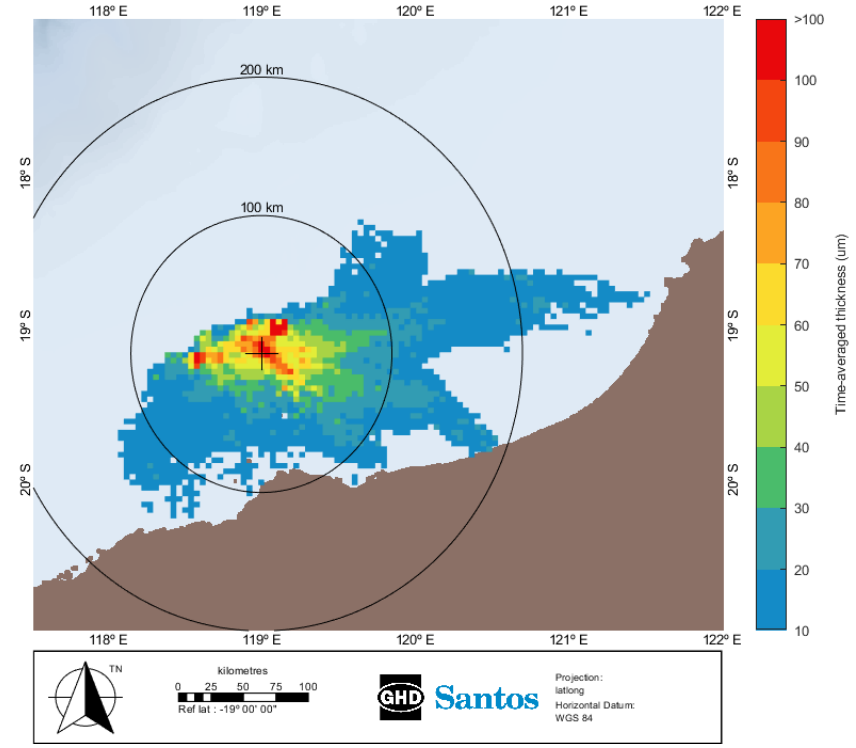
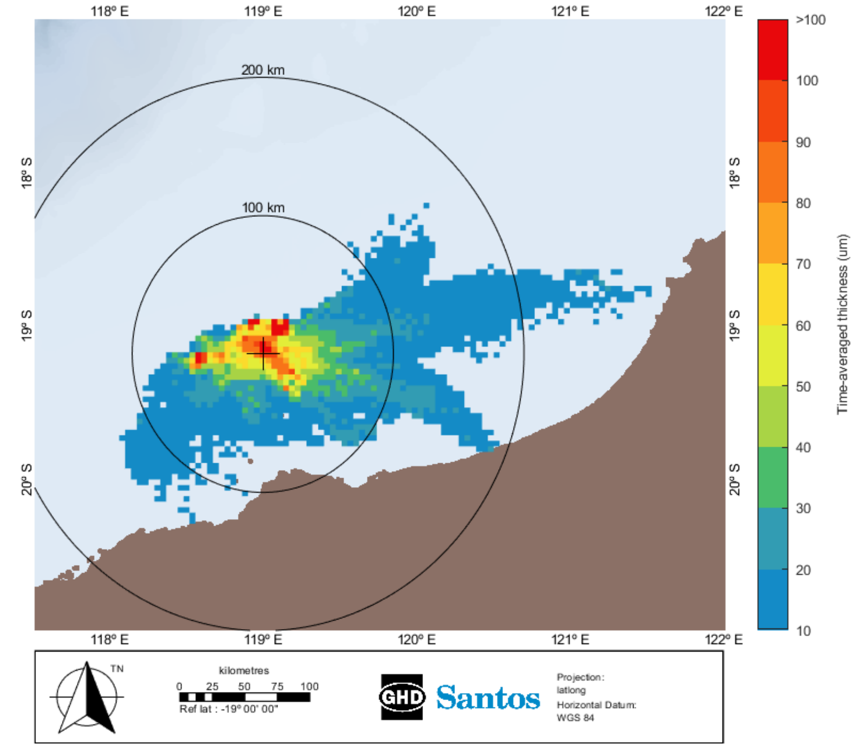
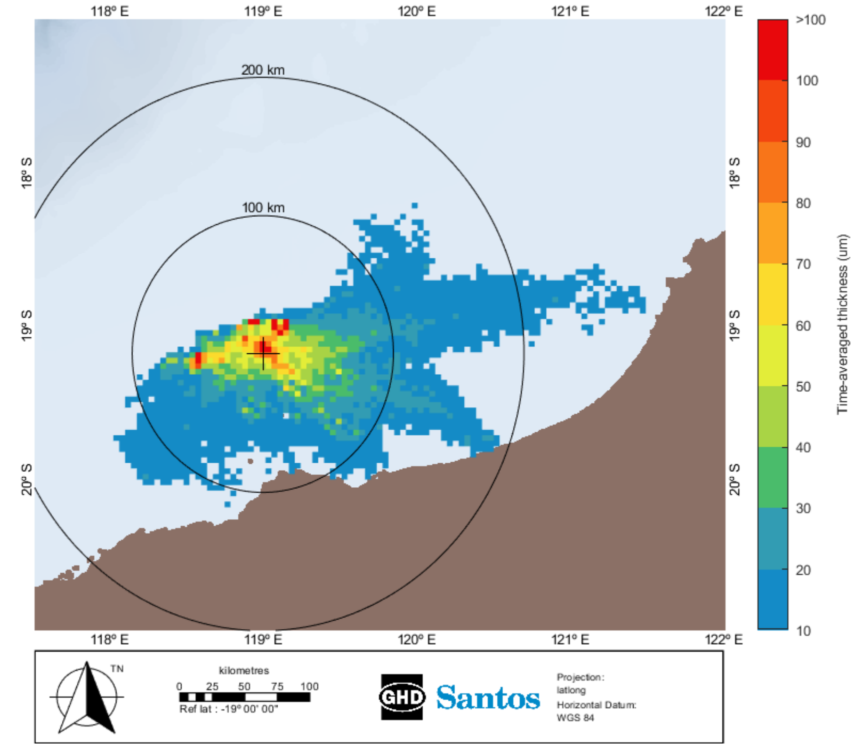
	Unmitigated	SDA	SDA w/o 25 km Zone
Surface Thickness > 10 µm			

Figure 52 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) surface thicknesses of oil greater than 10 µm

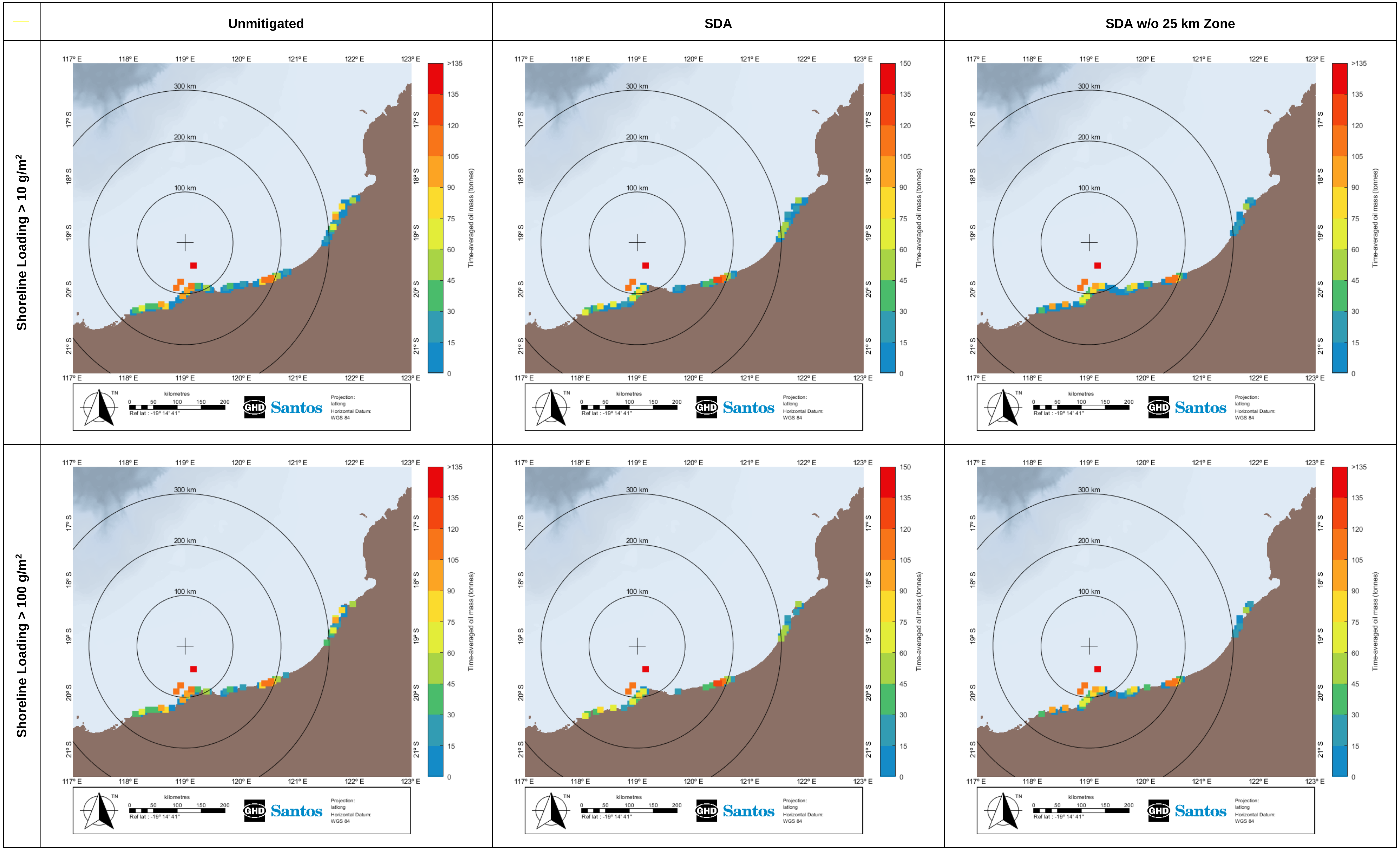


Figure 53 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) shoreline loading above 10 g/m² (top) and shoreline loading above 100 g/m² (bottom)

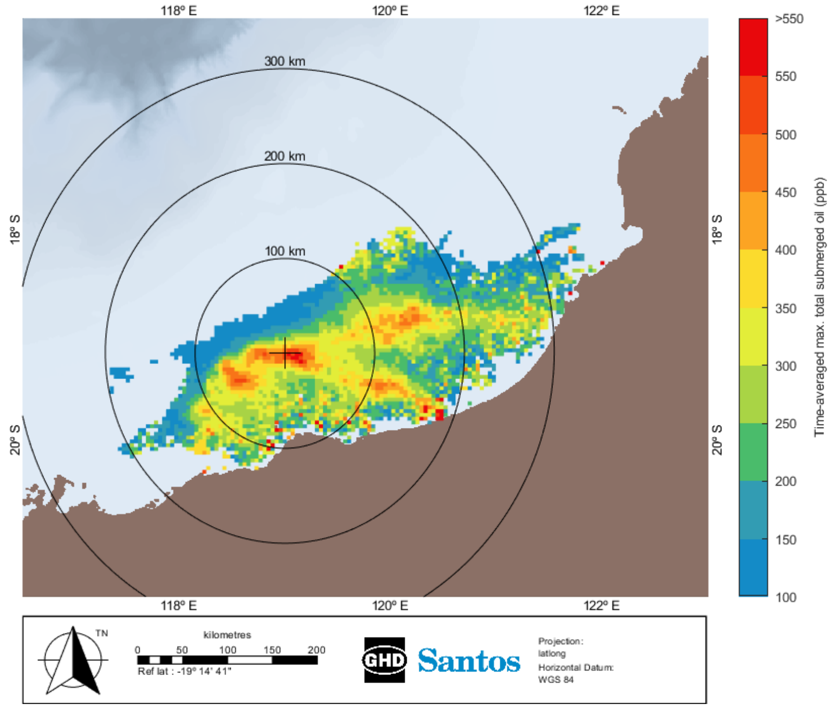
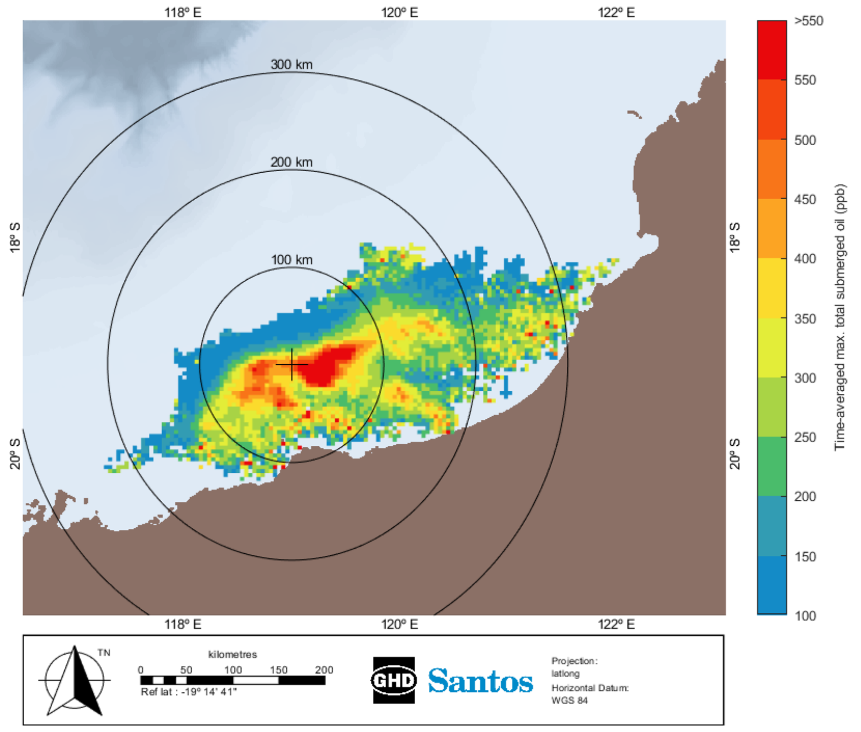
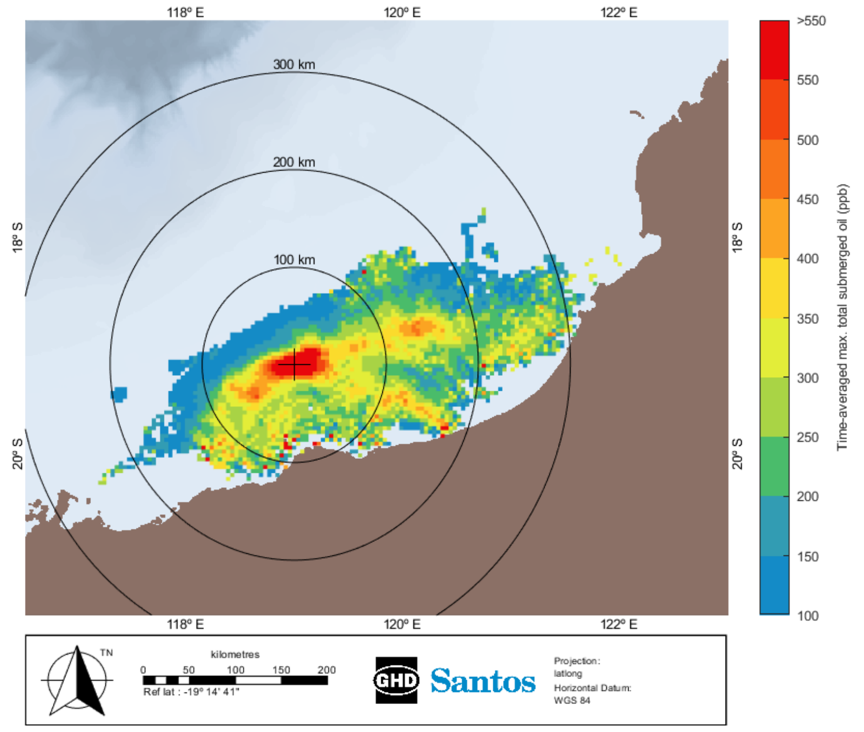
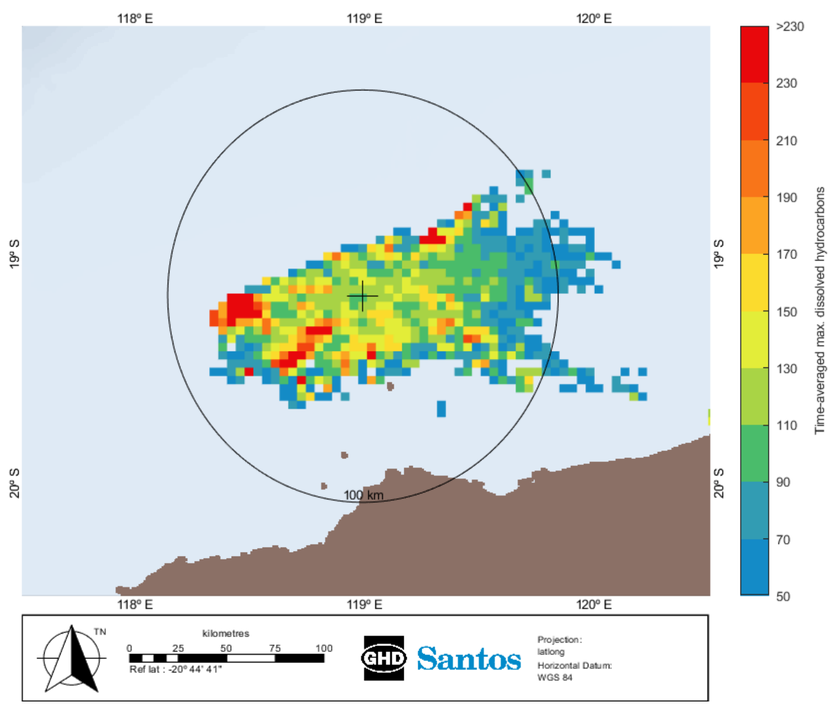
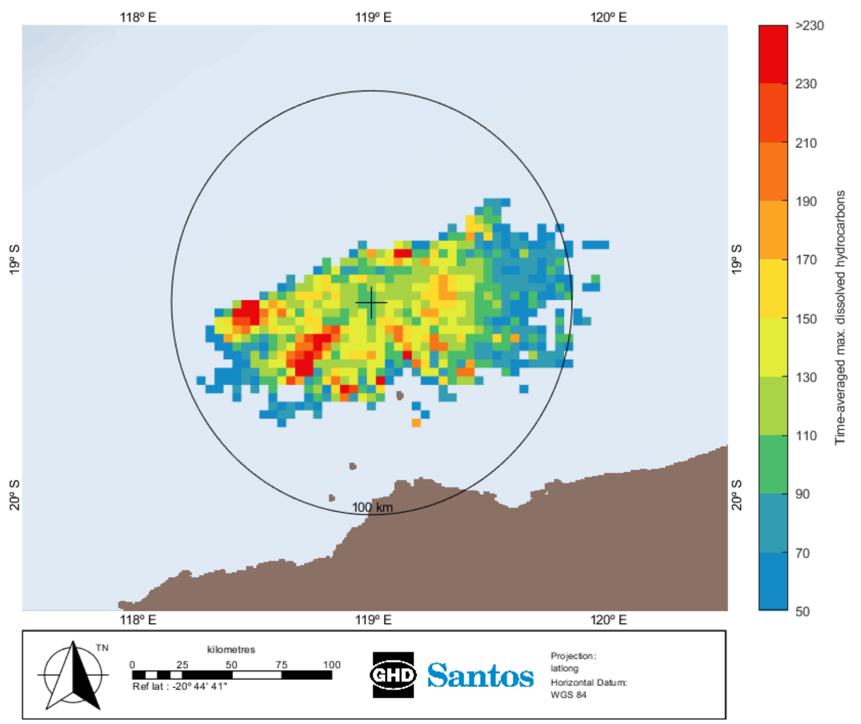
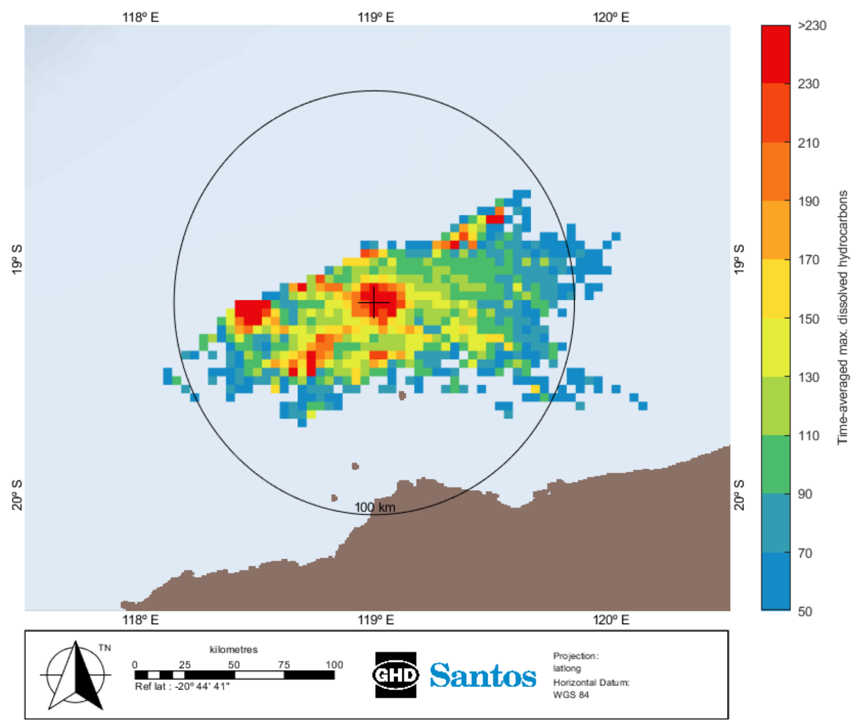
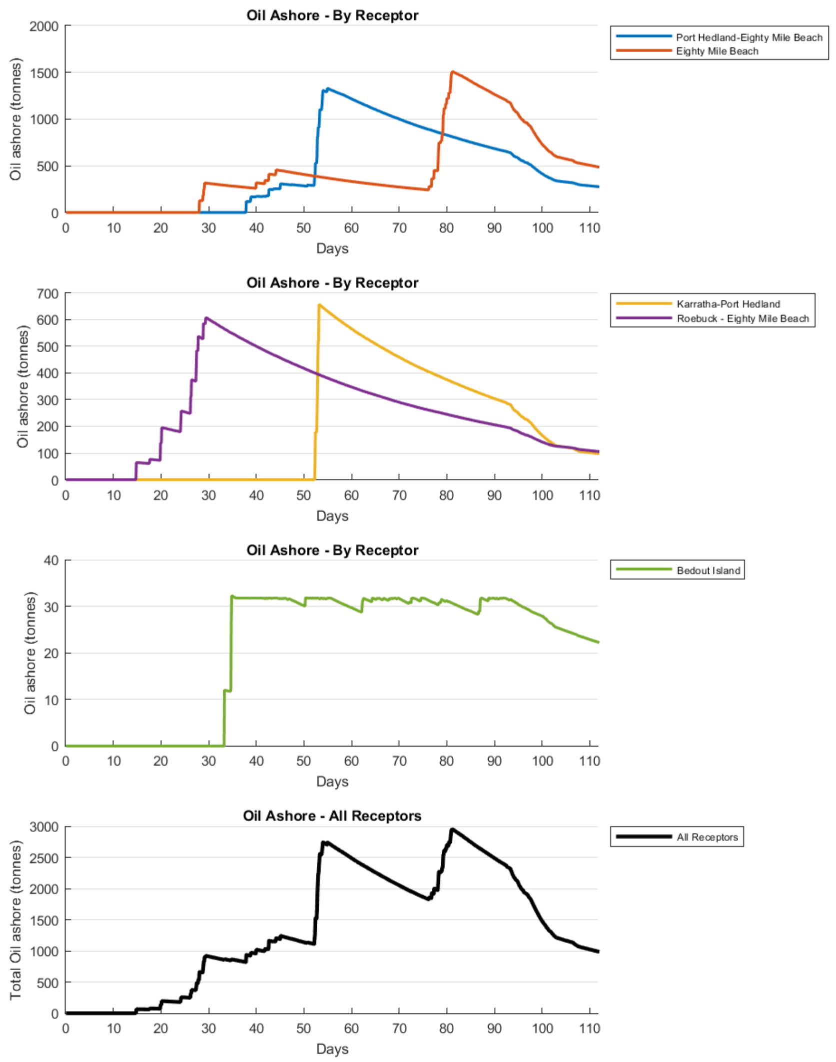
	Unmitigated	SDA	SDA w/o 25 km Zone
Maximum Total Submerged Oil > 100 ppb			
Maximum Dissolved Hydrocarbon > 50 ppb			

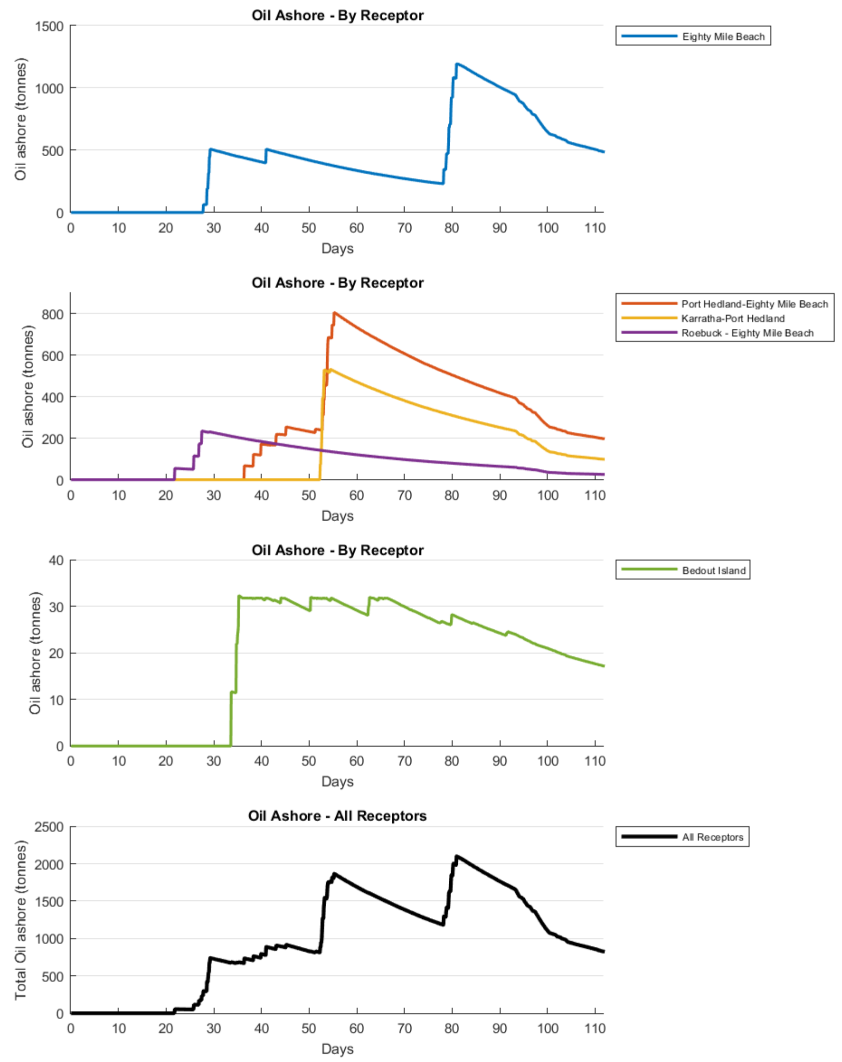
Figure 54 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) maximum total submerged oil greater than 10 ppb (top) and maximum dissolved hydrocarbon above 10 ppb (bottom)

Shoreline Loading Time-series

Unmitigated



SDA



SDA w/o 25 km Zone

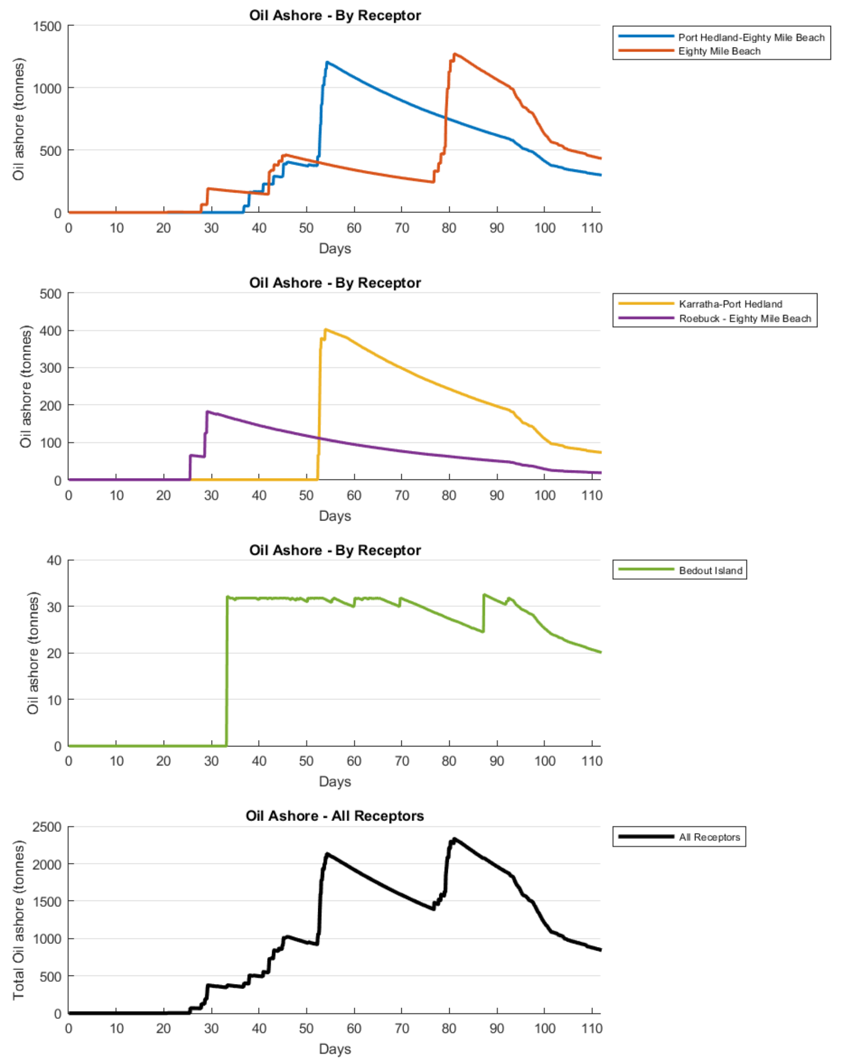


Figure 55 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) mitigated (right) time series of shoreline loading above 10 g/m^2

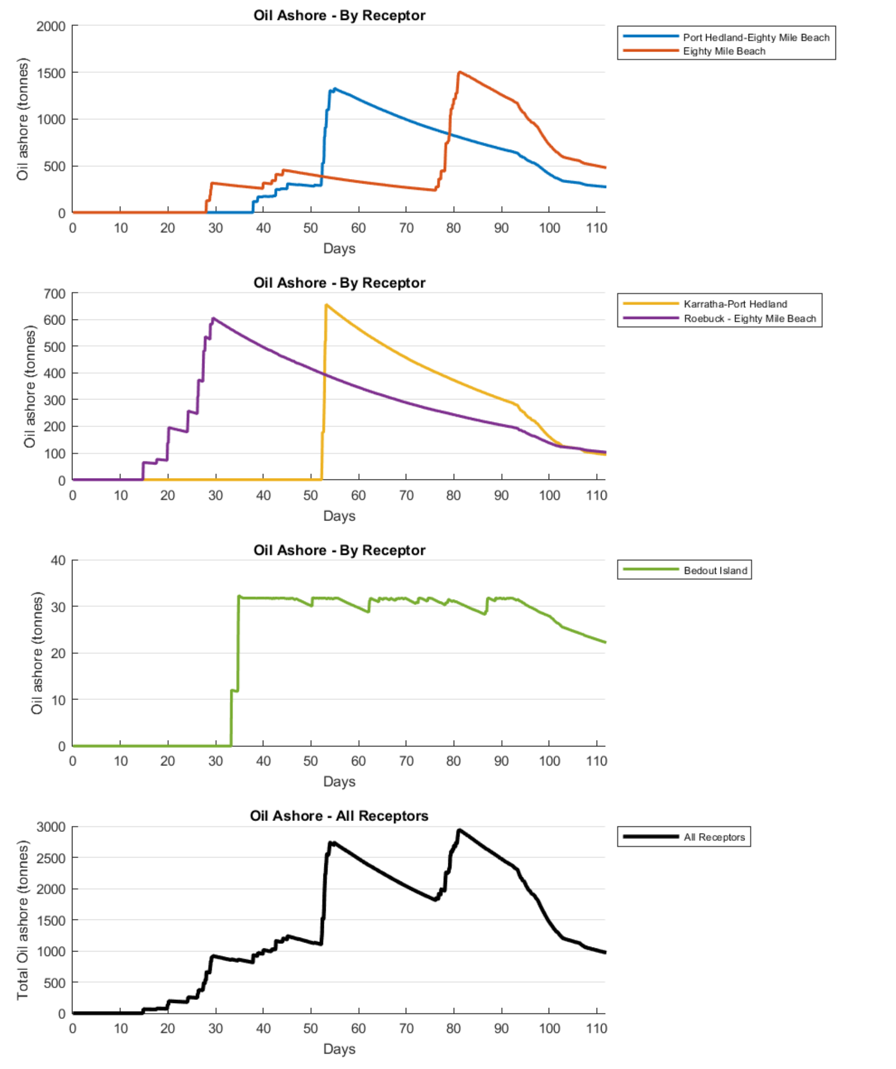
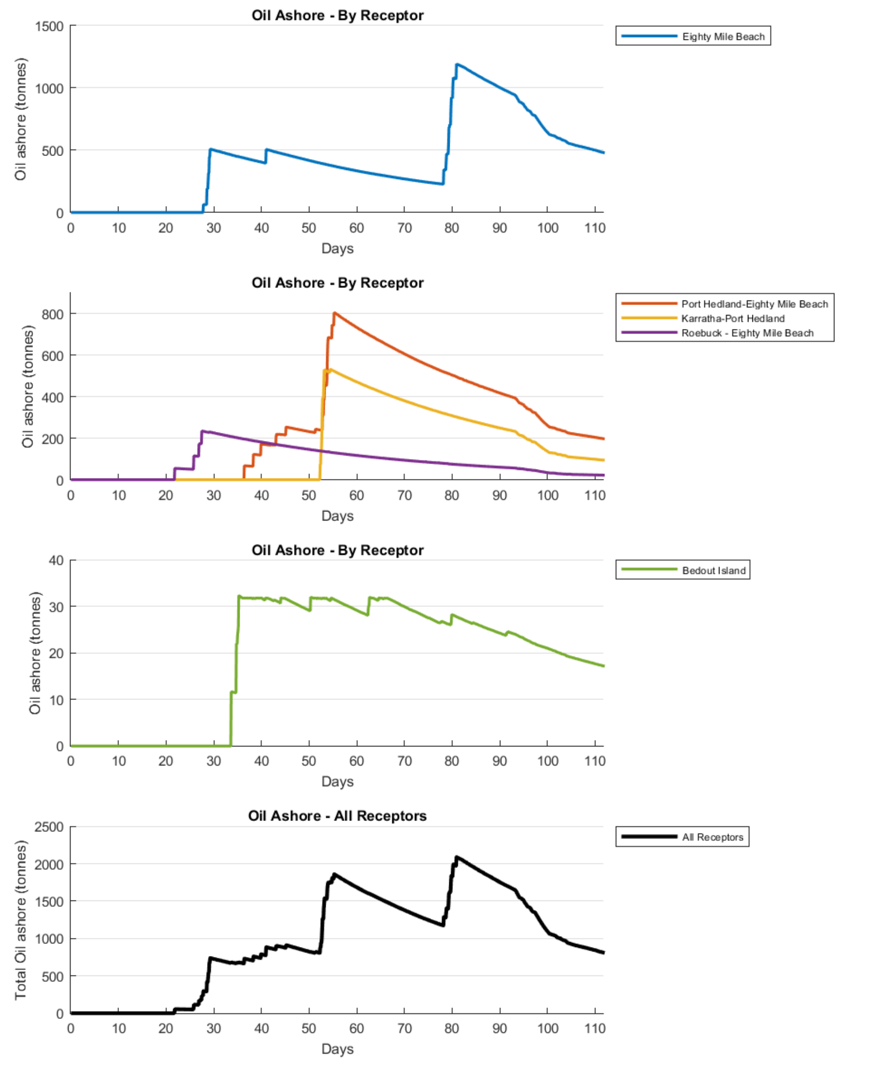
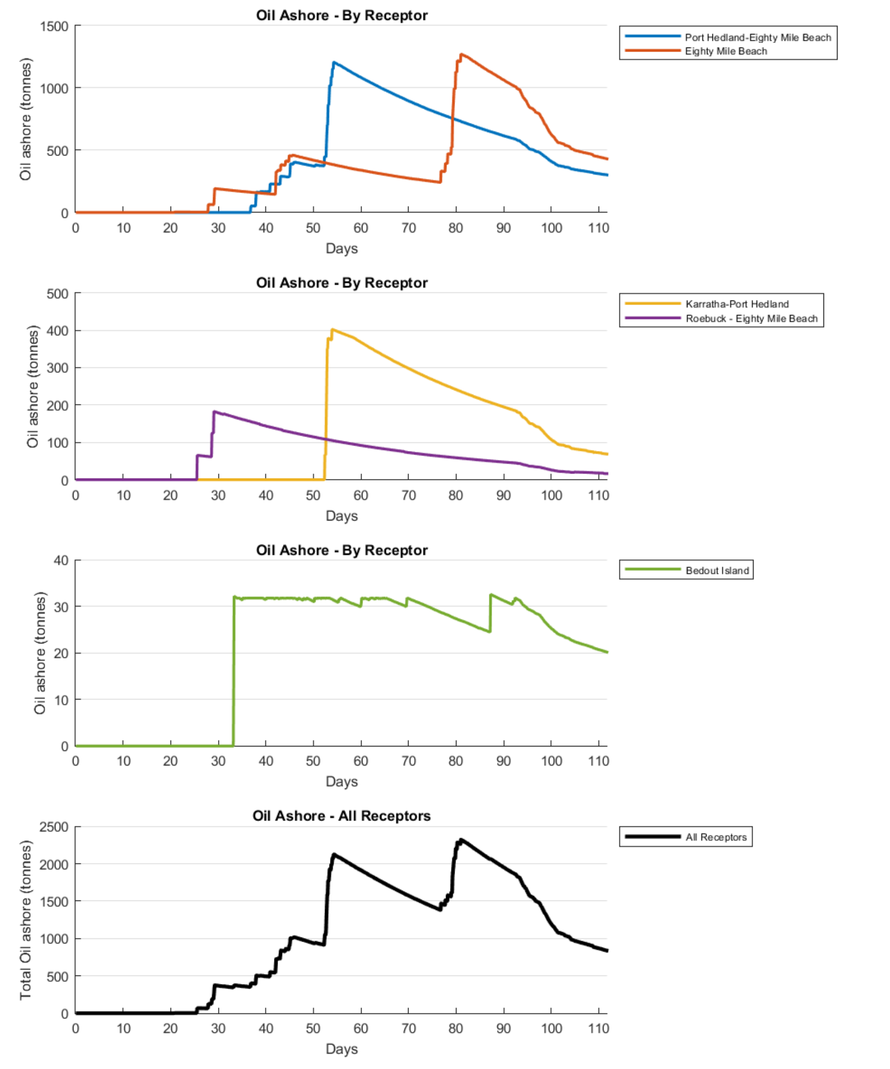
	Unmitigated	SDA	SDA w/o 25 km Zone
Shoreline Loading Time-series			

Figure 56 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) mitigated (right) time series of shoreline loading above 100 g/m²

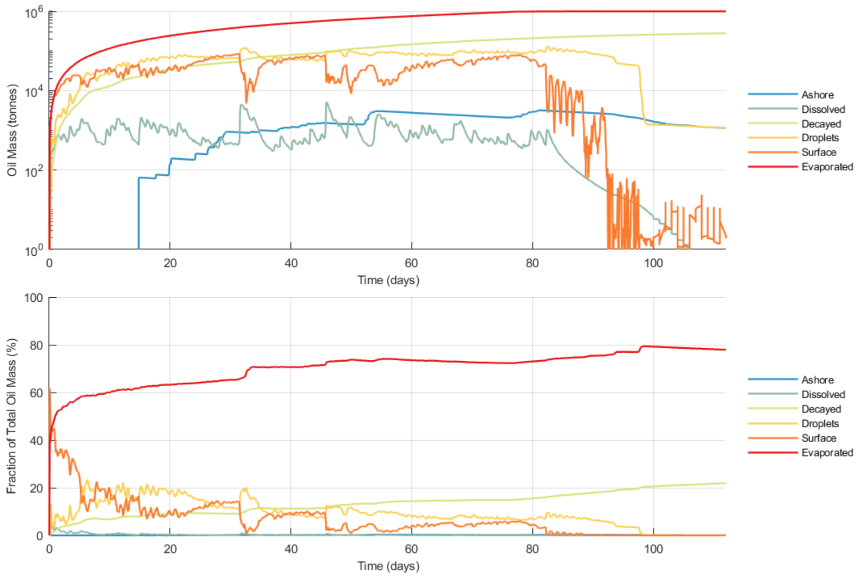
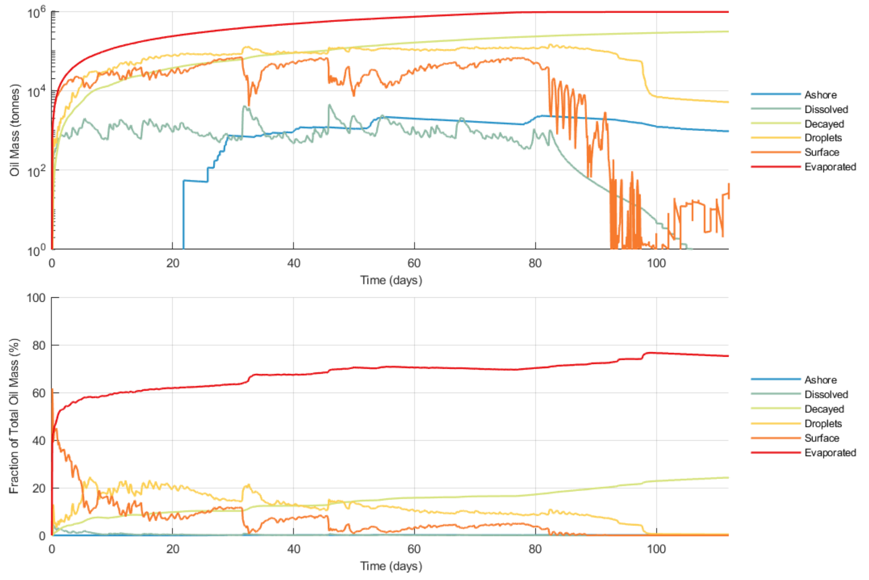
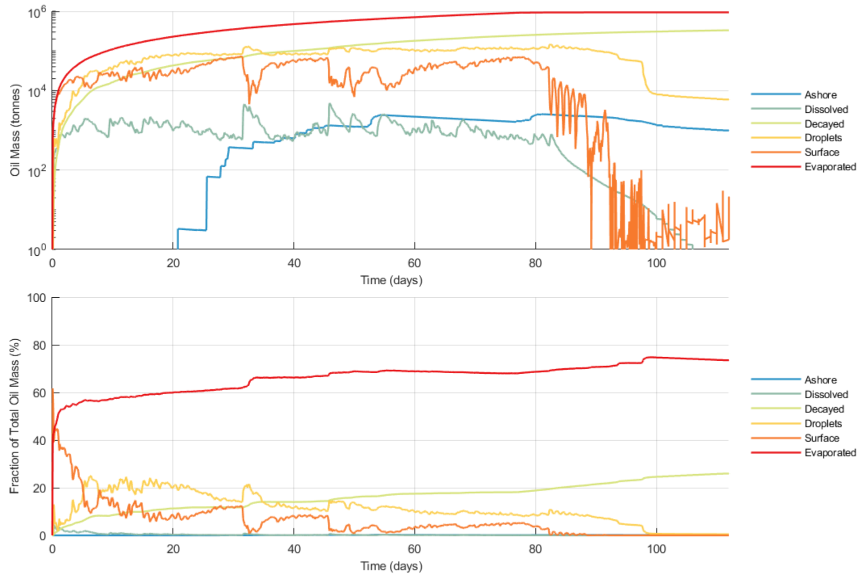
	Unmitigated	SDA	SDA w/o 25 km Zone
Hydrocarbon Mass Balance Time-series			

Figure 57 Apus Base Case Surface LOWC Scenario Realisation #31 – Comparison of unmitigated (left), SDA mitigated (middle) and SDA mitigated without 25km exlusion zone (right) hydrocarbon mass balance time series

4.2.5 Apus Base Case Surface LOWC Scenario #5

Stochastic realisation 5 of the Apus Base Case Surface LOWC scenario resulted in the earliest arrival time of shoreline accumulation above the low (10 g/m^2) and moderate (100 g/m^2) thresholds of 2 days (to Bedout Island).

The unmitigated simulation of this realisation resulted in a surface slick exceeding 10 µm thickness that extended up to ~500 km from the release location (Figure 58). Total submerged oil exceeding 100 ppb extended up to ~900 km, while dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~200 km from the release location (Figure 59). Shoreline loading greater than 10 and 100 g/m^2 extended up to ~900 km to the east of the release site (Figure 59).

Shoreline accumulation for this realisation above both thresholds (10 g/m^2 and 100 g/m^2) began during day 2 at Bedout Island, with significant shoreline loading events continuing at a range of shoreline receptors until day 106. A time-series of shoreline accumulation impacts during this realisation is presented in Figure 60 (for 10 g/m^2 and 100 g/m^2), while summarised shoreline loading predictions are displayed in Table 39 and Table 40 for 10 and 100 g/m^2, respectively. The following key shoreline impacts are predicted at the moderate threshold (100 g/m^2):

- Moderately high instantaneous peak loads of 140-317 tonnes were predicted at Port Hedland-Eighty Mile Beach, Dampier Archipelago, Montebello Islands, Barrow Island, Southern Islands Coast, Muiron Islands and Ningaloo Coast North. With the exception of Port Hedland-Eighty Mile Beach, which reached a peak load of 257 tones on day 4, the other locations received shoreline loading after day 60, with peak loading occurring between days 75-110.
- Lower, but significant peak shoreline loads were also predicted at Thevenard Islands (56 tonnes on day 106), Ningaloo Coast South (62 tonnes on day 110), Shark Bay – Coast Outer (17 tonnes on day 101) and Bedout Island (33 tonnes on day 2).
- Across all shorelines combined, a peak oil loading of 1,292 tonnes occurred during day 106, with a maximum oiled shoreline length of 496 km.

The predicted hydrocarbon weathering (i.e. mass balance partitioning) for the specific met-ocean conditions encountered during the deterministic simulation is presented in Figure 58, and summarised as follows:

- Evaporation is the primary weathering mechanism with evaporated oil accounting for ~75% of the total oil mass by day 90.
- Oil decay (i.e. biodegradation) accounts for an additional ~22% of the oil by the end of the simulation (day 112).
- Several large wind-driven entrainment events occurred throughout the simulation resulting in increases in the mass of entrained droplets that were concomitant with decreases in the mass of surface oil. For this surface discharge, entrained droplets typically accounted for ~10-20% of the total oil mass throughout the duration of the discharge (i.e. the first 77 days), while surface oil was typically 1-20% of all oil during this period.

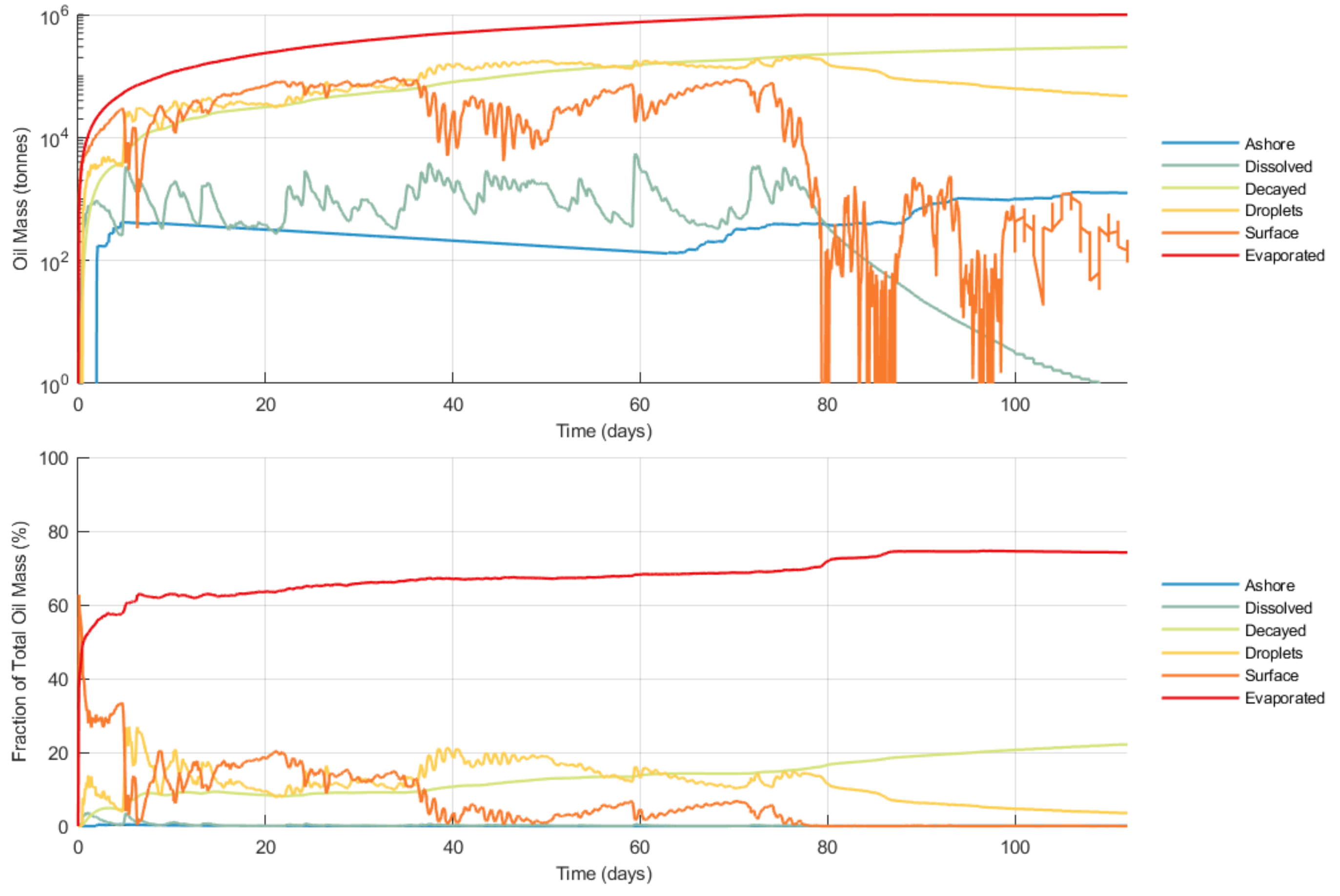
Table 39 Apus Base Case Surface LOWC Scenario Realisation #5 – Summary of unmitigated shoreline loading exceeding the moderate threshold (10 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)	Minimum Arrival Time (days)	Peak Loading Time (days)	Maximum Length of Oiled Shoreline (km)
Port Hedland-Eighty Mile Beach	257.9	3.0	4.6	62.5
Dampier Archipelago	140.3	64.8	75.1	62.5
Montebello Islands	198.5	63.0	101.1	22.7
Lowendal Islands	1.1	109.6	109.6	5.7
Barrow Island	186.3	64.1	105.6	79.6
Thevenard Islands	56.3	76.2	106.0	11.4
Southern Islands Coast	169.2	72.3	106.3	17.1
Muiron Islands	221.9	68.3	106.7	17.1
Ningaloo Coast North	319.6	77.1	110.5	199.0
Ningaloo Coast South	62.4	101.7	110.3	102.3
Shark Bay - Coast Outer	16.9	101.8	101.8	11.4
Bedout Island	32.8	2.0	2.1	1.1
All Shorelines	**1,292**	**2.0**	**106.3**	**563.9**

Table 40 Apus Base Case Surface LOWC Scenario Realisation #5 – Summary of unmitigated shoreline loading exceeding the moderate threshold (100 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)	Minimum Arrival Time (days)	Peak Loading Time (days)	Maximum Length of Oiled Shoreline (km)
Port Hedland-Eighty Mile Beach	257.2	3.0	4.6	28.4
Dampier Archipelago	140.3	64.8	75.1	56.9
Montebello Islands	198.5	63.0	101.1	22.7
Barrow Island	185.8	64.1	105.6	62.5
Thevenard Islands	56.3	90.1	106.0	11.4
Southern Islands Coast	168.9	72.3	106.3	11.4
Muiron Islands	221.9	68.3	106.7	17.1
Ningaloo Coast North	317.3	77.1	110.5	187.6
Ningaloo Coast South	62.4	101.7	110.3	102.3
Shark Bay - Coast Outer	16.9	101.8	101.8	11.4
Bedout Island	32.8	2.0	2.1	1.1
All Shorelines	**1,286**	**2.0**	**106.3**	**495.7**

Hydrocarbon Mass Balance Time Series	Surface Thickness > 10 µm



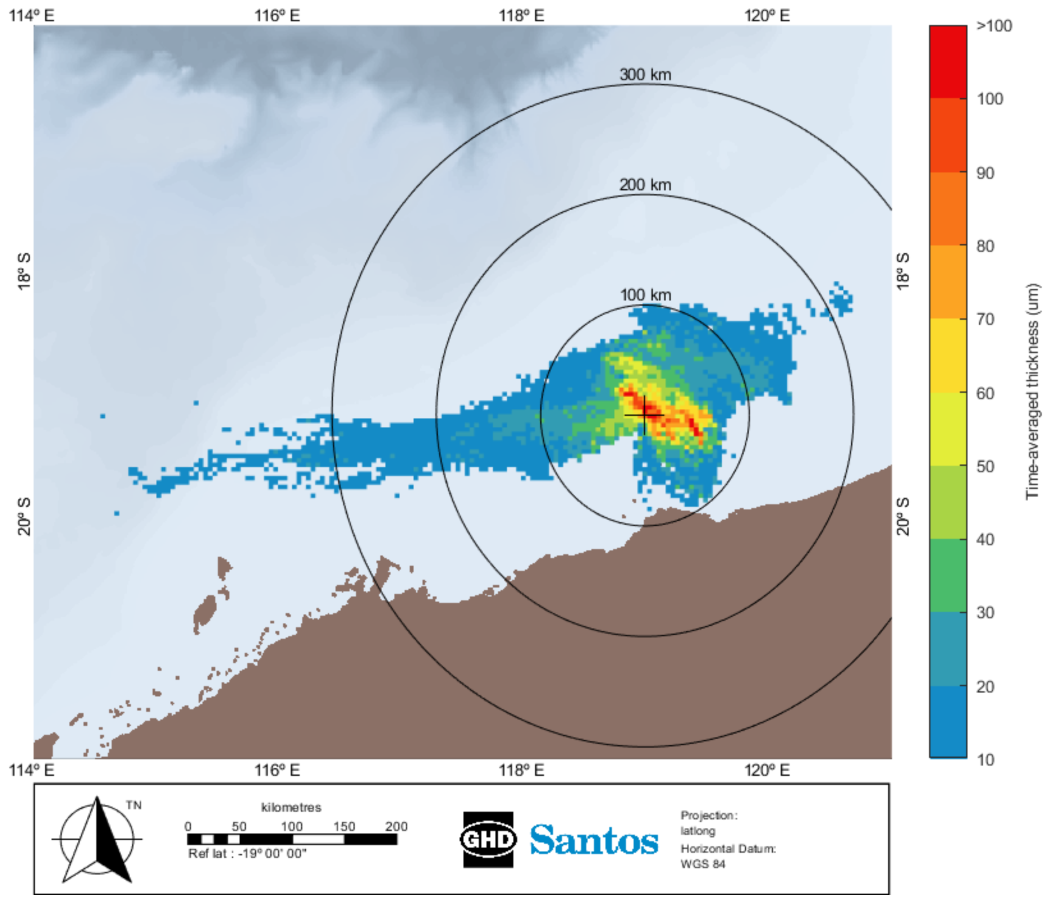
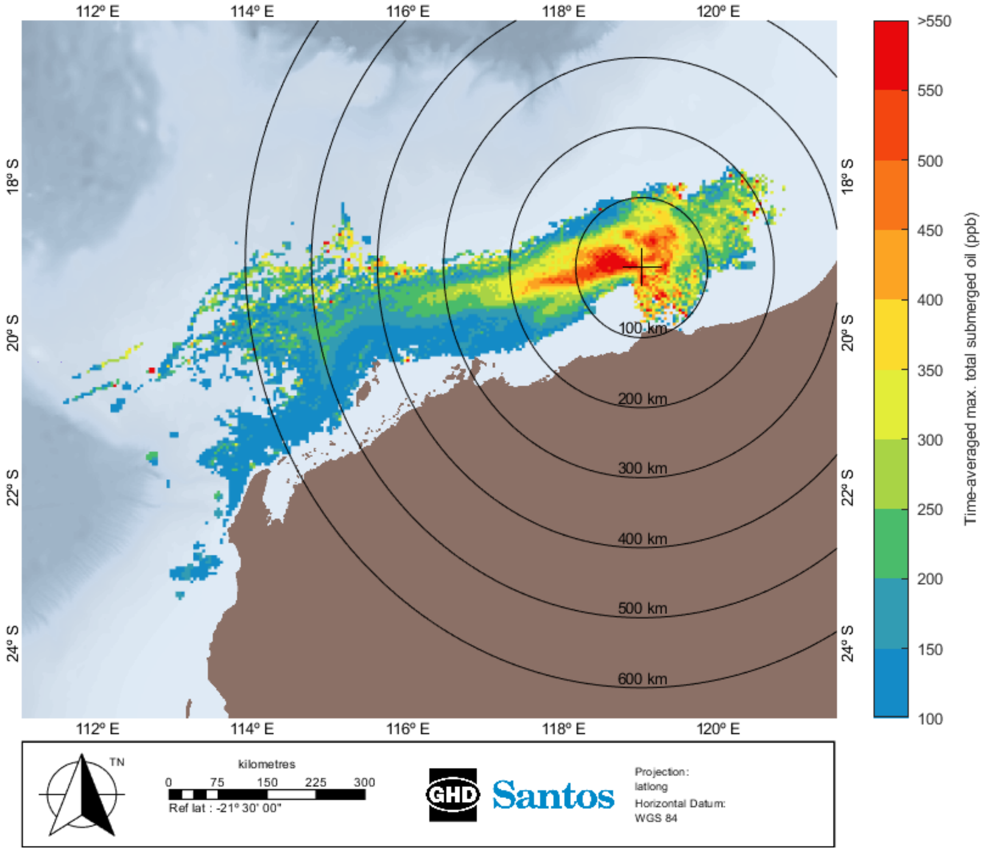
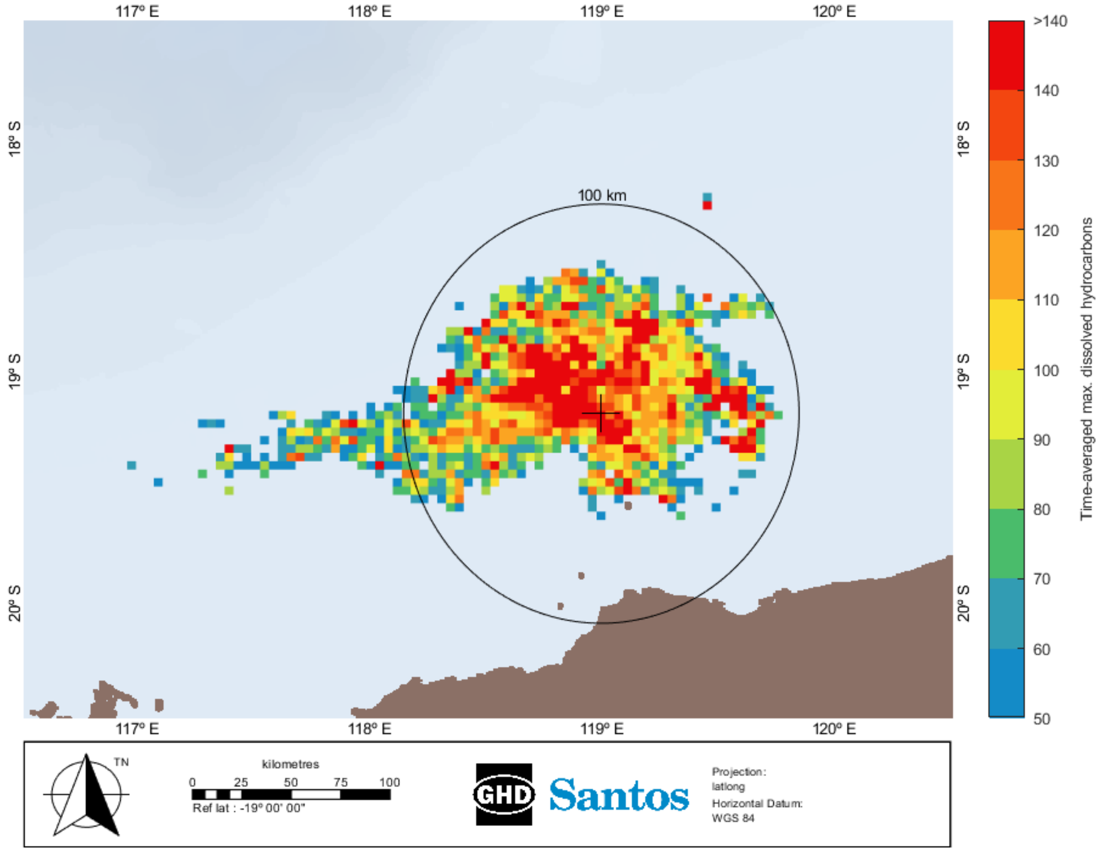


Figure 58 Apus Base Case Surface LOWC Scenario Realisation #5 – Hydrocarbon mass balance time series (left) and surface thicknesses of oil greater than 10 µm (right)

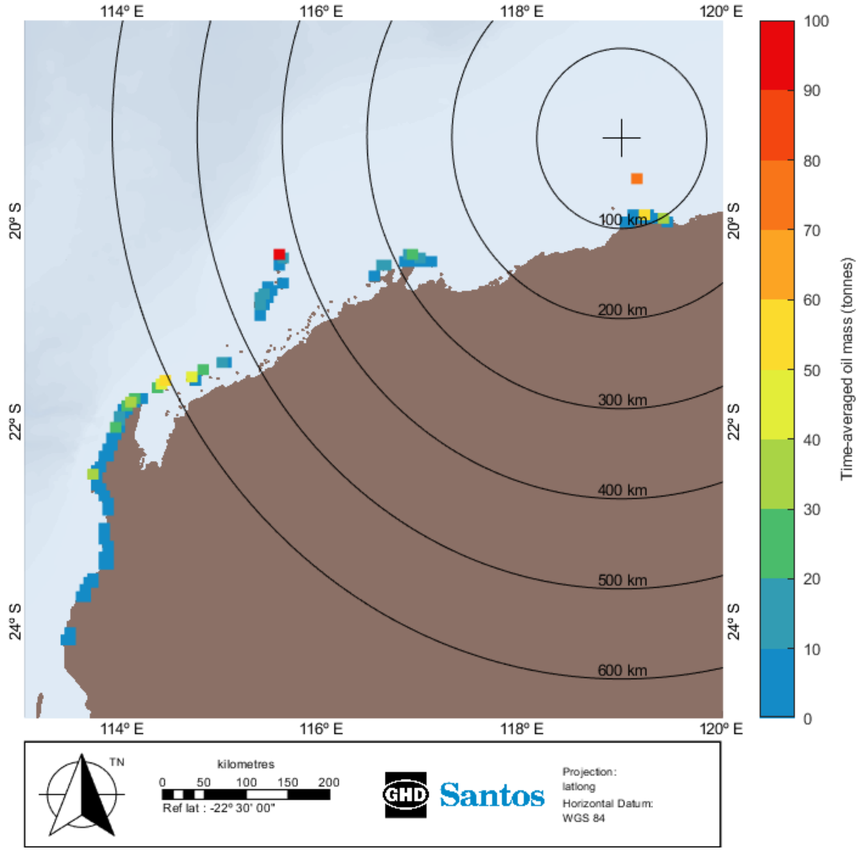
Maximum Total Submerged Oil > 100 ppb



Maximum Dissolved Hydrocarbon > 50 ppb



Shoreline Loading > 10 g/m²



Shoreline Loading > 100 g/m²

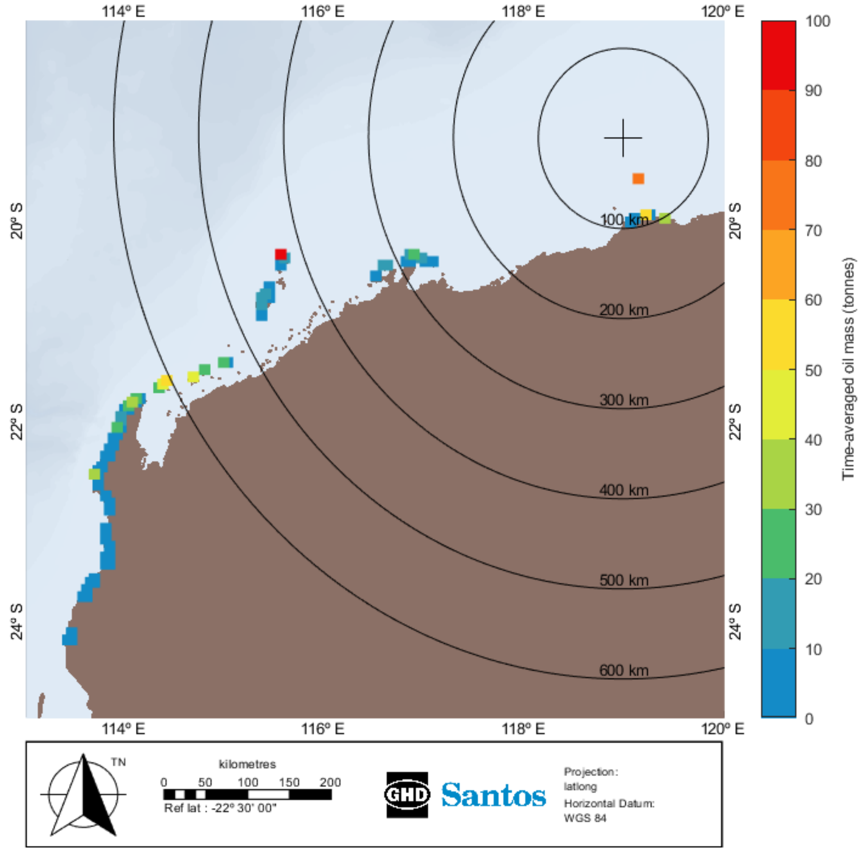


Figure 59 *Apus Base Case Surface LOWC Scenario Realisation #5 – Maximum total submerged oil greater than 100 ppb (top-left), maximum dissolved hydrocarbon greater than 50 ppb (top-right), shoreline loading above 10 g/m² (bottom-left) and shoreline loading above 100 g/m² (bottom-right)*

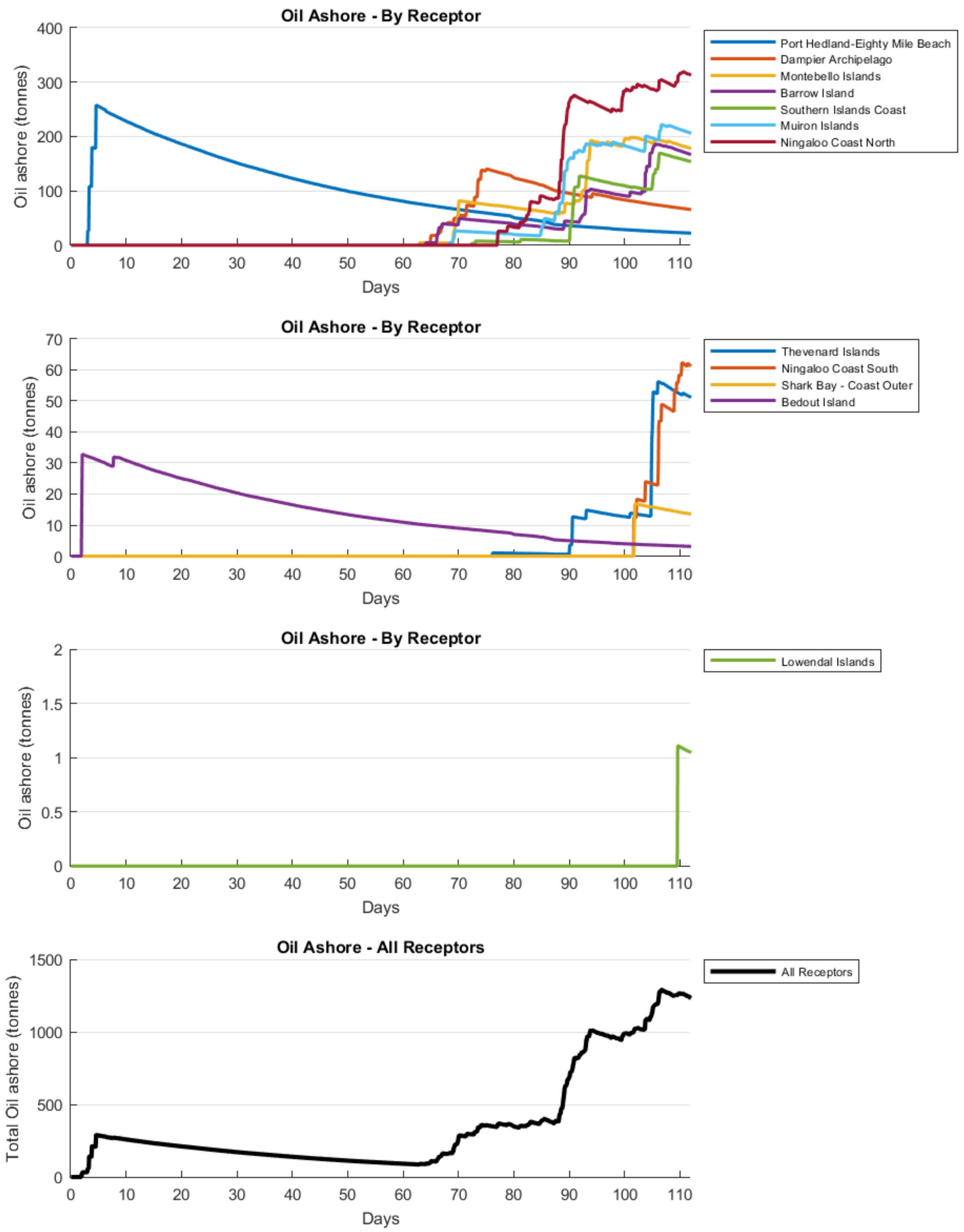
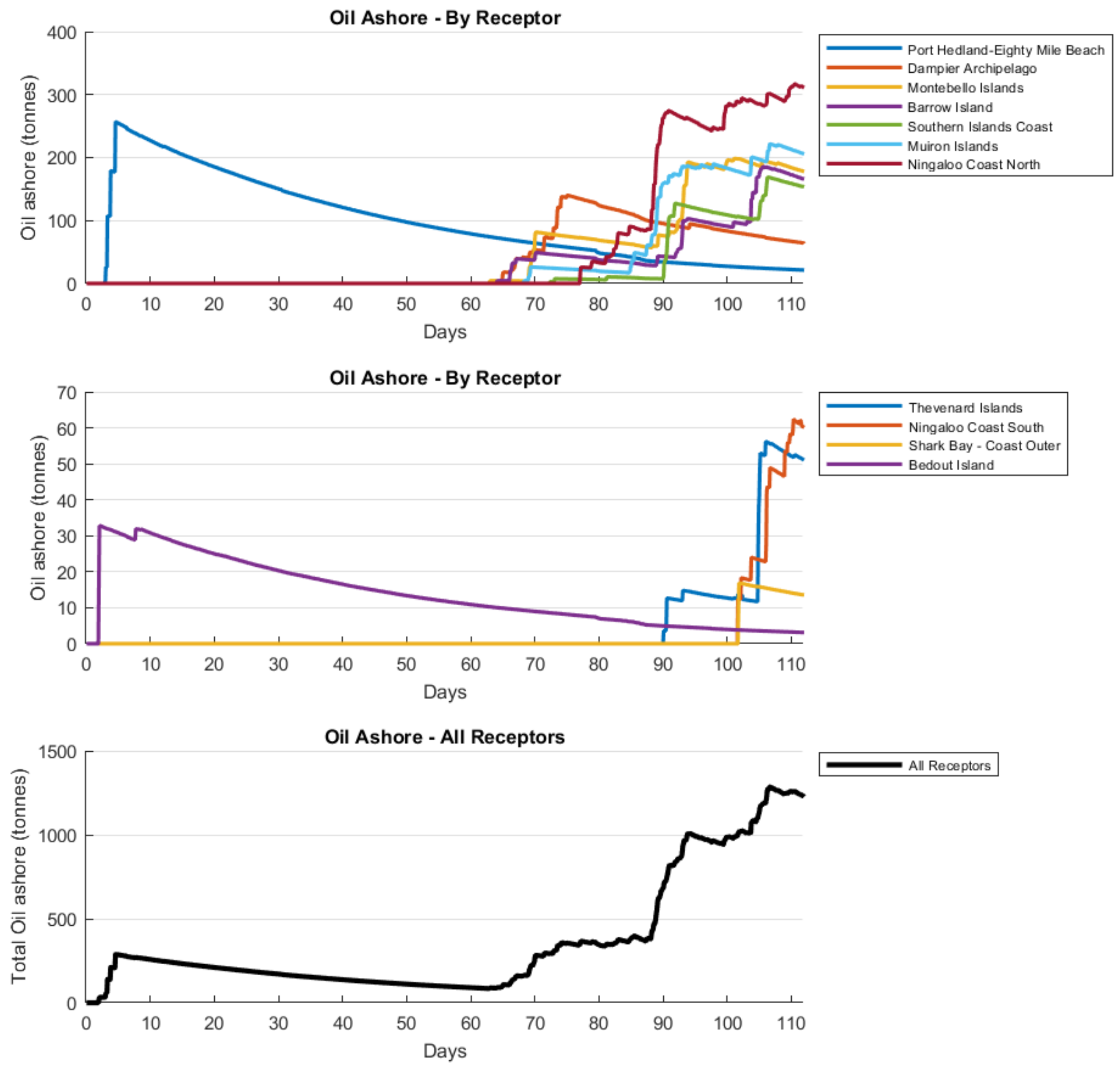
Time Series of Shoreline Loading Above 10 g/m^2	Time Series of Shoreline Loading Above 100 g/m^2
	

Figure 60 Apus Base Case Surface LOWC Scenario Realisation #5 – Time series of shoreline loading above 10 g/m^2 (left) and 100 g/m^2 (right)

4.2.6 Apus Base Case Surface LOWC Scenario #9

Stochastic realisation 9 of the Apus Base Case Surface LOWC scenario resulted in the maximum length of shoreline with accumulated oil above the low (10 g/m^2) threshold of 523 km, while also producing the maximum length for accumulated oil above the moderate (100 g/m^2) threshold of 500 km.

The unmitigated simulation of this realisation resulted in a surface slick exceeding 10 µm thickness that extended up to ~500 km from the release location (Figure 61). Total submerged oil exceeding 100 ppb extended up to ~850 km, while dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~200 km from the release location (Figure 62). Shoreline loading greater than 10 and 100 g/m^2 extended up to ~700 km to the east of the release site (Figure 62).

Shoreline accumulation for this realisation above both thresholds (10 g/m^2 and 100 g/m^2) began during day 28 at Dampier Archipelago, with significant shoreline loading events continuing at a range of shoreline receptors until day 89. A time-series of shoreline accumulation impacts during this realisation is presented in Figure 63 (for 10 g/m^2 and 100 g/m^2), while summarised shoreline loading predictions are displayed in Table 41 and Table 42 for 10 and 100 g/m^2, respectively. The following key shoreline impacts are predicted at the moderate threshold (100 g/m^2):

– Moderately high instantaneous peak loads of 190-443 tonnes were predicted at Dampier Archipelago, Montebello Islands, Barrow Island, Southern Islands Coast, Muiron Islands and Ningaloo Coast North. Shoreline loading events at these receptors generally occurred between days 28 to 89.
– Lower, but significant peak shoreline loads were also predicted at Northern Islands Coast (35 tonnes on day 64), Lowendal Islands (27 tonnes on day 62), Middle Islands Coast (3 tonnes on day 60), Thevenard Islands (67 tonnes on day 66), Ningaloo Coast South (21 tonnes on day 93) and Shark Bay – Coast Outer (13 tonnes on day 103).
– Across all shorelines combined, a peak oil loading of 1,790 tonnes occurred during day 89, with a maximum oiled shoreline length of 449 km.

Notably for this simulation, the deterministic predictions of oiled shoreline lengths at 10 g/m^2 (591 km) and 100 g/m^2 (449 km) are longer and shorter, respectively, than the stochastic outcomes of 523 km (10 g/m^2) and 500 km (100 g/m^2). As outlined in section 4.2.2, the increased length for the low threshold (10 g/m^2) is due to the inclusion of shoreline washing in the deterministic simulation which remobilises portions of stranded oil, allowing shoreline stranding to occur across longer stretches of shoreline. The reduction for the moderate threshold (100 g/m^2) is due to the weathering processes that occur on stranded oil in the deterministic simulation (that aren't accounted for by the stochastic 'accumulated' statistic), that cause several model cells to no longer exceed the threshold, thereby reducing the length of contacted shoreline reported for the threshold.

The predicted hydrocarbon weathering (i.e. mass balance partitioning) for the specific met-ocean conditions encountered during the deterministic simulation is presented in Figure 61, and summarised as follows:

– Evaporation is the primary weathering mechanism with evaporated oil accounting for ~75% of the total oil mass by day 90.
– Oil decay (i.e. biodegradation) accounts for an additional ~22% of the oil by the end of the simulation (day 112).
– Several large wind-driven entrainment events occurred throughout the simulation resulting in increases in the mass of entrained droplets that were concomitant with decreases in the mass of surface oil. For this surface discharge, entrained droplets typically accounted for ~10-20% of the total oil mass throughout the duration of the discharge (i.e. the first 77 days), while surface oil was typically 1-20% of all oil during this period.

Table 41 Apus Base Case Surface LOWC Scenario Realisation #9 – Summary of unmitigated shoreline loading exceeding the moderate threshold (10 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)	Minimum Arrival Time (days)	Peak Loading Time (days)	Maximum Length of Oiled Shoreline (km)
Dampier Archipelago	299.6	28.0	91.6	79.6
Northern Islands Coast	34.5	61.9	64.8	11.4
Montebello Islands	443.2	31.6	89.9	22.7
Lowendal Islands	27.3	56.0	62.3	5.7
Barrow Island	331.6	46.3	89.3	85.3
Middle Islands Coast	3.0	60.0	60.3	5.7
Thevenard Islands	66.9	46.0	66.3	11.4
Southern Islands Coast	190.8	36.4	85.1	17.1
Muiron Islands	283.4	39.8	60.8	17.1
Exmouth Gulf Coast	0.4	59.2	104.7	11.4
Ningaloo Coast North	409.8	34.8	60.9	238.8
Ningaloo Coast South	20.7	63.7	93.1	45.5
Shark Bay - Coast Outer	13.7	74.3	103.6	34.1
Abrolhos Islands Pelsaert Group	0.5	83.3	83.3	5.7
All Shorelines	**1,803**	**28.0**	**89.9**	**591.3**

Table 42 Apus Base Case Surface LOWC Scenario Realisation #9 – Summary of unmitigated shoreline loading exceeding the moderate threshold (100 g/m²)

Receptor Name	Peak Mass of Oil Ashore (tonnes)	Minimum Arrival Time (days)	Peak Loading Time (days)	Maximum Length of Oiled Shoreline (km)
Dampier Archipelago	298.6	28.0	91.6	51.2
Northern Islands Coast	34.5	61.9	64.8	11.4
Montebello Islands	443.2	31.6	89.9	22.7
Lowendal Islands	27.3	61.1	62.3	5.7
Barrow Island	329.7	46.3	89.3	62.5
Middle Islands Coast	3.0	60.0	60.3	5.7
Thevenard Islands	66.9	46.0	66.3	11.4
Southern Islands Coast	190.8	36.4	85.1	17.1
Muiron Islands	283.4	39.8	60.8	17.1
Ningaloo Coast North	408.6	34.8	60.9	204.7
Ningaloo Coast South	20.7	63.7	93.1	45.5
Shark Bay - Coast Outer	12.6	74.3	103.6	22.7
All Shorelines	**1,790**	**28.0**	**89.9**	**449.1**

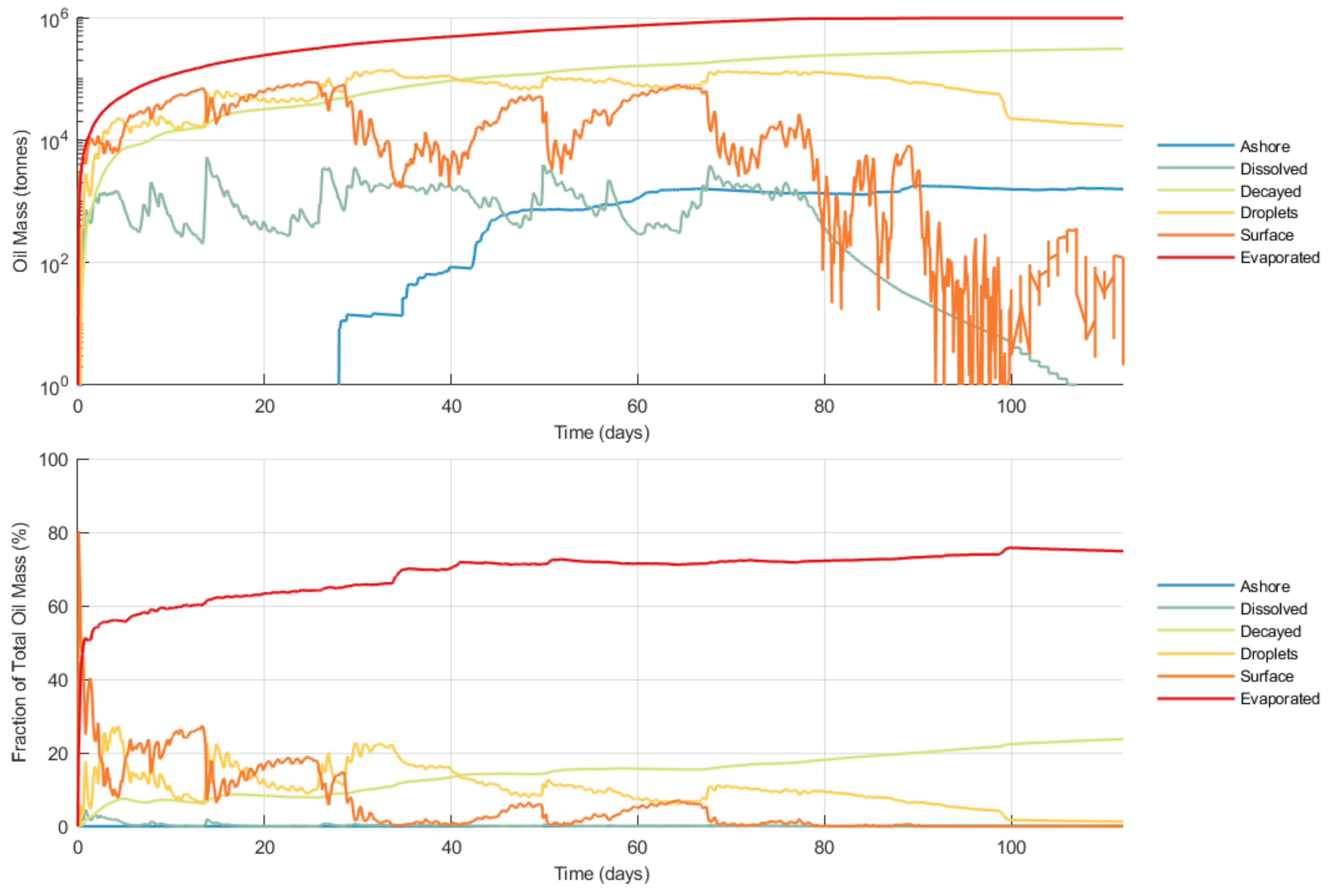
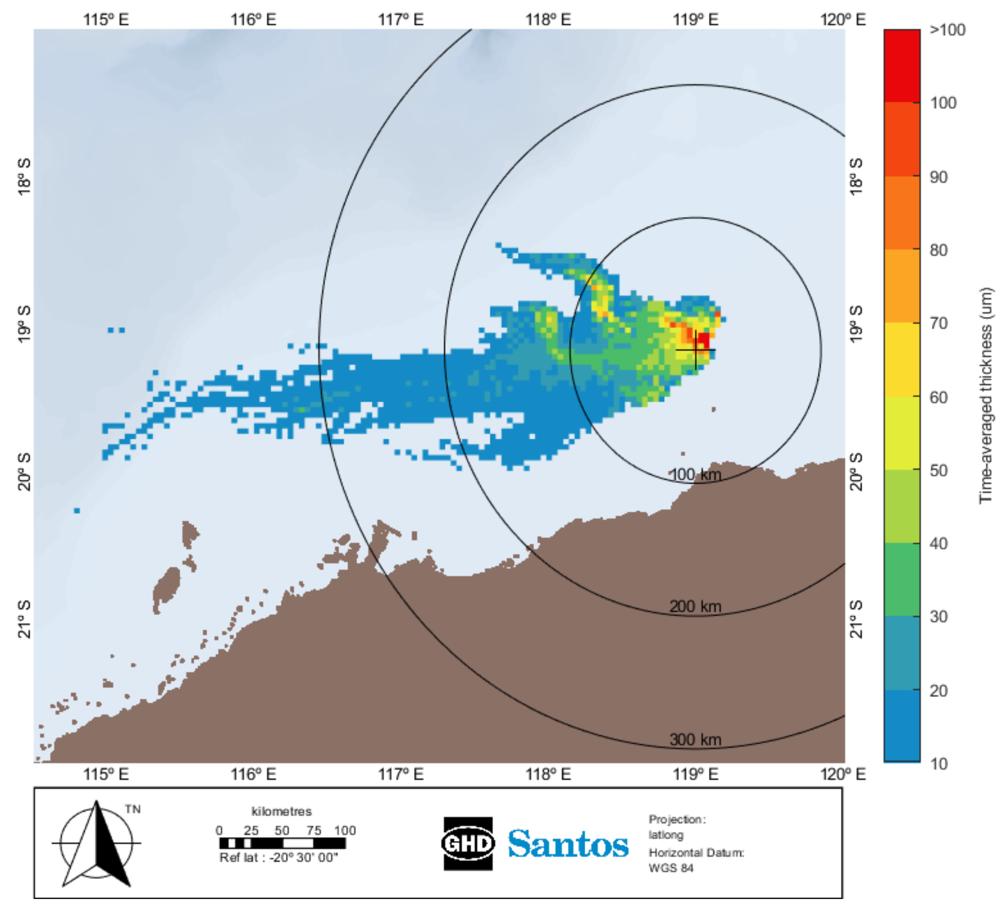
Hydrocarbon Mass Balance Time Series	Surface Thickness > 10 µm
	

Figure 61 *Apus Base Case Surface LOWC Scenario Realisation #9 – Hydrocarbon mass balance time series (left) and surface thicknesses of oil greater than 10 µm (right)*

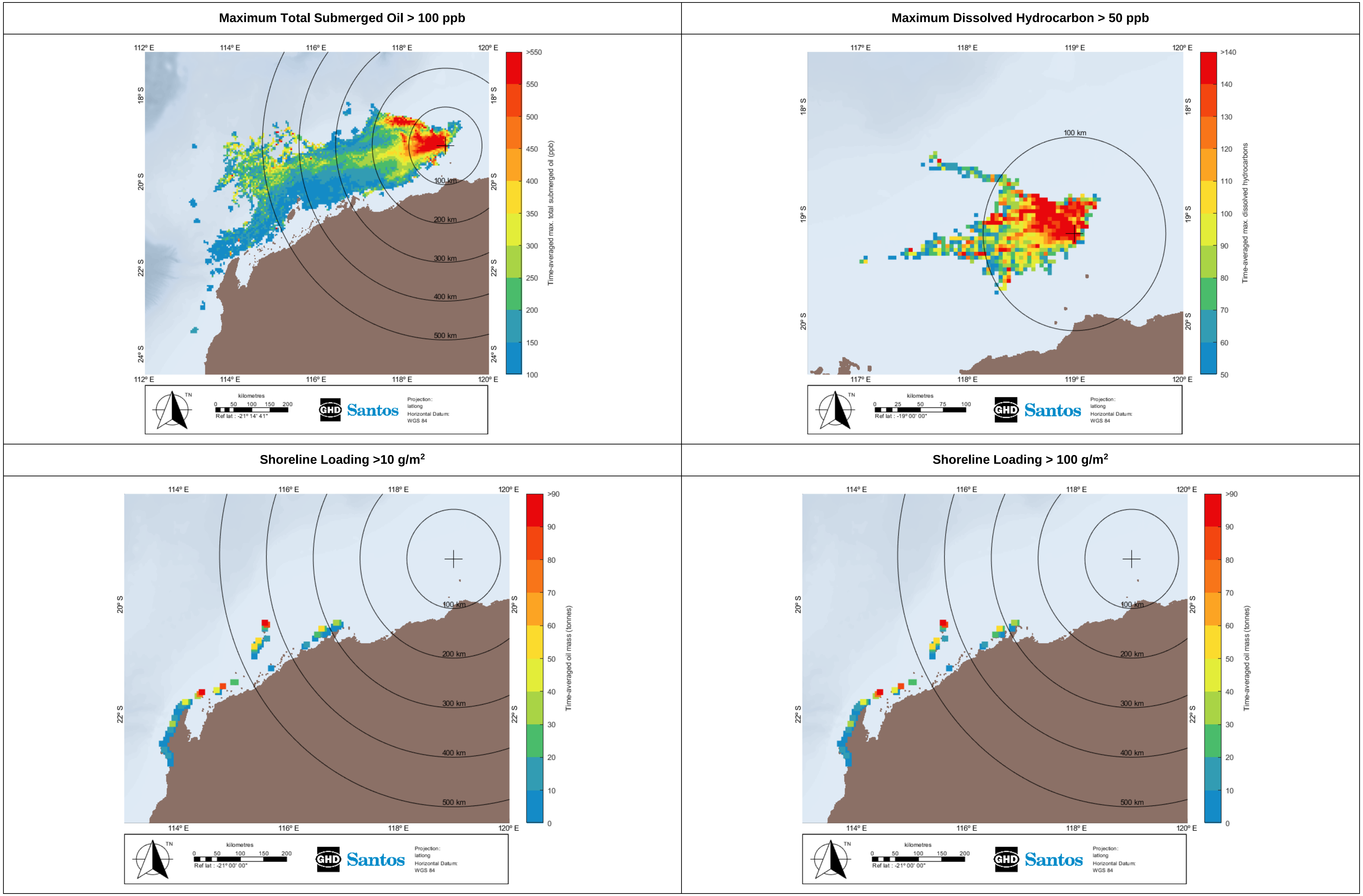
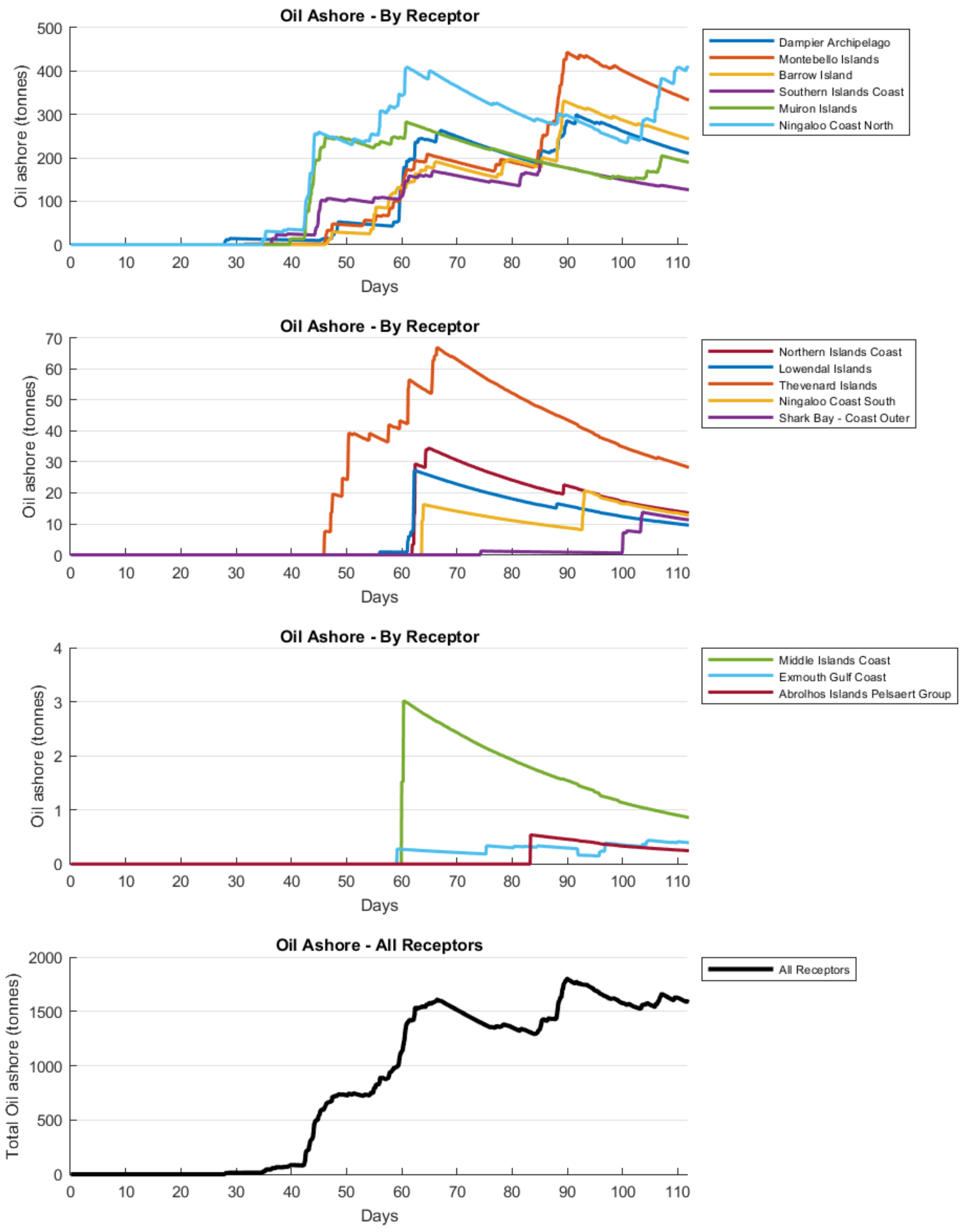


Figure 62 Apus Base Case Surface LOWC Scenario Realisation #9 – Maximum total submerged oil greater than 100 ppb (top-left), maximum dissolved hydrocarbon greater than 50 ppb (top-right), shoreline loading above 10 g/m² (bottom-left) and shoreline loading above 100 g/m²(bottom-right)

Time Series of Shoreline Loading Above 10 g/m^2	Time Series of Shoreline Loading Above 100 g/m^2



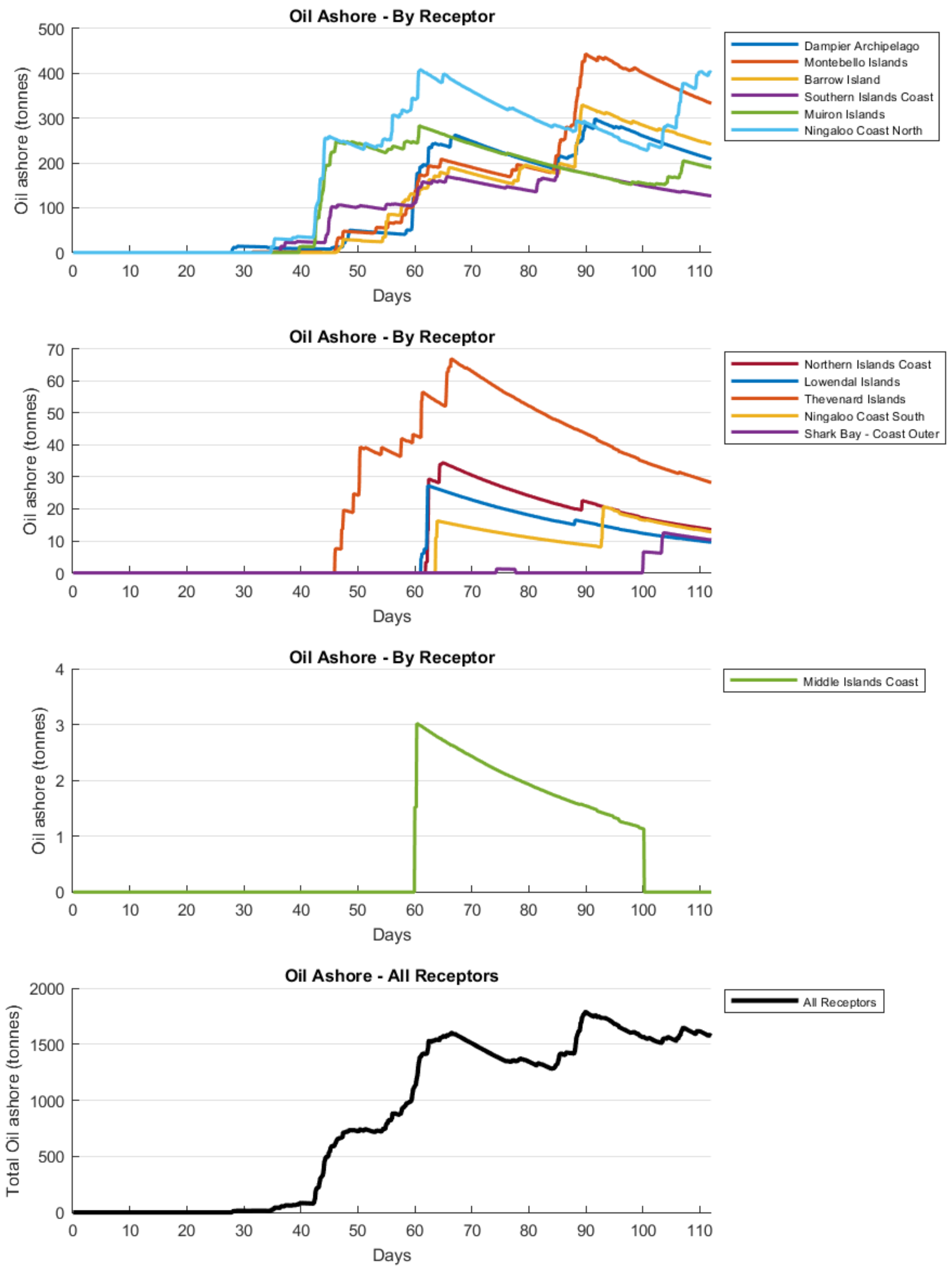


Figure 63 Apus Base Case Surface LOWC Scenario Realisation #9 – Time series of shoreline loading above 10 g/m^2 (left) and 100 g/m^2 (right)

4.2.7 Apus Base Case Surface LOWC Scenario #101

Stochastic realisation 101 of the Apus Base Case Surface LOWC scenario resulted in the highest mass of surface oil exceeding the high (response) threshold (50 g/m^2).

The unmitigated simulation of this realisation resulted in a surface slick exceeding 10 µm thickness that extended up to ~400 km from the release location, while the portion of the slick that exceeded 50 µm occurred up to ~150 km from the release location (Figure 66). Total submerged oil exceeding 100 ppb extended up to ~500 km, while dissolved hydrocarbons exceeding 50 ppb were limited in spatial extent to within ~125 km from the release location (Figure 66). Shoreline loading greater than 100 g/m^2 extended up to ~400 km to the east of the release site (Figure 62).

The mass of surface oil exceeding 50 µm thickness remains high throughout the initial 77 days of the simulation while oil is being released (Figure 65). The surface oil mass at the high threshold reaches 60,000 tonnes during day 9, and generally remains between 30,000 and 90,000 tonnes until day 72. A peak surface oil mass of 89,700 tonnes occurred during day 71. This indicates the maximum instantaneous mass of surface oil that could potentially by targeted by mitigative actions such as surface dispersant application or containment and recovery, and can be used to inform peak resource requirements for these responses.

Shoreline accumulation for this realisation above the moderate threshold (100 g/m^2) began during day 29 at Dampier Archipelago, with significant shoreline loading events continuing at a range of shoreline receptors until day 108. A time-series of shoreline accumulation impacts during this realisation is presented in Figure 67, while summarised shoreline loading predictions are displayed in Table 43. The following key shoreline impacts are predicted at the moderate threshold (100 g/m^2):

- A moderately high instantaneous peak load of 190 tonnes was predicted at Dampier Archipelago on day 108.
- Lower, but significant peak shoreline loads were also predicted at Imperieuse Reef (11 tonnes on day 98), Montebello Islands (9 tonnes on day 109) and Bedout Island (30 tonnes on day 83).
- Across all shorelines combined, a peak oil loading of 225 tonnes occurred during day 108, with a maximum oiled shoreline length of 92 km.

The predicted hydrocarbon weathering (i.e. mass balance partitioning) for the specific met-ocean conditions encountered during the deterministic simulation is presented in Figure 61, and summarised as follows:

- Evaporation is the primary weathering mechanism with evaporated oil accounting for ~80% of the total oil mass by the end of the simulation (day 112).
- Oil decay (i.e. biodegradation) accounts for the remaining ~20% of the oil by the end of the simulation (day 112).
- The surface slick for this scenario is relatively persistent, though several small wind-driven entrainment events occurred throughout the simulation resulting in increases in the mass of entrained droplets that were concomitant with decreases in the mass of surface oil. For this surface discharge, entrained droplets typically accounted for ~0-20% of the total oil mass throughout the duration of the discharge (i.e. the first 77 days), while surface oil was typically ~0-40% of all oil during this period, and was consistently 10-40% of the oil during the first 50 days.

Table 43 *Apus Base Case Surface LOWC Scenario Realisation #101 – Summary of unmitigated shoreline loading exceeding the moderate threshold (100 g/m²)*

Receptor Name	Peak Mass of Oil Ashore (tonnes)	Minimum Arrival Time (days)	Peak Loading Time (days)	Maximum Length of Oiled Shoreline (km)
Imperieuse Reef MP	11.2	98.1	98.3	11.4
Dampier Archipelago	189.5	87.0	108.1	68.2
Montebello Islands	9.2	99.7	109.0	11.4
Bedout Island	29.7	29.6	83.0	1.1
All Shorelines	**225.3**	**29.6**	**108.1**	**92.0**

Figure 64 *Apus Base Case Surface LOWC Scenario Realisation #101 – Hydrocarbon mass balance time series*

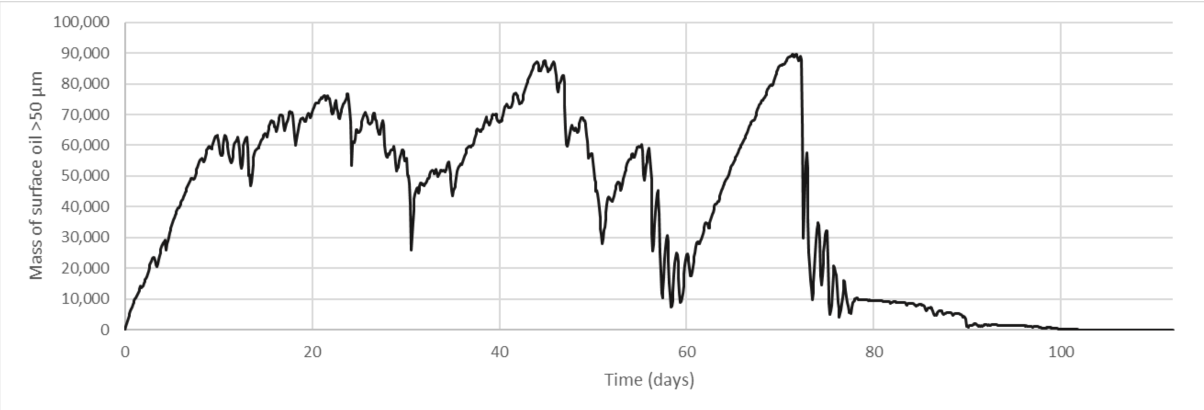


Figure 65 *Apus Base Case Surface LOWC Scenario Realisation #101 – Time series of surface oil mass >50 µm*

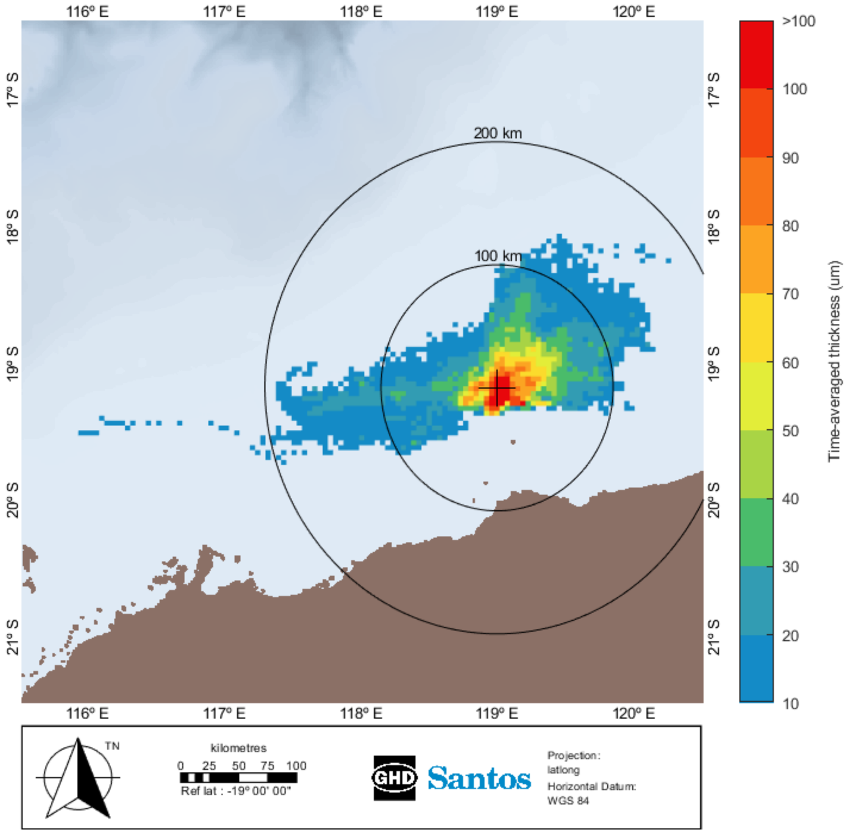
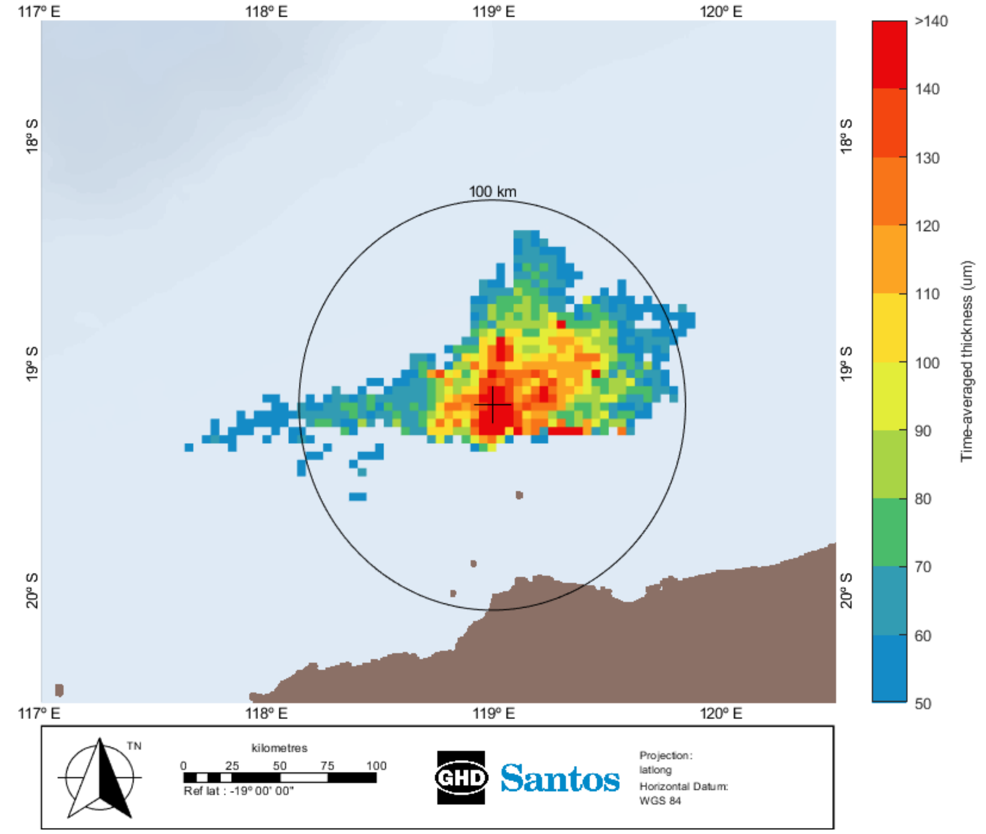
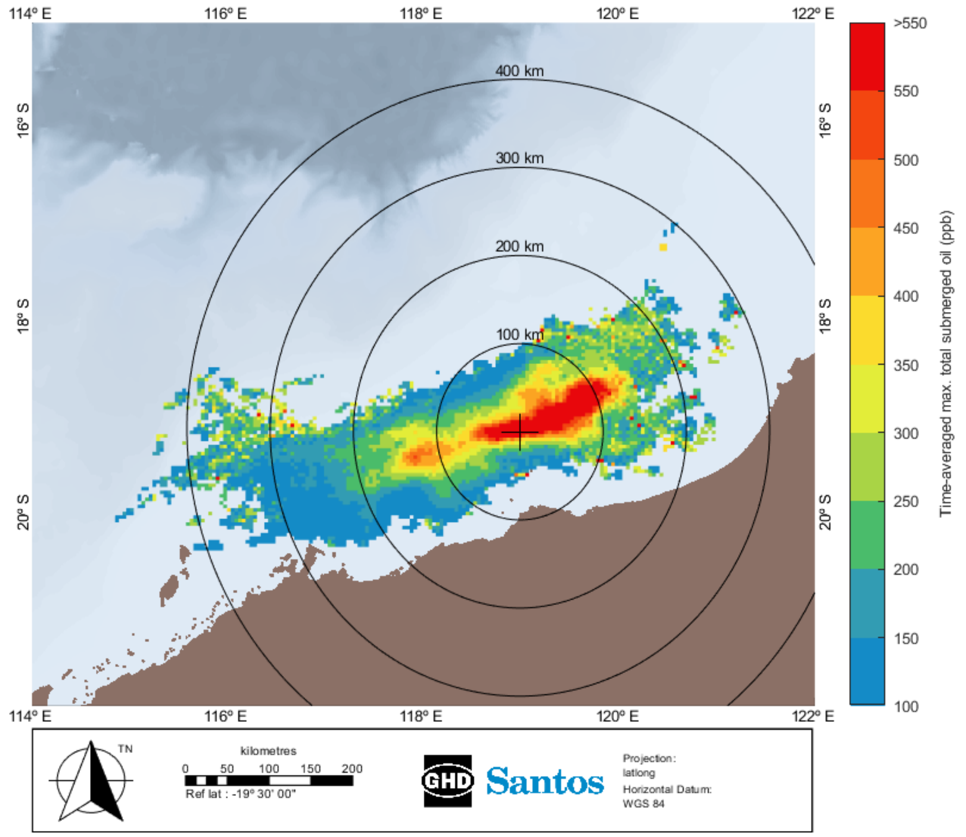
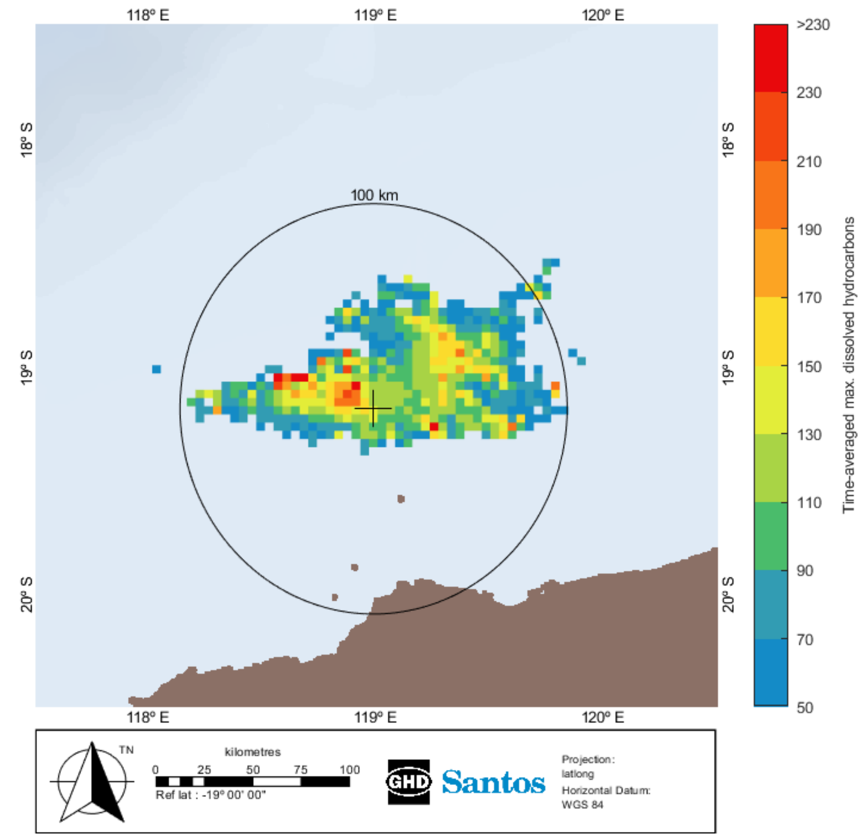
Surface Thickness > 10 µm	Surface Thickness > 50 µm
	
Maximum Total Submerged Oil > 100 ppb	**Maximum Dissolved Hydrocarbon > 50 ppb**
	

Figure 66 Apus Base Case Surface LOWC Scenario Realisation #101 – Surface thicknesses of oil greater than 10 µm (top-left), surface thicknesses of oil greater than 50 µm (top-right), maximum total submerged oil greater than 100 ppb (bottom-left) and maximum dissolved hydrocarbon greater than 50 ppb (bottom-right),

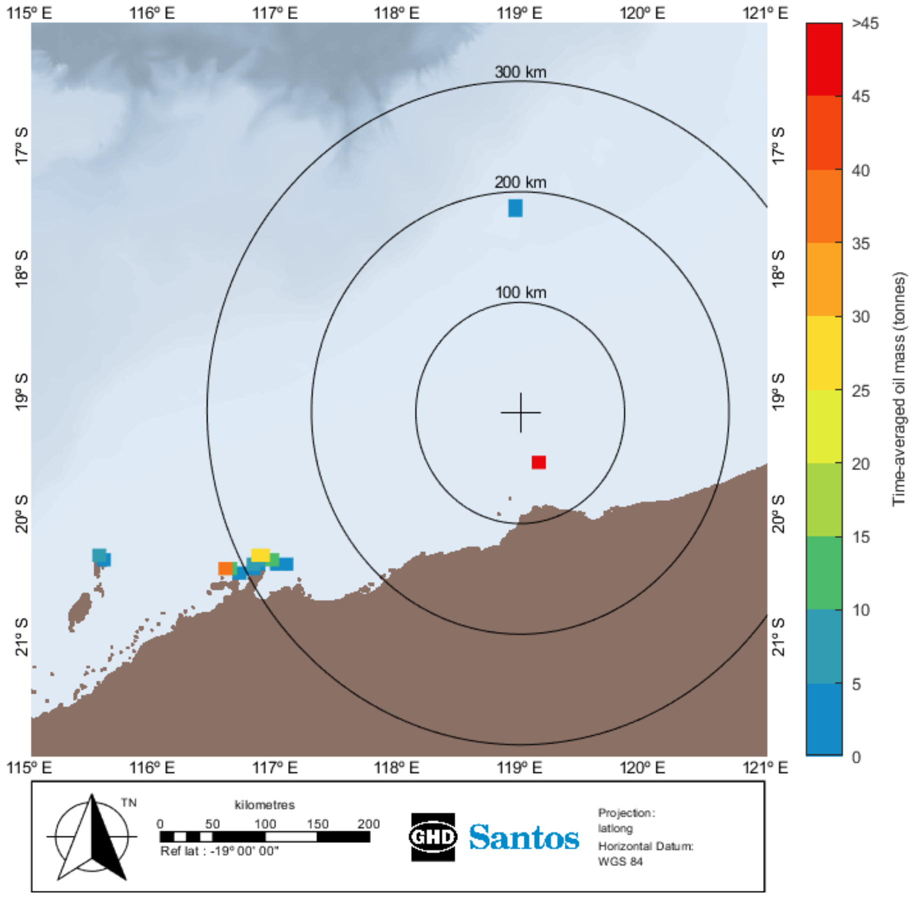
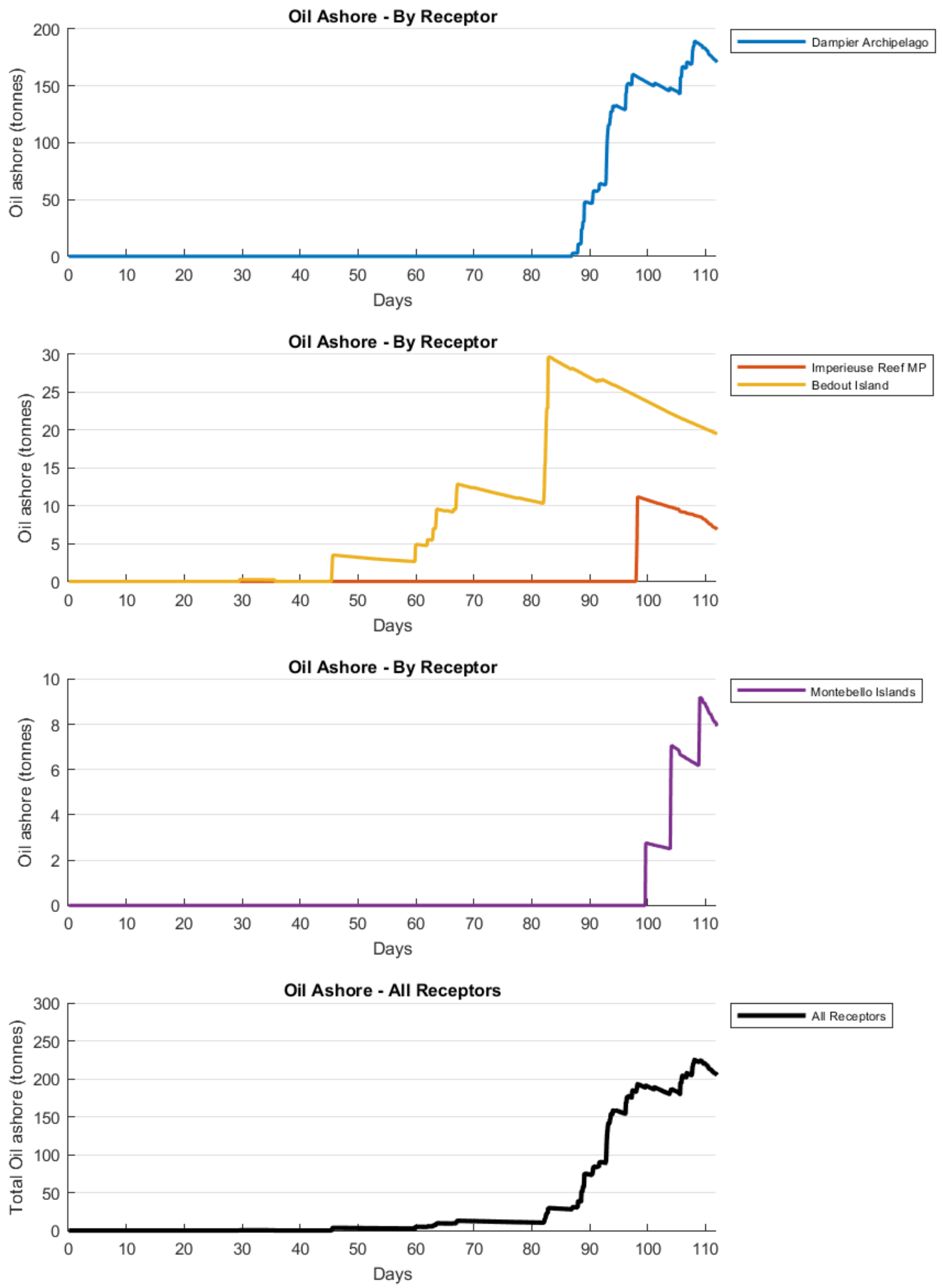
Shoreline Loading > 100 g/m²	Time Series of Shoreline Loading Above 100 g/m²
	

Figure 67 Apus Base Case Surface LOWC Scenario Realisation #101 –Shoreline loading above 100 g/m² (left) and Time series of shoreline loading above 100 g/m² (right)

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Attachment 8-2 Consequence Assessment

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
Outer Ningaloo Coast North (submerged)	1	***Threatened/Migratory Fauna*** Seasonal aggregations of whale sharks, manta rays, sea turtles and rays. Whale sharks March-July Logger head turtles Green Turtles Dec-March Low density Hawksbill turtles Pygmy Blue Whale feeding ***Physical Environment/ Habitat*** The Ningaloo Reef itself and its juxtaposition with coastal terraces, limestone plains, reef sediments. The contact of the reef by entrained oil may reduce the aesthetic appeal and diminish these values. Coral reef Macro Algae beds ***Protected Areas*** World Heritage Areas Australian Marine Park ***Socio-economic and heritage values*** Very significant for recreational fishing, game fishing and charter boat tourism	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	231.6	390.4	5, 215	5, 079			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	492	644			
Ashmore Reef AMP (Emergent)	1	***Threatened/Migratory Fauna*** Critical nesting and internesting habitat for green turtles Large and significant feeding populations of green, hawksbill and loggerhead turtles internationally significant for its abundance and diversity of sea snakes Small dugong population of less than 50 individuals Migratory pathway for pygmy blue whales Supports some of the most important seabird rookeries on the North West Shelf important staging points/feeding areas for many migratory seabirds ***Physical Environment/ Habitat***	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	227.4	229.7	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	7080	13498	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Only oceanic reef in the north-east Indian Ocean with vegetated islands (East, Middle and West Islands), Ashmore is also the largest of three emergent, oceanic reefs in the region. ***Protected areas*** Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF Continental slope demersal fish communities KEF ***Socio-economic and heritage values*** Ashmore lagoon as a rest/staging area for traditional Indonesian fishers Indonesian artefacts Grave sites Commonwealth heritage listing – Ashmore Reef Australian Marine Park Commercial tourism, recreation and scientific research are important socio-economic values	Maximum length of shoreline oiled (>100 g/m²)	(km)	39.8	39.8	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	NC	NC	234	221			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	NC	NC			
Eighty Mile Beach (emergent)	2	***Threatened/Migratory Fauna*** Invertebrates Large number and diversity of invertebrates within the intertidal mudflat areas Oil can reduce invertebrate abundance or alter the intertidal invertebrate community that provides food for non-breeding shorebirds Fish and sharks Not discussed in emergent area (see Eighty Mile Beach CMR (Submerged)) Ramsar site 97 wetland bird species, 42 of which are listed under CAMBA, JAMBA and ROKAMBA 500,000 birds use the area as a migration terminus annually, key period is Aug to Nov when contact with oil spill could result in impacts at a population level Marine reptiles Flatback turtles nest at scattered locations along shoreline Marine mammals Not discussed in emergent area, (see Eighty Mile Beach CMR (Submerged) below) ***Physical Environment/ Habitat*** Mangroves Limited stretch along coastline and in Mandora Saltmarsh area. minor stands 10 to 20 km close to tidal creeks. Intertidal mud/sand flats 225 km intertidal mudflats provide important food source for many of the bird species from the infauna present Mandora Saltmarsh area contains rare group of wetlands	Probability of contact by floating oil at 10 g/m²	(%)	4	1.7	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	IV III IV IV	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	13.7	4.6	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	481.5	2301	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	13899	15945	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	45.5	136.4	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1, 697	1, 419	5, 279	5, 322			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	199.6	915	1, 037			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Sandy beaches Sandy shores occupy the landward edge of the intertidal zone (approx. 220 km), provide important turtle nesting habitat and some tourism (see below) ***Protected areas*** Listed Ramsar site. The site comprises of two separate areas: 220 km of beach and associated intertidal mudflats from Cape Missiessy to Cape Keraudren ("the beach") and Mandora Salt Marsh 40 km to the east (inland) ***Socio-economic and heritage values*** Tourism activities include camping nearby, nature appreciation, recreational beach fishing and four wheel driving Indigenous values: wetlands are significant to three local groups, several aboriginal heritage sites present									
Mermaid Reef AMP (Intertidal)	2	***Threatened/Migratory Fauna*** Invertebrates A number of invertebrate (echinoderms, molluscs and crustaceans) species commonly found at Scott Reef are also found here although in higher densities due to lack of fishing/collection Fish and sharks Fish populations similar to those on shelf edge reefs in the Indo-Pacific region but unique in WA waters Birds Sandbanks exposed at low tide may be important resting areas for migratory seabirds, no breeding occurs Marine reptiles Small numbers of green turtles have been sighted Important foraging area for other marine turtles Marine mammals Northward humpback whale migration pathway adjacent to CMR, therefore individuals may be present CMR designated as important for other whales and dolphins The Rowley shoals comprise three reef systems 30 to 40 km apart: Mermaid reef, Clerke reef and Imperieuse reef ***Protected Areas*** Expired management plan recognised oil spills as potential pressure on water quality (Commonwealth of Australia, 2007) CMR in place to protect corals, sharks, marine turtles, cetaceans and migratory seabirds. It is an IUCN Category IA ***Physical Environment/ Habitat*** Coral reefs	Probability of contact by floating oil at 10 g/m²	(%)	0.7	0.7	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	17.5	17.9	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1729	752.1	6, 204	6, 146			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	165	234			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Key area for >200 hard coral species and >12 classes of soft corals in pristine condition Seagrasses Small patches in lagoonal area of two species which are commonly found throughout WA waters Macroalgae Small patches may be present in lagoonal area Sandy beaches Not present in submerged area within CMR. Recognise that some sand cays/sand banks are present and may be exposed at low water ***Socio-economic and heritage values*** Tourism: private and charter vessels for snorkelling/diving, limited shore based activities and recreational fishing (although prohibited with CMR) given distance to mainland Indigenous value: None identified Heritage value: 1 shipwreck present that could be contacted by entrained oil Commercial fishing: a number are licensed to operate in deeper waters surrounding the CMR 'Mermaid Reef and the Commonwealth waters surrounding Rowley shoals' are a designated KEF (an area of high biodiversity with enhanced productivity and feeding and breeding aggregations) Rowley shoals also have the KEF 'canyons linking the Argo Abyssal Plain with the Scott Plateau' (unique seafloor feature with enhanced productivity and feeding aggregations of species									
Muiron Islands (emergent)	2	***Threatened/Migratory Fauna*** Invertebrates Not identified within the area although noted in the deeper offshore environment or the more protected environment of the nearby Exmouth Gulf (refer Ningaloo Hot Spot) Fish and sharks Shark aggregations are seasonally reported and manta rays are commonly found in the area Seabirds Significant bird breeding. Several BIAs for breeding/nesting/roosting, foraging and resting include the Murion Islands	**Probability of contact by floating oil at 10 g/m²**	**(%)**	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	**Time (days)**	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	**tonnes**	287.8	350.3	NC	NC			
			Maximum accumulated concentration >100 g/m²	**g/m²**	17542	20143	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks Subsea	Future Tiebacks Surface	Dorado LOWC Subsea	Dorado LOWC Surface	Consequence Category	Consequence Ranking	Final
		there are five known rookeries as well isolated rookeries on the Muiron and Sunday Islands Marine reptiles – turtles Provides important aggregation and nesting areas for turtle populations, including the loggerhead (Caretta caretta) and green (Chelonia mydas) The North West Cape and Muiron Islands are major nesting sites for loggerhead turtles, with approximately 400 and 600 females nesting annually on the Ningaloo Coast (particularly, North West Cape area) and Muiron Islands respectively (DEP, 2001) The Recovery Plan for Marine Turtles in Australia (2003) identifies the Muiron Islands (as a principal rookery), and all waters within a 20 km radius as habitat critical to the survival of loggerhead turtles The Muiron Islands are minor nesting sites for flatback and hawksbill turtles (DEC 2009a) Marine mammals Seasonal aggregations of whale sharks, manta rays, sea turtles and rays. Whale sharks Mar to Jul Pygmy Blue Whale feeding ***Physical Environment/ Habitat*** Coral reefs Soft coral communities dominate the reefs on the western side of the Muiron Islands whilst habitats on the eastern side of the Muiron Islands are more sheltered, consisting of sandy beaches and shallow lagoons with diverse soft and hard coral communities (Cassata & Collins, 2008) The northern boundary substrate can be described as a combination of sand covered limestone pavement (Quadrant Energy, 2016) Seagrasses Identified on the eastern side of the Muiron Islands Macroalgae Seagrass and macroalgal habitats are present within the NWS region including Muiron Islands (eastern side) Sandy beaches The western shores comprise sandy beaches sloping away to the shelf backed by low dunes ***Protected areas*** The Ningaloo Coast World Heritage Area (WHA) also includes the Muiron Islands as having outstanding universal value for the Ningaloo Coast (Refer to Ningaloo Coast Hot Spot)	Maximum length of shoreline oiled (>100 g/m²)	(km)	17.1	17.1	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	121.3	232	NC	NC			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		The Ningaloo Coast WHA includes Muiron Island Marine Management Area (including the Muiron Islands) category IA – Sanctuary Zone (islands) and II – Marine National Park Zone ***Socio-economic and heritage values*** Significant for recreational fishing and charter boat tourism Social amenities and other tourism such as commercial dive charters The unclassified waters of the Muiron Islands Marine Management area are also open to commercial fishing in accordance with the Fish Resources Management Act 1994 (FRM Act) The Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area (2005 to 2015) identifies that the area has significant indigenous heritage value associated with historical and current use but the linkage appears to be directly related to the Ningaloo Reef and the adjacent foreshore as opposed to the Muiron Islands									
Ningaloo Coast North (Emergent)	2	***Threatened/Migratory Fauna*** Seasonal aggregations of whale sharks, manta rays, sea turtles and rays. Whale sharks March-July Loggerhead turtles Green Turtles Dec-March Low density Hawksbill turtles Pygmy Blue whale feeding Seabirds 33 species of seabirds and avifauna. Main breeding areas at Mangrove Bay, Mangrove Point, Point Maud, the Mildura Wreck Site and Fraser Island ***Physical Environment/ Habitat*** Contains part of the largest fringing reef in Australia Lagoonal., intertidal and subtidal coral communities Nine species of seagrass + macroalgae beds Mangrove bay – Significant for mangroves Yardie Creek – Significant mangroves and tidal creek ***Protected Areas*** Includes 13 out of the 18 sanctuary zones under the state MP. World Heritage Areas Exmouth Peninsula Karst System is an official value of the National Heritage Area ***Socio-economic and heritage values*** Tourism Recreational Fishing fishing and charter boat tourism	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	397.9	698.5	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	7498	10938	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	187.6	227.4	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	182.8	190.4	2, 073	1, 992			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	187	339			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
Imperieuse Reef MP (Emergent)	3	The Rowley Shoals comprise three reef systems 30 to 40 km apart: Mermaid reef, Clerke reef and Imperieuse reef ***Threatened/Migratory Fauna*** Marine fauna Invertebrates A number of invertebrate (echinoderms, cnidarians, molluscs and crustaceans) species commonly found at Scott Reef are also found here although in higher densities due to lack of fishing/collection (Commercial collection is prohibited) Fish and sharks Fish populations similar to those on shelf edge reefs in the Indo-Pacific region but unique in WA waters Rich diversity of fish (500+ species) Birds Wide range of seabirds observed at Rowley Shoals Marine reptiles Green and hawksbill turtles are present at the Rowley Shoals Reefs not known to be regionally significant turtle habitats Marine mammals Northward humpback whale migration pathway adjacent to Rowley Shoals, therefore individuals may be present Variety of toothed and baleen whales likely to be visitors to the area but not Rowley Shoals are not a key aggregation/calving/mating/foraging area ***Physical Environment/ Habitat*** Coral reefs Exceptionally rich and diverse intertidal and subtidal reefs Provide a source of invertebrate and fish recruits for reefs further south and are therefore regionally significant Seagrasses Sparse seagrass found within subtidal areas in Rowley Shoals Macroalgae Small patches may be present in lagoonal area Sandy beaches Area of sand banks (intertidal) and Cunningham Island (an unvegetated sand cay) ***Protected areas*** Rowley Shoals CMR in place to protect migratory seabirds and endangered loggerhead turtle, sharks, communities and habitats of 220 m to 5000 m, seafloor features, two KEFS and provides connectivity between Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals	Probability of contact by floating oil at 10 g/m²	(%)	NC	0.7	2	4	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	IV IV IV IV	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	48.3	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	1014	2040	3.7	3.3			
			Maximum accumulated concentration >100 g/m²	g/m²	27259	29886	-	-			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	56.9	56.9	1	1			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	937.9	958.7	10 088	10, 648			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	79.4	260	982			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Marine Park and the deeper waters of the region. It is an IUCN category zoning of II and VI. ***Socio-economic and heritage values*** Tourism: nature based tourism (charter boats, diving, snorkelling) and recreational fishing (although prohibited in certain zones) low usage given distance to mainland. approximately 300 visitors/season (DoE, 2007) Sanctuary zone within marine park Indigenous values: none identified Heritage values: none identified Prohibition on commercial fishing and a ban on the take of key demersal fish by recreational fishers since 1987 Low level of pressures on shoals make them an important global benchmark for Indo-West pacific reefs 'Mermaid Reef and the Commonwealth waters surrounding Rowley Shoals' are a designated KEF (an area of high biodiversity with enhanced productivity and feeding and breeding aggregations) Rowley shoals also have the KEF 'canyons linking the Argo Abyssal Plain with the Scott Plateau' (unique seafloor feature with enhanced productivity and feeding aggregations of species									
Clerke Reef MP (Emergent)	3	The Rowley Shoals comprise three reef systems 30 to 40 km apart: Mermaid Reef, Clerke Reef and Imperieuse Reef ***Threatened/Migratory Fauna*** Invertebrates A number of invertebrate (echinoderms, cnidarians, molluscs and crustaceans) species commonly found at Scott Reef are also found here although in higher densities due to lack of fishing/collection Diverse molluscan fauna on flats Fish and sharks Fish populations similar to those on shelf edge reefs in the Indo-Pacific region but unique in WA waters Rich diversity of fish (500+ species) Birds Bedwell island is site of second largest breeding colony of red-tailed tropic birds, an uncommon species in WA Wide range of seabirds observed at Rowley Shoals Marine reptiles Green and hawksbill turtles are present at the Rowley Shoals Reefs not known to be regionally significant turtle habitats	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	IV IV IV IV	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	919.1	1455	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	21768	23606	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	51.2	51.2	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1146	715.9	5,851	5, 829			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Marine mammals Northward humpback whale migration pathway adjacent to Rowley shoals, therefore individuals may be present Variety of toothed and baleen whales likely to be visitors to the area but not Rowley Shoals are not a key aggregation/calving/mating/foraging area ***Physical Environment/Habitat*** Coral reefs Exceptionally rich and diverse intertidal and subtidal reefs Provide a source of invertebrate and fish recruits for reefs further south and are therefore regionally significant Seagrasses Sparse seagrass found within subtidal areas in Rowley Shoals Macroalgae Small patches may be present in lagoonal area Sandy beaches Bedwell Island is a supratidal, unvegetated, elongated cay about 1.3 km long ***Protected areas*** The Rowley Shoals CMR is in place to protect migratory seabirds and endangered loggerhead turtle, sharks, communities and habitats of 220 m to 5000 m, seafloor features, two KEFS and provides connectivity between Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park and the deeper waters of the region. It is an IUCN category zoning of II and VI ***Socio-economic and heritage values*** Tourism: nature based tourism (charter boats, diving, snorkelling) and recreational fishing (although prohibited in certain zones) low usage given distance to mainland Sanctuary zone within marine park Indigenous values: none identified Heritage values: none identified Prohibition on commercial fishing and a ban on the take of key demersal fish by recreational fishers since 1987 Low level of pressures on shoals make them an important global benchmark for Indo-West pacific reefs 'Mermaid Reef and the Commonwealth waters surrounding Rowley Shoals' are a designated KEF (an area of high biodiversity with enhanced productivity and feeding and breeding aggregations)	Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	450	453			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Rowley shoals also have the KEF 'canyons linking the Argo Abyssal Plain with the Scott Plateau' (unique seafloor feature with enhanced productivity and feeding aggregations of species									
Broome-Roebuck (emergent)	3	**Threatened/Migratory Fauna** Invertebrates High diversity (300 to 500 species) and abundance of invertebrates within the intertidal mudflat areas, a key characteristic making the area an important shorebird habitat Fish Not present in emergent area but mangrove and salt marshes provide nursery habitat for fish Birds RASMAR site 84 waterbird species, 35 shorebird species, 47 of which are listed under CAMBA, JAMBA and ROKAMBA 170,000 waterbirds (a maximum count) and 300,000 shorebirds use the area as a migration terminus annually, key period is Aug-Nov when contact with oil spill could result in impacts at a population level Marine reptiles Flatback turtles nest in small numbers around Cape Villaret near southern end of the Bay Marine mammals Dugong (northern areas seagrass beds, intertidal zones close to Broome town) ***Physical Environment/ Habitat*** Seagrasses Northern shores of Roebuck Bay with substantial fluctuations in density and distribution recorded in the past years, dominated by Halophila sp. and Halodule sp. Macroalgae Past records indicate presence in northern section of the intertidal zone along with the seagrass Mangroves Stretches more than 40 km along the Roebuck Bay's shorelines with stands concentrated on the northern (Dampier Creek), eastern and southern shorelines. Highest diversity/abundance in Dampier, Crab and Yardoogarra Creek Intertidal mud/sand flats Intertidal mud and sand flats is dominant covering 45% of the total Bay area which supports very large numbers of migratory shorebirds by providing important food source from the benthic invertebrates present. Oil spill contact at	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	57.9	180.2	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	5096	7112	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	5.7	17.1	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	510.2	1488	2074	2113			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	40	384			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		any time of year could result in loss of the key staging and over-wintering area for Palaearctic shorebirds which use the intertidal foreshore as their feeding area Saltmarsh area: Terrestrial halophyte systems, at time extensive, found at the eastern edge of the Bay and around Dampier and Crab Creeks. Oil spill contact could result in loss of this valuable system Sandy beaches Sandy shores occupy several stretches of the Bay with significant sections include the northern beach areas (Mangalun), Cable Beach areas. Oil contact could result in disruption to their use and damage heritage, cultural and aesthetic values present Rocky shorelines Rocky reefs/foreshores present in northern shore of the Bay ***Protected areas*** Roebuck Bay was designated a "Wetland of International Importance" under the Ramsar Convention in June 1990. The soft bottom intertidal mudflats of the northern and eastern shores of Roebuck Bay, Roebuck Bay is one of less than twenty soft bottomed intertidal mudflats worldwide that support very large numbers of migratory shorebirds and comprise the primary staging and over-wintering areas for Palaearctic shorebirds on their annual southwards migrations. High tide roosts at Bush and Sandy Points are the most biologically significant parts of the site, which was listed for several reasons including, most notably, outstanding shorebird values. ***Socio-economic and heritage values*** Tourism: recreational (increased visitation dry season at Crab Creek, Dampier Creek, Fishermans Bend, Bush Point) paleontological, educational, aesthetics Economic activity associated with fishing/aquaculture, high tourism value Recreational fishing – high values by community Camping beaches, etc Small reserve in north gazetted for Broome Bird Observatory Indigenous population: the Bay and the Ramsar wetlands are significant to Yawuru people, at least 65 aboriginal heritage sites present									
Barrow-Montebello Surrounds (Intertidal)	3	***Threatened/Migratory Fauna*** Seabirds Migratory birds Turtles Internesting	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas	III II II II	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			

Santos

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Whales Humpback/pygmy blue whale migration ***Physical Environment/ Habitat*** Coral reefs habitat ***Socio-economic*** Significant for recreational fishing and charter boat tourism	Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC	Socio-Economic Receptors	Fauna consequence allocated III due to turtle nesting	
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	519.3	570.5	781	751			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	264	144			
Montebello Islands (Emergent)	3	***Threatened/Migratory Fauna*** Loggerhead and green (significant rookery), hawksbill, flatback turtles – Loggerhead turtle nesting: Dec-Jan; green turtle nesting: Nov to Apr, peak period from Jan-Feb; flatback turtle nesting: Dec-Jan; hawksbill turtle nesting: Oct to Jan Northwest and Eastern Trimouille Islands (hawksbill) Western Reef and Southern Bay at Northwest Island (green) Seabirds Migratory and threatened seabirds – 14 species Significant nesting (Sept to Feb), foraging and resting areas Whales Humpback (Jun to Jul), Pygmy blue (Apr to Aug) whale migration ***Physical Environment/ Habitat*** Reefs – coral spawning: Mar & Oct Algae (40%) Mangroves (considered globally unique as they are offshore) Fish habitat Intertidal sand flat communities ***Protected Areas*** Marine Park	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	2	5	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	IV IV IV IV	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	12.2	7			
			Maximum accumulated oil ashore >100 g/m²	tonnes	419.9	663.1	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	17238	25077	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	22.7	22.7	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	291.1	521.2	3, 591	3, 577			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Socio-economic Pearling (inactive/pearling zones) Very significant for recreational fishing and charter boat tourism Social amenities and other tourism Nominated place (national heritage)	Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	1, 122	1, 124			
Lowendal Islands (Emergent)	3	***Threatened/Migratory Fauna*** Turtles Important hawksbill (Beacon, Parakeelya, Kaia and Pipeline), loggerhead and green turtle nesting (minor) Varanus pipeline, Harriet and Andersons Beaches) Nesting is reported to occur throughout the year in WA, peaking between October and January Significant flatback rookery, nesting season for flatback turtles peaks in December and January with subsequent peak hatchling emergence in February and March Seabirds Approximately 89 species of avifauna, 12 to 14 species of migratory and threatened seabirds Marine mammals Seagrass beds around the Lowendal Islands thought to provide valuable food source for dugongs ***Physical Environment/ Habitat*** Important shallow lagoons with seagrass for dugongs Deep-water benthic (soft-sediment) habitats Dugong Reef and Batman Reef (eastern side Island) Mangroves are considered globally unique as they are offshore Macroalgal reefs (40%) ***Protected areas*** The Barrow Island Marine Management Area, most of the waters around Barrow Island, the Lowendal Islands and the Barrow Island Marine Park ***Socio-economic and heritage values*** Social amenities and other tourism, very significant for recreational fishing and charter boat tourism	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	IV III IV III	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	87.8	110.2	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	7726	9696	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	5.7	5.7	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	118.1	208.4	930	1,046			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	172	823			
Barrow Island (Emergent)	3	***Threatened/Migratory Fauna*** Turtles Regionally and nationally significant green turtle (western side) and flatback turtle (eastern side) nesting beaches Turtle Bay north beach	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	1	1	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas	IV III IV III	IV
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	40.8	16.08			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		North and west coasts – John Wayne Beach also loggerhead and hawksbill turtles. Peak turtle nesting periods – Loggerhead turtle nesting: Dec-Jan; green turtle nesting: Nov to Apr, peak period from Jan to Feb; flatback turtle nesting: Dec to Jan; hawksbill turtle nesting: Oct to Jan Seabirds Migratory birds (important habitat) (important bird area) 10th of top 147 bird sites Highest population of migratory birds in Barrow Island Nature Reserve (south-southeast island) Double island important bird nesting (shearwaters, sea eagles) Whales Pygmy blue whale northern migration (Apr to Aug) ***Physical Environment/ Habitat*** Bandicoot Bay – conservation area Fisheries Act (benthic fauna/seabird protection), mudflats, rock platforms, mangroves, clay pans Mangroves in Bandicoot Bay (considered globally unique) Coral reefs (eastern side) – Biggada Reef (coral spawning: Mar & Oct) Biggada Creek ***Cultural heritage*** Important Aboriginal cultural: 13 listed sites incl. pearling camps ***Socio-economic*** Significant for recreational fishing and charter boat tourism Nominated place (national heritage)	Maximum accumulated oil ashore >100 g/m²	tonnes	337.3	628.3	NC	NC	Socio-Economic Receptors		
			Maximum accumulated concentration >100 g/m²	g/m²	12989	13827	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	68.2	68.2	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	131.9	236.3	781	548			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	33	144			
Outer NW Ningaloo (Submerged)	3	***Threatened/Migratory Fauna*** Marine fauna Invertebrates Cetacean migration Finfish and rays Whale sharks – migratory and aggregation site Manta rays aggregation 500 finfish species recorded Birds 33 species seabirds and avifauna present (13 resident and 20 migratory) 13 JAMBA/CAMBA species Marine mammals	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		13 species of toothed whale and dolphin and seven species of baleen whale ***Physical Environment/ Habitat*** Coral reef Seagrasses Macroalgal beds Non-coral benthic habitats high and unique sponge biodiversity ***Protected area*** Key Ecological Feature (Commonwealth waters adjacent to Ningaloo Reef) and Continental Slope Demersal Fish Communities ***Socio-economic and heritage values*** Sanctuary zones under state MP National Heritage Place Shipwrecks important as diving sites	**Maximum length of shoreline oiled (>100 g/m²)**	**(km)**	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	**(ppb)**	320.5	1257	5215	5, 079			
			Maximum concentration of dissolved hydrocarbon >50 ppb	**(ppb)**	NC	NC	492	644			
Scott Reef South (Emergent)	3	Scott Reef is a large, emergent shelf atoll. South Reef is a crescent shaped reef 17 km across The place is regionally significant both because of its high representation of species not found in coastal waters off Western Australia and for the unusual nature of its fauna which has affinities with the oceanic reef habitats of the Indo-West Pacific as well as the reefs of the Indonesian region ***Threatened/Migratory Fauna*** Marine fauna Invertebrates Cetacean migration Seasnakes Nesting and foraging green and hawksbill turtles Finfish and rays Whale sharks High fish diversity (>550 species of fish recorded) and 5 endemic species ***Physical Environment/ Habitat*** Coral reef Seagrass Non-coral benthic habitats High coral and fish diversity Sandy beaches ***Protected area*** Key Ecological Feature (Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex)	**Probability of contact by floating oil at 10 g/m²**	**(%)**	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	**Time (days)**	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	**tonnes**	595.4	625.2	NC	NC			
			Maximum accumulated concentration >100 g/m²	**g/m²**	12772	10631	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	**(km)**	56.9	56.9	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	**(ppb)**	NC	122.7	231	216			
			Maximum concentration of dissolved	**(ppb)**	NC	NC	31	31			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Socio-economic and heritage values Important for traditional Indonesian fishers Commonwealth heritage place (Scott Reef and Surrounds – Commonwealth Area) Nature Reserve	hydrocarbon >50 ppb								
Scott Reef North (Intertidal)	3	As per Scott Reef South	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	200.8	136.5	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	4048	3189	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	45.5	51.2	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	NC	NC	218	167			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	11	27			
Ningaloo Coast South (Emergent)	3	Refer Outer NW Ningaloo and Ningaloo Coast North	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	51.8	44.2	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
			Maximum accumulated concentration >100 g/m²	g/m²	1700	2887	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	85.3	68.2	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	NC	NC	2, 073	1, 992			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	187	339			
Dampier Archipelago (Emergent)	3	***Threatened/Migratory Fauna*** Invertebrates Finfish and rays High fish biodiversity approx. 650 species, dwarf sawfish EPBC protected Birds Marine reptiles Turtles Flatbacks – nest on Legendre, Huay, Delambre Green – significant rookery in NWS Olive Ridley – known to forage Loggerhead – nesting and foraging Seasnakes Marine mammals Eight species (dugong, whales, dolphins) migratory pathway for protected humpback whale in Jul to Sept ***Physical Environment/ Habitat*** Coral reefs Seagrass Macroalgae Mangroves ***Protected area*** Commonwealth Marine Reserve	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	5	6	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	16.5	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	848.9	864.7	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	21712	21248	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	85.3	96.6	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	315.2	585.9	7944	7941			
			Maximum concentration of dissolved	(ppb)	NC	NC	2436	1325			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Socio-economic and heritage values National Heritage Listed Aboriginal rock art on shorelines, Burrup Peninsula	hydrocarbon >50 ppb								
Kimberley AMP (Submerged)	3	***Threatened/Migratory Fauna*** Fish and sharks Adjacent to important foraging and pupping areas for sawfish Overlays with the BIA for whale shark (distribution) Partial overlap with the BIA for pygmy Blue Whale distribution and migration Seabirds Important foraging areas for migratory seabirds including the Commonwealth waters in the Lacepedes playing an important role for feeding seabirds Marine reptiles Important foraging areas for turtles Adjacent to important nesting sites for green turtles Marine mammals Important foraging areas for dolphins and dugongs Important migration pathway and nursery areas for humpback whales Seasonal calving habitat for the world's largest population of the humpback whale in the Kimberley Commonwealth Marine Reserve (DoE, 2014) ***Physical Environment/ Habitat*** Coral reefs Features such as the continental shelf, slope, plateau, pinnacles, terraces, banks and shoals and deep holes/valleys are identified within the Kimberley CMR (submerged) Seagrasses Present within/around the South Kimberley islands Macroalgae Present but no significant areas Rocky shorelines Present but no significant areas identified ***Protected areas*** Part of the North-west Marine Reserves Network. Kimberley Commonwealth Marine Reserve with three IUCN Protected Area categories: II – Marine National Park Zone; IV – Habitat Protection Zone; and VI – Multiple use Zone Provides protection for the ancient coastline and continental slope demersal fish communities KEFs ***Socio-economic and heritage values***	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	2	2	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II II	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	82	83			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1789	1579	7378	8133			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	591	945			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Commercial fishing licence areas overlay the Kimberley CMR for skipjack tuna, and western tuna and billfish. However, there is no current effort on the NWS The significance of the coastline and Commonwealth waters is reflected by the National Heritage Listing of the West Kimberley. Dugongs, fish and turtles that transit between coastal and Commonwealth waters in the Region are important components of Aboriginal people's culture and diet (DoE, 2014d)									
Eighty Mile Beach AMP (Submerged)	4	CMR in place to protect communities and seafloor habitats, Eighty Mile Beach marine park also in place Note that habitats and fauna not usually submerged are discussed separately above in 'Eighty Mile Beach (emergent)' ***Threatened/Migratory Fauna*** Invertebrates Several invertebrate species targeted by recreational commercial fisheries Important food source for waterbirds Fish and sharks Fish populations dependent on habitat and substrate type Several fish species targeted by recreational commercial fisheries Sawfish foraging, nursing and pupping, diversity of sharks and rays (including protected species) Diversity of fish species provide recreational and commercial fishing opportunities Birds Migratory seabirds forage in the waters, peak season during Aug-Nov High diversity of waterbirds including 42 migratory species, waterbirds are nationally and internationally important 500,000 birds use the area as a migration terminus annually, key period is Aug to Nov when contact with oil spill could result in impacts at a population level Marine reptiles Flatback turtles forage and inter-nest in offshore waters Green, hawksbill, loggerhead, Olive Ridley and leatherback may frequent the waters all year round Marine mammals Humpback whale migration pathway though the CMR Dugongs and other cetaceans inhabit or migrate through the CMR/marine park although unlikely to be larger whale species due to water depths ***Physical Environment/ Habitat*** Coral reefs Subtidal filter feeding communities present, likely provide foraging habitat for flatback turtles	Probability of contact by floating oil at 10 g/m²	(%)	54	70	1	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III II	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	1.8	0.8	38.8	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1936	2611	5279	5340			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	93.8	346	951	1037			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		High diversity intertidal and subtidal coral reef communities Seagrasses Seasonally present but sparsely distributed Dugongs regularly found feeding on seagrass meadows here Macroalgae Provide habitat and feeding opportunities for fish, invertebrates and dugong ***Socio-economic and heritage values*** Tourism: nature based, fishing and wildlife viewing from vessels. Some vessel based fishing (mostly shore based recreational fishing in Eighty Mile Beach area) Indigenous values: the adjacent Marine park contains land and sea important to traditional indigenous owners, four special purpose zones included in marine park Heritage value: two shipwrecks and one plane wreck present that could be contacted by entrained oil Pearl Producers Association have previously indicated this is area is important as a seed stock. Diving for pearl oysters is limited to the 35 m depth contour (adjacent to the marine park) Commercial fishing: a number are licensed to operate in the CMR									
Bedout Island (emergent)	4	***Threatened/Migratory Fauna*** Fish Pelagic fishes, stingrays and reed sharks may be present at times Birds Important due to brown booby breeding Seabird breeding colonies present – island supports over 1,000 nesting pairs of Brown Boobies (one of the largest in the world) Supports nesting of other birds as well Season for breeding: May to Sep Marine reptiles May see green, hawksbill, loggerhead turtles foraging but not known if nesting site ***Physical Environment/ Habitat*** Coral reefs Fringing the small island (0.31 km2) Sandy beaches Sandy cay on limestone bedrock, heavily vegetated with beach spinifex ***Socio-economic and heritage values*** Tourism Heritage value: three shipwrecks in the surroundings Nature Reserve	Probability of contact by floating oil at 10 g/m²	(%)	23.3	46.7	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III I	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	3.3	1.5	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	324.0 (62.5)	299.0 (57.7)	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	28497	26295	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	5.7 (1.1)	5.7(1.1)	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1037	1292	2008	1743			
			Maximum concentration of	(ppb)	NC	304.1	49	296			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks Subsea	Future Tiebacks Surface	Dorado LOWC Subsea	Dorado LOWC Surface	Consequence Category	Consequence Ranking	Final
			dissolved hydrocarbon >50 ppb								
Rowley Shoals Surrounds (Submerged)	4	See information on Mermaid Reef, Imperieuse Reef, Clerke Reef for Rowley Shoals	Probability of contact by floating oil at 10 g/m²	(%)	5.3	18	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	18.2	16	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1987	1866	5,851	5, 829			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	99.9	450	453			
Offshore Ningaloo (Submerged)	4	***Threatened/Migratory Fauna*** Whale migration Whale shark foraging ***Physical Environment/ Habitat*** Waters adjacent to world heritage areas ***Protected areas*** Overlaps Gascoyne AMP Adjacent to Muiron Islands Marine Management Area and Ningaloo AMP Refer Ningaloo and Muiron Islands hot spots for further information.	Probability of contact by floating oil at 10 g/m²	(%)	2	5.3	11	11	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III III II	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	45.8	18.2	22.4	10.38			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated	g/m²	NC	NC	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
			concentration >100 g/m²								
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	858.7	1437	10088	10648			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	1100	1075			
Broome North Coast (emergent)	4	***Physical Environment/ Habitat*** Key ecological significance Mangrove habitats; vegetated dunes along Cable Beach; Turtle activity; Dugong Activity ***Socio-Economic Receptors*** Pearl farms High tourism value Local Aboriginal communities Recreational fishing – high values by community Camping beaches, etc Economic activity associated with fishing/aquaculture Aquaculture	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II III	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	108	197.6	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	5053	9841	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	22.7	34.1	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	310	669.7	2074	2113			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	255	384			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
Port Hedland – Eighty Mile Beach (Emergent)	5	***Threatened/Migratory Fauna*** Overlaps BIAs for: Little Tern Lesser Frigatebird Brown Booby Roseate tern Wedge tailed shearwater. Flatback turtle nesting, internesting, foraging Green, loggerhead and hawksbill turtle foraging Known to be Flatback turtle nesting on cemetery beach near Port Hedland and critical habitat from nesting along the coastline ***Protected Areas*** Adjacent to Eighty Mile Beach Marine Park ***Socio-Economic Receptors*** Jasuraus Submarine communication cable travels out of Port Hedland Port Hedland is a major port in the region	Probability of contact by floating oil at 10 g/m²	(%)	2.7	14	7	9	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	III III II I	III
			Minimum time to contact by floating oil 10 g/m²	Time (days)	18.6	2	2.8	2.8			
			Maximum accumulated oil ashore >100 g/m²	tonnes	641.8	2035	3.7	38.1			
			Maximum accumulated concentration >100 g/m²	g/m²	18322	23422	-	-			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	45.5	91	3.0	3.0			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	1823	3755	9339	9064			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	260.9	784	894			
Karratha-Port Hedland (Emergent)	5	***Threatened/Migratory Fauna*** Overlaps BIAs for Lesser Frigatebird Roseate tern Wedge tailed shearwater Flatback turtle nesting and internesting Loggerhead internesting Green turtle nesting and internesting Hawksbill turtle nesting Flatback turtle nesting at rookeries near Karratha ***Socio-Economic Receptors*** Jasuraus Submarine communication cable travels out of Port Hedland	Probability of contact by floating oil at 10 g/m²	(%)	NC	2.7	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II I I	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	29	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	138.5	972.1	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	6533	15156	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
		Port Hedland is a major port in the region Specimen shell managed fishery effort near Karratha	Maximum length of shoreline oiled (>100 g/m²)	(km)	34.1	51.2	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	301.7	1030.7	1782	1443			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	961	699			
Roebuck – Eighty Mile Beach (Emergent)	5	***Threatened/Migratory Fauna*** Overlaps BIAs for Foraging dugongs Little tern Roseate tern Flatback turtle nesting and internesting ***Protected Areas*** Adjacent to Roebuck Bay marine park (see roome-Roebuck (emergent))	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II I	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	340.3	811.2	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	10806	17261	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	34.1	56.9	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	843	1537	1340	1220			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	21	29			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
Southern Islands Coast (Emergent)	5	***Threatened/Migratory Fauna*** Overlaps BIAs for Humpback whales Green turtle and hawksbill critical habitat (nesting) Wedge tailed shearwater Lesser crested tern Fairy tern Roseate tern Flatback turtle nesting ***Physical Environment/ Habitat*** Seagrass meadows ***Protected Areas*** Adjacent to Exmouth Gulf Coast and Ningaloo hotspot (refer above) ***Socio-Economic Receptors*** Onslow port within area	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II II II I	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	315.6	441	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	17788	19942	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	17.1	22.7	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	272.1	203.8	-	-			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	-	-			
Perth Canyon AMP (Emergent)	2	**Threatened/Migratory Fauna** Blue whales feeding Minke whales Humpback whales ***Physical Environment/ Habitat*** Nutrient rich waters ***Protected Areas*** Marine Park ***Socio-Economic Receptors*** Tourism	Probability of contact by floating oil at 10 g/m²	(%)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	I I I I	I
			Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	33.9	14.8	478	473			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	NC	NC			
Lacepede Islands	4	**Threatened/Migratory Fauna** Birdlife international Important Bird Area, supporting 1% of the worlds population of brown boobies and roseate terns Turtle nesting area. ***Physical Environment/ Habitat*** Coral reef ***Protected Areas*** A Class reserve	Probability of contact by floating oil at 10 g/m²	(%)	0.7	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II I II I	II
			Minimum time to contact by floating oil 10 g/m²	Time (days)	38.5	NC	NC	NC			
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	NC	NC	1152	1124			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	27	13			

Receptor (hotspot) name	HEV Ranking	Values	Oil Spill Modelling Parameter NC = No Contact		Future Tiebacks		Dorado LOWC		Consequence Category	Consequence Ranking	Final
					Subsea	Surface	Subsea	Surface			
Abrolhos Islands- incluyding Wallabi, Easter and Pelsaert Group	2	**Threatened/Migratory Fauna** Blue whales feeding ***Physical Environment/ Habitat*** Coral Seagrass Macro algae ***Protected Areas*** A class nature reserve ***Socio-Economic Receptors*** Tourism - Diving Fishing recreational Commercial fisheries Aquaculture	Minimum time to contact by floating oil 10 g/m²	Time (days)	NC	NC	NC	NC	Threatened/Migratory Fauna Physical Environment/ Habitat Protected Areas Socio-Economic Receptors	II I II II	II
			Maximum accumulated oil ashore >100 g/m²	tonnes	NC	NC	NC	NC			
			Maximum accumulated concentration >100 g/m²	g/m²	NC	NC	NC	NC			
			Maximum length of shoreline oiled (>100 g/m²)	(km)	NC	NC	NC	NC			
			Maximum concentration of total submerged oil >100 ppb	(ppb)	NC	NC	928	1022			
			Maximum concentration of dissolved hydrocarbon >50 ppb	(ppb)	NC	NC	140	123			

Attachment 9 Artificial Light Emissions Modelling

CDM SMITH

DORADO FPSO LIGHT MODELLING

Prepared by

Pendoley Environmental Pty Ltd

For

CDM Smith

25 August 2020

DOCUMENT CONTROL INFORMATION

TITLE: DORADO FPSO LIGHT MODELLING

Disclaimer and Limitation

This report has been prepared on behalf of and for the use of CDM Smith. Pendoley Environmental Pty Ltd. takes no responsibility for the completeness or form of any subsequent copies of this Document.

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1 INTRODUCTION

Santos is proposing to develop the Dorado oil field, located in the Bedout basin, approximately 150 km north of Port Hedland. Surface components of the proposed development will comprise an unmanned wellhead platform and a Floating Production, Storage and Offloading facility (FPSO).

Light emissions have the potential to impact biological receptors, thus CDM Smith has engaged Pendoley Environmental (PENV) on behalf of Santos to undertake modelling of these emissions to help inform an impact assessment. The FPSO presents the greatest source of light emissions based on the size of the facility and that it will be permanently manned and operational while infield. Light emissions from the wellhead platform will be restricted to navigational lights only, unless during specific, short term activities such as well intervention campaigns. For this reason, lighting of the wellhead platform was not considered further.

2 METHODOLOGY

Light modelling was undertaken for two scenarios; flaring (all lights, plus flare) and non-flaring (lights only), to predict the extent of biologically relevant light spill. The facility’s lighting design and luminaire specifications were applied to the ILLUMINA Artificial Light At Night (ALAN) model (Aube *et al*. 2005). The ILLUMINA model is a three-dimensional model that accounts for both line of sight and atmospheric scattering, allowing the attenuation of light over distance and extent of light glow to be modelled. The reader is directed to Aube *et al*. (2005) for details of equations and model parameterisation.

Unlike a simple line of sight model based on the inverse square law formula, this is a more sophisticated model which allows individual light sources (i.e. individual luminaires) to be placed within the area of interest (as opposed to assuming a single large light point source for the entire FPSO). The model input parameters also include project specific details about light type, spectral distribution, height and orientation of individual luminaires, including any shielding, which substantially increases the model precision and accuracy.

2.1 Model Inputs

Information regarding the light inventory for the non-flaring scenario was provided by Santos and is shown in **Table 1**. This includes:

- number of each type of light
- spectral output of light type (**Figure 1**)
- angular distribution of light (shielding)
- lumen output of each type of light
- elevation (above sea level) of each light

Table 1: Lighting inventory for non-flaring scenario

Light type	Quantity	Power (lm)	Height (m)	Spectrum/CCT	Shielding
eLLK 92 LED 800A NE	400	5350	11	4000K LED	Nil
eLLK 92 LED 800A NE	600	5350	16		
eLLK 92 LED 800A NE	600	5350	26		
eLLK 92 LED 800A NE	150	5350	35		
Series 6525 LED Floodlight	5	21000	11		
Series 6525 LED Floodlight	5	21000	47		

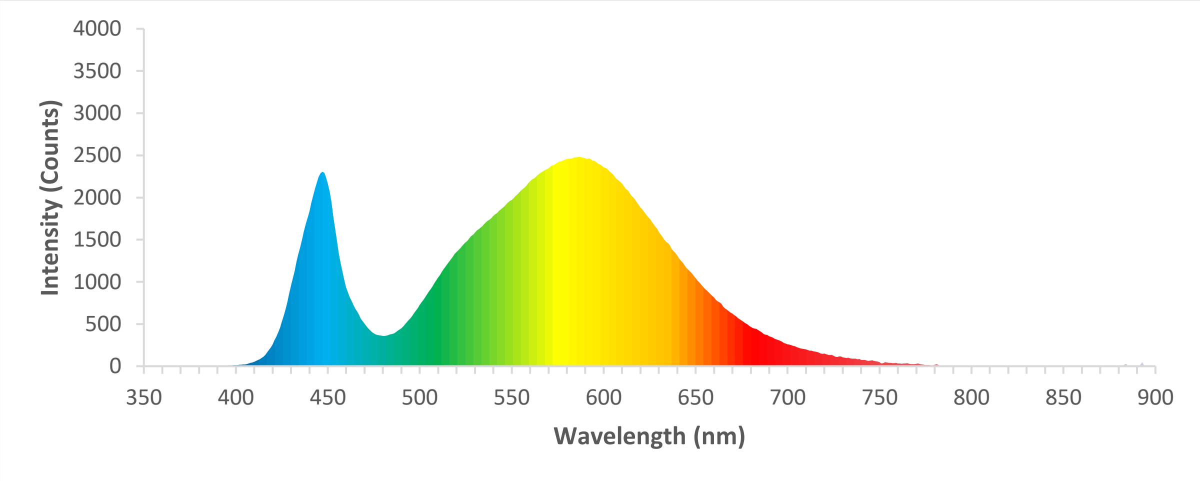


Figure 1: Spectral power distribution of a 4000K LED.

The second scenario with flaring, is more complex. There is currently no published information on the lumen/radiance output of gas flares used in industry. While PENV was provided with estimated flow rates for the flare, methodology for deriving radiance output from flow rates is unproven and results could vary significantly based on gas composition. An alternative route was taken by using VIIRS-DNB4 (satellite) radiance data of known maintenance (i.e. worst case) flaring events at existing LNG facilities to obtain a base radiance value for a flare before applying to the model. As marine turtles typically have a field of view focused towards the horizon, satellite data measures of upward-radiance and would not normally be suitable for determining horizontal emissions. However, in this case the flare is treated as a spherical emission source and thus our upward-radiance measured values can be applied to a horizontal perspective. This approach was considered more reliable than calculations based on flow rate. Based off this data, the value for the output radiance of the flare was estimated to be 500 $\mu W/m^2/sr$ at a height of 110 m.

Surface reflectance and elevation values are incorporated into the model from aerial imagery supplied by the National Aeronautics and Space Administration (NASA) Earthdata and the National Oceanic and Atmospheric Administration (NOAA) (NASA, 2020; NOAA, 2020) as per the methodology outlined in Aube *et al*. (2005).

Both scenarios assume that all lights emit as a perfect sphere and the FPSO structure itself is absent, thereby having no influence on reflection/absorption of light. While light intensity inputs are provided as lumens (light emission), model outputs are provided in radiance ($W/m^2/sr$, where W = watts, m^2 =meters squared and sr = steradian), which describes the light received in a specific area.

2.2 Interpretation and Limitations

In the absence of any published or generally accepted units of measurement, or scale, for measuring the impact of ALAN on marine turtles, moonlight was selected as a proxy and the light model output (radiance, units of $W/m^2/sr$) was converted to units of full moon equivalents in an attempt to give the radiance output some biological relevance and to aid interpretation in an environmental impact assessment context. The reasoning used was:

- the range of moon brightness across a whole lunar cycle is a realistic scale representative of the ambient light levels that turtle eyes are adapted to. At the lower end of the scale the radiant output is equivalent to no light in the sky while the upper limit is greater than the radiance from a single full moon and was selected to try to account for the increase in radiance levels that would occur if the light was reflected from clouds (recognizing that cloudy conditions are not the norm for this site). Extending the scale beyond this limit was deemed unnecessary.
- the scale for the units "the proportion of radiance of one full moon" was derived from the logarithmic nature of light decay with distance (a function of the inverse square law), e.g. the scale of <0.01, 0.01 – 0.1, 0.1 – 1, 1 – 10 represents a range of radiant brightness from a minimum of <0.01 full moon (so essentially a new moon) to a maximum radiant brightness of the equivalent to 10 full moons.

While the behavioural response of marine turtles to light is relatively well understood (see Witherington and Martin (2003) for review), there is currently no agreed upon intensity limits for determining what the impact of a given light might be. Studies suggest that hatchling turtles are the most vulnerable life stage to potential impacts from artificial light (e.g. Witherington, 1992). A large range of factors influence the visibility and impact of light on hatchlings including light intensity, visibility (a function of lamp orientation and shielding), spectral power distribution (wavelength and colour), atmospheric scattering, cloud reflectance, spatial extent of sky glow, duration of exposure, horizon elevation, lunar phase, hatchling swimming speeds, tide and current speeds and flow direction etc. Using the scale of light radiance derived from the calculated decrease in light intensity with distance (proportion radiance of a full moon). Due to the increased vulnerability of hatchlings, potential impact criteria developed for hatchlings are considered inclusive of other life stages (including internesting and nesting females). Together with our extensive SME experience observing marine turtles and their response to both onshore and offshore construction light in field settings, we have proposed conservative, potential impact criteria for marine turtles based on radiance thresholds relative to moon radiance, as shown in **Table 2**.

Although the potential effects of ALAN on other marine fauna, such as seabirds or migratory shorebirds, is gaining more recognition, the vulnerability of individuals to negative impacts of

ALAN is highly species specific and can vary depending on the life stage or behaviour being undertaken at the time (see Commonwealth of Australia (2020) for review). Accordingly, while presenting radiance as a measure relative to that of a full moon is biological relevant to other marine taxa, potential impact criteria could not be defined.

Table 2: Artificial light impact potential criteria (marine turtles)

Proportion of radiance of a full moon*	Impact potential to marine turtles
> 1	Light or light glow visible and impact likely, represents a very bright light greater than a full moon. This light radiance will override the moderating influence of the ambient full moon at the time of exposure.
0.1 - 1	Light or light glow visible and behavioural impact possible, depending on ambient moon phase at the time of exposure, which will influence the visibility of the artificial light sources, equivalent to the light output. Artificial lights will be more visible to marine turtles under a first quarter moon than under a full moon.
0.01 - 0.1	Light or light glow visible but behavioural impact unlikely (i.e. not biologically relevant). Equivalent to the light output from the first quarter moon to new moon.
< 0.01	Light or light glow is considered ambient and no impact expected, equivalent to a new moon

*Where 1 equals the radiance of one full moon and 0.01 equals 100th the radiance of one full moon

3 RESULTS

Results from the ILLUMINA model undertaken for the FPSO facility located at coordinates 19.04694 S, 118.74333 E are presented in **Table 3** and **Figure 3**.

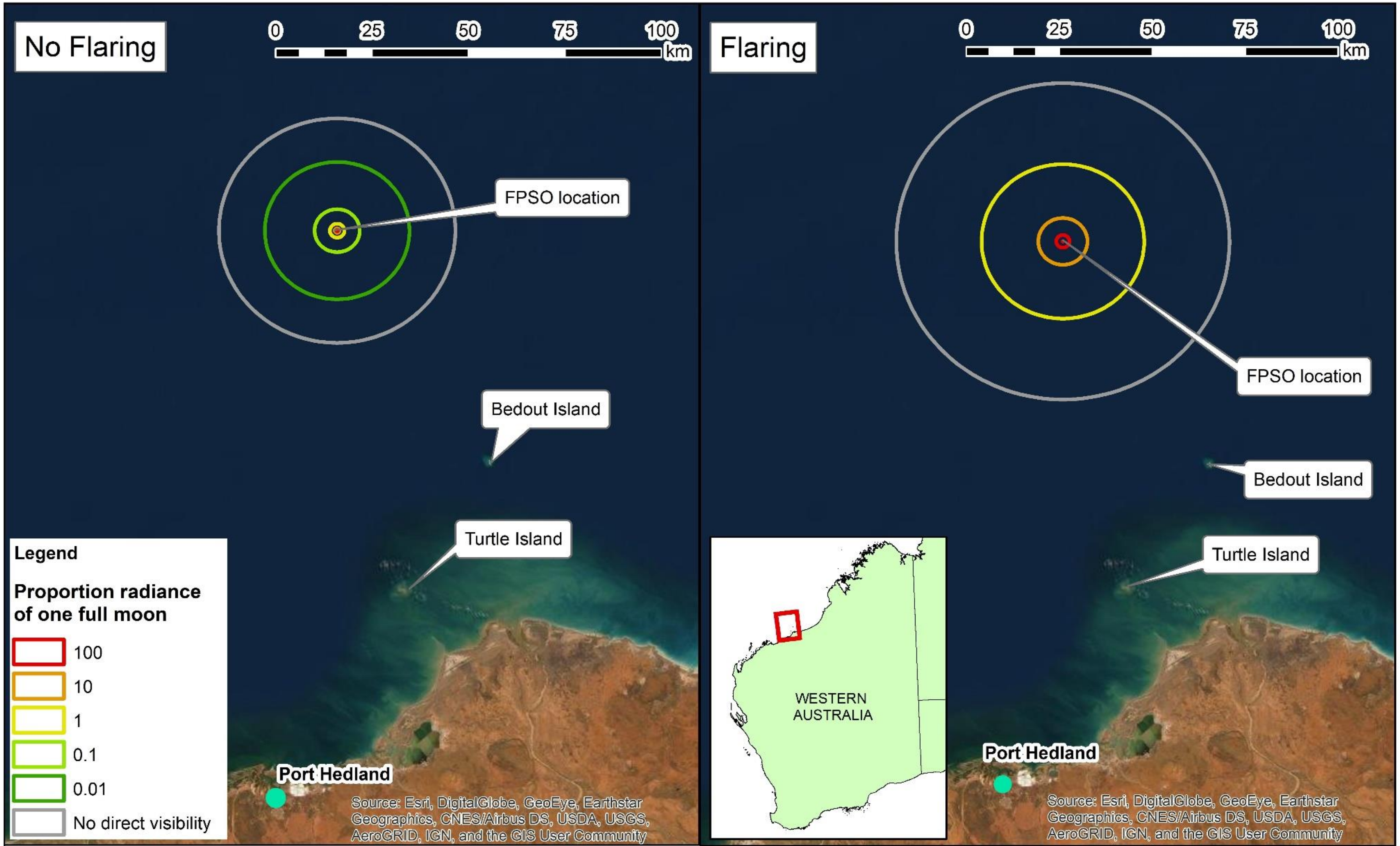
When applying the potential impact criteria in **Table 2**, the results show that, at ~17.7 km from the source, radiance has reduced to ambient in the non-flaring scenario. At distances between ~ 5.5 km and ~17.7 km from the source, radiance is equivalent to between 0.1 and 0.01 radiance of a full moon and, therefore, light may be visible but unlikely to result in a behavioural impact to marine turtles. Impacts to marine turtles may occur within ~5.5 km of the FPSO, depending on moon phase, and are more likely within ~1.8 km of the FPSO, when radiance is equivalent to that of one full moon.

In the flaring scenario, the flare is no longer directly visible at 42.4 km, when the flare drops below the horizon. At this distance, the radiance is equivalent to 0.25 full moons. Thus, impacts to marine turtles may occur at any point within this distance, becoming more likely within 20.7 km. The nearest shorelines are Bedout and Turtle Island, at approximately 70 km and 95 km from the facility respectively. No direct light will be visible from beaches on these islands, as shown in **Figure** 2**.**

Table 3: Distance of equivalent moon radiances for the non-flaring scenario

Proportion of radiance of a full moon*	**Distance from FPSO at which equivalent moon radiance is reached (m)**	
	Non-Flaring	**Flaring**
1000		450
100	180	1690
10	550	6260
1	1790	20700
0.1	5539	
0.01	17740	

*Where 1 equals the radiance of one full moon and 0.01 equals 100th the radiance of one full moon



J54002 Dorado FPSO Light Modelling

Figure 2: Radiance of light sources with distance from the FPSO facility for non-flaring and flaring scenarios.

Drawn: A.Knipe
Date: 18/05/2020
Drawing File Ref:
PENV-J54002-992-B
Coordinate System: GDA 1994 MGA Zone 50

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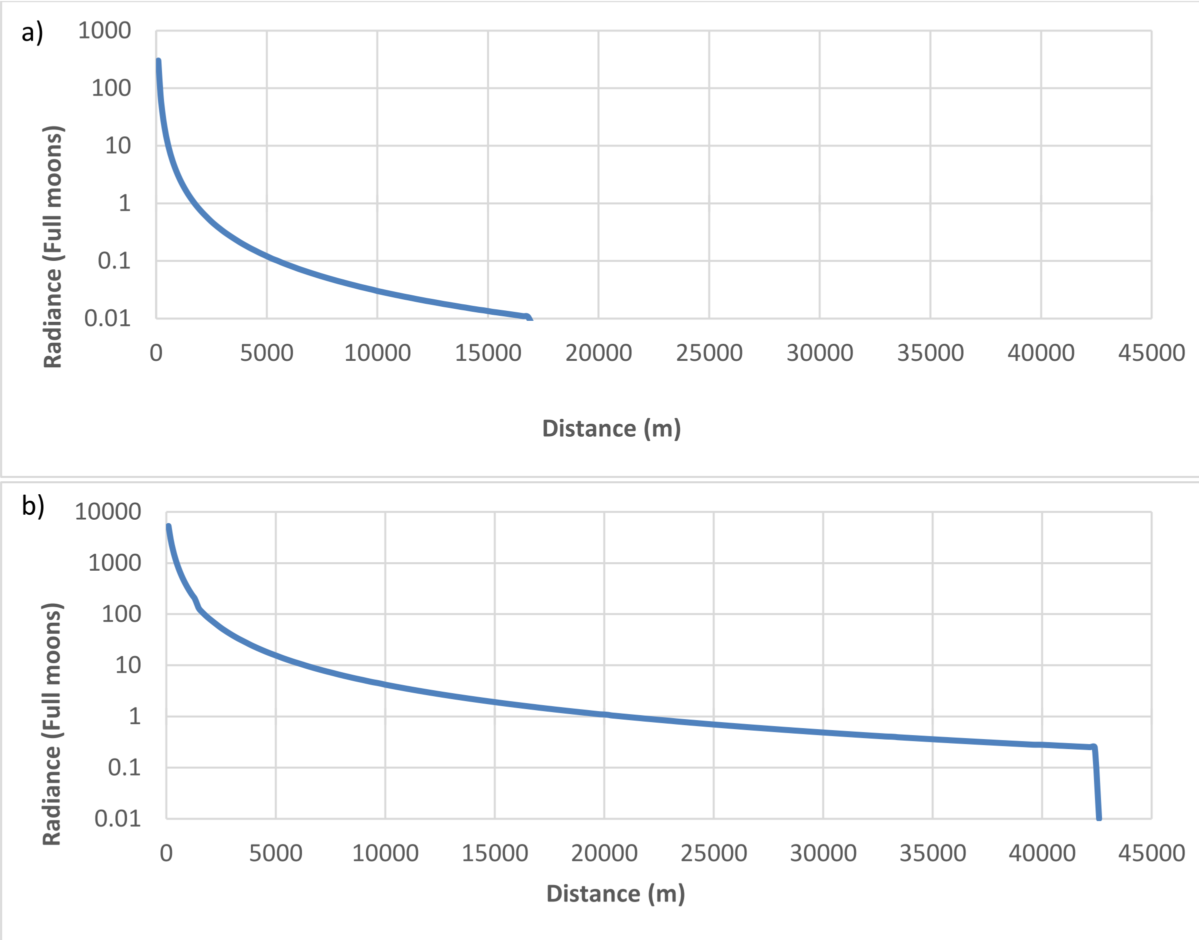

Figure 3: Radiance of light sources with distance from the FPSO facility. a) Non-flaring scenario. b) Flaring scenario. The sudden drop off in (b) at 42,400 m represents the distance at which the flare drops below the horizon and is no longer visible.

4 SUMMARY

Model outputs are in radiance ($W/m^2/sr$) and presented as a proportion of the radiance of a full moon as a realistic scale representative of the natural conditions experienced by a marine fauna receptor in the field and to provide biological context.

The distance from source at which a given level of radiance was reached (reported as proportion of radiance of a full moon) was greater for the flaring scenario, as expected. Light emissions were predicted to reduce to ambient levels (0.01, or 1%, radiance of a full moon) at 17.7 km for the non-flaring scenario, and do not reach ambient in the flaring scenario before the flare disappears from the observer’s view, instead reaching a radiance equivalent to a quarter moon. The closest shorelines are Bedout Island (70 km) and Turtle Island (95 km), from which no direct light will be visible.

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Attachment 10 Underwater Noise Modelling

Dorado OPP Acoustic Modelling

Assessing Marine Fauna Sound Exposures

Submitted to:

Warren Chisholm
CDM Smith Australia

Contract: 10 December 2019

Authors:

Matthew Koessler
Craig McPherson

12 July 2020

P001518-002
Document 02076
Version 1.1

JASCO Applied Sciences (Australia) Pty Ltd
Unit 1, 14 Hook Street
Capalaba, Queensland, 4157
Tel: +61 7 3823 2620
www.jasco.com

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

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Executive Summary

Santos WA Northwest Pty Ltd (referred to herein as Santos) are proposing to develop the Dorado oil field, on the North West Shelf of Western Australia. Referred to as the Dorado Development, the project will include a Well Head Platform (WHP) and a Floating Production Storage and Offloading (FPSO) facility. The FPSO will have a turret mooring system that will be stabilised using mooring lines secured to the seabed by piles. This modelling study provides the basis to assess the impacts of noise from these activities on marine mammals, sea turtles, fish (adults, larvae, eggs), plankton, sponges and corals.

This modelling study considered the following representative activities to inform the impact assessment:

- Installing a single subsea WHP jacket pile per day through impact piling.
- Installing a single subsea FPSO mooring pile per day through impact piling.
- Vertical Seismic Profiling (VSP) from a crane suspended source during drilling operations.
- FPSO operational noise for an FPSO under normal operating conditions.
- An Offshore Support Vessel (OSV) supporting offtake operations
- FPSO operational noise during offtake, represented by:
  - The FPSO under dynamic positioning (DP).
  - The FPSO under DP, with a noiseless condensate tanker, and the OSV supporting the offtake.

Pile Installation

The predicted distances to all per-strike isopleths (contours of equal sound level) are farthest from the piles at the start of piling, when the most of the pile is in the water column, and smallest at the end of piling, when most of the pile is buried in the sediment. This is despite the increased frictional resistance of sediments and stronger stress-wave reflections at the pile toe at later stages of insertion.

For exposure criteria based on cumulative metrics, the ranges must be considered in the context of the duration of operations. Given that one pile will be driven per day at each location, the corresponding sound level is denoted as the accumulated sound exposure level over 24 h (SEL_{24h}); the effective time estimates for driving piles, however, are 1.6 h for the WHP jacket piles and 4.7 h for the FPSO anchor piles. A single subsea hammer (MHU 600T) was modelled for driven piles at each location.

SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within the pile driving period, based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure since, more realistically, marine fauna such as mammals and fish would not stay in the same location or at the same distance from a sound source for an extended period. Therefore, a reported radius for SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be injured, but rather that it *could* be injured if it remained within that range for the entire duration of the pile driving.

Ranges to Exposure Thresholds

The analysis considered multiple effects criteria commonly used in pile driving noise assessments. Key results of the acoustic modelling are summarised below.

Marine Mammals

- United States National Oceanic and Atmospheric Administration (NOAA) (2019) acoustic threshold for behavioural effects in cetaceans: Pile driving impulse sounds are predicted to exceed the SPL threshold of 160 dB re 1 µPa for behavioural effects of marine mammals between

3.4–5.4 km, the minimum and maximum distances depending on the depth of penetration and type of pile being driven.

- Southall et al. (2019) criteria for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The assessment considers both metrics within the criteria (peak pressure level (PK) and SEL)), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 1.

Table 1. Maximum-over-depth distances (in km) to marine mammal PTS and TTS thresholds for pile driving from Southall et al. (2019).

Hearing group	WHP jacket pile		FPSO anchor pile	
	Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
PTS				
Low-frequency cetaceans	SEL_{24h}	5.29	SEL_{24h}	5.84
High-frequency cetaceans	SEL_{24h}	–	SEL_{24h}	0.03
Very-high-frequency cetaceans	PK	0.55	SEL_{24h}	1.04
TTS				
Low-frequency cetaceans	SEL_{24h}	22.6	SEL_{24h}	28.2
High-frequency cetaceans	SEL_{24h}	0.29	SEL_{24h}	0.36
Very-high-frequency cetaceans	SEL_{24h}	2.78	SEL_{24h}	4.27

For the SEL_{24h} criteria, the model does not account for shutdowns.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea Turtles

- U.S National Marine Fisheries Service (NMFS) criterion for behavioural response (SPL of 166 dB re 1 µPa) and a criterion for increased behavioural disturbance (SPL of 175 dB re 1 µPa) (Moein et al. 1995, McCauley et al. 2000b, 2000a): The maximum distances to the two criteria considered are summarised in Table 2.
- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The assessment considers both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 3.

Table 2. Maximum (R_{max}) horizontal distances (in km) from the pile to modelled maximum-over-depth turtle behavioural response thresholds, maximum across all three penetration depths.

Threshold	WHP jacket pile	FPSO anchor pile
	R_{max} (km)	R_{max} (km)
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	3.51	2.91
Turtle behaviour, SPL: 175 dB re 1 µPa (McCauley et al. 2000b, McCauley et al. 2000a)	1.39	1.07

Table 3. Maximum-over-depth distances (in km) from the pile to turtle PTS and TTS thresholds (Finneran et al. 2017).

Threshold	WHP jacket pile		FPSO anchor pile	
	Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
PTS	SEL_{24h}	0.72	SEL_{24h}	0.68
TTS	SEL_{24h}	4.11	SEL_{24h}	3.98

For the SEL_{24h} criteria, the model does not account for shutdowns.

Fish, Fish Eggs, and Fish Larvae

- This study assessed the ranges for quantitative criteria from Popper et al. (2014) associated with mortality and potential mortal injury and impairment in the following:
    - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
    - Fish with a swim bladder not used for hearing
    - Fish that use their swim bladders for hearing
    - Fish eggs, and fish larvae
- The maximum distance from pile driving at which sound levels exceeded mortality and potential mortal injury (SEL_{24h} metric) for the most sensitive fish groups is 560 m for the WHP jacket pile and 520 m for the FPSO anchor pile.
- Fish (including sharks) could experience TTS (SEL_{24h} metric) from the proposed pile driving activity. It is predicted that this will occur within 5.59 km for the WHP jacket pile and 5.88 km for the FPSO anchor pile.

Vertical Seismic Profiling

The modelling scenarios for VSP considered a single 750 in^3 array suspended at 5 m from the sea surface at the WHP. Modelling assessed both individual impulses and multiple impulses within a 24 h period to determine SEL_{24h}.

The analysis considered multiple effects criteria commonly used in seismic survey noise assessments. Key results of the acoustic modelling are summarised below.

Marine Mammals

- NOAA (2019) acoustic threshold for behavioural response in marine mammals: The maximum distance to the SPL threshold of 160 dB re 1 µPa was 2.42 km from the centre of the VSP array.
- Southall et al. (2019) criteria for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The SEL_{24h} threshold distance considers multiple impulses within a 24 h period, ranging from 1 to 300. The applicable metric from the criteria, associated with the longest distance associated with either metric, depends upon the number of impulses within the 24 h. The ranges presented are based upon a maximum of 300 impulses. A reported radius for SEL_{24h} criteria does not mean that marine mammals travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with effect (either PTS or TTS) if it remained in that location for either 24 hours or the duration of the activity if less.
    - For low-frequency cetaceans, the PTS and TTS thresholds associated with the PK metric were predicted to be less than 20 m from the centre of the acoustic source; the PTS and TTS ranges were therefore determined by SEL_{24h}, with the maximum distances reached at 470 m for PTS and 3.1 km for TTS.
    - PTS and TTS are not predicted to occur for high-frequency cetaceans.

- For PTS in very high-frequency cetaceans, the PK metric was always associated with the longest range (63 m), as was the case for TTS (241 m).

Sea Turtles

- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The SEL_{24h} threshold distance considers multiple impulses within a 24 h period, ranging from 1 to 300. Similarly to marine mammals, the reported radii for SEL_{24h} criteria do not mean that sea turtles travelling within this distance of the source will be injured, but rather that an animal could be exposed to the sound level associated with effect (TTS) if it remained in that location for either 24 h or the duration of the activity if less.
  - Within the range of considered impulses (1–300), the PTS threshold was first exceeded at a maximum distance of 30 m when considering the SEL_{24h} criteria for 150 impulses. The PK threshold may be exceeded at distances less than 20 m from the centre of the acoustic source, if at all.
  - While the TTS criterion due to the PK metric was not exceeded, depending upon the number of impulses the TTS SEL_{24h} criterion may be exceeded at a maximum distance of 380 m for 300 impulses.
- Behavioural effects in sea turtles: The maximum distance to the NMFS criterion (NSF 2011) for behavioural effects in sea turtles of 166 dB re 1 µPa (SPL) is 1.22 km, and the maximum distance to the McCauley et al. (2000b), McCauley et al. (2000a) disturbance criterion of 175 dB re 1 µPa (SPL) is 0.38 km.

Fish, Fish Eggs, and Fish Larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury and with impairment in the groups listed in the piling section:
- The distance from pile driving at which sound levels exceeded the limit for mortality and potential mortal injury for the most sensitive fish groups was 37 m (PK metric).
- Within the range of considered impulses (1–300), the distance to the threshold for the SEL_{24h} metric for injury was first reached at a maximum distance of 50 m for 200 impulses.
- Sound levels at the seafloor do not exceed any of the fish criteria.

Sponges and Coral

To assist with assessing the potential effects on these receptors, the following have been determined:

- Sponges and coral: The PK sound level at the seafloor directly underneath the VSP source was estimated at both modelling sites and did not reach the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018);

Vessel Operations

The modelled scenarios for vessels consider the following sources:

- An FPSO facility 370 m long and 67 m wide:
  - under typical operations, with no thrusters and no offtake, only topsides equipment; and
  - under dynamic positioning representative of typical operational loads during moderate weather conditions to inform an offtake scenario.
- A representative Offshore Support Vessel (OSV), namely a dynamic positioning Class 2 (DP2) vessel within 700 m of the FPSO under dynamic positioning representative of typical operational loads during moderate weather conditions while assisting FPSO offtake into a noiseless condensate tanker.

The analysis considered multiple effects criteria commonly used in seismic survey noise assessments. Key results of the acoustic modelling are summarised below.

Marine Mammals

- The results for the Southall et al. (2019) criteria applied for marine mammal PTS and TTS for vessels were assessed for a 24 h period with the maximum distances to PTS summarised in Table 4.
- The maximum distances to the NOAA (2019) marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) are summarised in Table 5.

Table 4. Maximum (R_{max}) horizontal distances (km) from the vessels to modelled maximum-over-depth marine mammal PTS threshold from Southall et al. (2019).

Hearing group	Threshold for PTS, SEL_{24h} (dB re 1 µPa²·s)	Distance R_{max} (km)			
		FPSO under DP	FPSO without DP	OSV	Offtake operations*
Low-frequency cetaceans	199	0.07	–	0.03	0.08
High-frequency cetaceans	198	–	–	–	–
Very-high-frequency cetaceans	173	0.21	–	0.05	0.21

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
* Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.

Table 5. Summary of maximum marine mammal behavioural disturbance distances for vessels

Threshold	Distance R_{max} (km)			
	FPSO under DP	FPSO without DP	OSV	Offtake operations*
Marine mammal behaviour, SPL: 120 dB re 1 µPa (NOAA 2019)	10.4	1.49	4.57	11.0

* Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.

Sea Turtles

- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): TTS is not predicted to occur for the FPSO without DP within the modelling resolution of 20 m, and only at distances of up to 50 m for the FPSO under DP and offtake operations. PTS is not predicted to occur. Behaviour is assessed through the relative risk criteria.

Fish

- Popper et al. (2014): Sound produced by the vessel operations could cause physiological effects and recoverable injury to some fish species, but only if the animals are in very close proximity to the sound sources—within a planar distance of 30 m, for 48 h. Temporary impairment due to TTS could occur at similar short distances if a fish remained at the same location within the sound field for a duration exceeding 12 h.

1. Introduction

JASCO Applied Sciences (JASCO) performed a modelling study of underwater sound levels associated with the development of the Dorado oil field, on the North West Shelf of Western Australia. The Dorado Development will include a Well Head Platform (WHP) and a Floating Production Storage and Offloading (FPSO) facility. The FPSO will have a turret mooring system that will be stabilised using mooring lines secured to the seabed by piles. The modelling study considered the installation of piles for the WHP and FPSO anchors, vertical seismic profiling (VSP) during drilling operations, and operation of the FPSO, including offload activities.

This study specifically assessed distances from the considered operations to where underwater sound levels reached thresholds corresponding to various levels of impact to marine fauna. The fauna considered in this study included marine mammals, sea turtles, fish (including fish eggs and larvae), plankton, sponges and corals. Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance.

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), and either single-impulse (i.e., per-strike) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria for either continuous (vessels) or impulsive (piling and VSP) noise sources.

1.1. Activity Description

The Dorado Development, located in offshore waters approximately 90 m deep, will include the following noise generating:

- The installation of a single subsea WHP requiring four driven jacket piles for anchoring the platform risers to the seafloor
- The installation of a single subsea FPSO mooring requiring ten piles to tether and anchor the FPSO to the seafloor.
- Vertical Seismic Profiling (VSP) from a crane suspended source during drilling operations.
- FPSO operation under normal operating conditions.
- FPSO offtake operations, including the FPSO under dynamic positioning (DP), an Offshore Support Vessel (OSV) assisting the offtake and a noiseless condensate tanker.

An overview of the modelled area and the modelled vessel configuration for FPSO offtake operations (described in Section 1.2) are shown in Figure 1. A concept layout of the project facilities described above is shown in Figure 2.

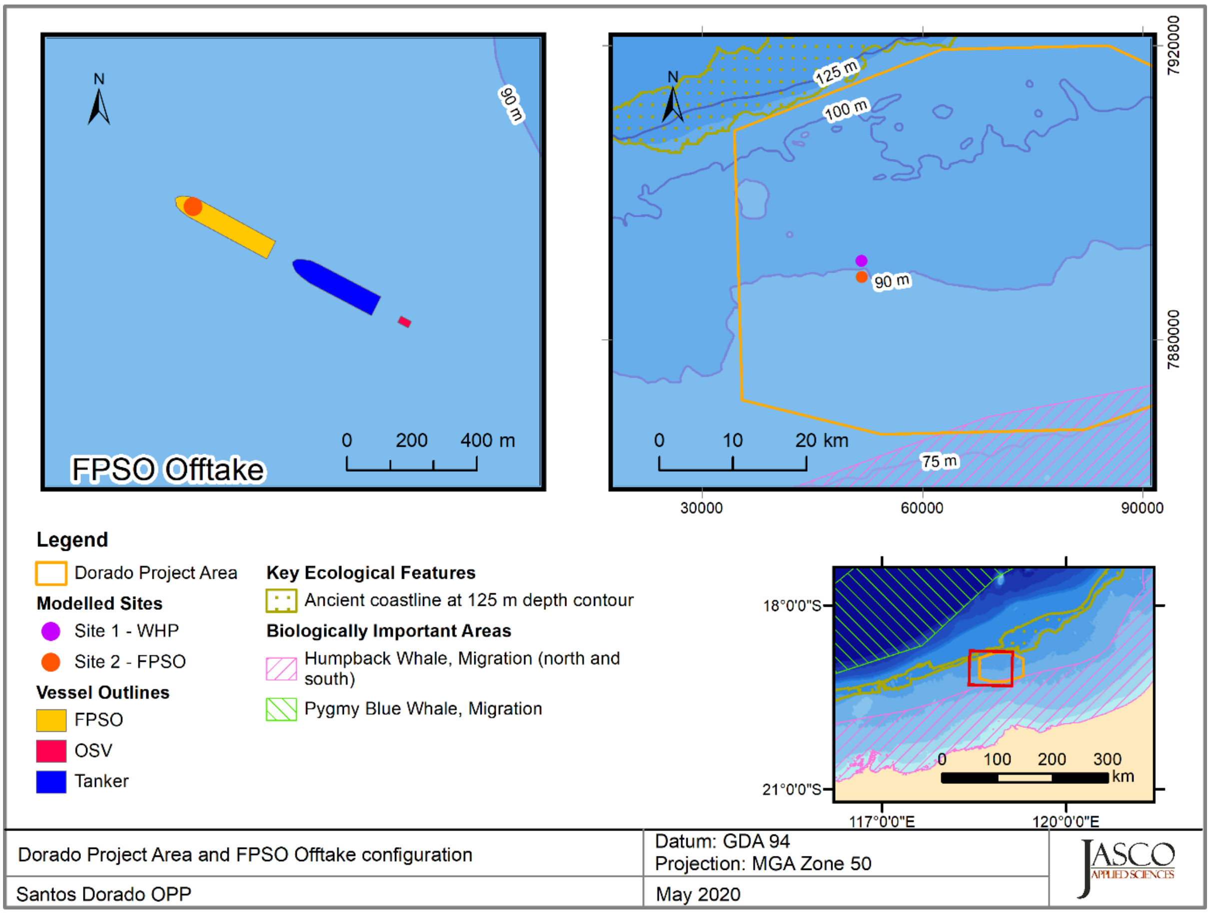

Figure 1. Project overview map and FPSO Offtake configuration used in modelling scenario.

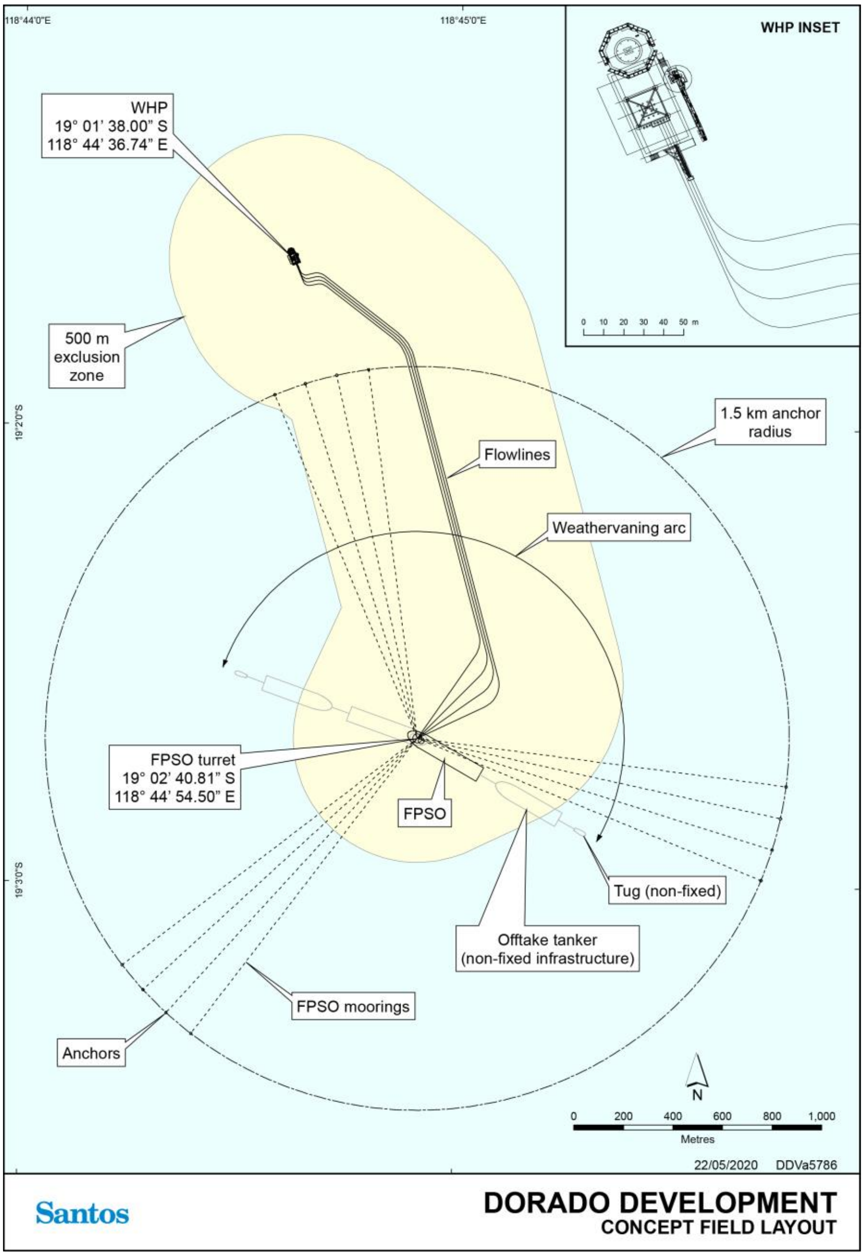

Figure 2. Dorado Development facility layout, the Tug vessel is referred to as an OSV in this report.

1.2. Acoustic Modelling Scenario Details

From the description of the project above, the following representative scenarios have been considered in the underwater noise study to inform the impact assessment. The specific scenarios considered are:

- The installation of a single subsea WHP jacket pile (representative of all four piles).
- The installation of a single subsea FPSO mooring pile (representative of all ten piles).
- Vertical Seismic Profiling (VSP) from a crane suspended source during drilling operations.
- FPSO operational noise for an FPSO under normal operating conditions.
- An Offshore Support Vessel (OSV) supporting offtake operations
- FPSO operational noise during offtake, represented by:
    - The FPSO under dynamic positioning (DP).

- The FPSO under DP, with a noiseless condensate tanker, and the OSV supporting the offtake.

The geographic coordinates for the modelled sites are provided in Table 6. An overview of the modelled area and the modelled vessel configuration for FPSO offtake operations are shown in Figure 1. Site 1 represents the centre of the WHP (and is also used for the VSP) and Site 2 the centre of the turret mooring system on the FPSO.

Table 6. Location details for the modelled sites.

Site	Location Description	Latitude (S)	Longitude (E)	MGA (GDA94), Zone 50		Water depth (m)
				X (m)	*Y* (m)	
1	WHP	19° 01' 38.0010"	118° 44' 36.7440"	683500	7895250	91
2	FPSO	19° 02' 49.5460"	118° 44' 36.7440"	683478	7893050	89

The operations considered in this study will occur at the WHP and FPSO, at depths of approximately 90 m (Table 6). Because activities could take place at any time in the year, a conservative water column sound speed profile (i.e., the profile leading to the longest acoustic propagation) was selected for modelling (July, Appendix F.3.2). The seabed vicinity of the modelled sites consists of a layer of unconsolidated fine sandy sediment underlain by a package of carbonate rock with various degrees of lithification, but likely increasing in cementation/lithification with depth.

JASCO modelled the MHU 600T impact hammer with for use with driving two different pile diameters and wall thicknesses. The MHU 600T subsea impact hammer was considered for driven piles at both sites. The general specifications used for modelling underwater noise from impact piling are provided below in Table 7, detailed scenario specific model input parameters and associated methodology are provided Section 3.1. Only one pile of any type will be driven during a single day.

Table 7. Pile specifications for driven cylindrical steel piles.

Site	Location description	Dimension			Final penetration depth (m)
		Length (m)	Diameter (m)	Wall thickness (mm)	
1	WHP	50	3.0	55	21.5
2	FPSO	40	2.5	100	40.0

2. Noise Effect Criteria

To assess the potential impacts of a sound-producing activity, it is necessary to first establish exposure criteria (thresholds) for which sound levels may be expected to have a negative impact on animals. Whether acoustic exposure levels might injure or disturb marine fauna is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), United States National Marine Fisheries Service (NMFS 2018) and Southall et al. (2019). The number of studies that investigate the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A). In this report, the duration of the SEL accumulation is defined differently depending on the source considered, as per the following:

- For piling: As either a “per-strike” value (i.e., integrated over the time of a single strike), or over all strikes that occur over the driving of a single pile, one pile per 24 h period.
- For VSP: As either a “per-pulse” value (i.e., integrated over the time of a single pulse), or over all impulses that occur in a 24 h period.
- For vessels: Integrated over a 24 h period.

Appropriate subscripts indicate any applied frequency weighting applied (Appendix A.3). The acoustic metrics in this report reflect the updated ANSI and ISO standards for acoustic terminology, ANSI S1.1 (R2013) and ISO 18405:2017 (2017).

This study applies the following noise criteria (Sections 2.1–2.2 and Appendix A.2), chosen for their acceptance by regulatory agencies and because they represent current best available science:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Southall et al. (2019) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals (low-frequency (LF), high-frequency (HF), and very-high-frequency (VHF) cetaceans).
2. Marine mammal behavioural threshold based on the current U.S. National Oceanic and Atmospheric Administration (NOAA 2019) criterion for marine mammals of 160 dB re 1 µPa and 120 dB re 1 µPa (SPL; L_{p}) for impulsive and non-impulsive sound sources, respectively.
3. Sound exposure guidelines for fish, fish eggs, and larvae (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in sea turtles.
5. Turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_{p}) (NSF 2011), as applied by the US National Marine Fisheries Service (NMFS), along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_{p}) (McCauley et al. 2000b, 2000a).
6. Additionally, for comparison to published literature, for VSP only, a no effect sound level for sponges and corals of 226 dB re 1 µPa (PK; L_{pk}), is reported for comparing to Heyward et al. (2018).

A detailed description of the criteria and the background literature is provided in Lucke and McPherson (2020).

2.1. Marine Mammals

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal’s hearing organs; and Temporary Threshold Shift (TTS), a temporary reduction in an animal’s hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To help assess the potential for the possible injury and hearing sensitivity changes in marine mammals, this report applies the criteria recommended by Southall et al. (2019), considering both

PTS and TTS. These criteria, along with the applied behavioural criteria (NOAA 2019), are summarised in Tables 8 and 9, with descriptions included in Appendix A.2.1 (auditory impairment) and Appendix A.2.2 (behavioural response), with frequency weighting explained in Appendix A.2.

Table 8. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL_{24h}, and PK thresholds

Hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
High-frequency cetaceans		185	230	170	224
Very-high-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

Table 9. Acoustic effects of continuous noise on marine mammals: Unweighted SPL and SEL_{24h} thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)	
	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
Low-frequency cetaceans	120	199	179
High-frequency cetaceans		198	178
Very-high-frequency cetaceans		173	153

L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

2.2. Fish, Sea turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Sea Turtles was formed to continue developing noise exposure criteria for fish and sea turtles, work begun by a NOAA panel two years earlier. The Working Group developed guidelines with specific thresholds for different levels of effects for several species groups (Popper et al. 2014). The guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. However, as these depend upon activity-based subjective ranges, these effects are not addressed in this report and are included in Tables 10 and 12 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Sea turtles, fish eggs, and fish larvae are considered separately.

2.2.1. Impulsive noise

Impulsive noise from both piling and airguns (VSP) is assessed in this study, the relevant effects thresholds from Popper et al. (2014) are listed in Table 10. In general, whether an impulsive sound adversely effects fish behaviour depends on the species, the state of the individual exposed, and other factors.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move. Integration times in this study for piling have been applied over the time a single pile was driven since only one pile is expected to be driven per day, while for VSP operations it is over the total number of impulses per day.

Table 10. Criteria for pile driving and seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL_{24h} or > 213 dB PK	> 216 dB SEL_{24h} or > 213 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	186 dB SEL_{24h}	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL_{24h} or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.2.1.1. Sea turtles

There is a paucity of data regarding responses of sea turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. McCauley et al. (2000b) observed the behavioural response of caged sea turtles–green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)–to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (Moein et al. 1995), but the received levels were unknown and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 180 and 166 dB re 1 µPa (SPL) for injury and behavioural response, respectively. Popper et al. (2014) suggested injury to sea turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa^2·s (SEL_{24h}). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun.

Finneran et al. (2017) presented revised thresholds for turtle injury (PTS) and TTS, considering both PK and frequency weighted SEL, which have been applied in this study, along with the NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa), and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) (Moein et al. 1995, McCauley et al. 2000b, 2000a) (Table 11).

Table 11. Acoustic effects of impulsive noise on sea turtles: Unweighted SPL, SEL_{24h}**,** and PK thresholds

NSF (2011)	**Moein et al. (1995), McCauley et al. (2000b), (2000a)**	**Finneran et al. (2017)**			
Behaviour		**PTS onset thresholds* (received level)**		**TTS onset thresholds* (received level)**	
SPL (L_p; dB re 1 µPa)		Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
166	175	204	232	189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

2.2.2. Continuous noise

Table 12 lists the relevant effects thresholds from Popper et al. (2014) for shipping and continuous noise. Some evidence suggests that fish sensitive to acoustic pressure show a recoverable loss in hearing sensitivity, or injury when exposed to high levels of noise (Scholik and Yan 2002, Amoser and Ladich 2003, Smith et al. 2006); this is reflected in the SPL thresholds for fish with a swim bladder involved in hearing.

Finneran et al. (2017) presented revised thresholds for turtle injury, considering frequency weighted SEL, which have been applied in this study for vessels (Table 13).

Table 12. Criteria for vessel (continuous) noise exposure for fish, adapted from Popper et al. (2014)

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Table 13. Acoustic effects of continuous noise on sea turtles, weighted SEL_{24h}, Finneran et al. (2017).

PTS onset thresholds (received level)	TTS onset thresholds (received level)
220	200

3. Methods

This section describes the methods used to characterise acoustic sources (driven piles, vessel noise and VSP), as well as the acoustic propagation models and frequency ranges considered for estimation of acoustic fields.

3.1. Pile driving

To predict the acoustic field around the pile driving, JASCO's Pile Driving Source Model (PDSM; Appendix B) was used in conjunction with JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM, Appendix E.2) at frequencies from 10 Hz to 1 kHz. In addition, an empirical extrapolation was applied to these results to extend the frequency range up to 25 kHz.

The 24 hour SEL results were determined through the accumulation of energy across the entire pile driving operation, accounting for the per-strike sound fields modelled for three phases representing different seafloor penetration depths.

3.1.1. Per-strike Modelling

For impact pile driving sounds, time-domain representations of the pressure waves generated in the water are required for calculating sound pressure level (SPL), sound exposure level (SEL), and peak sound pressure level (PK). Appendix A.1 describes these sound level metrics. The following steps describe the general approach applied in this study to model sounds from impact pile driving activities:

1. The theory of underwater sound propagation is applied to predict how sound propagates from the pile into the water column as a function of range, depth, and azimuthal direction. Propagation depends on several conditions including the frequency content of the sound, the bathymetry, the sound speed in the water column, and seabed geoacoustics (Appendix F.3 describes environmental properties such as bathymetry, sound speed profile, and geoacoustics).
2. Piles driven into the seabed by impact piling are characterised as vertically distributed sound-radiating sources. This characterisation strongly depends on the rate and extent of pile penetration, pile dimensions, and pile driving equipment.
3. The propagated sound field is used to compute received levels over a grid of simulated receivers from which distances to criteria thresholds and maps of ensonified areas are generated.

To model sounds resulting from impact pile driving of cylindrical pipes, PDSM (Appendix B), a physical model of pile vibration and near-field sound radiation (MacGillivray 2014), is used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010). Figure 3 shows the time history of the hammer force at the top of the pile that is predicted by GRLWEAP.

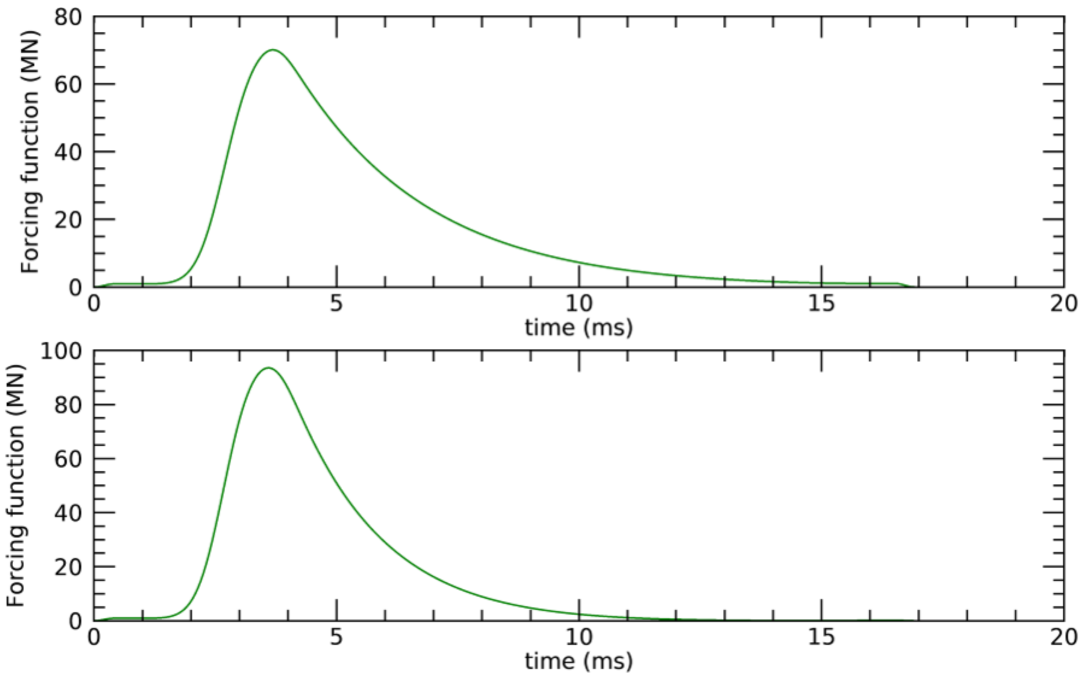

Figure 3. Force (in meganewtons) at the top of the pile corresponding to impact pile driving using the MHU 600T impact hammer for the WHP jacket pile (top) and FPSO anchor pile (bottom), computed using the GRLWEAP 2010 wave equation model for the WHP jacket pile and FPSO anchor pile.

The forcing functions (Figure 3) are used by the PDSM to obtain equivalent pile driving signatures for a vertical array of discrete point sources (Appendix B). These represent the pile as an acoustic source and account for parameters (pile type, material, size, and length), the pile driving equipment, and approximate pile penetration rate. The amplitude and phase of the point sources along the pile are computed so they collectively mimic the time-frequency characteristics of the acoustic wave at the pile wall that results from a hammer strike at the top of the pile. This approach accurately estimates spectral levels within the band 10–1000 Hz where most of the energy from impact pile driving is concentrated.

Time-domain Full Waveform Range-dependent model (FWRAM; Appendix E.2) calculates sound propagation from physically distributed impulsive sources and is valid at all distances. In the present study, received sound levels were calculated using FWRAM along transects at 180 azimuths out to 80 km from the source.

Source band levels at 1000 Hz were extrapolated up to 25 kHz using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly-sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009).

Receiver depths are chosen to span the entire water column over the modelled area, from 2 to 230 m, with a 2 m depth increment. To produce maps of received sound level distributions and to calculate distances to specified sound level thresholds, the maximum-over-depth level is calculated at each modelled easting and northing position within the considered region. The radial grids of maximum-over-depth levels are then resampled (by linear triangulation) to produce a regular Cartesian grid with a cell size of 20 m. The contours and threshold ranges were calculated from these flat Cartesian projections of the modelled acoustic fields (Appendix F.1).

3.1.2. Accumulated SEL Modelling for Pile Driving

The modelling approach outlined in Sections 3.1.1 provides per-strike SEL for three stages of pile driving (i.e., three penetration depths). Because a single pile will be driven per day and the piling noise level far exceeds any background, the corresponding sound exposure level can be denoted as SEL_{24h} even though the effective period of accumulation is the estimated time for fully driving a single pile. The accumulated SEL over a single pile, or the SEL_{24h}, depends on the total number of strikes

Total driving time was estimated assuming continuous piling at a rate of approximately 0.50 strikes/second (30 strikes/minute) for the MHU 600T hammer. The number of strikes required for the driving of the pile were determined based upon a drivability profile estimated in consultation with Santos. The SEL_{24h} was computed by adjusting the single-strike SEL by $10*\log_{10}(N)$, where the total number of strikes. A summary of the total number of strikes per penetration depth and over the entire pile is provided in Table 14.

Table 14. Total number of strikes and driving time. Strikes were broken down into stages corresponding to the three modelled penetrations for the MHU 600T hammer.

Pile Type	Hammer	Modelled penetration (m)	Penetration range for accumulated SEL (m)	Number of strikes	Average Penetration rate (mm/strike)	Total number of strikes	Time for full penetration (hr)
WHP jacket pile	MHU 600T	3.5	1 to 6	500	10	2883	1.6
		11	6 to 16	1333	7.5		
		18.75	16 to 21.25	1050	5		
FPSO anchor pile	MHU 600T	3.5	1 to 6	500	10	8530	4.7
		13.6	6 to 21.25	2480	6.3		
		30.6	21.25 to 40	5550	3.3		

3.2. Vertical Seismic Profiling (VSP)

The pressure signature of the individual airguns and the composite 1/3-octave-band point-source equivalent directional levels (i.e., source levels) of the 750 in^3 VSP source suspended at 5 m were modelled with JASCO's Airgun Array Source Model (AASM; Appendix C.1).

Three sound propagation models were used to predict the acoustic field around the VSP source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz; Appendix E.3).
- FWRAM (5 Hz to 1024 Hz; Appendix E.2).
- Wavenumber integration model (VSTACK, 10 Hz to 2048 Hz; Appendix E.4).

The models were combined to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix E details each model. MONM was used to calculate SEL of a 360° area around the source location. VSTACK was used to calculate PK and PK-PK transects at the seafloor at close range from the seismic source. FWRAM was used to calculate PK and PK-PK in the entire water column along four selected transects, and to obtain a range dependent conversion factor to estimate SPL from the MONM-BELLHOP SEL results.

3.2.1. Acoustic Source Model

AASM accounts for the notional pressure signatures of each source element with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

The VSP source considered was modelled over AASM's full frequency range, up to 25 kHz; Appendix C.1 details this model.

3.2.2. Per-pulse Modelling

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances at least 80 km from the source, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of N = 144 radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 230 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using Bellhop for frequencies from 2 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

FWRAM was run to 80 km along only four radials for computational efficiency from 5 to 1024 Hz in 1 Hz steps. In the context of VSP source geometry (see Appendix C.2) the radials were modelled perpendicular to the sagittal plane of the array and parallel to the sagittal plane of the array. This was done to compute SEL-to-SPL conversions (Appendix F.2) but also to quantify water column PK and PK-PK. The horizontal range step was dependent on frequency and ranged from 50 m at lower frequencies to 10 m above 800 Hz.

The maximum modelled range for VSTACK was 1000 m and a variable receiver range increment that increased away from the source, from 10 to 25 m, was used. Received levels were computed at the seafloor.

3.2.3. Multiple-pulse Modelling

The VSP operation was assessed in this report by considering several potential scenarios for a maximum number of pulses per 24 h. The SEL was assessed over 24 h by adjusting the single-pulse SEL by $10*\log_{10}(N)$, where the total number of pulses N was 5, 10, 15, 25, 50, 100, 150, 200, and 250,and 300 per 24 h at the Dorado WHP location (Site 1).

3.3. Vessel noise (FPSO and OSV)

JASCO's Marine Operations Noise Model (MONM-BELLHOP Appendix E.3) was used to predict the acoustic field at frequencies of 10 Hz to 63 kHz for all vessels.

For all vessels, the sound pressure level (SPL) modelling results were converted to SEL by the duration of the measurement, which is appropriate for a continuous noise source. As SEL was assessed over 24 h, the conversion from SPL was obtained by increasing the levels by $10*\log_{10}(T)$, where T is 86,400 (the number of seconds in 24 h).

The acoustic source parameters for the FPSO are detailed in Section 3.3.1 and those for the OSV in Section 3.3.2.

3.3.1. Floating Production, Storage, and Offloading (FPSO) facility

The proposed FPSO facility is a dynamically positioned production vessel approximately 370 m long and 67 m wide with a draft of 16 m. While in DP mode, it operates on one stern thruster positioned laterally on the keel at the stern of the ship. The vessel type and specifications are similar to production vessels *Ngujima Yin* and *Nganhurra*, from which JASCO gathered measurements in 2010 (Erbe et al. 2013). The measured spectra for these two vessels were averaged and used as a surrogate for the FPSO facility. Because the *Ngujima Yin* and *Nganhurra* were moored, they were not offloading, and the weather was calm, they were not under DP when they were measured. These averaged source levels were used in this report to model FPSO operations without DP.

To model operations that include DP, sound levels of thruster noise were added to the (non-DP) source spectrum. Sound levels for DP thruster noise were based on measurements of the dive support vessel *DSV Fu Lai* (MacGillivray 2006). The composite source spectrum (i.e., non-DP and DP components) was adjusted for the difference in total operational power level between the DSV *Fu Lai* and the FPSO facility using the following equation:

$$SL = SL_{FuLai} + 10\log(HP/HP_{ref}) \,, \quad (1)$$

where HP_{ref} is the level of reference power. The source spectrum was additionally modified to consider the operational level of the *Fu Lai* thrusters relative to the desired operational level for the FPSO facility. Given that DP does not require full thrust, the *Fu Lai*'s thrusters only operated at between 20% and 30% of capacity when measured. To achieve a conservative estimate, the FPSO facility thruster was modelled at 50% power capacity. In addition to the adjustment in Eq.1, an offset of $10*\log_{10}(5/2.94)$ was applied to the composite source spectrum, to account for the difference in thruster power between the *Ngujima Yin* and *Nganhurra*, and the FPSO considered in this study.

The acoustic modelling source depth was determined by assuming the bottoms of the thruster was at the draft of the vessel, but the noise from cavitation is known (Wright and Cybulski 1983) to be centralised at approximately three quarters of the propeller's height.

In the absence of information about the propeller diameter and vertical position, modelling was conducted assuming point sources at 16 m to be conservative. For modelling, it was assumed that the thruster operated at the middle (50%) of their constant power range, at a constant speed. The thrusters are located at the stern section of the vessel; for modelling purposes, however, the source location was placed in the planar centre of the vessel to approximate a point source. Because this assessment is focused on the far-field noise from all sources on the vessel (including not just thruster noise, but also noise from ancillary equipment for power generation, etc.) the point source approximation is suitable. Figure 4 shows 1/3-octave-band source levels and the legend in Figure 4 indicates the overall broadband source level for the FPSO facility (with and without DP).

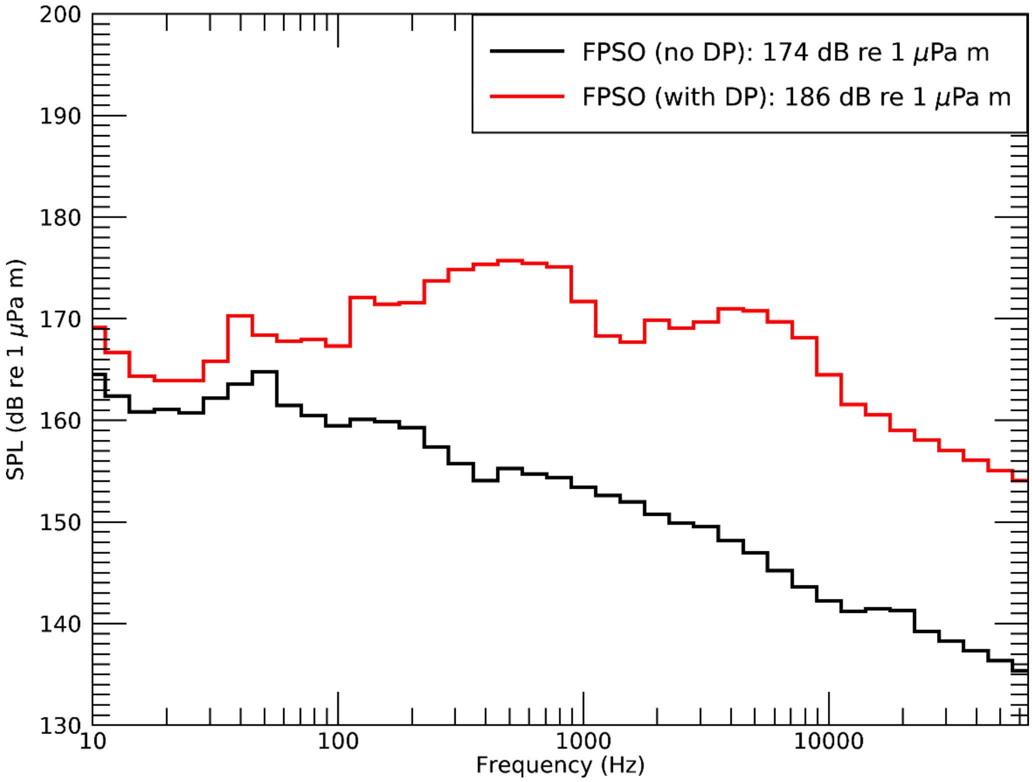

Figure 4. *FPSO*: 1/3-octave-bands of modelled FPSO facility without and with dynamic positioning (DP).

3.3.2. Offshore Support Vessel (OSV)

The estimates of acoustic source levels and sound spectrum for the support vessel were based on the *MMA Inscription* platform supply vessel, referred to in this report as an Offshore Support Vessel (OSV) (Figure 5). The *MMA Inscription*, of length 87.08 m, breadth of 18.8 m and maximum draft of 5.9 is equipped with two bow (main) azimuthal thrusters, one stern retractable azimuthal thruster, and one bow thruster. Since parameters such as propeller size or thruster vertical position were not available, thrusters were modelled at depth 5.9 m, equal to the draft. The bow thrusters are 2000 kW maximum continuous power input each, while the bow thruster is 910 kW maximum continuous power input. For this modelling, the stern retractable thruster was not included. Figure 6 shows the thruster locations.

Source levels for the *MMA Inscription* were obtained based on those of the Damen platform supply vessel 3300CD (length 80.08 m, breadth of 16.8 m and maximum draft of 6.9), which was used in previous studies (Zykov 2016). For the Damen 3300CD, the bow (main) thrusters are 2000 kW maximum continuous power input each, while smaller bow thrusters are 735 kW maximum continuous power input. Unlike Zykov (2016), in which thrusters were assumed to operate at full capacity, modelling in this study was conducted assuming a 25% capacity. For this reason, thrusters levels from Zykov (2016) were offset by $10*\log_{10}(0.25)$ for the main thrusters, and by $10*\log_{10}(0.25)+10*\log_{10}(910/735)$ for the bow thruster. The source levels for individual thrusters are shown in Figure 7.

Figure 5. Image of the *MMA Inscription* (MMA Offshore 2019).

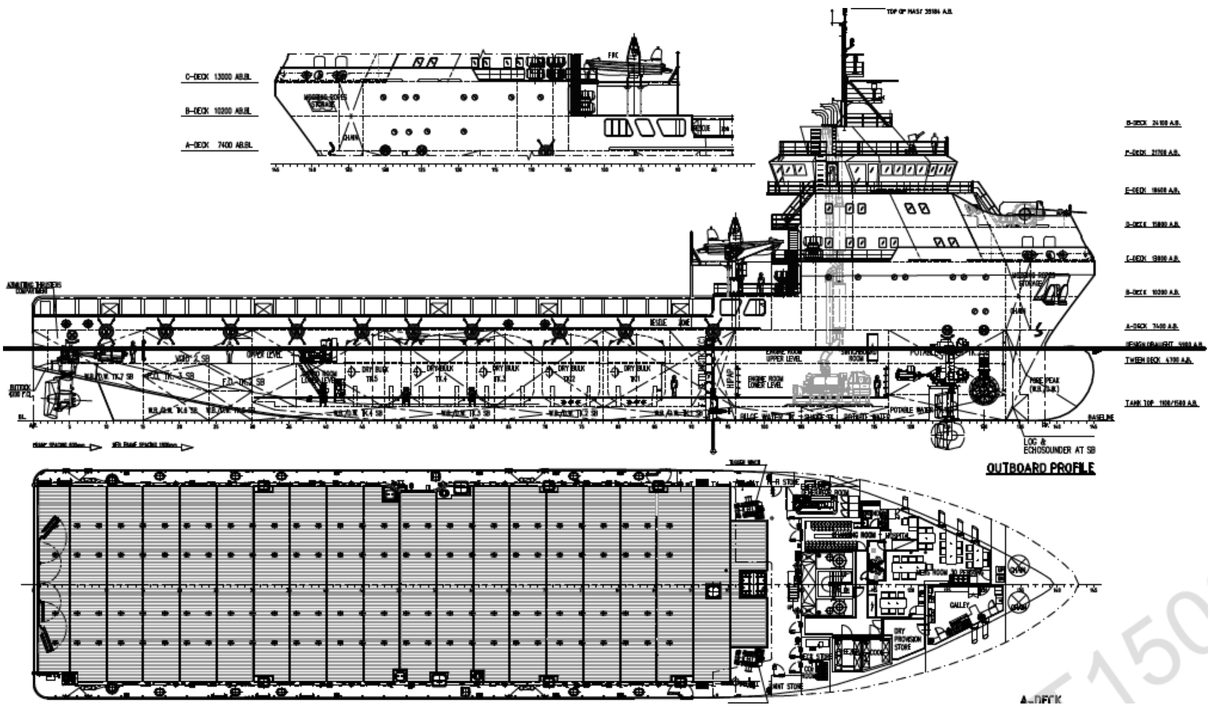

Figure 6. Nominal dimensions and thruster locations (circles) of the *MMA Inscription* (MMA Offshore 2019).

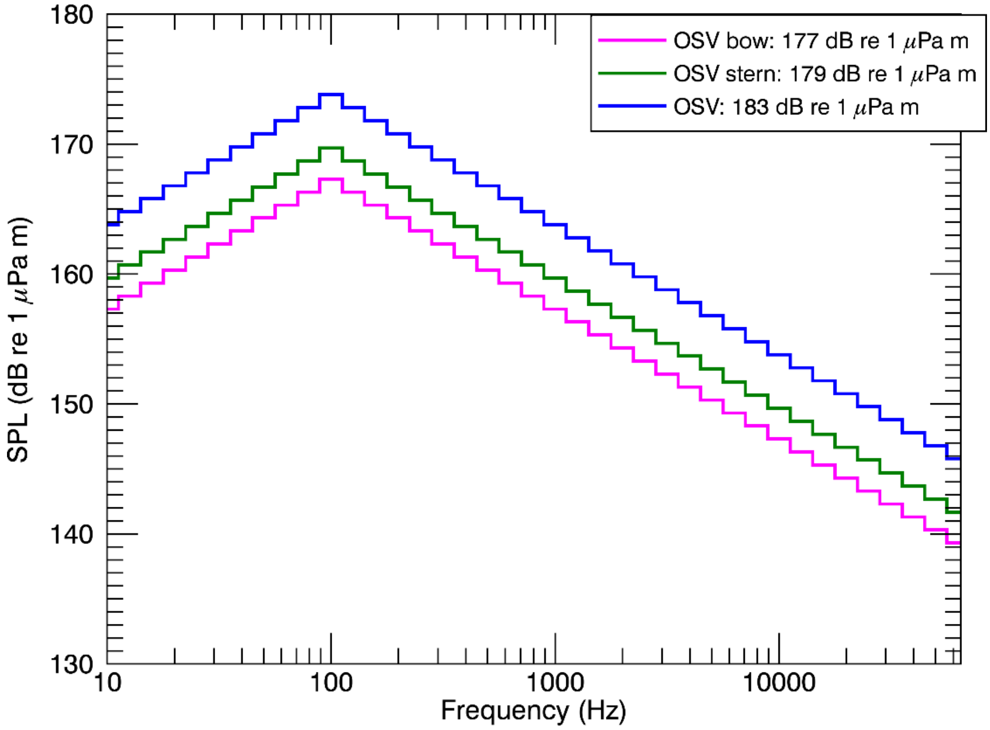

Figure 7. *OSV*: 1/3-octave-band source levels of both individual bow and stern thrusters and composite curve including the two individual stern thrusters and the bow thruster.

4. Results

For the results and tables presented below where a dash is used in place of a horizontal distance, these thresholds may or may not be reached due to the discretely sampled radial increments of the modelled sound fields. A dash therefore is an indication that effect levels for the associated metric may only be reached within a very close proximity to a given source.

4.1. Well Head Platform (WHP) Piling

4.1.1. Received levels at 10 m

Since piles are distributed and directional sources, they cannot be accurately approximated by a point source with corresponding source levels (extended detail is provided in Appendix B). It is possible to compare the maximum modelled levels at short distances from the piles. Figure 8 shows the 1/3-octave-band levels for the receiver with the highest SEL at a horizontal range of 10 m, for the three modelled penetrations. The levels above 1000 Hz were extrapolated using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009). The modelled results at a distance of 10 m are included to provide results comparable to other pile driving reports and literature, such as Illingworth & Rodkin (2007), and Denes et al. (2016).

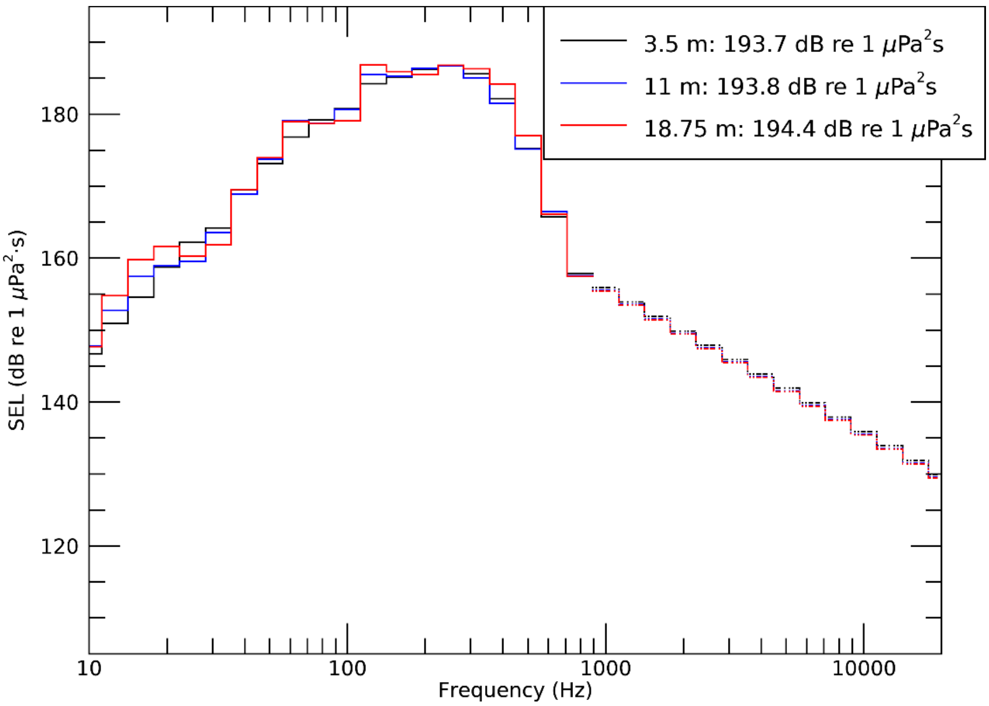

Figure 8. *WHP piling*: 1/3-octave-band levels for the receiver with highest SEL at 10 m horizontal range for impact pile driving using the MHU 600T hammer, after high-frequency extrapolation (dashes indicate extrapolated portion of the spectrum). Legend items indicate the modelled pile penetration and the broadband SEL in dB re 1 µPa²·s.

4.1.2. Per-strike sound fields

Per-strike results for the proposed pile driving are presented in this section for maximum-over-depth SPL, SEL, and PK (tables in Section 4.1.2.1), maps and sound field vertical slices (Section 4.1.2.2).

4.1.2.1. Tabulated results

Tables 15–19 show the estimated distances for the various applicable per-strike effects criteria and isopleths of interest as maximum-over-depth.

Table 15. *WHP piling, per-strike SEL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths for the MHU 600T hammer.

Per-strike SEL (L_E; dB re 1 µPa²·s)	Penetration depth					
	3.5 m		11 m		18.75 m	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.03	0.03	0.06	0.06	0.06	0.06
180	0.35	0.34	0.34	0.33	0.31	0.30
170	0.77	0.73	0.73	0.71	0.70	0.68
160	2.82	2.71	2.73	2.62	2.65	2.54
150	6.46	6.22	6.34	6.12	6.62	6.39
140	18.2	17.0	18.9	17.7	19.9	18.8
130	56.0	50.6	56.5	51.6	57.4	53.2
120	>80.0	/	>80.0	/	>80.0	/

A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 16. *WHP piling, SPL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths for the MHU 600T hammer.

SPL (L_p; dB re 1 µPa)	Penetration depth					
	3.5 m		11 m		18.75 m	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–	0.02	0.02	0.05	0.05
190	0.30	0.30	0.30	0.29	0.28	0.27
180	0.63	0.61	0.60	0.58	0.62	0.60
170	2.51	2.41	2.40	2.31	2.33	2.24
160	5.30	5.05	5.24	5.00	5.40	5.20
150	15.2	14.4	16.1	15.2	17.7	16.3
140	49.5	44.8	49.8	45.1	51.0	46.2
130	>80.0	/	>80.0	/	>80.0	/

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 17. *WHP piling, marine mammal and turtle behavioural response thresholds, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth for the MHU 600T hammer.

Threshold	**Penetration depth**					
	3.5 m		**11 m**		**18.75 m**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Marine mammal behavioural response (160 dB re 1 µPa SPL) (NOAA 2019)	5.30	5.05	5.24	5.00	5.40	5.20
Turtle behavioural response (166 dB re 1 µPa SPL) (NSF 2011)	3.51	3.36	3.41	3.27	3.33	3.20
Turtle behavioural disturbance (175 dB re 1 µPa SPL) (McCauley et al. 2000b, 2000a)	1.39	1.34	1.32	1.27	1.29	1.23

Table 18. *WHP piling, marine mammal and turtle PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (in m) from the pile to maximum-over-depth isopleths for the MHU 600T hammer.

Hearing group	**PK threshold (L_{pk}; dB re 1 µPa**	**Penetration depth**		
		3.5 m	**11 m**	**18.75 m**
		R_{max} (m)	R_{max} (m)	R_{max} (m)
Low-frequency cetaceans (PTS)	219	20	20	63
Low-frequency cetaceans (TTS)	213	172	156	89
High-frequency cetaceans (PTS)	230	–	–	–
High-frequency cetaceans (TTS)	224	–	–	–
Very-high-frequency cetaceans (PTS)	202	550	525	477
Very-high-frequency cetaceans (TTS)	196	1039	945	797
Sea turtles (PTS)	232	–	–	–
Sea turtles (TTS)	226	–	–	–

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 19. *WHP piling, mortality, and potential mortal recoverable injury thresholds (peak pressure level metric) for fish, fish eggs, and fish larvae*: Maximum (R_{max}) horizontal distances (in m) from the pile.

Marine fauna group	**PK threshold (L_{pk}; dB re 1 µPa**	**Penetration depth**		
		3.5 m	**11 m**	**18.75 m**
		R_{max} (m)	R_{max} (m)	R_{max} (m)
Fish: No swim bladder	213	172	156	89
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	420	396	358

4.1.2.2. Sound field maps and vertical slices

Maps of the per-strike SPL results associated with the three modelled penetration depths for driving the WHP jacket pile are shown in Figures 9–11 for the MHU 600T hammer. The isopleths for marine mammal behavioural criteria (160 dB re 1 µPa) for each of the three considered penetration depths are also provided. Vertical slice plots for all penetrations are shown in Figures 12–14. Per-strike SEL maps are shown in Appendix G.1.

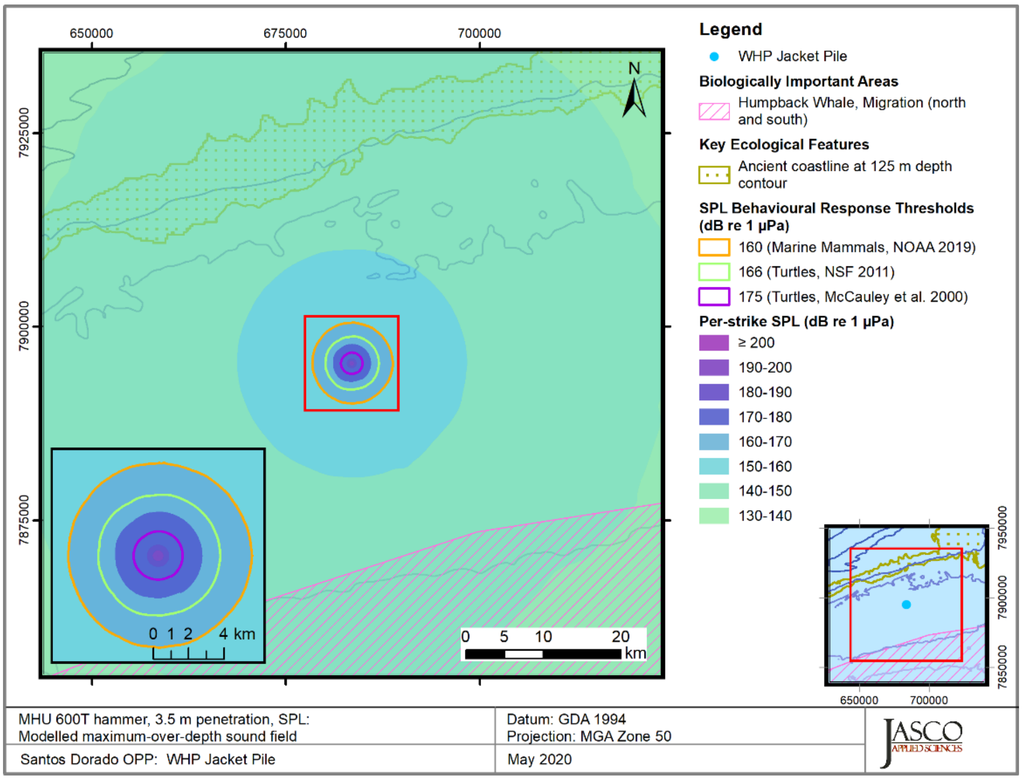

Figure 9. *WHP piling, SPL, 3.5 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

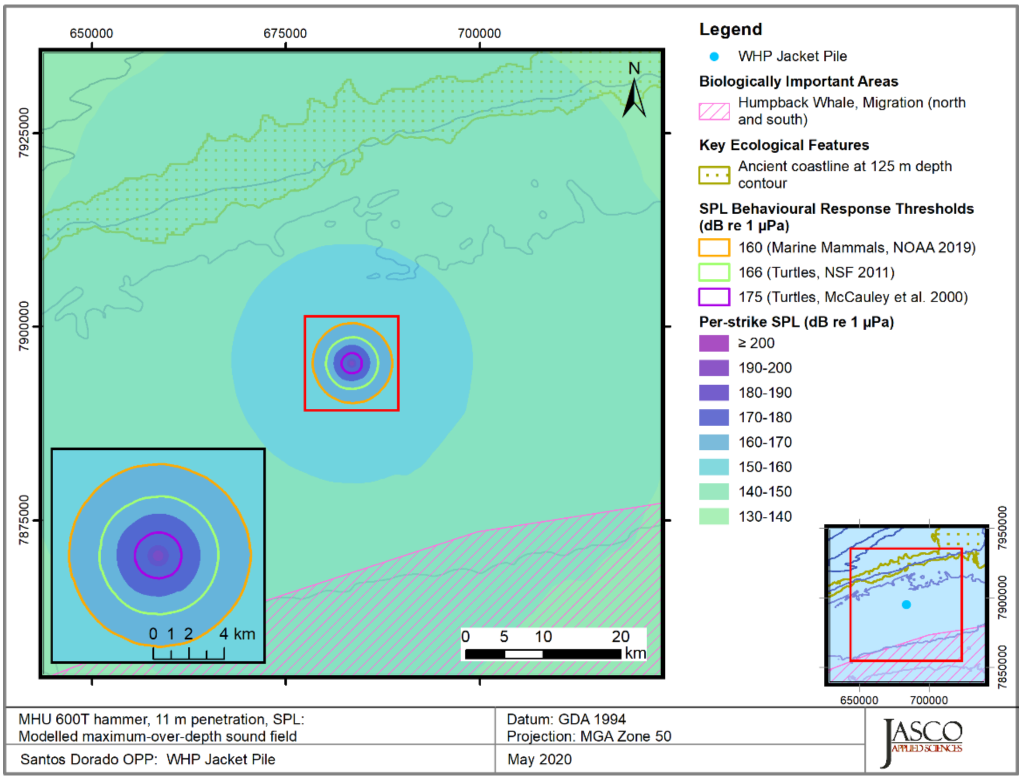

Figure 10. *WHP piling, SPL, 11 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

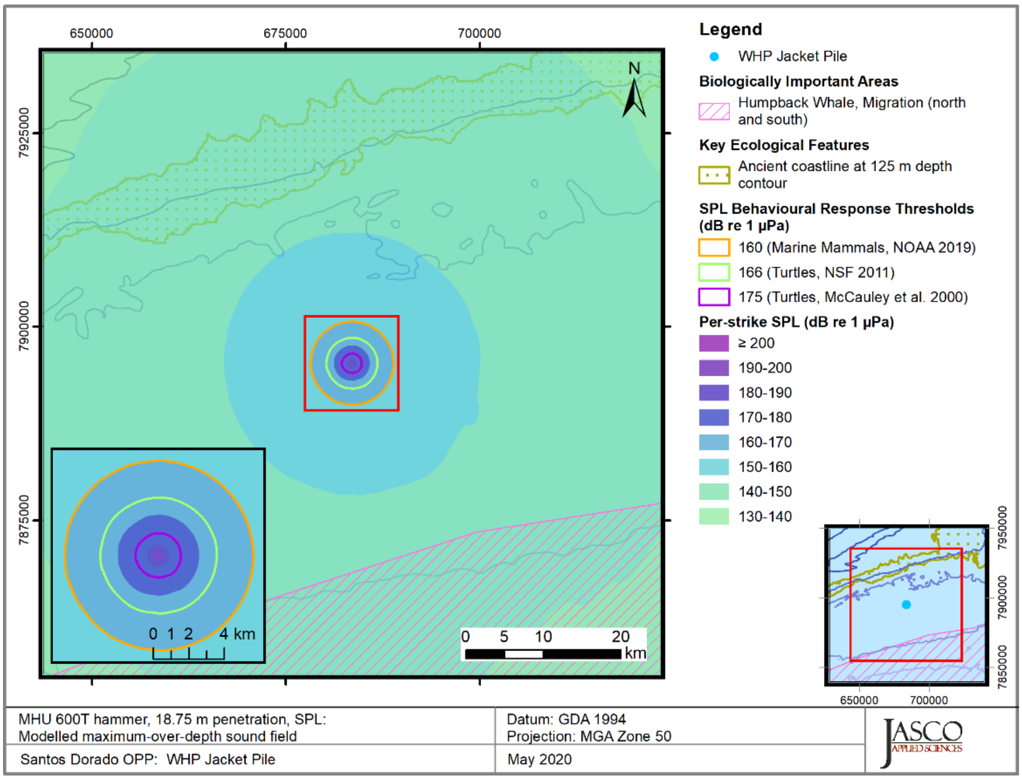

Figure 11. *WHP piling, SPL, 18.75 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

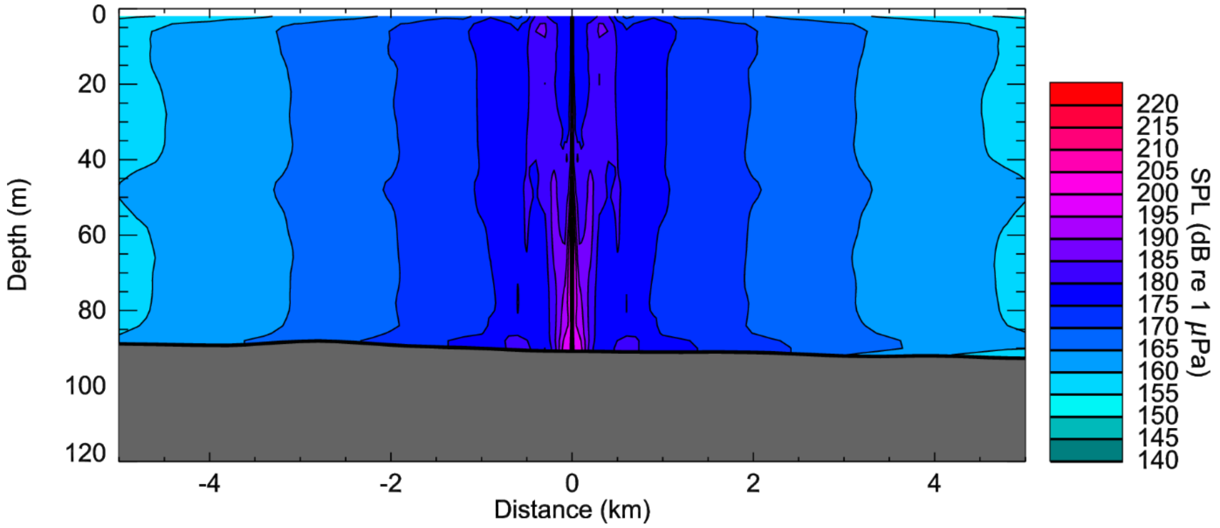

Figure 12. *WHP piling, vertical slice, SPL, 3.5 m penetration depth*: 0–5 km. Levels are shown along a single north-south transect.

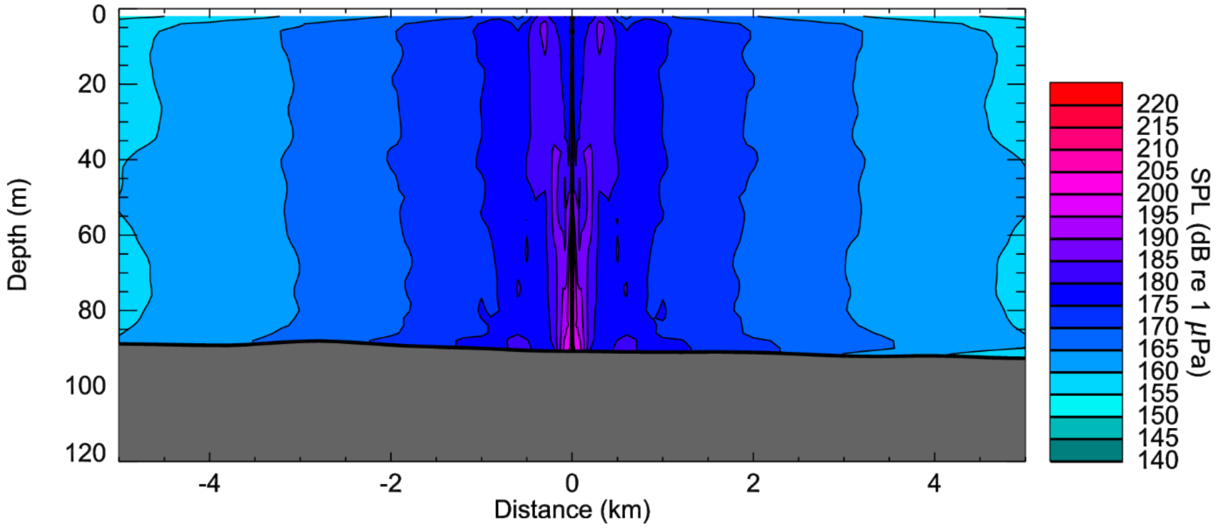

Figure 13. *WHP piling, vertical slice, SPL, 11 m penetration depth*: 0–5 km. Levels are shown along a single north-south transect.

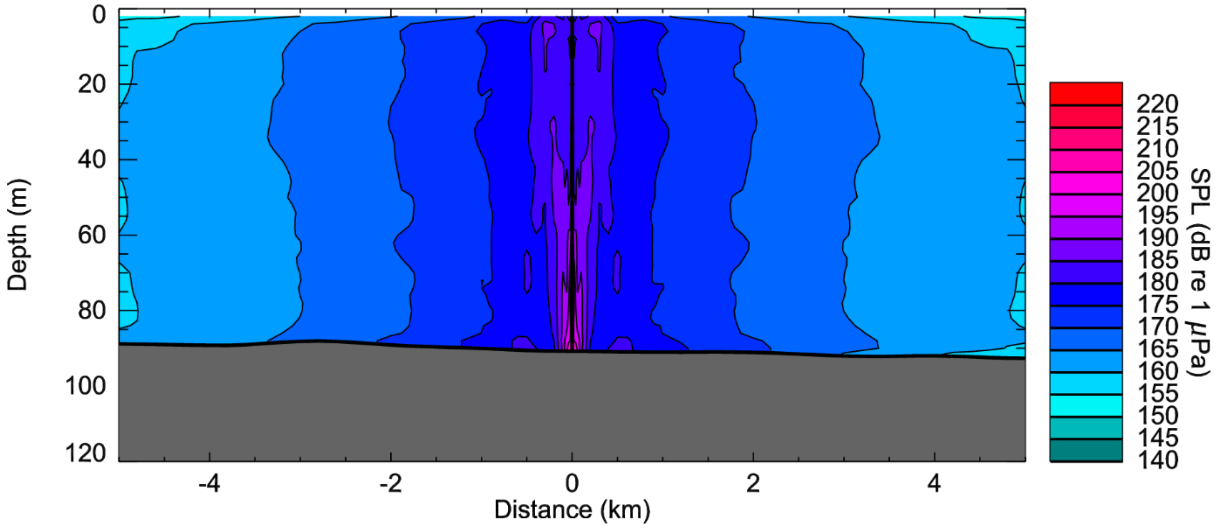

Figure 14. *WHP piling, vertical slice, SPL, 18.75 m penetration depth*: 0–5 km.Levels are shown along a single north-south transect.

Multiple Strike Sound Fields

Table 20 presents the SEL_{24h} results relevant to marine mammals for the proposed pile driving operations for the WHP, while Table 21 shows modelled distances to the cumulative exposure criteria contours for fish, fish eggs and larvae. The sound level contour map for marine mammals and sea turtles is presented in Figure 15, and the map for fish is shown in Figure 16.

Table 20. *WHP piling*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammal (Southall et al. 2019) and sea turtles (Finneran et al. 2017)

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s) #	R_{max} (km)	Area (km²)
PTS			
Low-frequency cetaceans	183	5.29	83.2
High-frequency cetaceans	185	–	–
Very High-frequency cetaceans	155	0.54	0.92
Sea turtles	204	0.72	1.64
TTS			
Low-frequency cetaceans	168	22.6	1518
High-frequency cetaceans	170	0.29	0.27
Very High-frequency cetaceans	140	2.78	21.4
Sea turtles	189	4.11	51.2

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).
Frequency weighted.

Table 21. *WHP piling*: Maximum-over-depth distances (in km) to SEL_{24h} based fish criteria. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth	
		R_{max} (km)	Area (km²)
Mortality and potential mortal injury			
I	219	0.13	0.05
II, fish eggs and fish larvae	210	0.47	0.70

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth	
		R_{max} (km)	Area (km²)
III	207	0.56	0.97
Fish recoverable injury			
I	216	0.27	0.24
II, III	203	1.00	3.05
Fish TTS			
I, II, III	186	5.59	94.9

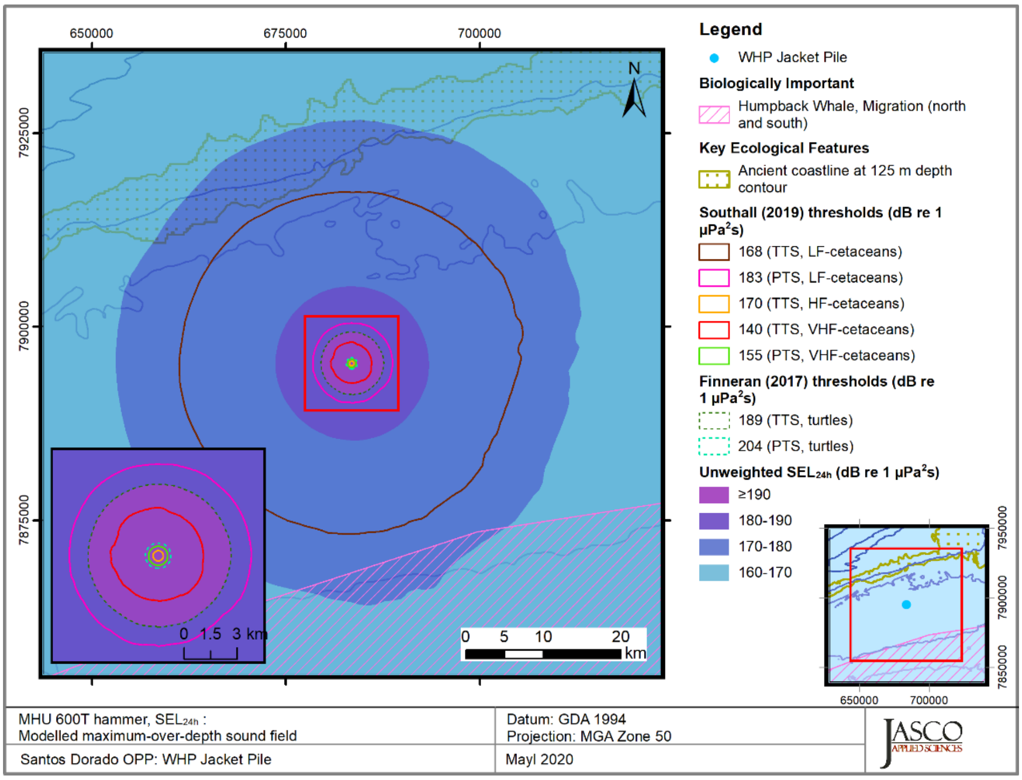

Figure 15. *WHP piling, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-, high-, and very-high-frequency cetaceans and sea turtles. Threshold for high-frequency cetacean PTS was not reached.

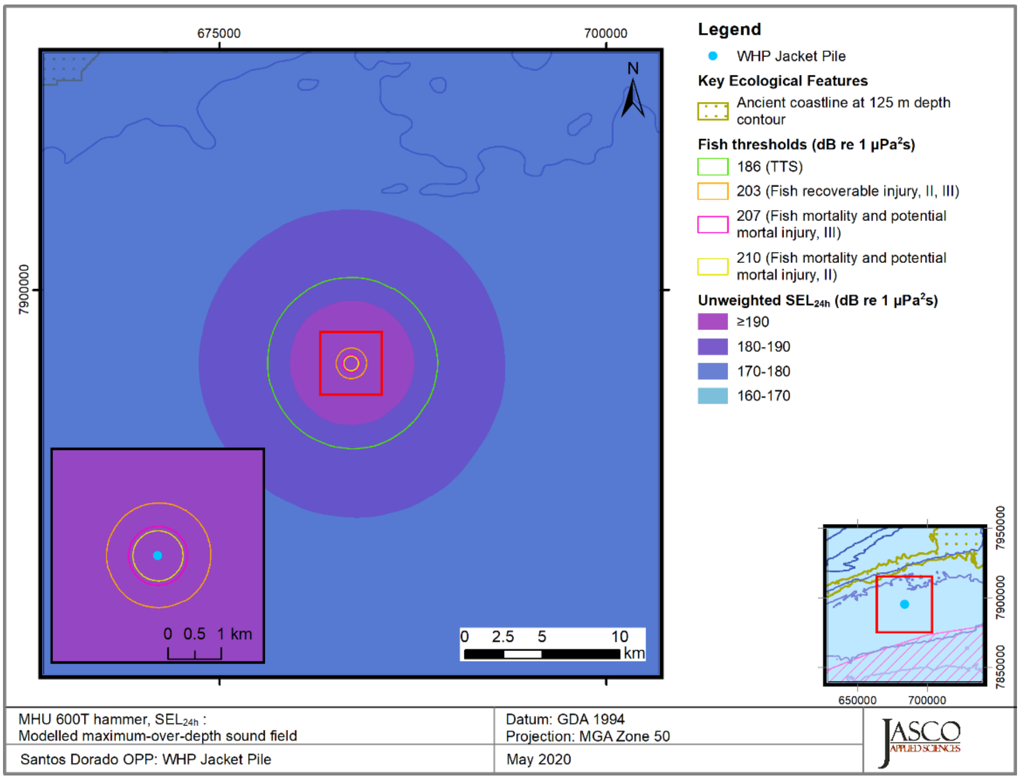

Figure 16. *WHP piling, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths relevant to fish injury and TTS.Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

4.2. FPSO Anchor Piling

4.2.1. Received levels at 10 m

Since piles are distributed and directional sources, they cannot be accurately approximated by a point source with corresponding source levels (extended detail is provided in Appendix B). It is possible to compare the maximum modelled levels at short distances from the piles. Figure 17 shows the 1/3-octave-band levels for the receiver with the highest SEL at a horizontal range of 10 m for the three modelled penetrations. The levels above 1000 Hz were extrapolated using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009). The modelled results at a distance of 10 m are included to provide results comparable to other pile driving reports and literature, such as Illingworth & Rodkin (2007), and Denes et al. (2016).

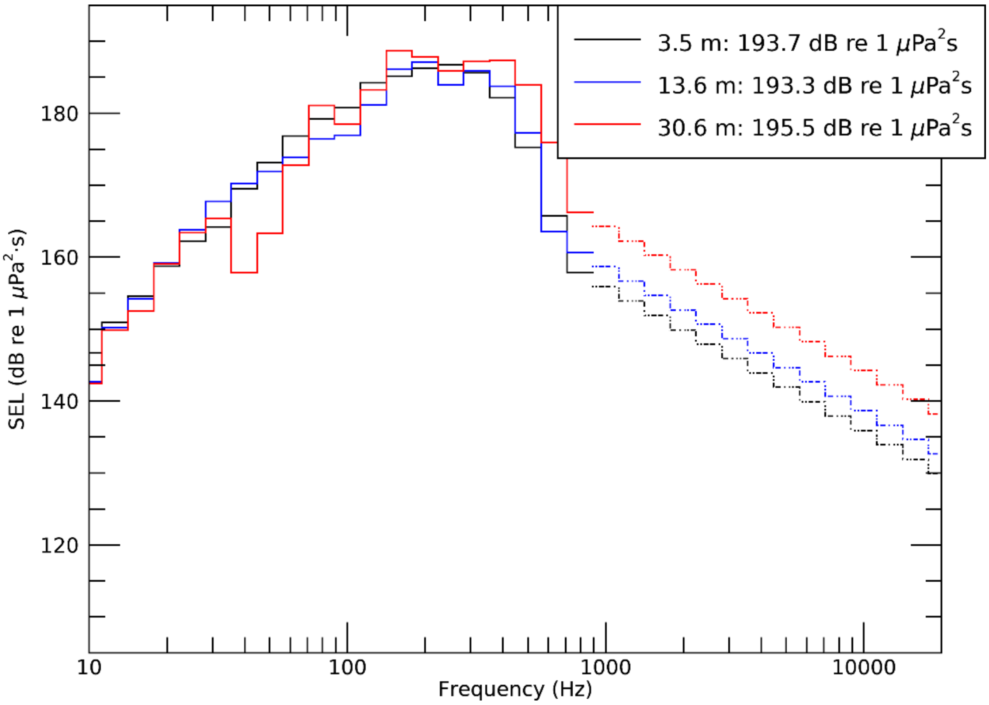

Figure 17. *FPSO anchor piling*: 1/3-octave-band levels for the receiver with highest SEL at 10 m horizontal range for impact pile driving using the MHU 600T hammer, after high-frequency extrapolation (dashes indicate extrapolated portion of the spectrum). Legend items indicate the modelled pile penetration (Table 14) and the broadband SEL in dB re 1 μPa²·s.

4.2.2. Per-strike sound fields

Per-strike results for the proposed pile driving are presented in this section for maximum-over-depth SPL, SEL, and PK (tables in Section 4.1.2.1), maps and sound field vertical slices (Section 4.2.2.2).

4.2.2.1. Tabulated results

Tables 22–26 show the estimated distances for the various applicable per-strike effects criteria and isopleths of interest as maximum-over-depth.

Table 22. *FPSO anchor piling, per-strike SEL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths for the MHU 600T hammer.

Per-strike SEL (L_E; dB re 1 µPa²·s)	Penetration depth					
	3.5 m		13.6 m		30.6 m	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.03	0.03	0.05	0.05	0.02	0.02
180	0.28	0.27	0.23	0.22	0.06	0.06
170	0.57	0.55	0.49	0.48	0.37	0.36
160	2.24	2.13	1.96	1.86	1.21	1.16
150	5.26	4.98	4.79	4.56	3.91	3.79
140	12.7	12.0	12.5	11.9	11.3	10.9
130	42.4	39.6	39.3	36.6	31.8	28.7
120	>80.0	/	>80.0	/	>80.0	/

A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 23. *FPSO anchor piling, SPL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths for the MHU 600T hammer.

SPL (L_p; dB re 1 µPa)	Penetration depth					
	3.5 m		13.6 m		30.6 m	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–	0.02	0.02	–	–
190	0.23	0.23	0.09	0.09	0.06	0.06
180	0.54	0.53	0.46	0.44	0.32	0.31
170	2.02	1.92	1.74	1.64	1.00	0.96
160	4.59	4.35	4.14	3.94	3.39	3.28
150	10.4	9.94	10.3	9.87	9.99	9.56
140	37.4	35.0	35.0	32.7	28.6	25.7
130	>80.0	/	>80.0	/	>80.0	/

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 24. *FPSO anchor piling, marine mammal and turtle behavioural response thresholds, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth for the MHU 600T hammer.

Threshold	Penetration depth					
	3.5 m		13.6 m		30.6 m	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Marine mammal behavioural response (160 dB re 1 µPa SPL) (NOAA 2019)	4.59	4.35	4.14	3.94	3.39	3.28
Turtle behavioural response (166 dB re 1 µPa SPL) (NSF 2011)	2.91	2.79	2.55	2.44	1.78	1.70
Turtle behavioural disturbance (175 dB re 1 µPa SPL) (McCauley et al. 2000b, 2000a)	1.07	1.02	0.93	0.89	0.56	0.54

Table 25. *FPSO anchor piling, marine mammal and turtle PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (in m) from the pile to maximum-over-depth isopleths for the MHU 600T hammer.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa	Penetration depth		
		3.5 m	13.6 m	30.6 m
		R_{max} (m)	R_{max} (m)	R_{max} (m)
Low-frequency cetaceans (PTS)	219	28	45	20
Low-frequency cetaceans (TTS)	213	113	80	28
High-frequency cetaceans (PTS)	230	–	–	–
High-frequency cetaceans (TTS)	224	–	–	–
Very-high-frequency cetaceans (PTS)	202	492	405	216
Very-high-frequency cetaceans (TTS)	196	747	611	433
Sea turtles (PTS)	232	–	–	–
Sea turtles (TTS)	226	–	–	–

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 26. *FPSO anchor piling, mortality, and potential mortal recoverable injury thresholds (peak pressure level metric) for fish, fish eggs, and fish larvae*: Maximum (R_{max}) horizontal distances (in m) from the pile.

Marine fauna group	PK threshold (L_{pk}; dB re 1 µPa	Penetration depth (m)		
		3.5 m	13.6 m	30.6 m
		R_{max} (m)	R_{max} (m)	R_{max} (m)
Fish: No swim bladder	213	113	80	28
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	361	288	85

4.2.2.2. Sound field maps and vertical slices

Maps of the per-strike SPL results associated with the three modelled penetration depths for driving the FPSO anchor pile are shown in Figures 18–20 for the MHU 600T hammer. The isopleths for marine mammal behavioural criteria (160 dB re 1 µPa) for each of the three considered penetration depths are also provided. Vertical slice plots for all penetrations are shown in Figures 21–23. Per-strike SEL maps are shown in Appendix G.2.

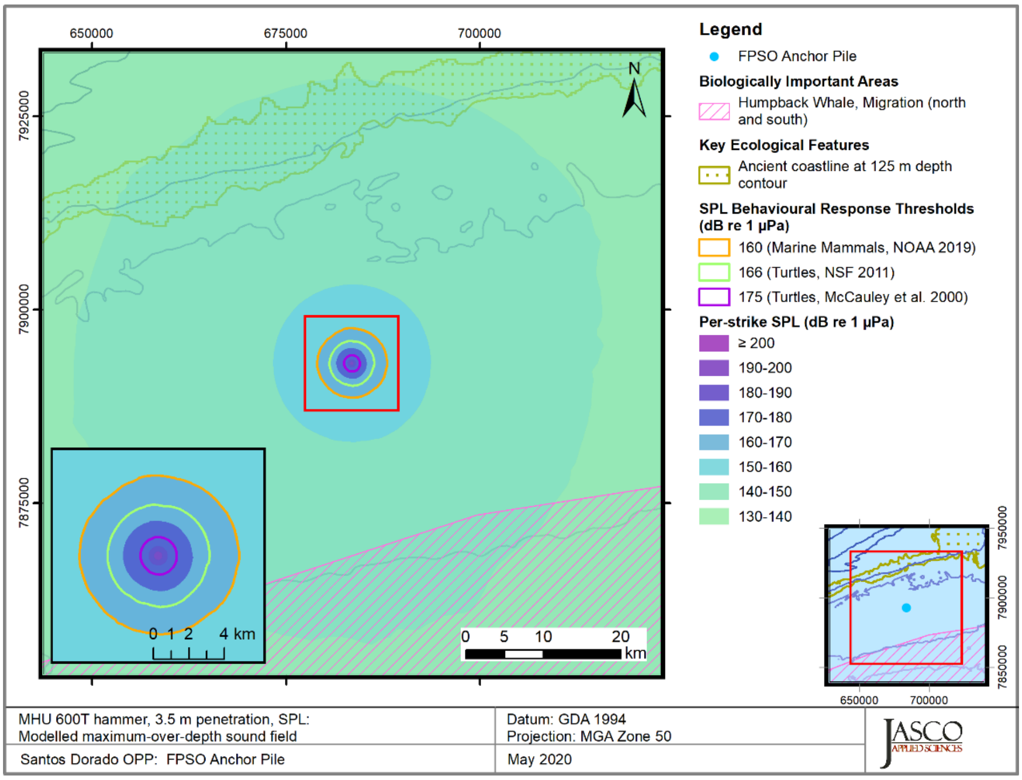

Figure 18. *FPSO anchor piling, SPL, 3.5 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

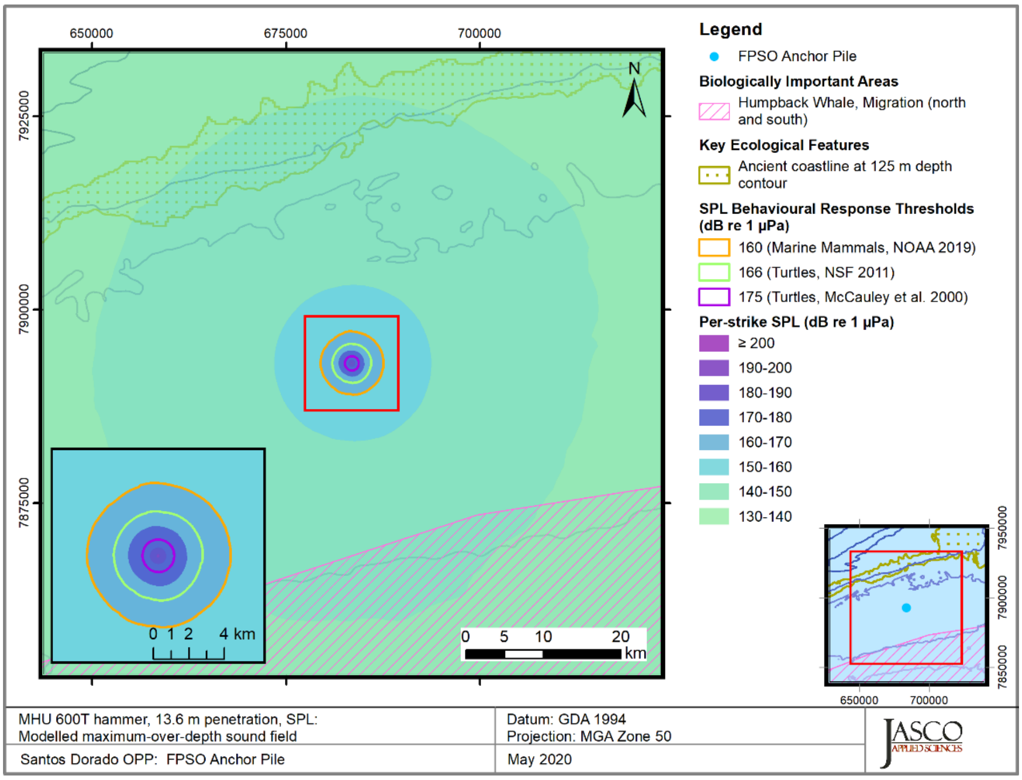

Figure 19. *FPSO anchor piling, SPL, 13.6 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

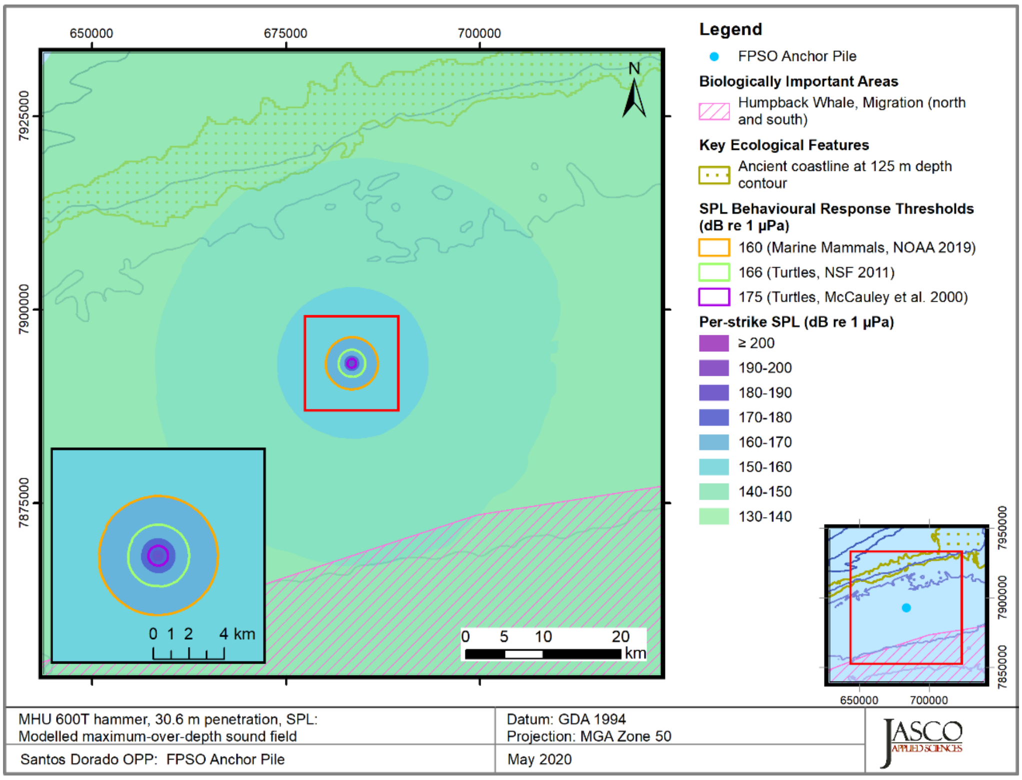

Figure 20. *FPSO anchor piling, SPL, 30.6 m penetration depth:* Sound level contour map, showing maximum-over-depth results. Isopleths for sea turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

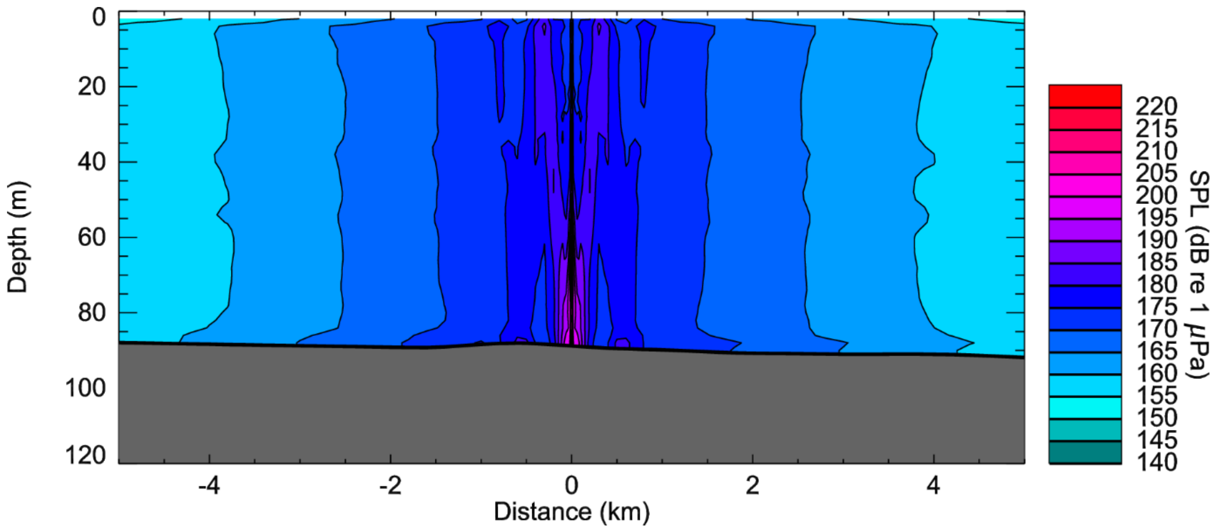

Figure 21. *FPSO anchor piling, vertical slice, SPL, 3.5 m penetration depth*: 0–5 km. Levels are shown along a single north-south transect.

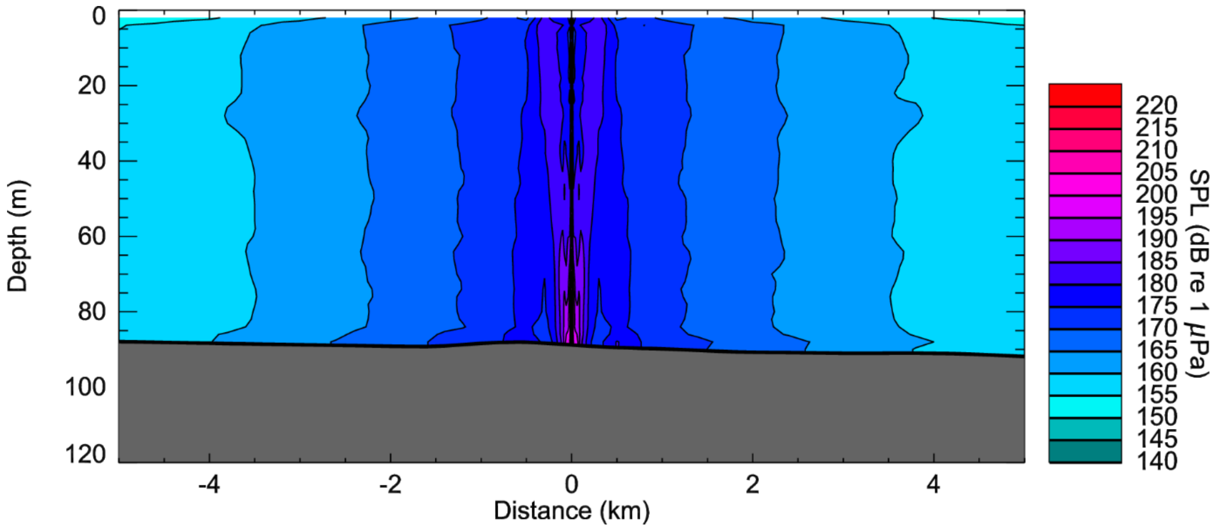

Figure 22. *FPSO anchor piling, vertical slice, SPL, 13.6 m penetration depth*: 0–5 km. Levels are shown along a single north-south transect.

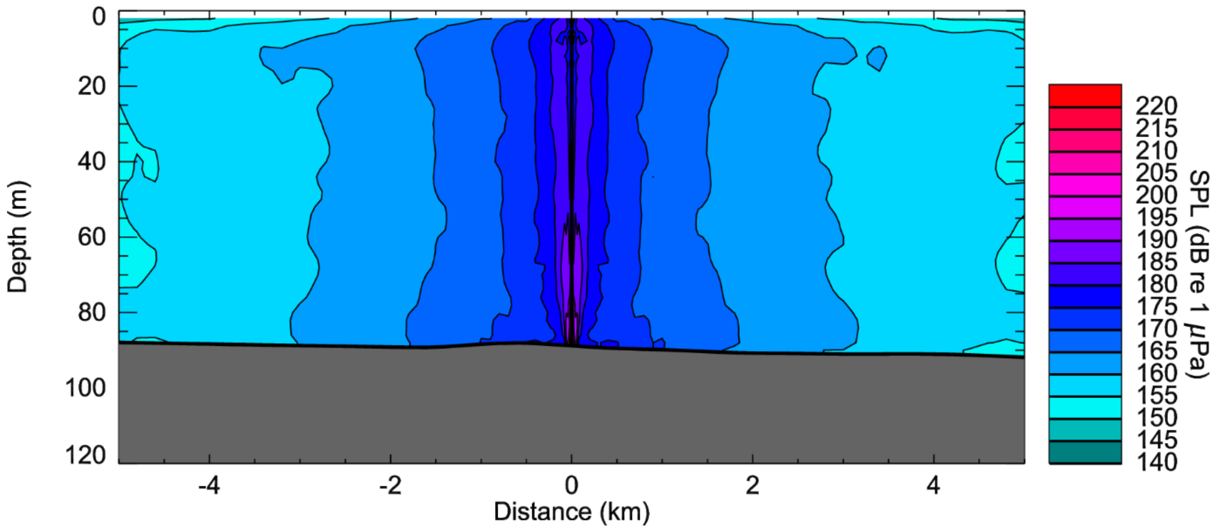

Figure 23. *FPSO anchor piling, vertical slice, SPL, 30.6 m penetration depth*: 0–5 km. Levels are shown along a single north-south transect.

4.2.3. Multiple Strike Sound Fields

Table 27 presents the SEL_{24h} results relevant to marine mammals for the proposed pile driving operations, while Table 29 shows modelled distances to the cumulative exposure criteria contours for fish, fish eggs and larvae. The sound level contour map for marine mammals and sea turtles is presented in Figure 24 and the map for fish is shown in Figure 25.

Table 27. *FPSO anchor piling*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammal (Southall et al. 2019) and sea turtles (Finneran et al. 2017).

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s) #	R_{max} (km)	Area (km²)
PTS			
Low-frequency cetaceans	183	5.84	104
High-frequency cetaceans	185	0.03	0.001
Very High-frequency cetaceans	155	1.04	2.68
Sea turtles	204	0.68	1.44
TTS			
Low-frequency cetaceans	168	28.2	2182
High-frequency cetaceans	170	0.36	0.41
Very High-frequency cetaceans	140	4.27	54.1
Sea turtles	189	3.98	48.7

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).
Frequency weighted.

Table 28. FPSO anchor piling: Ensonified areas (km²) corresponding to maximum-over-depth low-frequency cetacean PTS and TTS thresholds (Southall et al. 2019).

Threshold	Area ensonified (km²)	Area of HW migration BIA ensonified (km²)
Low-frequency cetaceans PTS	104	0
Low-frequency cetaceans TTS	2182	39

Table 29. *FPSO anchor piling*: Maximum-over-depth distances (in km) to SEL_{24h} based fish criteria. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth	
		R_{max} (km)	Area (km²)
Mortality and potential mortal injury			
I	219	0.09	0.02
II, fish eggs and fish larvae	210	0.39	0.48
III	207	0.52	0.84
Fish recoverable injury			
I	216	0.23	0.17
II, III	203	0.96	2.79
Fish TTS			
I, II, III	186	5.88	105.6

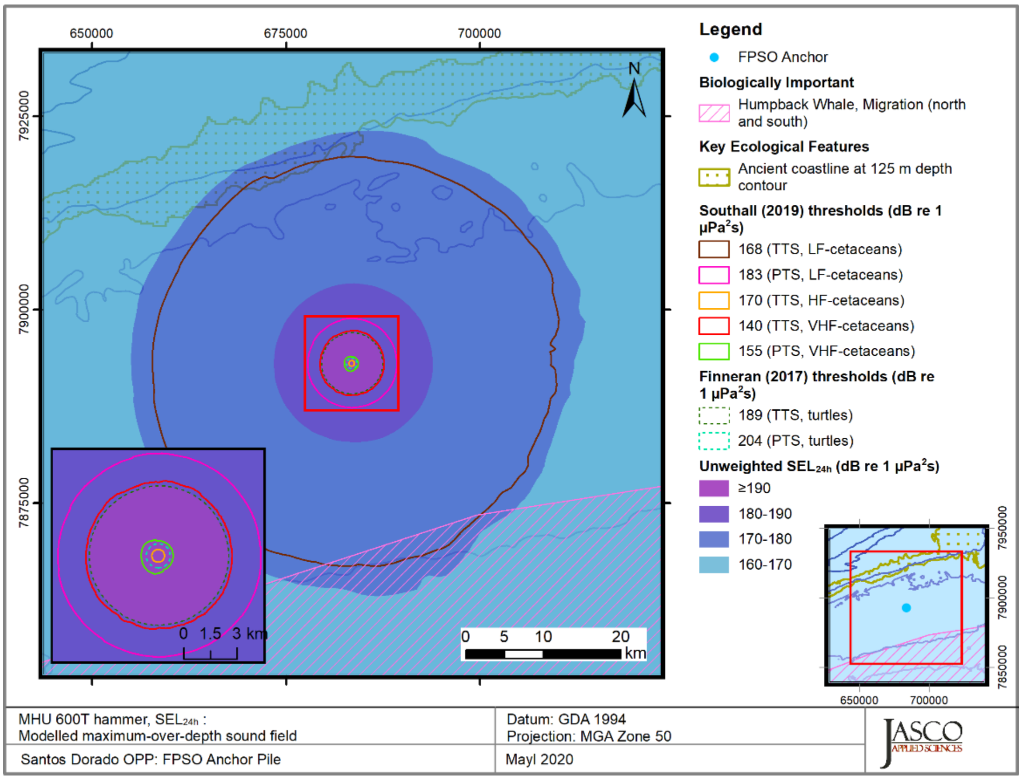

Figure 24. *FPSO anchor piling, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-, high-, and very-high-frequency cetaceans and sea turtles. Threshold contour for high-frequency cetacean PTS is too small to be displayed on a map. Refer to the radii in Table 27 for distances.

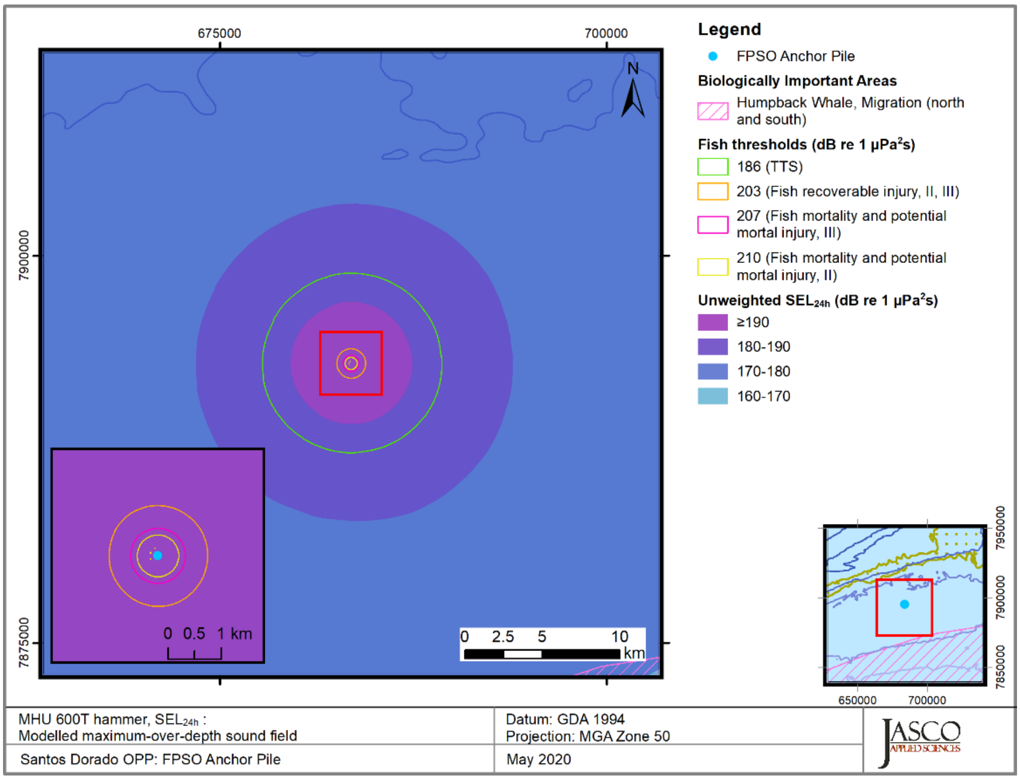

Figure 25. *FPSO anchor piling, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths relevant to fish injury and TTS. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

4.3. Vertical Seismic Profiling (VSP)

4.3.1. Acoustic Source Levels and Directivity

AASM (Section 3.2.1) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic source, with results provided in Appendix C.2 along with the horizontal directivity plots.

Table 30 shows the PK and per-pulse SEL source levels in the horizontal-plane perpendicular to the sagittal plane of the array, parallel to the sagittal plane of the array, and vertical directions. The vertical source level that accounts for the “surface ghost” (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Figure C-2 shows overpressure signatures and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 300 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 30. Far-field source level specifications for the 750 in3 source, for a 5 m source depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 μPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 μPa²m²s)	
		10–2000 Hz	2000–25000 Hz
Sagittal Perpendicular	239.2	214.5	168.8
Sagittal Parallel	239.4	214.5	165.8
Vertical	239.2	214.5	173.6
Vertical (surface affected source level)	239.3	216.1	176.6

4.3.2. Per-Pulse Sound Fields

4.3.2.1. Tabulated results

Table 31. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in³ source to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the modelled single impulse site at the WHP.

Per-pulse SEL (L_E; dB re 1 μPa²·s)	R_{max} (km)	$R_{95\%}$ (km)
190	–	–
180	0.05	0.05
170	0.26	0.25
160†	0.97	0.94
150	3.10	2.98
140	7.39	7.05
130	17.09	15.52
120	43.64	38.63

† Low power zone assessment criteria DEWHA (2008).
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 32. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in³ source to modelled maximum-over-depth SPL isopleths from the modelled single impulse site at the WHP.

SPL (L_p; dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–
190	0.03	0.03
180	0.21	0.21
175#	0.38	0.37
170	0.74	0.71
166†	1.22	1.18
160‡	2.42	2.34
150	5.96	5.71
140	14.23	13.07
130	38.85	33.83

Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 33. *VSP, PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (m) from the 750 in³ VSP array to modelled maximum-over-depth peak pressure level (PK) PTS and TTS thresholds for marine mammals (Southall et al. 2019), sea turtles (Finneran et al. 2017) and fish (Popper et al. 2014) the modelled single impulse site at the WHP.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)
Low-frequency cetaceans (PTS)	219	–
Low-frequency cetaceans (TTS)	213	–
High-frequency cetaceans (PTS)	230	–
High-frequency cetaceans (TTS)	224	–
Very-high-frequency cetaceans (PTS)	202	63
Very-high-frequency cetaceans (TTS)	196	241
Fish (Recoverable injury): No swim bladder (also applied to sharks)	213	–
Fish (Recoverable injury): Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	37
Sea turtles (PTS)	232	–
Sea turtles (TTS)	226	–

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 34. *VSP, seafloor* PK: Maximum (R_{max}) horizontal distances (in m) from the 750 in³ VSP array to modelled seafloor peak pressure level thresholds (Popper et al. 2014) (PK) from the modelled single impulse site at the WHP.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)
Sound levels for sponges and corals†	226	Not Reached
Fish (Recoverable injury): No swim bladder (also applied to sharks)	213	
Fish (Recoverable injury): Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	

† Heyward et al. (2018)

4.3.2.2. Sound field maps and graphs

A map of the per-pulse SPL results for VSP at the WHP is shown in Figure 26 and a vertical slice plot is shown in Figure 27. Per-pulse SEL maps are shown in Appendix G.3.

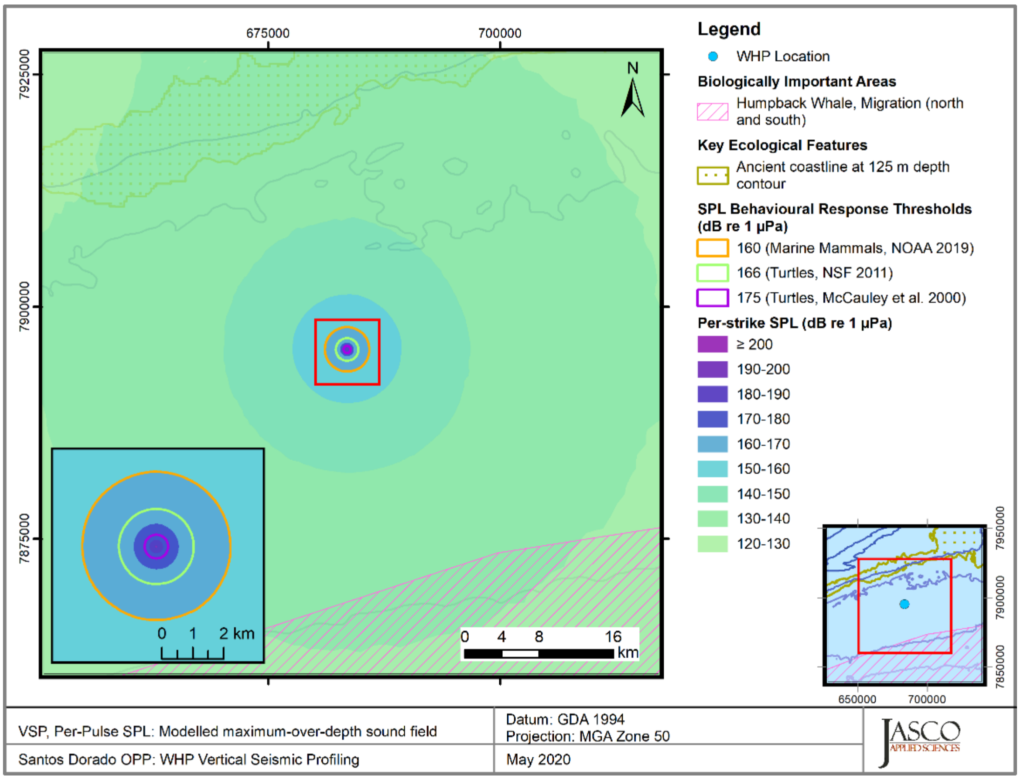

Figure 26. *VSP, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

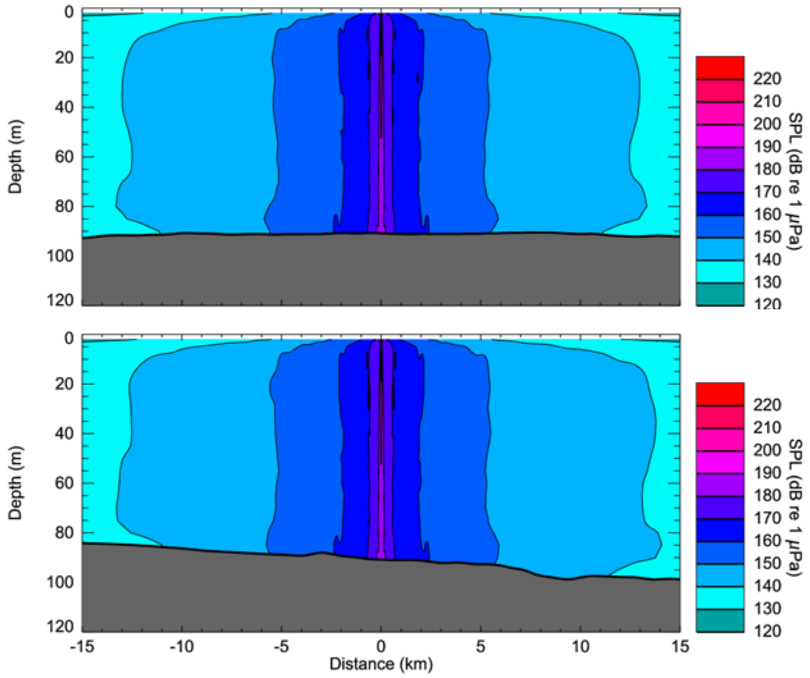

Figure 27. *VSP, SPL*: *Vertical sound field slice,* broadside (top) and endfire (bottom).

4.3.3. Multiple Pulse Sound Fields

Multiple pulse results for a range of VSP impulses which potentially could occur within a 24 h period are shown in Tables 35 and 36. These results assume both stationary source and receivers, and are frequency-weighted in accordance with Southall et al. (2019) and Finneran et al. (2017).

Table 35. *VSP, multiple-pulse SEL*: Maximum ranges to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds Southall et al. (2019), and sea turtles (Finneran et al. 2017) from VSP operations, assuming different numbers of impulses during a 24 h period.

Hearing group	**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)**	**Number of impulses**								
		5 R_{max} (km)	10 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)	200 R_{max} (km)	250 R_{max} (km)	300 R_{max} (km)
PTS										
Low-frequency cetaceans	183	0.03	0.05	0.07	0.13	0.29	0.35	0.38	0.41	0.47
High-frequency cetaceans	185	–	–	–	–	–	–	–	–	–
Very-high-frequency cetaceans	155	–	–	–	–	–	–	–	0.02	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
Low-frequency cetaceans	168	0.35	0.48	0.84	1.25	1.90	2.36	2.86	3.02	3.10
High-frequency cetaceans	170	–	–	–	–	–	–	–	–	–
Very-high-frequency cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.04	0.06	0.10	0.22	0.30	0.33	0.36	0.38

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 36. *VSP, multiple-pulse SEL:* Maximum ranges to SEL_{24h} based fish criteria (Popper et al. 2014) from VSP operations, assuming different numbers of impulses during a 24 h period.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Number of impulses								
		5 R_{max} (km)	10 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)	200 R_{max} (km)	250 R_{max} (km)	300 R_{max} (km)
Mortality and potential mortal injury										
I	219	–	–	–	–	–	–	–	–	–
II, fish eggs and fish larvae	210	–	–	–	–	–	–	–	0.02	0.02
III	207	–	–	–	–	–	0.02	0.03	0.03	0.03
Fish recoverable injury										
I	216	–	–	–	–	–	–	–	–	–
II, III	203	–	–	–	0.02	0.03	0.03	0.05	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.07	0.21	0.30	0.40	0.52	0.66	0.73	0.84

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

4.3.3.1. Sound field maps

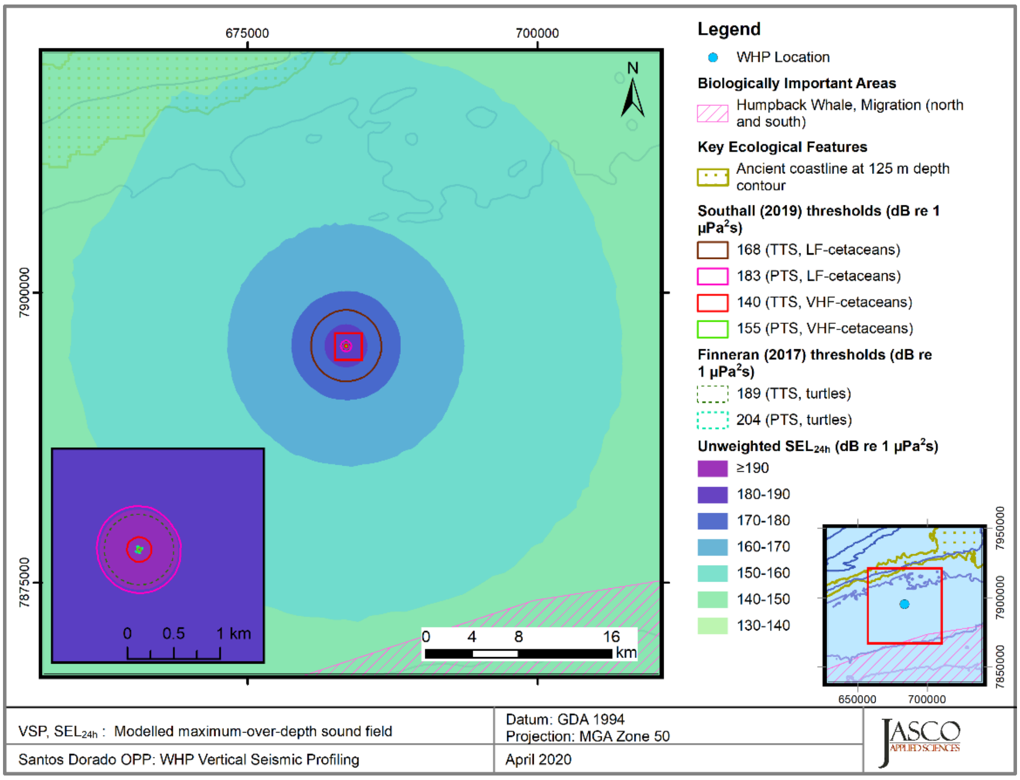

Figure 28. *VSP, multiple-pulse SEL*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results for 300 VSP impulses, along with isopleths for low-, and very-high-frequency cetaceans and sea turtles. Refer to the radii tables in Section 4.3.3 for distances.

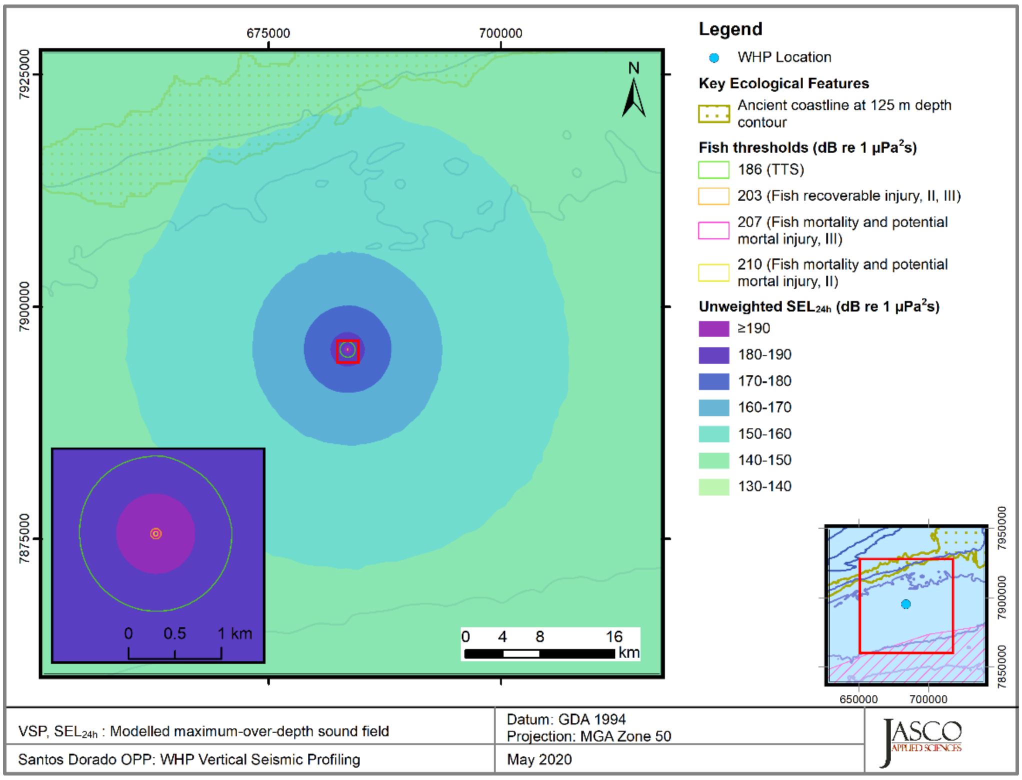

Figure 29. *VSP, multiple-pulse SEL*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results for 300 VSP impulses, along with the isopleths for fish thresholds from Popper et al. (2014). Where contours are too small to identify on the map refer to the radii in Table 36 for distances. Mortality and recoverable injury thresholds for Fish I were not reached.

4.4. Vessel Noise

Sound field results are presented for SPL (Tables 37 and Table 38) and SEL_{24h} (Tables 39) for the modelling scenarios involving:

- FPSO thruster noise for an FPSO under dynamic positioning (DP).
- FPSO operational noise for an FPSO under normal operating conditions.
- An Offshore Support Vessel (OSV) supporting offtake operations
- FPSO operational noise during offtake, represented by:
  - The FPSO under dynamic positioning (DP).
  - The FPSO under DP, with a noiseless condensate tanker, and the OSV supporting the offtake.

4.4.1. Tabulated results

Table 37.*Vessel Operations, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the midpoint of the modelled vessels (OSV and FPSO) or from the centre of the vessel (FPSO).

SPL (dB re 1 µPa)	FPSO on DP		FPSO without DP		OSV		Offtake operations*	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	–	–	–	–	–	–	–	–
180	–	–	–	–	–	–	–	–
170	–	–	–	–	–	–	0.02	0.02
160	0.02	0.02	–	–	–	–	0.02	0.02
150	0.09	0.09	–	–	0.06	0.06	0.09	0.09
140	0.49	0.48	0.06	0.06	0.34	0.33	0.90	0.80
130	2.45	2.34	0.34	0.33	1.25	1.20	3.06	2.79
120†	10.4	9.60	1.49	1.44	4.57	4.34	11.0	10.3
110	45.9	40.4	4.70	4.49	11.9	11.3	47.3	41.7

† Threshold for marine mammal behavioural response to continuous noise(NOAA 2019).
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).
Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.

Table 38. *Dorado Vessel Operations*: Maximum (R_{max}) horizontal distances (km) from the vessels to modelled maximum-over-depth SPL thresholds based on the quantifiable thresholds for fish (Popper et al. 2014).

SPL (dB re 1 µPa)	FPSO on DP		FPSO without DP		OSV		Offtake operations	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
170	–	–	–	–	–	–	0.02	0.02
158	0.03	0.03	–	–	0.02	0.02	0.03	0.03

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 39. *Dorado Vessel Operations, SEL24*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammal (Southall et al. 2019) and sea turtles (Finneran et al. 2017).

Hearing group	Threshold for SEL_{24h} (dB re 1 µPa²·s)	FPSO on DP		FPSO without DP		OSV		Offtake operations*	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS									
Low-frequency cetaceans	199	0.07	0.018	–	–	0.03	0.004	0.08	0.019
High-frequency cetaceans	198	–	–	–	–	–	–	–	–
Very-high-frequency cetaceans	173	0.21	0.141	–	–	0.05	0.009	0.21	0.140
Sea turtles	220	–	–	–	–	–	–	–	–
TTS									
Low-frequency cetaceans	179	2.13	11.03	0.10	0.035	0.79	1.90	2.62	15.5
High-frequency cetaceans	178	0.16	0.077	–	–	0.03	0.004	0.16	0.080
Very-high-frequency cetaceans	153	4.14	49.0	0.16	0.078	0.93	2.71	4.51	50.6
Sea turtles	200	0.05	0.009	–	–	0.05	0.009	0.05	0.009

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
† Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.

4.4.2. Sound field maps

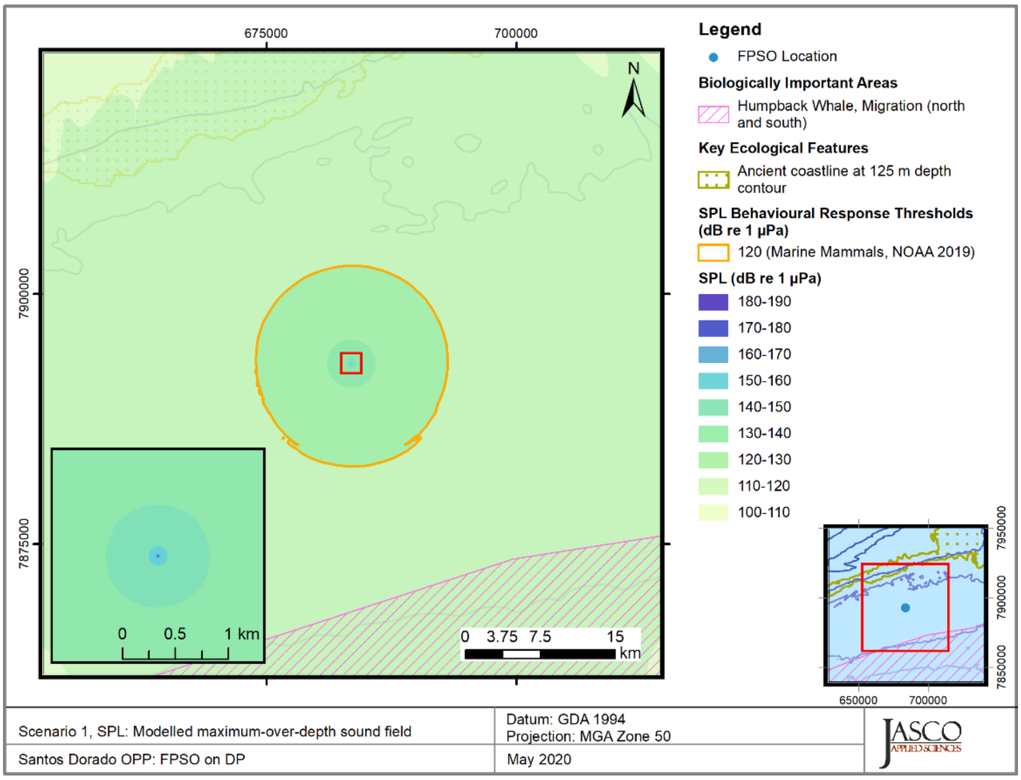

Figure 30. *Vessel Operations, FSPO on DP, SPL*: Sound level contour map showing maximum-over-depth results.

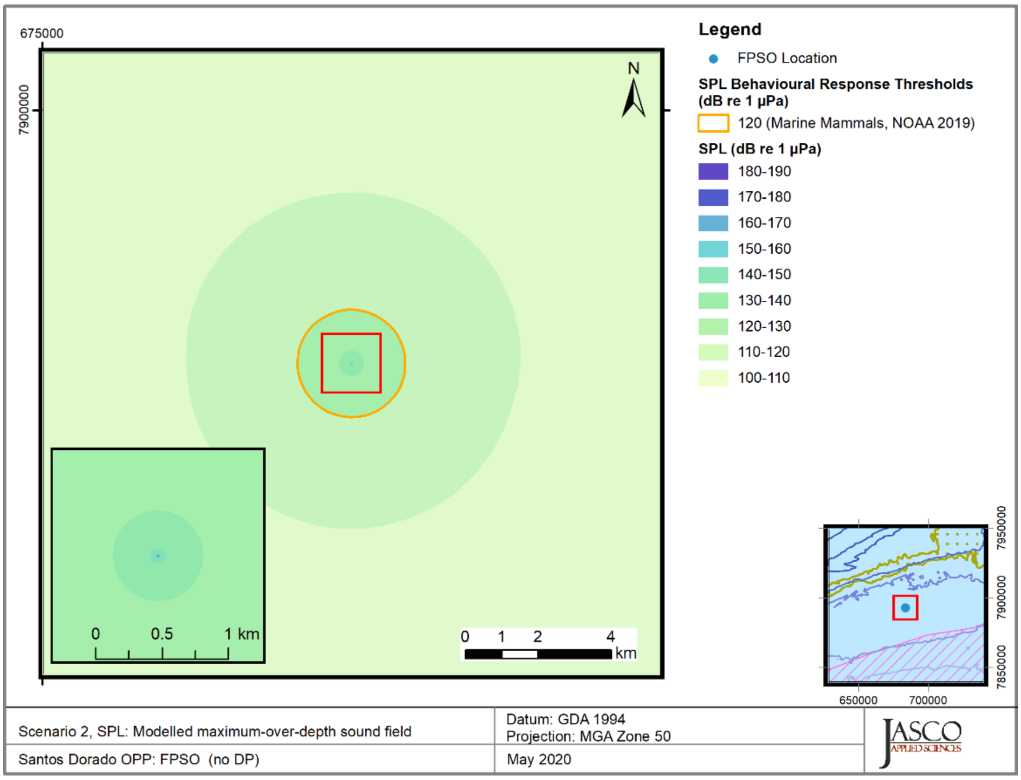

Figure 31. *Vessel Operations, FSPO without DP, SPL*: Sound level contour map showing maximum-over-depth results.

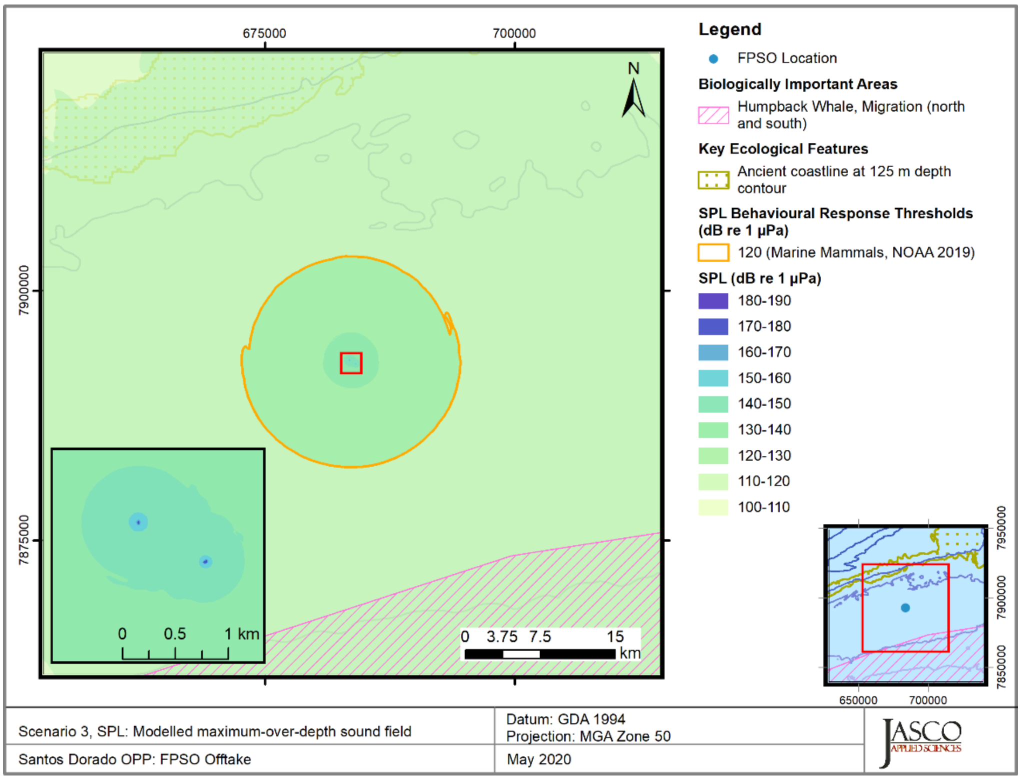

Figure 32. *Vessel Operations, FSPO offtake operations, SPL*: Sound level contour map showing maximum-over-depth results.

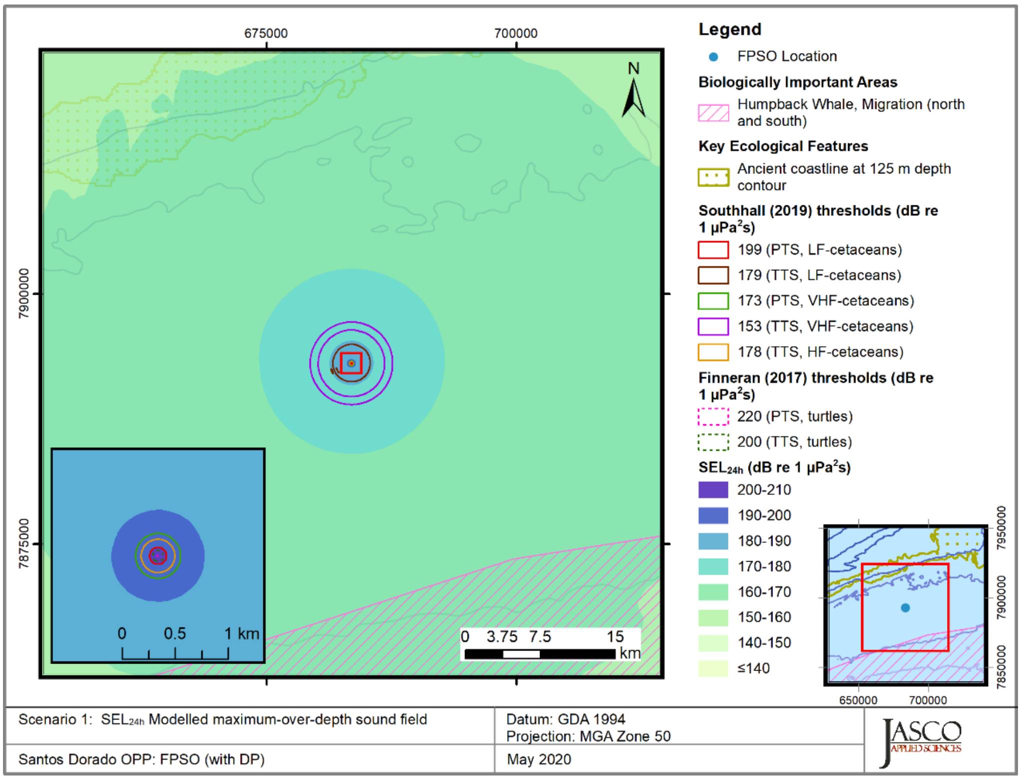

Figure 33. *Vessel Operations, FSPO on DP, SEL_{24h}*: Sound level contour map showing maximum-over-depth results.

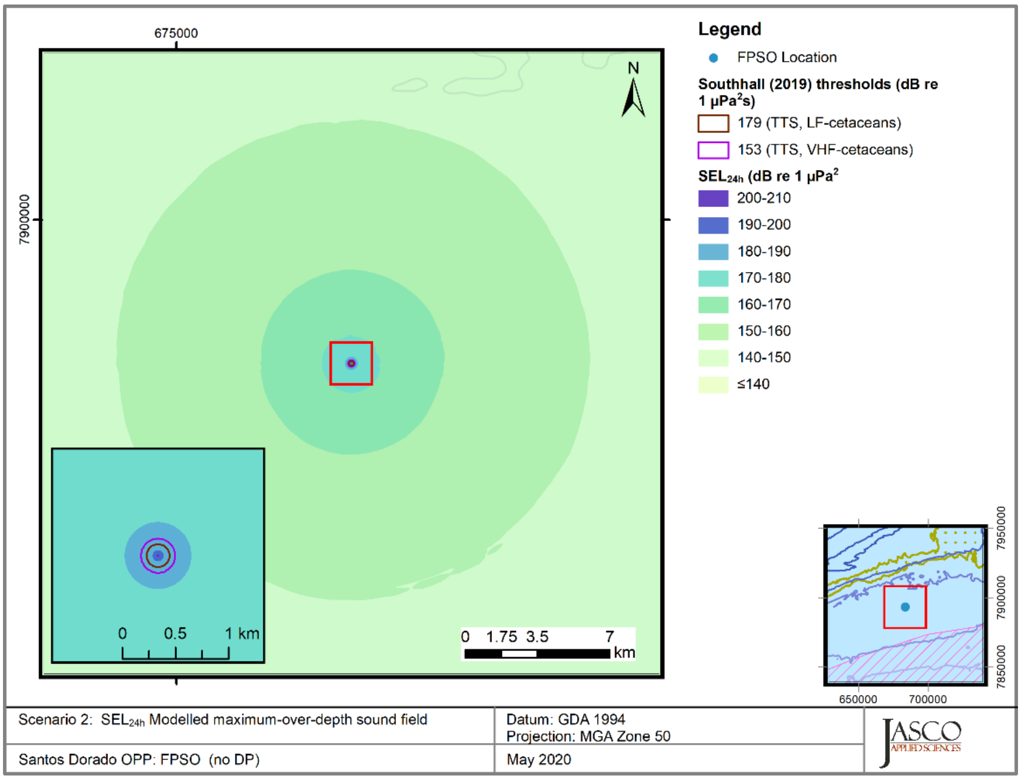

Figure 34. *Vessel Operations, FSPO without DP, SEL24h*: Sound level contour map showing maximum-over-depth results.

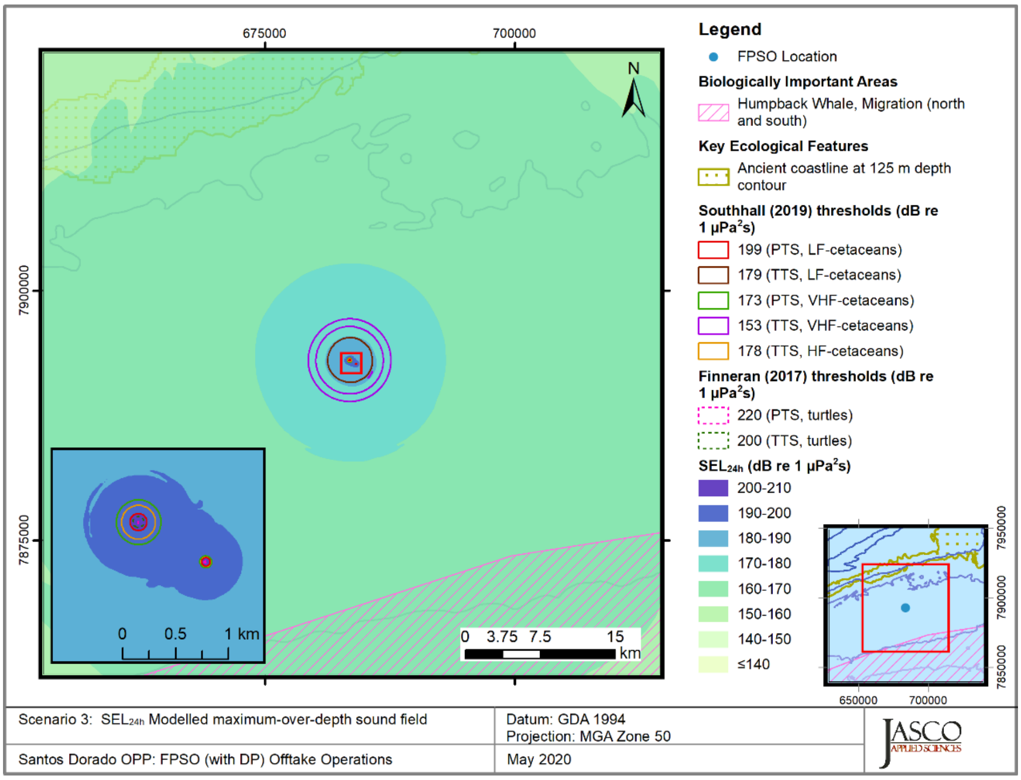

Figure 35. *Vessel Operations, FSPO offtake operations SEL24h*: Sound level contour map showing maximum-over-depth results.

5. Discussion and Summary

An analysis of seasonal sound speed profiles, the results of which are presented in Appendix F.3.2, indicated that July was the month most conducive to sound propagation due to the presence of an upward refracting layer near the sea surface; as such it was selected to ensure a conservative estimation of distances to received sound level thresholds. Modelling also accounted for site-specific bathymetric variations (Appendix F.3.1) and local seabed geoacoustic properties (Appendix F.3.3).

As the FPSO and WHP modelled sites are situated on the central North West Shelf, variations in bathymetry were generally gradual within the modelled area. Any variations in the bathymetry had a small effect on the predicted sound field footprints as manifested in the generally symmetric sound field footprints. This applied to all source types considered.

5.1. Ranges to exposure thresholds

For the results and summary tables presented above and below where a dash is used in place of a horizontal distance, these thresholds may or may not be reached. Due to the discretely sampled 20 m radial increments of the modelled sound fields, distances to those levels could not be estimated to the computational resolution of the closest step to the source. It is likely that in the case of per-pulse or per-strike SPL, SEL, PK, and continuous SPL some thresholds would be reached at distances between the source and the modelled horizontal resolution (20 m); the injury thresholds based on accumulated SEL on the other hand may not be reached at any range due the species specific frequency weighing functions. A dash therefore is an indication that effect levels for the associated metric may only be reached within a very close proximity to a given source, if at all.

5.2. Pile Driving

5.2.1. Acoustic propagation

This study predicted underwater sound levels associated with impact driving of subsea piles for the WHP and seabed anchor for FPSO facility.

For the WHP jacket piles, the underwater sound field was modelled for 50 m long piles with a 3.0 m diameter with 55 mm wall thickness; The WHP jacket piles will be driven a total of 21.5 m into the seabed. The broadband sound energy at 10 m for each penetration depth ranged from 193.7 – 194.4 dB re 1 µPa^2·s with the peak sound energy concentrated in the frequency range 100 to 400 Hz (Figure 8), with levels from the pile at the 18.75 m penetration depth having the highest energy.

For the FPSO anchor piles, the underwater sound field was modelled for 40 m long piles with a 2.5 m diameter with 100 mm wall thickness. The FPSO anchor piles will be driven completely into the seabed. The broadband sound energy at 10 m for each penetration depth ranged from 193.7 to 195.5 dB re 1 µPa^2·s with the peak sound energy concentrated in the frequency range 100 to 400 Hz (Figure 17), with levels from the pile at the 30.6 m penetration depth having the highest energy.

Noise emissions from pile driving were considered here to be cylindrically isotropic (i.e., omnidirectional in the horizontal plane). As such, variations in noise that propagates across azimuths are attributed to the bathymetry alone. When the hammer strikes the pile, noise propagates into the water as a downward Mach cone (see Appendix B). A portion of the energy from the strike is also reflected at the pile bottom, generating an upward Mach cone. This cycle of downward propagation, reflection, and upward propagation occurs multiple times per strike. At close range from the pile, noise levels are determined by the summation of Mach cones, which might add constructively (i.e., their summation results in a total wave with higher amplitude than the original ones) or destructively (i.e., wavefronts can cancel each other, resulting in lower amplitudes). The way in which Mach cones combine with each other is strongly dependent on their frequency content, which is determined by the hammer forcing function and the pile dimensions.

Due to the relation between the speed of sound in steel (~5000 m/s) relative to the speed of sound in the water (~1527 m/s at the depth of the pile), the Mach cone propagates away from the pile and impinges the seabed at an angle of ~17°. The first bottom bounce occurs within 15 m from the pile, and the first surface bounce occurs within 27 m from the pile. As shown in Figures 12–14 ,21–22 the Mach cone corresponding to the shallowest pile penetration introduces substantial energy that propagates through the water column, compared to the 30.6 m pile penetration for the FPSO anchor pile scenario in Figure 23, for which underground sound propagation tends to dominate near the pile.

The modelling of the three penetration depths for each pile provides a detailed quantification of the associated sound levels for each penetration. The distances to per-strike isopleths are generally farthest when most of the pile is in the water column, and distances are shortest at the end of piling when most of the pile is buried in the sediment. This is despite the per-strike pile penetration being less during the final stages of driving and the increased resistance generating stronger stress-wave reflections at the pile toe.

For criteria based on SEL_{24h} metrics, the ranges above must be considered in context of the duration of operations. One pile will be driven per day; therefore, the corresponding sound level is denoted as SEL_{24h}. However, the estimated time for driving a single pile was 1.6 h for the WHP anchor piles and 4.7 h for FPSO anchor piles (Table 14). The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within the driving period and assumes that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure since. More realistically, marine fauna (mammals, sea turtles or fish) would not stay in the same location or at the same range for an extended period. Therefore, a reported radius associated with the accumulated SEL criteria does not mean that any animal travelling within this radius of the source *will* be injured, but rather that it *could* be injured if it remained in that range for the entire period of driving (1.6 and 4.7 hours).

5.2.2. Marine mammals

- NOAA (2019) acoustic threshold for behavioural response in marine mammals: Distances to the SPL threshold of 160 dB re 1 µPa are between 3.4–5.4 km, depending on the penetration depth and type of pile being driven. The maximum distance for the WHP jacket pile is 5.4 km, while maximum distance for the FPSO anchor pile is 4.59 km (Tables 17 and 24).
- Southall et al. (2019) criteria for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The assessment considers both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 40.

Table 40. *Pile driving*: Maximum-over-depth distances (in km) to marine mammal PTS and TTS thresholds from Southall et al. (2019). PK results are in Tables 18 and 25 while those for SEL_{24h} are in Tables 20 and 27.

Hearing group	WHP jacket pile		FPSO anchor pile	
	Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
PTS				
Low-frequency cetaceans	SEL_{24h}	5.29	SEL_{24h}	5.84
High-frequency cetaceans	SEL_{24h}	–	SEL_{24h}	0.03
Very-high-frequency cetaceans	PK	0.55	SEL_{24h}	1.04
TTS				
Low-frequency cetaceans	SEL_{24h}	22.6	SEL_{24h}	28.2
High-frequency cetaceans	SEL_{24h}	0.29	SEL_{24h}	0.36
Very-high-frequency cetaceans	SEL_{24h}	2.78	SEL_{24h}	4.27

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

5.2.3. Sea turtles

- NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa) and a criterion for increased behavioural disturbance (SPL of 175 dB re 1 µPa) (Moein et al. 1995, McCauley et al. 2000b, McCauley et al. 2000a): Maximum distances are associated with the shallowest penetration of 3.5 m for both piling locations, with the maximum distances summarised in Table 41.
- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The assessment considers both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 42.

Table 41. *Pile driving*, turtle behavioural response thresholds, SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths, maximum across all three modelled penetration depths. Results are presented in Tables 17 and 24.

Threshold	WHP		FPSO	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	3.51	3.36	2.91	2.79
Turtle disturbance, SPL: 175 dB re 1 µPa (McCauley et al. 2000b, 2000a)	1.39	1.34	1.07	1.02

Table 42. *Pile driving*: Maximum-over-depth distances (in km) to turtle PTS and TTS thresholds (Finneran et al. 2017). PK thresholds were not reached within the limits of the modelled resolution while those for SEL_{24h} are in Tables 20 and 27.

Threshold	WHP jacket pile		FPSO anchor pile	
	Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
PTS	SEL_{24h}	0.72	SEL_{24h}	0.68
TTS	SEL_{24h}	4.11	SEL_{24h}	3.98

5.2.4. Fish, fish eggs, and fish larvae

The modelling study assessed the ranges for quantitative criteria from Popper et al. (2014) associated with mortality and potential mortal injury and impairment in the following:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- Fish with a swim bladder not used for hearing
- Fish that use their swim bladders for hearing
- Fish eggs, and fish larvae

Considering both per-strike modelled penetrations and associated SEL_{24h} scenario, along with both PK and SEL_{24h} metrics, in line with the conditions of the criteria, the maximum distances are summarised in Table 43.

Table 43. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Tables 18 and 25, SEL_{24h} values from Tables 21 and 29).

Relevant hearing group	Injury criteria	WHP		FPSO	
		Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.17	PK	0.13
	TTS	SEL_{24h}	5.59	SEL_{24h}	5.88
Fish: Swim bladder not involved in hearing	Injury	SEL_{24h}	0.47	SEL_{24h}	0.39
	TTS	SEL_{24h}	5.59	SEL_{24h}	5.88
Fish: Swim bladder involved in hearing	Injury	SEL_{24h}	0.56	SEL_{24h}	0.52
	TTS	SEL_{24h}	5.59	SEL_{24h}	5.88
Fish eggs and larvae	Injury	SEL_{24h}	0.47	SEL_{24h}	0.39

5.3. VSP

5.3.1. Acoustic propagation

This study predicted underwater sound levels associated with VSP sources at the WHP. The underwater sound field was modelled for a 750 in^3 seismic source array deployed at depth 5 m (Appendix C). Since the VSP source is mostly isotropic (vertically and horizontally), sound propagation for this source is driven by gradual changes in bathymetric features.

5.3.2. Marine mammal injury and behaviour

- NOAA (2019) acoustic threshold for behavioural response in marine mammals: The maximum distance to the SPL threshold of 160 dB re 1 µPa was 2.42 km from the centre of the VSP array.
- Southall et al. (2019) criteria for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The SEL_{24h} threshold distance considers multiple impulses within a 24 h period, ranging from 1 to 300. The applicable metric from the criteria, associated with the longest distance associated with either metric, depends upon the number of impulses with the 24 h. The ranges presented are based upon no more than 300 impulses within 24 h. A reported radius for SEL_{24h} criteria does not mean that marine mammals travelling within this radius of the source *will* be injured, but rather that an animal *could* be exposed to the sound level associated with effect (either PTS or TTS) if it remained in that location for either 24 hours or the duration of the activity if less. Results are presented in Tables 33 and 35.
    - For low-frequency cetaceans, the PTS and TTS thresholds associated with the PK metric were predicted to be less than 20 m from the centre of the acoustic source, otherwise the PTS and TTS ranges were determined by SEL_{24h}, with the maximum distances reached at 470 m for PTS and 3.1 km for TTS.
    - PTS and TTS are not predicted to occur for high-frequency cetaceans.
    - For PTS in very high-frequency cetaceans, the PK metric was always associated with the longest range (63 m), as was the case for TTS (241 m).

5.3.3. Sea turtles

- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The SEL_{24h} threshold distance considers multiple impulses within a 24 h period, ranging from 1 to 300. Similarly to marine mammals, the reported radii for SEL_{24h} criteria do not mean that sea turtles travelling within this distance of the source will be injured, but rather that an animal could be exposed to the sound level associated with effect (TTS) if it remained in that location for either 24 h or the duration of the activity if less.
    - Within the range of considered impulses (1–300), the PTS threshold was first exceeded at a maximum distance of 30 m when considering the SEL_{24h} criteria for 150 impulses. The PK threshold may be exceeded at distances less than 20 m from the centre of the acoustic source, if at all. Refer to Tables 33 and 35.
    - While the TTS criterion due to the PK metric was not exceeded, depending upon the number of impulses the TTS SEL_{24h} criterion may be exceeded at a maximum distance of 380 m for 300 impulses.
- The distances to where the NMFS criterion (NSF 2011) for behavioural effects in sea turtles of sea turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) McCauley et al. (2000b), McCauley et al. (2000a) could be exceeded are summarised in Table 44.

Table 44. Distances to turtle behavioural response criteria (from Table 32)

Threshold	R_{max} (km)	$R_{95\%}$ (km)
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	1.22	1.18
Turtle behaviour, SPL: 175 dB re 1 µPa (McCauley et al. 2000b, 2000a)	0.38	0.37

5.3.4. Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury and with impairment in the following groups:
  - Fish without a swim bladder (also appropriate for sharks in the absence of other information);
  - Fish with a swim bladder that do not use it for hearing;
  - Fish that use their swim bladders for hearing; and
  - Fish eggs and fish larvae.
- Sound levels at the seafloor do not exceed any of the criteria (Table 34).
- Based on PK metrics, acoustic injury could be sustained within a horizontal distance less than 20 m from the centre of the VSP source for fish without a swim bladder, and within a maximum horizontal distance of 37 m for fish with a swim bladder, fish eggs, and fish larvae (Table 33).
- Within the range of considered impulses (1–300), the distance to the threshold for the SEL_{24h} metric for injury was first reached at a maximum distance of 50 m for 200 impulses(Table 36).

5.3.5. Sponges and Coral

To assist with assessing the potential effects on these receptors, the following have been determined:

- The PK sound level at the seafloor estimated by modelling directly underneath the VSP source remained below the no effect sound level for sponges and coral of 226 dB re 1 µPa PK (Heyward et al. 2018).

5.4. Vessel Noise (FPSO and OSV)

5.4.1. Acoustic propagation

This study predicted underwater sound levels associated with the operations of an FPSO with and without DP operating, and an OSV near the FPSO (Sections 3.2) plus a noiseless condensate tanker.. Minor variation in the sound field footprint were caused by gradual changes in bathymetric features. Scenarios where the FPSO was under DP produced the largest isopleth distances, this is expected due to the significantly higher source levels for the vessel under DP than not (Section 3.3.1).

5.4.2. Marine mammal injury and behaviour

- Southall et al. (2019) criteria for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): The criteria were assessed for a 24 h period, and the maximum distances to PTS are summarised in Table 45
- NOAA (2019) acoustic threshold for behavioural response in marine mammals: The maximum distances to the SPL threshold of 120 dB re 1 µPa for each scenario are summarised in Table 46

Table 45. *Vessels, marine mammal SEL_{24h} thresholds*: Maximum (R_{max}) horizontal distances (km) from the vessels to modelled maximum-over-depth marine mammal PTS threshold from Southall et al. (2019).

Hearing group	Threshold for PTS, SEL_{24h} (dB re 1 µPa²·s)	Distance R_{max} (km)			
		FPSO on DP	FPSO without DP	OSV	Offtake operations*
Low-frequency cetaceans	199	0.07	–	0.03	0.08
High-frequency cetaceans	198	–	–	–	–
Very-high-frequency cetaceans	173	0.21	–	0.05	0.21

* Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 46. *Vessels, marine mammal behavioural response thresholds, SPL*: Summary of maximum distances.

Threshold	Distance R_{max} (km)			
	FPSO on DP	FPSO without DP	OSV	Offtake operations*
Marine mammal behaviour, SPL: 120 dB re 1 µPa (NOAA 2019)	10.4	1.49	4.57	11.0

* Radial distances for isopleths/thresholds that envelope the FPSO and OSV were reported from the mid-point between the FPSO and the OSV modelled sites. Otherwise radial distances were reported from the FPSO modelled location.

5.4.3. Sea Turtles

- Finneran et al. (2017) criteria for sea turtle Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS): TTS is not predicted to occur for the FPSO without DP within the modelling resolution of 20 m, and only at distances of up to 50 m for the FPSO under DP and offtake operations. PTS is not predicted to occur.

5.4.4. Fish

- Popper et al. (2014): Sound produced by the vessel operations could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 30 m, for 48 h. Temporary impairment due to TTS could occur at similar short distances if fish remain at the same location within the sound field for a duration exceeding 12 h.

6. Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

absorption
The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

acoustic impedance
The ratio of the sound pressure in a medium to the rate of alternating flow of the medium through a specified surface due to the sound wave.

ambient noise
All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

Auditory frequency weighting (auditory weighting function, frequency-weighting function)
The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017). One example is M-weighting introduced by Southall et al. (2007) to describe "Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterising auditory effects of strong sounds".

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 10^5 Pa or 10^{11} µPa.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decade
Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 2006).

decidecade
One tenth of a decade (ISO 2017). Note: An alternative name for decidecade (symbol ddec) is “one-tenth decade”. A decidecade is approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a “one-third octave”.

decidecade band
Frequency band whose bandwidth is one decidecade. Note: The bandwidth of a decidecade band increases with increasing centre frequency.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

fast-average sound pressure level
The time-averaged sound pressure levels calculated over the duration of a pulse (e.g., 90%-energy time window), using the leaky time integrator from Plomp and Bouman (1959) and a time constant of 125 ms. Typically used only for pulsed sounds.

fast Fourier transform (FFT)
A computationally efficiently algorithm for computing the discrete Fourier transform.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, high-, and very-high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level for any frequency of the hearing group that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialised for high-frequency hearing. Mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019).

intermittent sound
A level of sound that abruptly drops to the background noise level several times during the observation period.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialised for hearing low frequencies.

masking
Obscuring of sounds of interest by sounds at similar frequencies.

median
The 50th percentile of a statistical distribution.

Monte Carlo simulation
The method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but they use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of

toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

peak-to-peak pressure level (PK-PK)
The difference between the maximum and minimum instantaneous pressure levels. Unit: decibel (dB).

percentile level, exceedance
The sound level exceeded *n*% of the time during a measurement.

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

pressure, hydrostatic
The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 µPa²·s. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: µPa²·s/Hz.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa²:

$$L_p = 10\log_{10}(p^2/p_0^2) = 20\log_{10}(p/p_0)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 µPa·m (pressure level) or dB re 1 µPa²·s·m (exposure level).

spectrogram
A visual representation of acoustic amplitude compared with time and frequency.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

very-high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialised for very-high-frequency hearing. High-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019).

wavelength
Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level (PK; L_{pk}; $L_{p,pk}$; dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max(|p(t)|)}{p_0}\right] \quad \text{(A-1)}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (PK-PK; $L_{pk\text{-}pk}$; $L_{p,pk\text{-}pk}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound, $p(t)$:

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2}\right\} \quad \text{(A-2)}$$

The sound pressure level (SPL; L_p; dB re 1 µPa) is the rms pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \quad \text{(A-3)}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalisation, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL. A fixed window length of 0.125 s (critical duration defined by Tougaard et al. (2015)) is used in this study for impulsive sounds.

The sound exposure level (SEL; L_E; $L_{E,p}$; dB re 1 µPa^2·s) is a measure related to the acoustic energy contained in one or more acoustic events (N). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, SEL can be computed by summing (in linear units) SEL of the *N* individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right). \tag{A-5}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.3). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should else be specified.

A.2. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources–primarily airguns used in seismic surveys–could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.2.1. Auditory Impairment

There are two categories of auditory threshold shifts (also termed Noise Induced Threshold Shift, NITS): Permanent Threshold Shift (PTS), a physical injury to an animal's hearing system; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of physiological and mechanical processes in the inner ear. While PTS undoubtedly constitutes an injury, TTS (as a temporary effect) was not considered in the same way. However, recent research clearly indicates that already moderate levels (<12 dB) of TTS produced an accelerated hearing loss (PTS) resulting from progressive neural degeneration with age (Kujawa and Liberman 2006, 2009, Maison et al. 2013, Kujawa and Liberman 2015).

The most recent criteria for assessing possible effects of impulsive sounds (such as pile driving or seismic impulses) noise and non-impulsive sound (such as vessel noise) on marine mammals, Southall et al. (2019), was applied in this study.

A.2.2. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For non-impulsive noise, NMFS currently uses step function (all-or-none) threshold of 120 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2019). The 120 dB re 1 µPa threshold is associated with continuous sources and was derived based on studies examining behavioural responses to drilling and dredging (NOAA 2018), referring to Malme et al. (1983), Malme et al. (1984), and Malme et al. (1986), which were considered in Southall et al. (2007). Malme et al. (1986) found that playback of drillship noise did not produce clear evidence of disturbance or avoidance for levels below 110 dB re 1 µPa (SPL), possible avoidance occurred for exposure levels approaching 119 dB re 1 µPa. Malme et al. (1984) determined that measurable reactions usually consisted of rather subtle short-term changes in speed and/or heading of the whale(s) under observation. It has been shown that both received level and proximity of the sound source is a contributing factor in eliciting behavioural reactions in humpback whales (Dunlop et al. 2017, Dunlop et al. 2018).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.3. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.3.1. Marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-6)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans, but the weighting functions remain the same. Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
High-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
Very-high-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

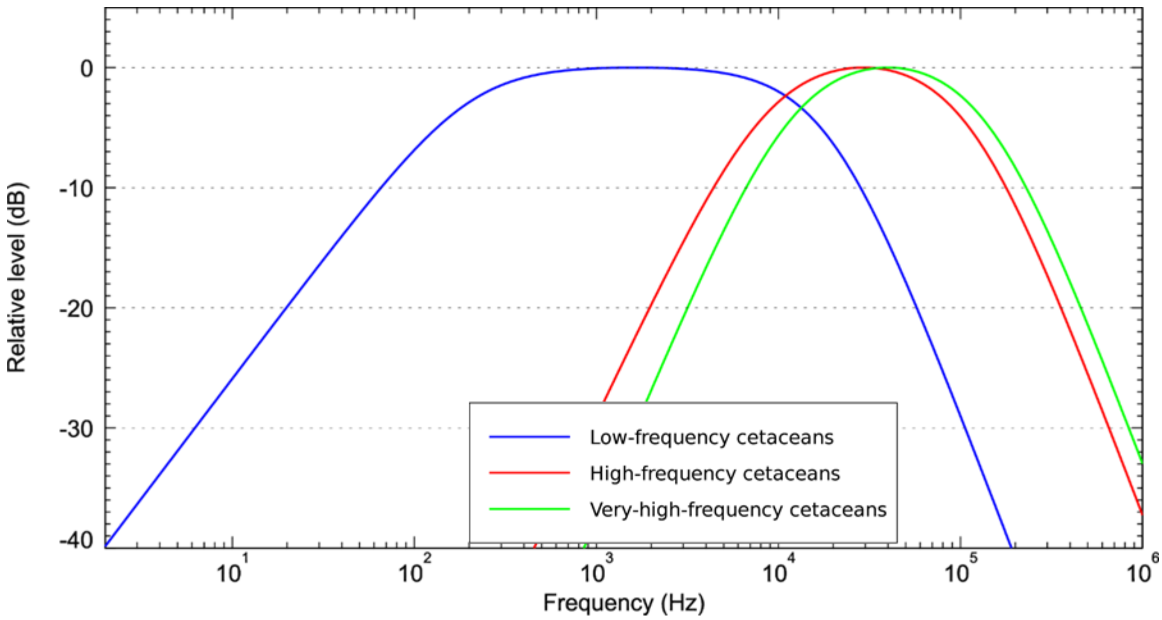

Figure A-1. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2019).

Appendix B. Pile Driving Acoustic Source Model

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure B-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modelled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers–both impact and vibratory–based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical VSP array of discrete point sources. The point sources are centred on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity–calculated using a near-field wave-number integration model–matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source VSP array is then calculated using a time-domain acoustic propagation model (FWRAM, Appendix E.2). MacGillivray (2014) describes the theory behind the physical model in more detail. The accuracy of JASCO's pile driving model has been verified by comparing its output against benchmark scenarios (Lippert et al. 2016) and detailed measurement programs (Austin et al. 2016, Denes et al. 2016, MacGillivray 2018).

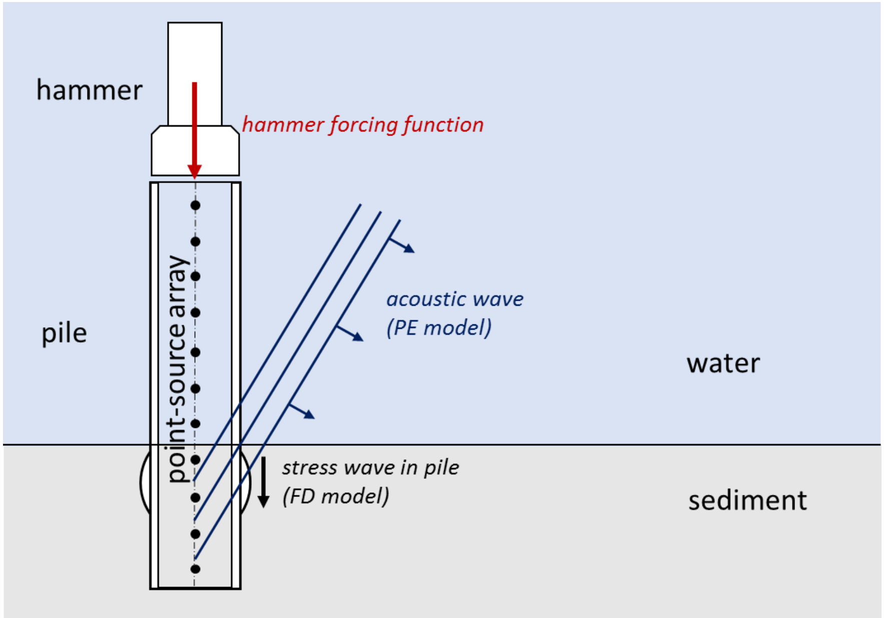

Figure B-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical VSP array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

Appendix C. VSP Source

C.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landrø (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, operating depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{nf} < \frac{l^2}{4\lambda} \quad \text{(C-1)}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

C.2. VSP Source Parameters

The layout of the seismic source is provided in Figure F-1. Details of the airgun parameters are provided in Table C-1. In the context of this source geometry the broadside direction is perpendicular to the sagittal plane of the array and the endfire direction is parallel to the sagittal plane of the array.

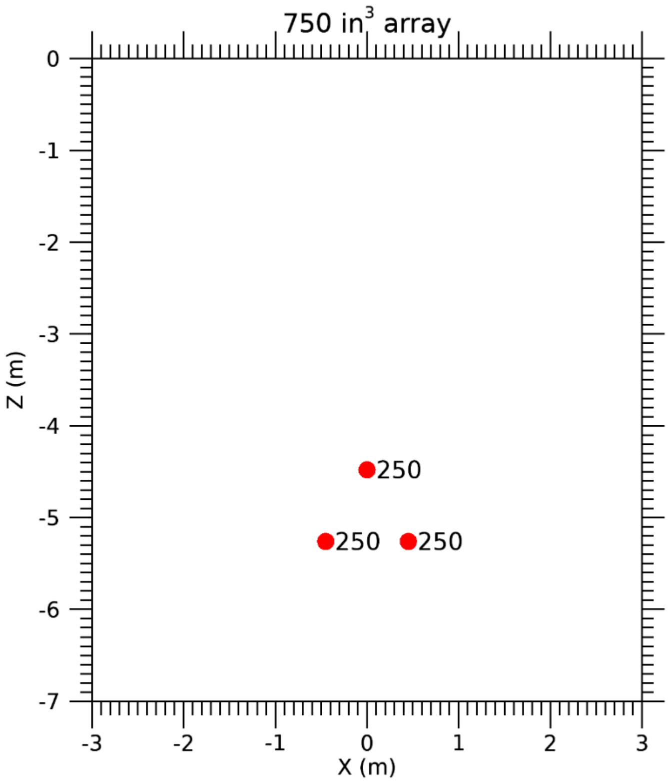

Figure C-1. Layout of the modelled 750 in^3 seismic source array. Operational depth is 5 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table C-1.

Table C-1. Layout of the modelled 750 in^3 seismic source array. Operational depth is 5 m. Firing pressure for all guns is 2000 psi. Also see Figure C-1.

Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	0.0	0.0	4.48	250
2	0.0	0.45	5.26	250
3	0.0	-0.45	5.26	250

C.3. Array Source Levels and Directivity

Figure C-2 shows the broadside (perpendicular to the sagittal plane), endfire (parallel to the sagittal plane), and vertical overpressure signature and corresponding power spectrum levels for the 750 in^3 array (Appendix C.2). Horizontal 1/3-octave-band source levels shown as a function of band centre frequency and azimuth (Figure C-3) indicate that this array is mainly isotropic.

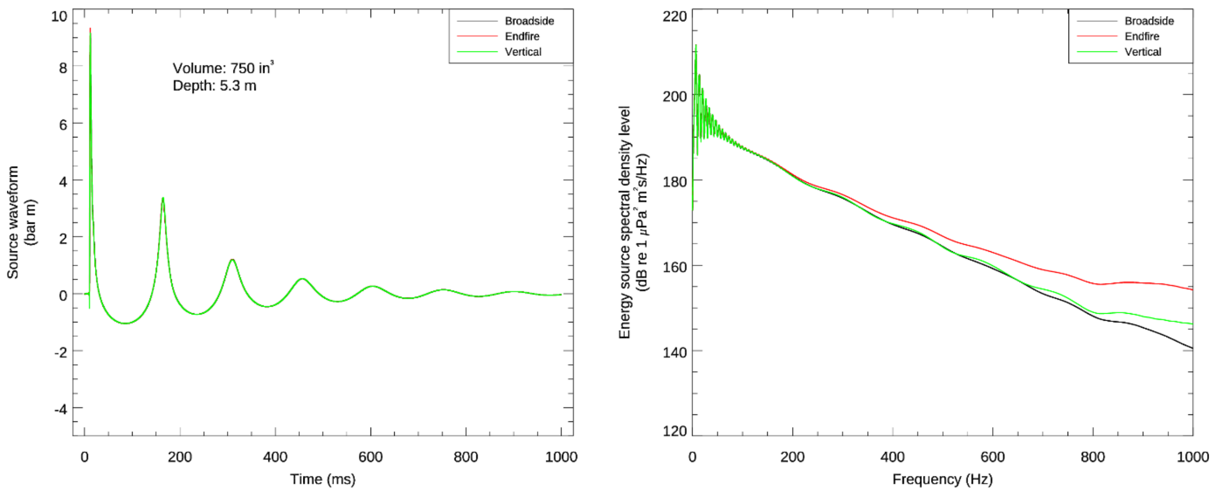

Figure C-2. Predicted source level details for the 750 in^3 array at a 6 m operational depth.(Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

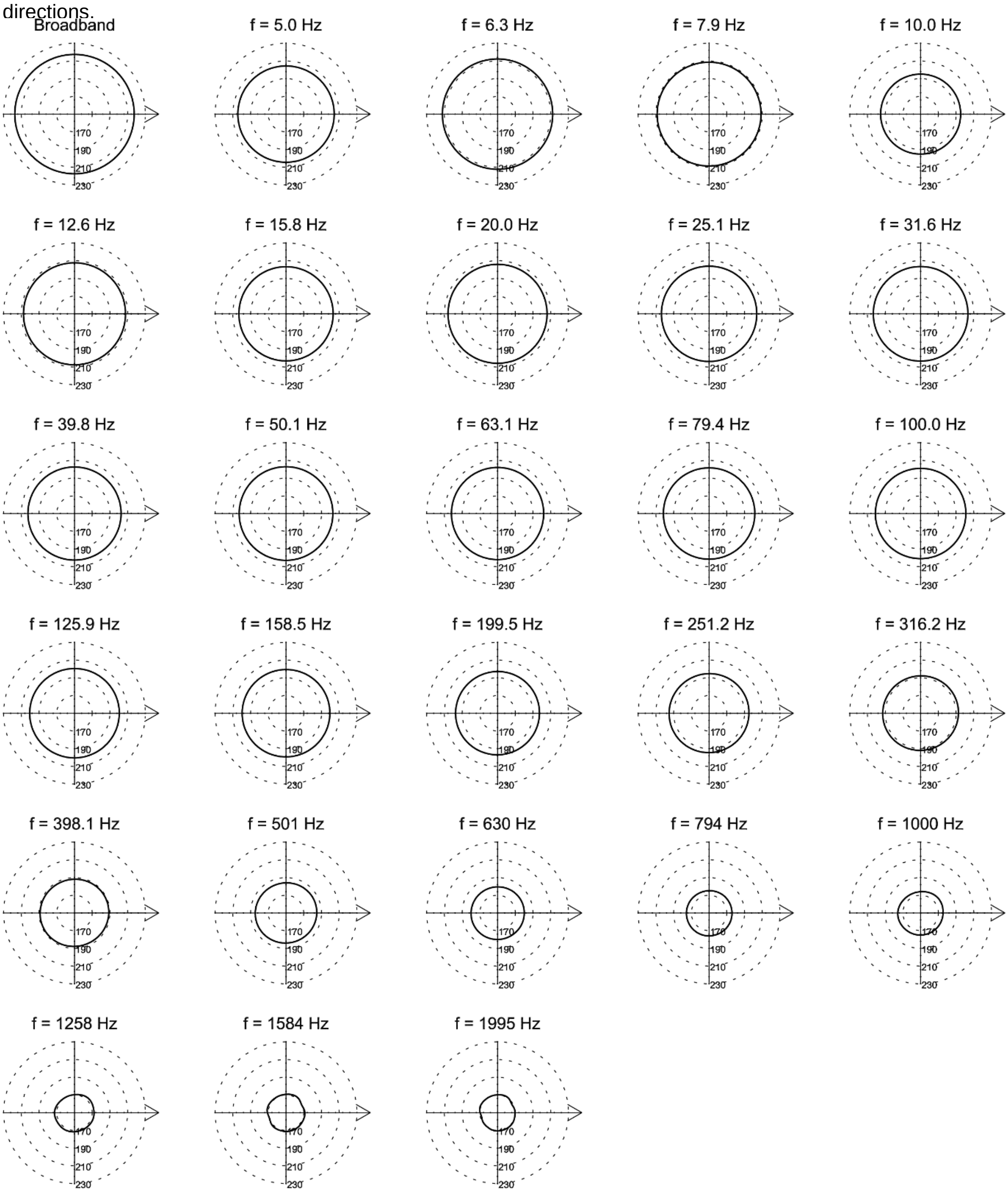

Figure C-3. Directionality of the predicted horizontal source levels for the 750 in^3 seismic source array, 10 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. The endfire axis is to the right. Operational depth is 5 m.

Appendix D. Thruster Source Level Estimation

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of sound produced by sound transmitted through the hull, such as by engines, gearing, and other mechanical systems. Sound levels tend to be the highest when thrusters are used to position the vessel and when the vessel is transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, propulsion system, and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband acoustic energy with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins–normally around 8–12 knots on many commercial vessels (Spence et al. 2007). Under higher speeds and higher propulsion system load, the acoustic output from the cavitation processes on the propeller blades dominates other sources of sound on the vessel such as machinery or hull vibration (Leggat et al. 1981).

A vessel equipped with propellers/thrusters has two primary sources of sound that propagate from the unit: the machinery and the propellers. For thrusters operating in the heavily loaded conditions, the acoustic energy generated by the cavitation processes on the propeller blades dominates (Leggat et al. 1981). The sound power from the propellers is proportional to the number of blades, the propeller diameter, and the propeller tip speed.

Based on an analysis of acoustic data, Ross (1976) provided the following formula for the sound levels from a vessel's propeller, operating in calm, open ocean conditions:

$$L_{100} = 155 + 60\log(u/25) + 10\log(B/4)\,, \tag{D-1}$$

where L_{100} is the spectrum level at 100 Hz, u is the propeller tip speed (m/s), and B is the number of propeller blades. Equation D-1 gives the total energy produced by the propeller cavitation at frequencies between 100 Hz and 10 kHz. This equation is valid for a propeller tip speed between 15 and 50 m/s. The spectrum is assumed to be flat below 100 Hz. Its level is assumed to fall off at a rate of −6 dB per octave above 100 Hz (Figure D-1).

Another method of predicting the source level of a propeller was suggested by Brown (1977). For propellers operating in heavily loaded conditions, the formula for the sound spectrum level is:

$$\mathrm{SL}_B = 163 + 40\log D + 30\log N + 10\log B + 20\log f + 10\log(A_c/A_D)\,, \tag{D-2}$$

where D is the propeller diameter (m), N is the propeller revolution rate per second, B is the number of blades, A_C is the area of the blades covered by cavitation, and A_D is the total propeller disc area. Similar to Ross's approach, the spectrum below 100 Hz is assumed to be flat. The tests with a naval propeller operating at off-design heavily loaded conditions showed that Equation D-2 should be used with a value of $(A_c/A_D) = 1$ (Leggat et al. 1981).

The combined source level for multiple thrusters operating together can be estimated using the formula:

$$\mathrm{SL}_{\mathrm{total}} = 10\log_{10}\sum_i 10^{\frac{SL_i}{10}}, \tag{D-3}$$

where $\mathrm{SL}_{1,\ldots,N}$ are the source levels of individual thrusters. If the vessel is equipped with the same type of thrusters, the combined source level can be estimated using the formula:

$$\mathrm{SL}_N = \mathrm{SL} + 10\log N \tag{D-4}$$

where N is the total number of thrusters of the same type.

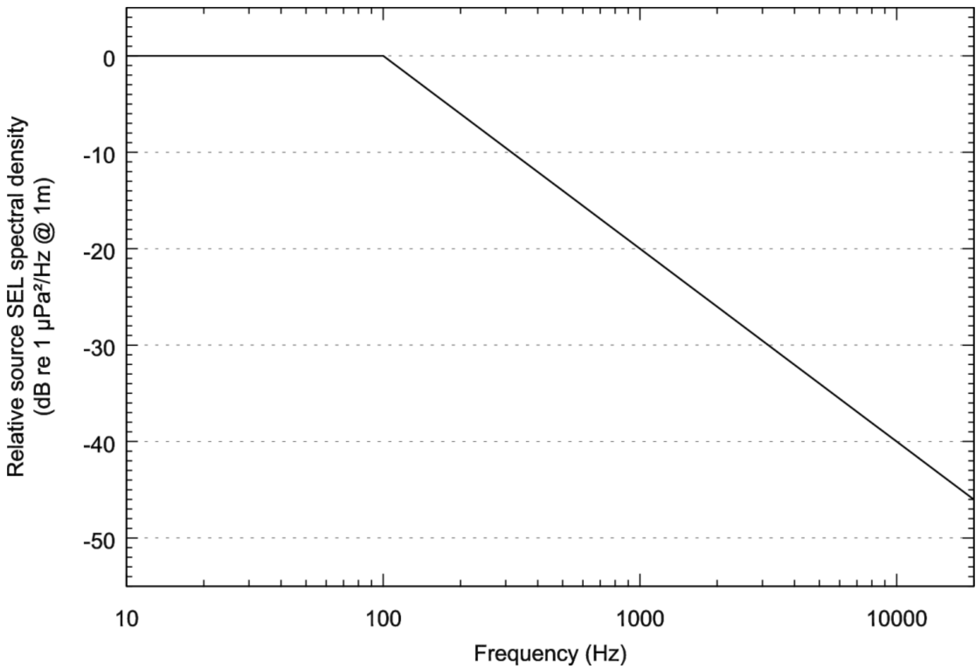

Figure D-1. Estimated sound spectrum from cavitating propeller (Leggat et al. 1981).

Appendix E. Sound Propagation Models

E.1. Transmission Loss

The propagation of sound through the environment was modelled by predicting the acoustic transmission loss–a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs. Transmission loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Transmission loss depends on the acoustic properties of the ocean and seabed, its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 µPa^{2}m^2, and transmission loss (TL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 µPa by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{TL} \tag{E-1}$$

E.2. Noise Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required to calculate SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM). FWRAM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for an elastic seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). FWRAM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. FWRAM incorporates the following site-specific environmental properties: a modelled area bathymetric grid, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the VSP array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Synthetic pressure waveforms from pile driving strikes were modelled and post-processed, after applying a travel time correction, to calculate standard SPL, SEL and PK metrics versus range and depth from the source.

E.3. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed but is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1.6 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1.6 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure E-1).

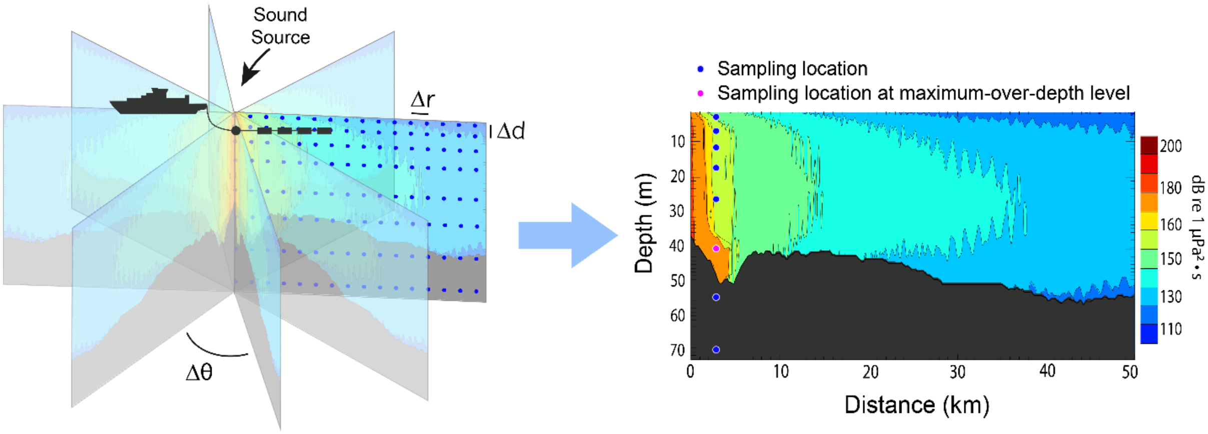

Figure E-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received 1/3-octave-band levels.

The received per-pulse (VSP source) or per-second vessel (FPSO, and OSV sources) SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse or per-second SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as colour contours around the source.

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure E-2). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure E-2) upward so that the trend line encompasses 90% of all the data (dashed line, Figure E-2).

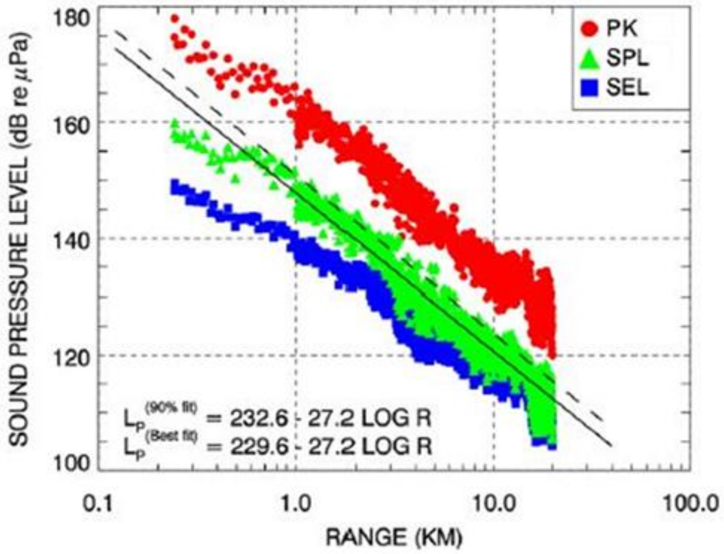

Figure E-2. PK and SPL and per-pulse SEL versus range from a 20 in^3 seismic source. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

E.4. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

Appendix F. Methods and Parameters

This section describes the specifications of the seismic source that was used at all sites and the environmental parameters used in the propagation models.

F.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure F-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure F-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure F-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

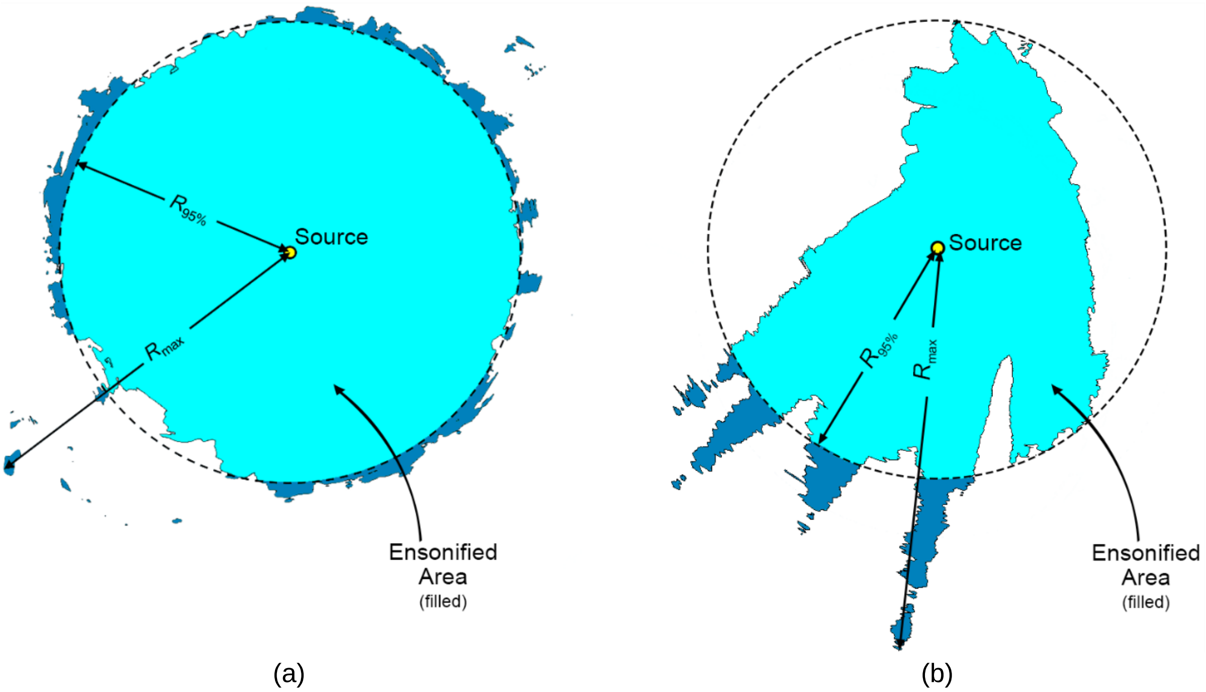

Figure F-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

F.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix E.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at modelled site 1. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. A 125 ms fixed time window positioned to maximise the SPL over the pulse duration was applied. The resulting SEL-to-SPL offsets were averaged in 0.01 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for the site. The range-dependent conversion function was then applied to predicted per-pulse SEL results from MONM to model and map SPL values. Figure F-2 shows the conversion offsets for the WHP site; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source

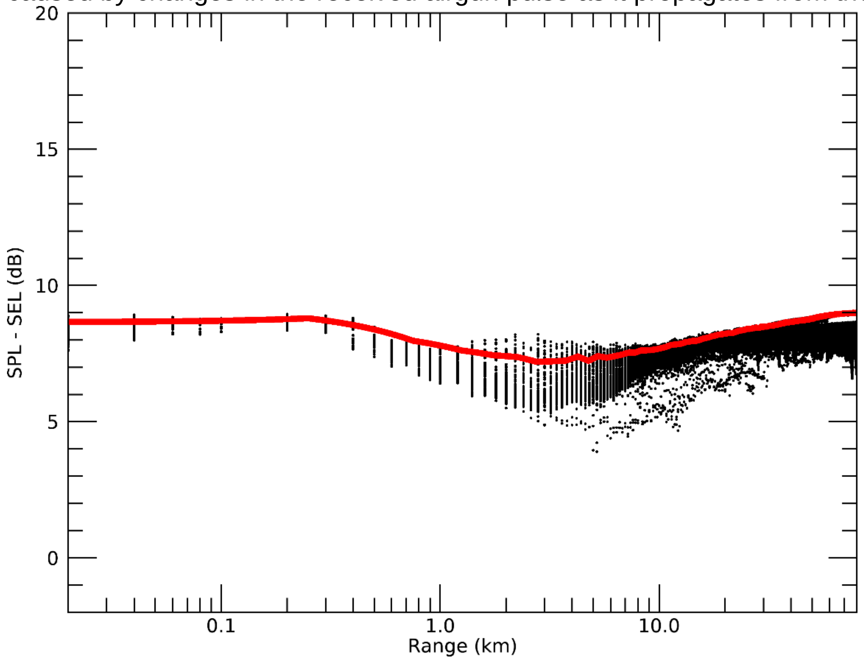

Figure F-2. Range-and-depth-dependent conversion offsets for converting SEL to SPL for VSP pulses for Dorado WHP site. Black dots are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

F.3. Environmental Parameters

F.3.1. Bathymetry

Water depths throughout the modelled areas were extracted from a dataset provided by the client (Berry 2019) and these data were re-gridded from several overlapping sub dataset using bathymetry acquired during recent surveys in the area of the dorado development project. The Australian Bathymetry and Topography Grid, a 9 arc-second grid data (Whiteway 2009) was used as a base layer for re-gridding. Bathymetry data were re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 54) with a regular grid spacing of 100 × 100 m. For large the scale overview inset maps in the report, Australian Bathymetry and Topography Grid, a 9 arc-second grid data (Whiteway 2009) was used to supplement client supplied data.

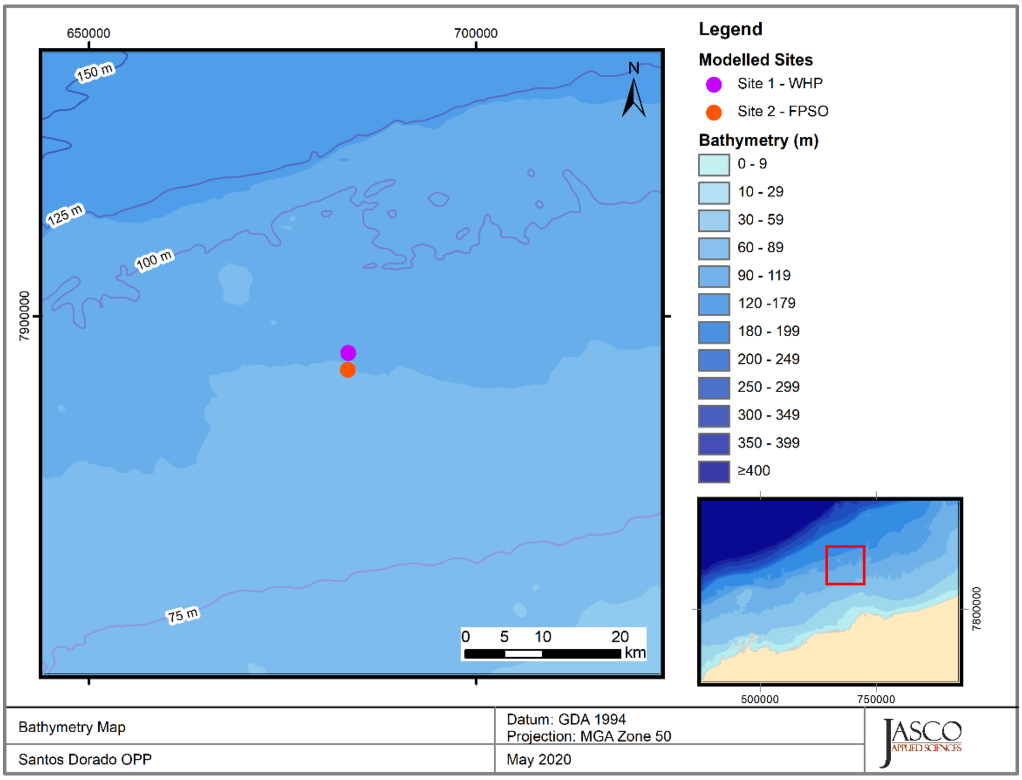

Figure F-3. Bathymetry in the modelled area.

F.3.2. Sound speed profile

The sound speed profile in the area was derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles within a 100 km box radius encompassing all modelled sites. The July sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, July was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure F-4shows the resulting profile used as input to the sound propagation modelling.

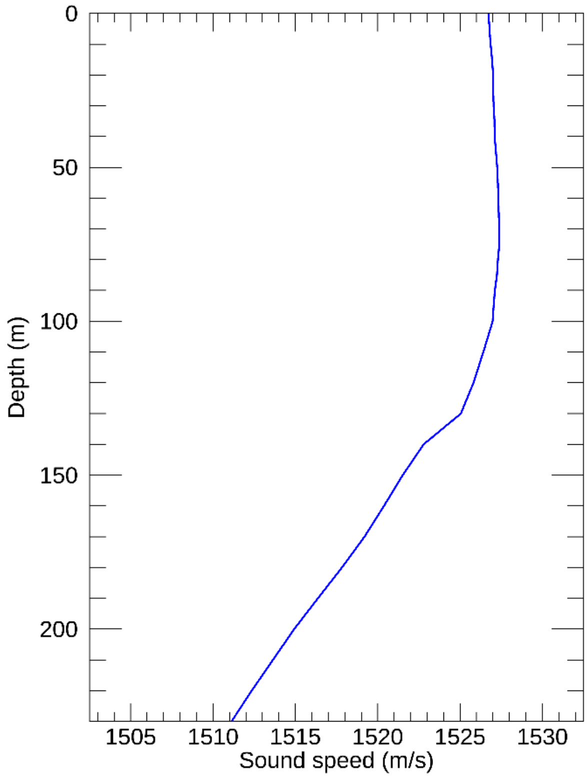

Figure F-4. The modelling sound speed profile corresponding to July Profiles are calculated from temperature and salinity profiles from *Generalized Digital Environmental Model* V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

F.3.3. Geoacoustics

For the modelled sites the seabed in the area has been described as a calcarenite substrate overlain with a layer of sand (NGI 2017). This is very similar to a profile described in association with measurement data (McCauley et al. 2016), and other modelling studies in the region (AIMS 2018). The geoacoustic parameters used for modelling at Sites 1–2 (Table F-1) are based on Duncan et al. (2009).

Table F-1. Geoacoustic profile for the Sites 1–2

Depth below seafloor (m)	Predicted lithology	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–10	Medium carbonate sand	1.8	1700	0.8	350	2.5
>10	Calcarenite	2.4	2800	0.1		

F.4. Model Validation Information

Predictions from JASCO's propagation models (MONM, FWRAM, and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix G. Additional Results

G.1. WHP Piling SEL Contour Maps

Maps of the per-strike SEL results associated with the three modelled penetration depths are shown in Figures G-1–3 for the MHU 600T hammer.

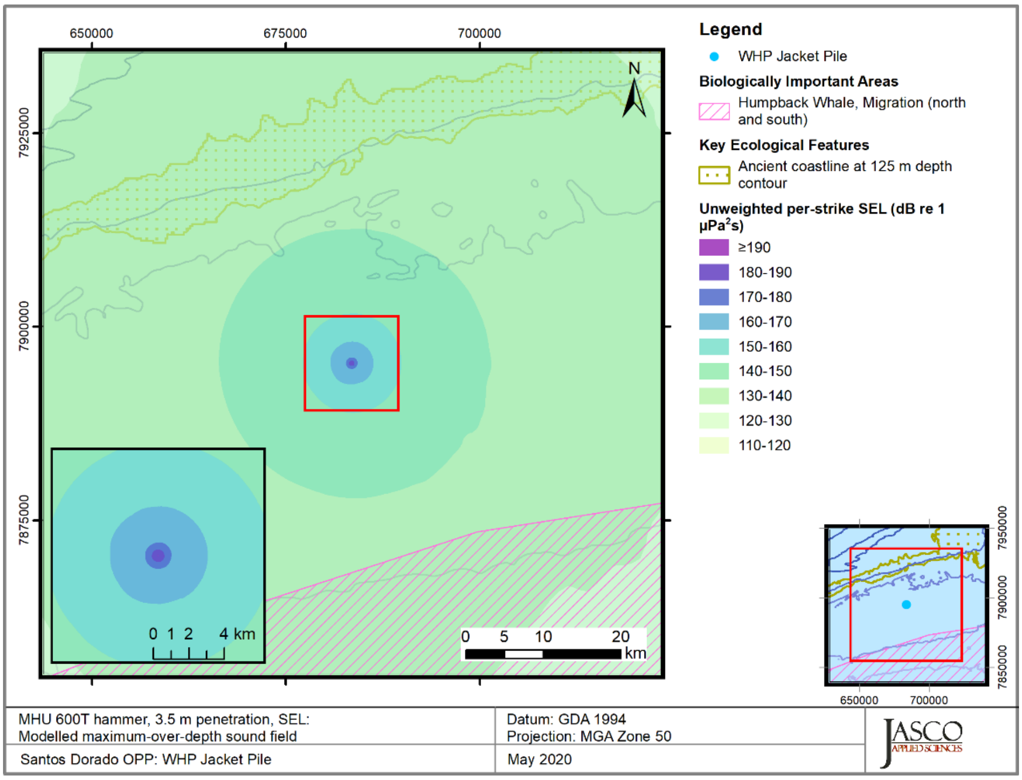

Figure G-1. *WHP piling, per-strike SEL, 3.5 m penetration depth*: Sound level contour map showing maximum-over-depth results.

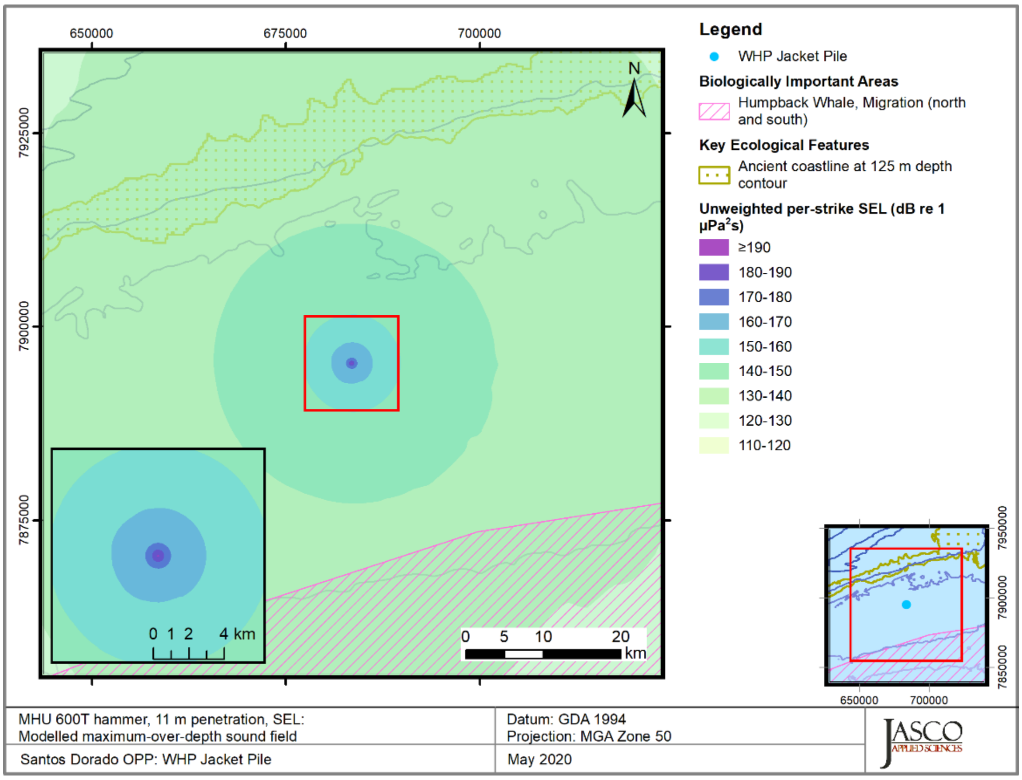

Figure G-2. *WHP piling, per-strike SEL, 11 m penetration depth*: Sound level contour map showing maximum-over-depth results.

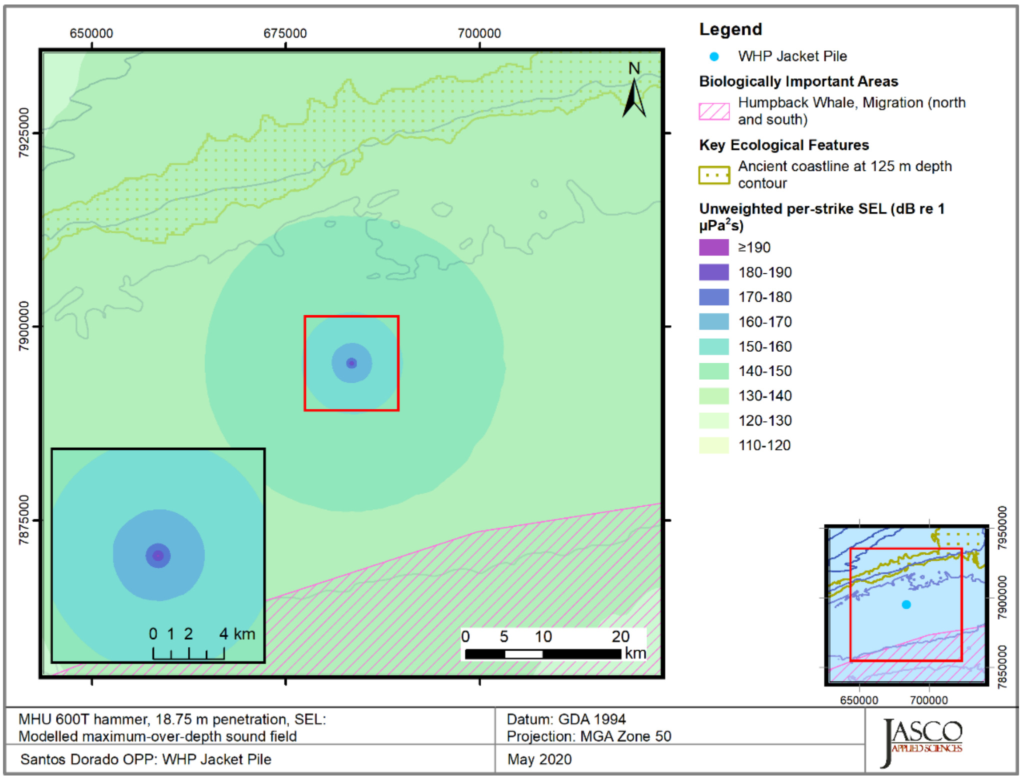

Figure G-3. *WHP piling, per-strike SEL, 18.75 m penetration depth*: Sound level contour map showing maximum-over-depth results.

G.2. FPSO Piling SEL Contour Maps

Maps of the per-strike SEL results associated with the three modelled penetration depths are shown in Figures G 4–6 for the MHU 600T hammer.

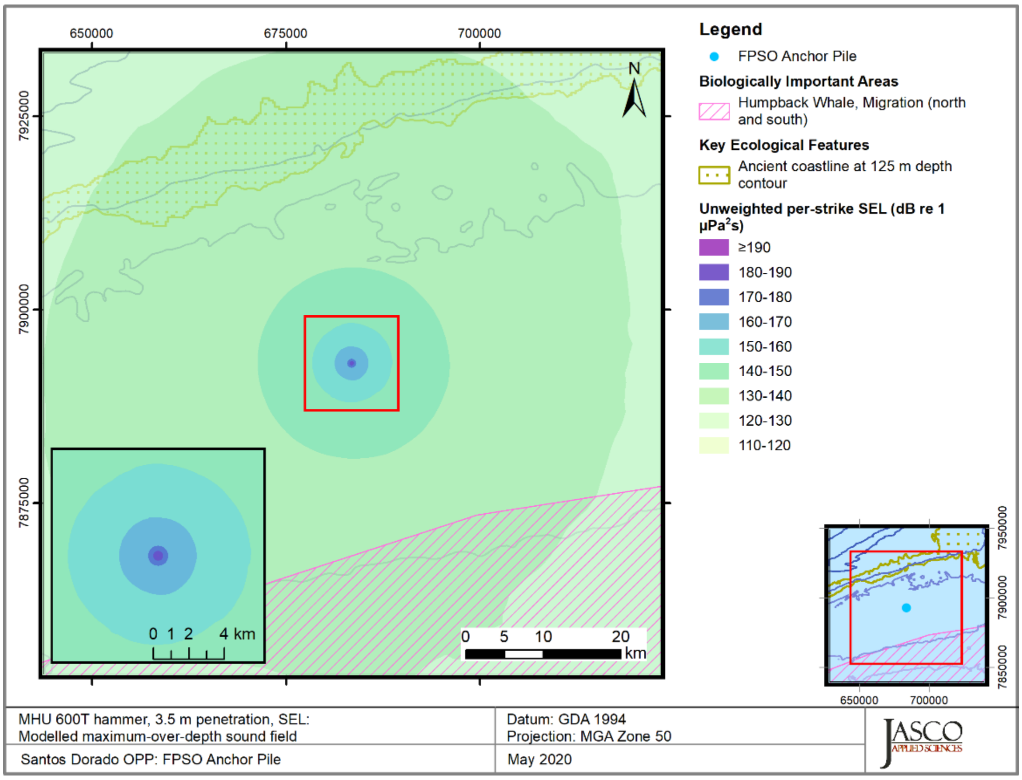

Figure G-4. *FPSO anchor piling, per-strike SEL, 3.5 m penetration depth*: Sound level contour map showing maximum-over-depth results.

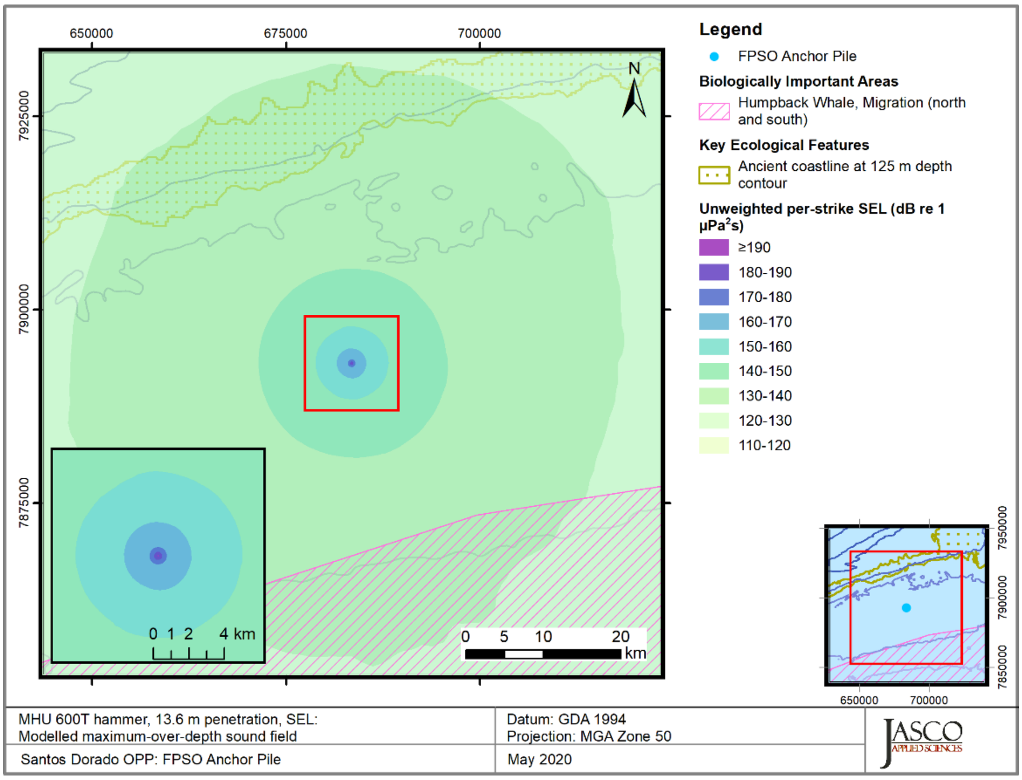

Figure G-5. *FPSO anchor piling, per-strike SEL, 13.6 m penetration depth*: Sound level contour map showing maximum-over-depth results.

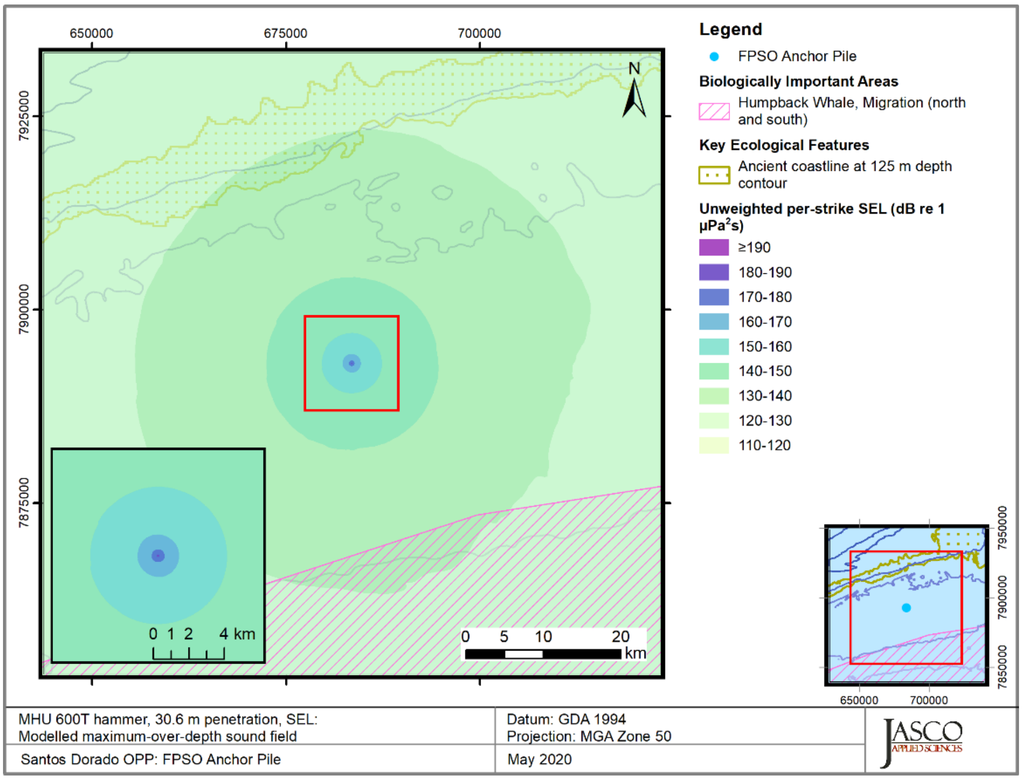

Figure G-6. *FPSO anchor piling, per-strike SEL, 30.6 m penetration depth*: Sound level contour map showing maximum-over-depth results.

G.3. WHP VSP SEL Contour Map

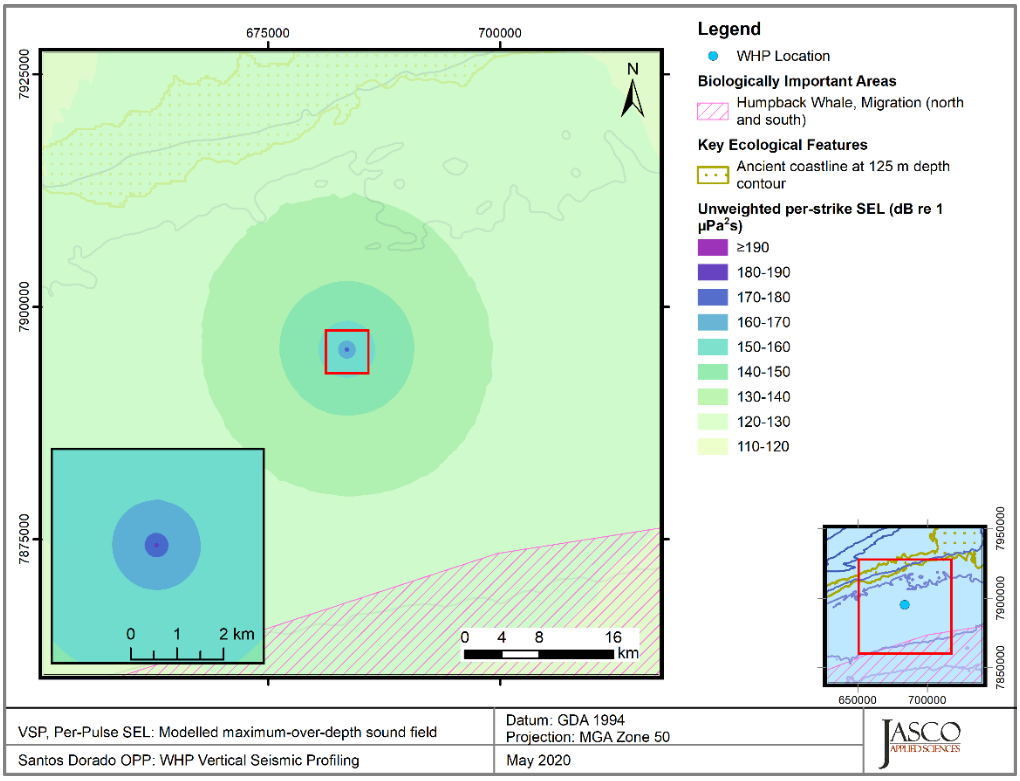

Figure G-7. *VSP, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

Attachment 11 Underwater Noise Impacts on Marine Fauna

Underwater Noise Impacts on Marine Fauna

Technical Appendix

Submitted to:
Sonja Mavrick
Santos WA Energy Ltd.
Contract: PO 4300108326

Authors:
Klaus Lucke
Craig R. McPherson

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JASCO Applied Sciences (Australia) Pty Ltd
Unit 1, 14 Hook Street
Capalaba, Queensland, 4157
Tel: +61 7 3823 2620
www.jasco.com

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Contents

Figures

Tables

1. Purpose

Petroleum activities undertaken by Santos may produce noise and associated vibrations in air, underwater and beneath the earths' surface. Activities and facilities associated with the petroleum activities generate routine acoustic emissions during drilling, installation and commissioning, and operations. This document has been prepared to support environment impact and risk assessment for underwater acoustic emissions as a result of the following Santos petroleum activities:

- Vertical Seismic Profiling
- Offshore Pile Driving (Impact Driving)
- Drilling
- Vessel Operations

The document summarises relevant research completed to date and aims to:

- characterise the noise sources associated with each activity, and the potential impacts from the noise;
- describe marine fauna sensitivity to the noise sources;
- provide an overview of the existing knowledge and understanding of the potential noise-induced effects; and
- assist with adopting appropriate thresholds for marine animals for impact assessment of the petroleum activities.

As this document supports Santos environment risk assessments, it will be reviewed when it is used to support Santos environment risk assessment processes such as the preparation of environment plan or the assessment of environment risk associated with specific petroleum activities.

This document does not represent all potential sources of underwater sound associated with Santos petroleum activities, however it includes all of those relevant to this impact assessment.

2. Background

Sound is a natural phenomenon occurring in all aquatic environments, and marine fauna have evolved and adapted in the presence of this natural soundscape. Natural sounds vary constantly due to biological, oceanographic, and meteorological processes. Anthropogenic activities introduce additional sound into the water. The multitude of parameters influencing the natural and anthropogenic contributions to the overall soundscape create a complex scenario for an impact assessment.

Acoustic signals have evolved as the principal mode of information transmission for many marine species. Marine invertebrates and sea turtles are sensitive to sound, but it remains unclear if and to what extent underwater sound has a functional role for these species. The sensitivity of fish to sound varies, but sound plays an important role in their life. Many fish species can hear and use sounds for learning about their environment (Ladich and Fay 2013). including to actively communicate, most often aiming at nearby prospective mates (Lobel et al. 2010) and mainly associated with two behavioural contexts: reproduction and aggression. The hearing system of marine mammals is very sensitive, and these animals use underwater sound passively when listening to the environment and actively when communicating. It is also well known that odontocetes (toothed whales) use sound actively when foraging.

The sounds that marine animals hear and generate vary in characteristics such as dominant frequency, bandwidth, energy, temporal pattern, and directivity. Just as many terrestrial animals integrate multiple stimuli from their visual landscape, marine life must discriminate a signal (a meaningful sound) among multiple stimuli in their acoustic seascape. Anthropogenic sounds can affect marine life in a variety of ways.

The potential for sound-induced impacts varies with the temporal and acoustic characteristics of the sound source, sound propagation characteristics of the physical environment, and biological factors. Biological factors include the hearing range of the species (broad range and most sensitive frequencies), an animals' state of activity (feeding versus resting or migrating), individual hearing loss, previous exposure to sound type (habituation), life history stage, reproductive status, and health status all contribute to the impacts of anthropogenic sound on marine animals. Past studies on the reactions of marine mammals to anthropogenic sound have shown widely varied responses, depending on the individual, context, age, gender, and activity in which the animals were engaged (Simmonds et al. 2003, Ellison et al. 2012).

Relevant to all marine fauna four zones of noise-influence with decreasing size and increasing intensity of the signal can be defined (see Section 6). With the highest levels of sound at the sound source at the centre of the model, the noise level and severity of noise-induced impacts decline with increasing distance from the source. The four zones of acoustic influence are:

- *Audibility*: Signal source levels decrease with range from a source due to propagation losses. Their audibility is limited by the signal dropping either below the animal's hearing threshold or below ambient sound levels.
- *Responsiveness*: The zone of behavioural response is generally smaller than the zone of audibility, as an animal is not likely to respond to a sound that is barely detectable.
- *Masking*: This zone overlaps with zone of responsiveness. Masking occurs when a noise impedes the ability of the animal to perceive a biologically relevant signal.
- *Injury or impairment*: Direct physical injury resulting in mortality, temporary or permanent impairment of the auditory (hearing) system, or (non-lethal) injury to non-auditory organs.

3. Underwater Sound

Sound is always present in the underwater environment. It is naturally caused by biological sources such as whales, fish, and invertebrates (e.g., snapping shrimp) and by meteorological and oceanographical sources (such as rain, wind driven waves, and currents). The existing sound in an environment can be summed up as the ambient sound or soundscape. While the term ‘sound’ is objective, the term ‘noise’ can be considered as the ‘unwanted’ sound, i.e., sound that has an impact on a receptor. Underwater sound is a vibration wave that can be measured in terms of two distinct physical components—sound pressure and particle motion. These serve as input to the sensory systems in marine animals and different species (or taxa) developed sensors for either one of these sound components, and some are sensitive to both. While marine mammal hearing is sensitive to sound pressure, fish and marine invertebrates sense particle motion and some fish species are capable of detecting both. Anthropogenic sound is emitted by almost all activities at sea, either intentional (e.g. an echosounder) or as a by-product (e.g. shipping). Assessing the impact of anthropogenic underwater noise on marine receptors requires an understanding of the basic physical principles of underwater sound. A brief overview of the most important aspects and most relevant terms and metrics can be found in Appendix A.

The following section gives an introduction into sound propagation and important differences between sound types and provides an overview of the acoustic characteristics of the sound sources considered in this technical appendix.

3.1. Sound Propagation

Sound is altered by the aquatic environment as it propagates away from a source to a receiver some distance away. Factors influencing propagation include the bathymetry and composition of the seabed and the temperature and salinity of the water column. The physical processes affecting sound along its propagation path are attenuation due to geometric spreading, reflection, scattering at the sea surface and seabed, refraction due to sound speed gradients, and absorption by sea water. Each factor substantially changes the acoustic characteristics of the emitted signal and its propagation from the sound source to the receiver.

A given sound emitted in different locations, or in the same location at different times, may therefore be detectable for varying distances, depending on regional and temporal changes in sound propagation conditions (Richardson et al. 1995). In general, low-frequency sound (<200 Hz) is transmitted most efficiently in deep water due to sound channels within the water column (Jensen et al. 2011), while intermediate-frequency sound (100–1000 Hz) is transmitted most efficiently in shallower coastal waters, such as those less than 200 m deep (Richardson et al. 1995). However, specifics depend upon the local geology and sound speed profiles (Jensen et al. 2011).

3.2. Impulsive Sounds versus Non-Impulsive Sound

Impulsive and non-impulsive sounds are primarily distinguished by their temporal pattern. Impulsive or ‘pulsed’ sounds can be described as discrete sounds (e.g., single pulses) and sometimes intermittent sounds (e.g., multiple pulses) produced by sources such as seismic airguns and pile driving. These sounds, sometimes also termed transients, are typically brief signals consisting of a high peak sound pressure with a rapid rise time and a rapid decay (NIOSH 1998). However, there are no quantitative metrics specified to identify and define the impulsiveness of acoustic signals, which makes it problematic to characterise the impulsiveness of their acoustic signatures (discussed further in Section 5.2.1).

Non-impulsive sounds, which can be intermittent or continuous, are produced by sound sources such as ships and marine vibrator signals. Non-impulsive sounds have a longer duration than impulsive ones, and they usually do not have the high peak sound pressure and rapid rise and decay time that impulsive sounds have (NIOSH 1998). However, especially in respect to their auditory effects on marine fauna, the term non-impulsive does not imply long duration signals.

3.3. Metrics

Three pressure related metrics are commonly used for analysing and describing the acoustic characteristics of underwater sound and for evaluating underwater sound impacts on marine fauna: peak pressure (PK), sound pressure level (SPL), and sound exposure level (SEL) (see Appendix A). The period of accumulation associated with SEL must always be defined. Subscripts indicate any applied frequency weighting (see Section 5.1.4.2 for details). Particle motion can be measured in terms of three different (but related) quantities: displacement, velocity, or acceleration (Appendix A.4), however the relevance of the different quantities to effects of fauna is currently under investigation, and no cumulative metric for particle motion currently exists.

For impulsive sources, SPL is gradually being supplemented or replaced by fast time-weighted average SPL. The publication of ISO 18405 Underwater Acoustics – Terminology (ISO 2017) provides a dictionary of underwater bioacoustic terms (previous standards: IEC 1994, ANSI S1.1-2013 R2013). This technical appendix follows the definitions and conventions of ISO (2017) unless directly referring to metrics used in published literature.

The US National Marine Fisheries Service (NMFS) issued a Technical Guidance document providing regulatory criteria for noise exposure of marine mammals (NMFS 2018). The Technical Guidance is using a slightly different notation for the acoustic metrics (Table 1) with a dual criterion for assessing injurious exposures, including a peak (unweighted/flat) sound pressure level metric PK (L_{pk}) and a cumulative sound exposure level $\mathrm{SEL}_{\mathrm{cum}}$ ($\mathrm{SEL}_{\mathrm{24h}}$) metric with frequency weighting. The acoustic metric terminology used in Southall et al. (2019) is equivalent to this guidance. Following the ISO standard, the L_{pk} as used by NMFS and Southall et al. (2019) is denoted as PK in this technical appendix. The $\mathrm{SEL}_{\mathrm{cum}}$ metric as used by NMFS and Southall et al. (2019) describes the sound energy received by a receptor over 24 hours. Accordingly, following the ISO (2017) standard, this is denoted as $\mathrm{SEL}_{\mathrm{24h}}$ in this Technical Appendix. There are no defined impact assessment criteria for particle motion, and relevant metrics and reporting guidelines are a current research topic, therefore no summary is presented.

Table 1. Acoustic metrics used in this Technical Appendix as compared to other publications.

Metric	NMFS (2018) and Southall et al. (2019)	Technical appendix (as per ISO 2017)		Unit
		Abbreviation in main text	Symbol in equations/tables	
Sound pressure level	n/a	SPL	L_p	decibel (dB) re 1 micropascal (μPa)
Peak sound pressure level	PK	PK	L_{pk}	dB re 1 μPa
Sound exposure level (per pulse)	n/a	Per-pulse SEL	L_E	dB re 1 $\mu\mathrm{Pa}^2\cdot\mathrm{s}$
Sound exposure level (accumulated over time), $\mathrm{SEL}_{\mathrm{time\text{-}period}}$	$\mathrm{SEL}_{\mathrm{cum}}$	$\mathrm{SEL}_{\mathrm{24h}}$	$L_{E,\mathrm{24h}}$	dB re 1 $\mu\mathrm{Pa}^2\cdot\mathrm{s}$
Source level	SL	SL	$L_{\mathrm{S,pk}}$ $L_{\mathrm{S},p}$ $L_{\mathrm{S,E}}$	dB re 1 μPa·m (Peak source pressure level, SPL source level) or dB 1 $\mu\mathrm{Pa}^2\mathrm{m}^2\mathrm{s}$ (Per-pulse source SEL)
Particle acceleration (not accumulated)	n/a	n/a	n/a	$\mathrm{m/s^2}$, $\mu\mathrm{m/s^2}$, and $\mathrm{nm/s^2}$, and logarithmic scale (dB) relative to these units

3.4. Sound Pressure versus Particle Motion

The particle motion generated by an active sound source refers to the vibration of the particles that make up the media when a sound is present (Martin et al. 2016). It can be quantified in terms of particle velocity, particle displacement, and particle acceleration (Appendix A.3). These are vector quantities (having magnitude and direction) inferred from the sound pressure (a scalar quantity having only magnitude).

While often collectively reported and/or referred to as particle motion, marine animals seem to be most sensitive to particle acceleration. The units for this metric differ between m/s^2, $\mu m/s^2$, and nm/s^2 and can also be reported in a logarithmic scale (decibel, dB) relative to any of these units.

In a free sound field such as in mid-water in the open ocean (i.e., in the absence of acoustic boundaries such as sea surface or sea floor) and within the acoustic far field of the sound source, the sound pressure radiated from a simple acoustic source falls off as $1/r$, where r is the distance from the source (Ainslie and de Jong 2016). Under these conditions, particle motion is directly correlated with sound pressure. Estimations of particle motion based on sound pressure measurements, however, can lead to substantial errors (Gray et al. 2016), as sound pressure measured under different conditions may be accompanied by very different levels of particle motion (Popper et al. 2019).

4. Sources of Anthropogenic Noise

This document has been prepared to support environment impact and risk assessment for underwater acoustic emissions as a result of the following Santos petroleum activities:

- Vertical Seismic Profiling
- Offshore Pile Driving (Impact Driving)
- Drilling
- Vessel Operations

Each of these sources is discussed in this section as relevant to the current assessment.

4.1. Vertical Seismic Profiling

Vertical Seismic Profiling (VSP) has four important roles to play in assessing the rock and fluids close to the borehole:

1. to provide in situ rock properties in depth, particularly seismic velocity, impedance, anisotropy, and attenuation.
2. to assist in understanding seismic wave propagation (e.g., source signatures, multiples, and conversions).
3. to make well understood reflectivity images in depth, and
4. to use all of the above in further surface seismic data processing and interpretation (Stewart 2001).

The acoustic sources used in VSPs are seismic airguns, which are essentially stainless-steel cylinders charged with high-pressure air. An acoustic signal is generated when that air is (almost instantaneously) released into the surrounding water column (Figure 1). For a single airgun, the amplitude of its acoustic signal is a function of the volume and pressure of the air inside the airgun and the ambient pressure (i.e. its depth below the water surface). The pressure inside the cylinder far exceeds the ambient pressure and, when triggered, generates an oscillating bubble around the release aperture. This difference in pressure causes the bubble to rapidly expand in the water, and this initial expansion generates a radiating impulsive pressure wave, typically broadband in nature. Because of the momentum of its expansion, the bubble grows until the internal pressure becomes less than the ambient pressure. At that point, the bubble starts to collapse. Elasticity in the process generates the characteristic oscillating pressure cycle, which continues until the bubble reaches the sea surface and vents into the atmosphere. Given that energy is lost during each cycle, the bubble behaves as a damped oscillator, producing increasingly smaller bubble pulses with each cycle.

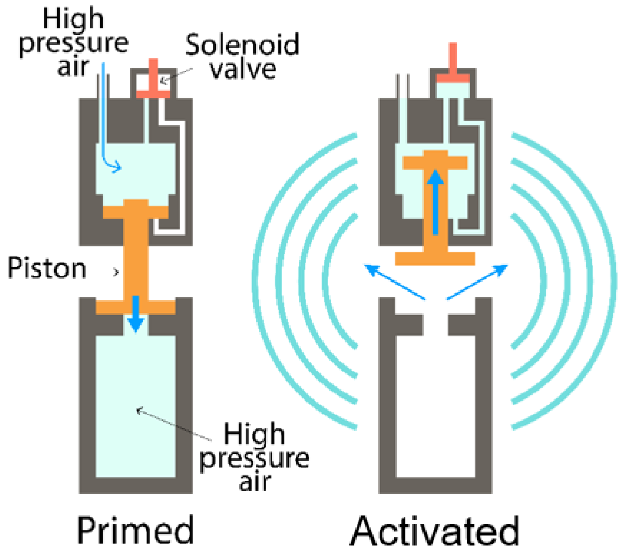

Figure 1. Schematic showing the functioning of a seismic airgun.

4.1.1. Operational Configurations

A VSP survey is typically conducted at each well after a final depth is reached (but may be conducted at a shallower depth depending upon operations) before a production tubing/casing is placed in the well bore or the well is abandoned.

The following are typical types of VSP surveys:

- Zero-offset or check-shot survey, when the seismic source is placed very near to the vertical array of sensors.
- Walk-away survey, when the seismic source is placed in a series of positions along a radial line from the vertical array of sensors
- Three-dimensional (3-D) VSP survey, when the source is deployed in an area surrounding the vertical array of sensors.
- Inverse survey, where the locations of the source and receiver are reversed.

The most common type of VSP in Australian waters are zero-offset surveys suspended from a crane onboard a platform (Figure 2), followed by walk-away surveys; each survey type is designed to acquire specific information.

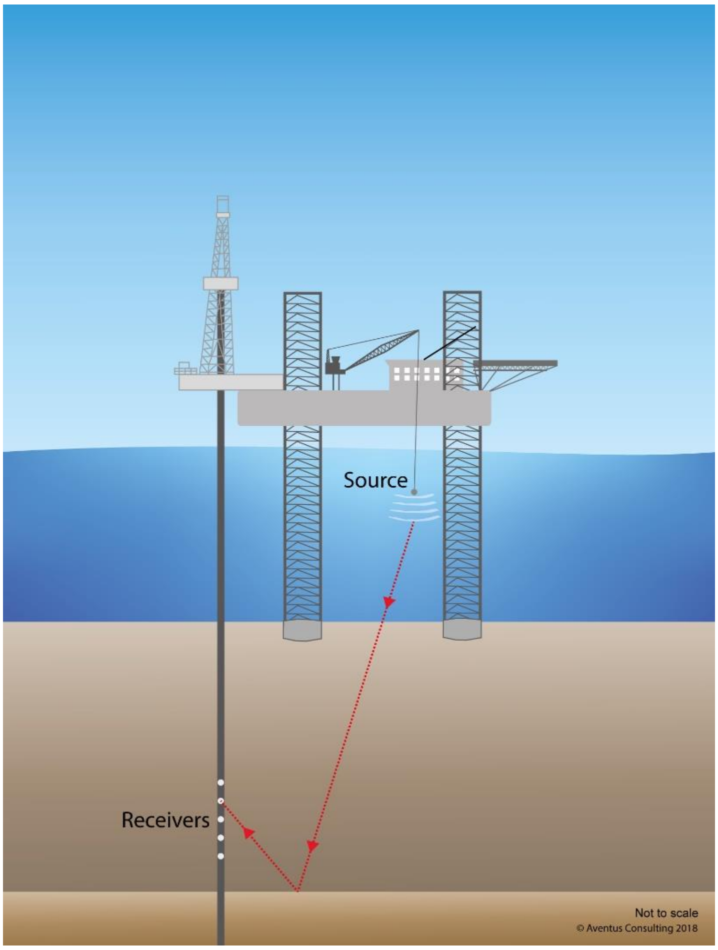

Figure 2. Example of a zero-offset VSP configuration (supplied by Adventus Consulting).

Typical VSP arrays can be configured in a number of ways, depending on the number of airguns within the array, e.g., 2 x 150, 3 x 150, 2 x 250, and 3 x 350 in^3, operating at 1800 psi (Nakanishi 2009). When there are only two airguns in an array, they are set at the same depth; however, when there are more than two, a single airgun is often positioned above the other two to focus the array signature downwards.

The total duration of a VSP survey depends on the specific type of survey, the survey objectives, and the equipment used. For a zero-offset survey or a walk-away survey, the duration may be less than a day. Each survey is different, with timings set by operational considerations. However, a common approach for a zero-offset survey is for the airguns to be activated four to eight times for a period of 20 s, followed by a 5- to 20-min quiet time during which the sensor string in the borehole or well is raised. The airguns are then activated again for four to eight times for 20 s and so on until the survey is completed.

4.1.2. Acoustic emissions

The small arrays used for VSP produce most energy at frequencies below 500 Hz (Figure 3). Airgun signatures consist of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. For all types of arrays, frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the array, and they correspond with the volumes and locations of the airguns relative to each other. Therefore, each array has a unique spectrum.

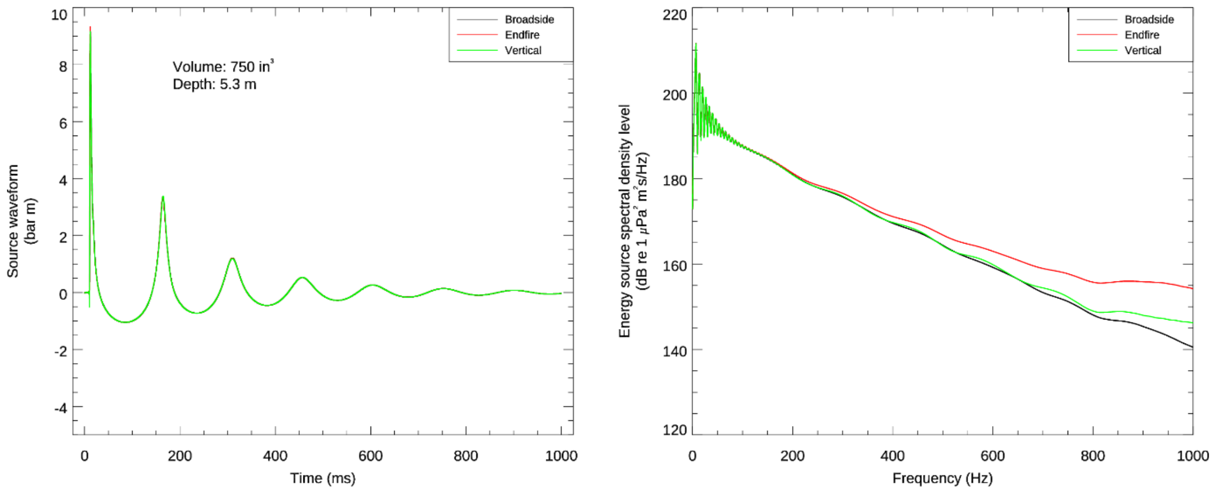

Figure 3. Predicted source level details for an example 750 in^3 array at a 5.3 m operational depth.(Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

4.2. Offshore Pile Driving

Pile driving operations can be conducted from above and below the sea surface. Pile driving is often required for installing anchor points for floating and fixed offshore facilities drill rigs, foundation supports, and jetty/ wharf infrastructure. There are numerous methods of pile driving, however, only impact piling is included in this document.

4.2.1. Operational Configurations

Impact pile driving is carried out using an impact hammer, which consists of a falling ram that repeatedly strikes the top of a pile to drive it into the ground. When the ram strikes the pile, the impact creates stress waves traveling down the length of the pile, which couples with the surrounding medium, radiating acoustic energy into the water. Pile driving also generates vibration waves in the sediment, which can radiate acoustic energy back into the water from the seabed. The sound from impact pile driving is impulsive - transient, repetitive, and discontinuous (Reinhall and Dahl 2011, McPherson et al. 2017). Depending upon the pile and hammer combinations, the strike interval can range from one to two seconds.

4.2.2. Acoustic Emissions

Sound levels produced by pile driving depend on several interdependent factors such as pile size, hammer strike energy, and geoacoustic properties of the seabed. Field measurements of pile driving show that source, or near-source levels are typically in the 210 to 250 dB re 1 µPa range (McHugh 2005, Tougaard et al. 2009, Bailey et al. 2010) and the frequency is predominantly <1 kHz (Robinson et al. 2007, Tougaard et al. 2009), although they can extend to much higher frequencies (MacGillivray 2018), including at least 100 kHz (Tougaard et al. 2009). Deep and shallow-water conductor driving generate similar sound pressures; however, in deep water the pile is much longer so the ensonified area is greater (MacGillivray 2018). The radiated pile driving impulses vary in sound received levels as a function of range and azimuth, rise and decay times, pulse duration, and kurtosis (Amaral et al. 2020).

4.3. Drilling

Offshore drilling is a mechanical process where a wellbore is drilled into the seabed. Drilling can be used to explore for and extract hydrocarbons (oil and gas) from the ground. Drilling operations are typically conducted by jack-up drill rigs, semi-submersible drill rigs or drill ships collectively referred to as Mobile Offshore Drilling Units (MODUs). They are hull-based vessels equipped with drilling derricks which are either moored or under dynamic positioning whilst drilling.

4.3.1. Acoustic Emissions

Drilling sound usually exhibits tones below 2 kHz, with harmonics present to 10 kHz and can vary substantially between operations (Kyhn et al. 2014, Austin et al. 2018). These two studies are the most recent and detailed published studies on noise from offshore drilling operations, and they provide information about the current fleet of larger drilling units, as opposed to older, smaller units (e.g. Gales 1982, Greene 1987, Richardson et al. 1995), and supplement grey literature (e.g. MacDonnell 2017, Martin et al. 2019). Large offshore units are quite different in terms of their scale, operations involved, and sound emitted compared to smaller geotechnical drill rigs (Erbe and McPherson 2017).

The dynamic positioning of MODUs and drillships forms a significant component of the acoustic signature (Kyhn et al. 2014, MacDonnell 2017, Martin et al. 2019) and are often significantly louder than any drilling noise components. This is because thrusters generate high levels of thrust in poor flow conditions, resulting in significant propeller cavitation and consequently high underwater noise levels (Erbe et al. 2013).

4.4. Vessel Operations

The operation of motorised vessels involves numerous mechanical processes that create underwater sound as a by-product. These processes range from sound of the propeller, cavitation caused by propellers, flow noise from a vessel moving through water, engines and auxiliary machinery in the vessel hull. Sound emitted from vessels differs strongly, depending mainly on meteorological and oceanographic factors such as sea surface conditions and currents, type and state of propulsion system (including if the vessel is operating under dynamic positioning (DP)), vessel installed power, size, transit speed, and load (MacGillivray et al. 2018) (Figure 4).

Vessels, such as moored Floating Production Storage Offload (FPSO) facilities and Floating Liquid Natural Gas (FLNG) facilities, operate significant onboard machinery, and can use thrusters to assist in manoeuvring to assist offload or minimise weather impacts on operations (Erbe et al. 2013, Duncan 2014)

4.4.1. Acoustic Emissions

Figure 4 provides generic examples of frequency-dependent source levels for the most common vessel categories in 1/3-octave-bands (McPherson et al. 2019). The categories include vessel types relevant to the oil and gas industry such as tankers and Floating Production Storage and Offloading (FPSO) units. The only vessel in this example under DP is the FPSO. With an FPSO, processing equipment is mostly located on the deck with storage facilities below the deck. This setup, as well as the fact that FPSOs are usually double-hulled, helps insulate the marine environment from machinery noise on deck, however they still emit an obvious signature (Erbe et al. 2013).

Service, support, supply and construction vessels often are required to use DP to maintain position. The majority of measurement studies of vessels under DP are in grey literature, and associated with environmental approvals (e.g. Austin and Li 2016, MacDonnell 2017, Quijano and McPherson 2018, Martin et al. 2019), however there is some published literature (Kyhn et al. 2014).

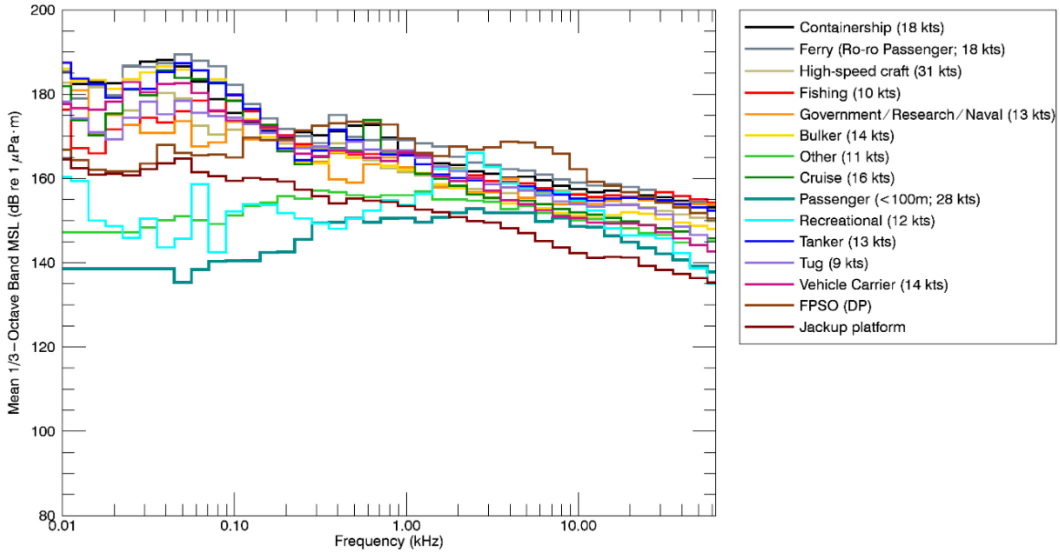

Figure 4. Example of frequency-dependent source levels for several categories of vessels in 1/3-octave-bands (source: McPherson et al. 2019).

5. Sound Perception

5.1. Hearing Sensitivity of Marine Animals

Marine animals only respond to acoustic signals they can detect. The sensitivity of an individual's auditory (i.e. hearing) system is described as a function of sound frequency. The lowest intensity of a sound at a particular frequency that an individual can hear describes its hearing threshold. The graphical representation of these thresholds over the range of frequencies that are audible to the individual is called its hearing curve or audiogram. Only a few individuals in a small number of marine species have been tested for their hearing sensitivity in all taxonomic groups of marine animals.

5.1.1. Marine Invertebrates

Some studies have been done on the sound perception of the following marine invertebrate groups:

- Plankton (including larval stages of larger marine invertebrates and fish);
- Bivalves (scallops, oysters) and decapods (crabs, prawns);
- Cephalopods (squid, octopus); and
- Other benthic invertebrate species.

Available literature suggests particle motion, rather than sound pressure, is a more important factor for marine invertebrate hearing. The sensory organs of marine invertebrates involved in receiving underwater sound can be classified into the following three groups (Budelmann 1992b):

- *Superficial receptor systems*: These receptors on the body surface are sensitive to water displacements; therefore; they mainly encode hydrodynamic cues;
- *Internal statocyst receptor systems*: Found in a wide range of aquatic invertebrates, these inertial gravity receptor systems may function as acoustic particle motion detectors and thus play a role in underwater hearing (Budelmann 1992b) or in substrate-borne vibrations (Cohen et al. 1953, Cohen 1955).
- *Chordotonal organs*: These proprioceptive receptors monitor joint movement, the direction of movement, and static position. These organs are sensitive to water oscillating in column surrounding them (Budelmann 1992a).

At the seafloor interface, marine invertebrates are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves (such as Scholte waves which are propagating at a water-sediment interface (Vinh 2013)). However, it is unclear which aspect(s) of these waves is/are most relevant to animals, either when the animals normally sense the environment or their physiological responses to loud sounds.

A few studies provide quantitative information on the sensitivity thresholds of marine invertebrates to sound. Electrophysiological studies measuring auditory evoked potentials (AEP) showed that cephalopods are capable of perceiving sound between 10 and 400 Hz (Packard et al. 1990, Parks et al. 2007b, Hu et al. 2009, Mooney et al. 2010, Hughes et al. 2014). In a behavioural study, Mooney et al. (2016) showed that squid (*Doryteuthis pealeii*) can perceive sound pressure of signals as low as 80 Hz and have their optimal hearing range between 200–400 Hz. Lovell et al. (2005) measured AEP responses in prawns (*Palaemon serratus*) between 100 Hz to 3 kHz, and Pye and Watson (2004) tested lobster (*Homarus americanus*) up to 5 kHz using the AEP technique. However, as pointed out by several authors (Ladich 2013, Popper et al. 2014, Hawkins et al. 2015, Sisneros et al. 2016), studies employing the AEP technique may not reflect the true sensitivity to acoustic stimuli as the studies fail to incorporate natural soundscapes and processing at higher cortical levels.

Packard et al. (1990) used a classical conditioning approach to test low-frequency hearing in cephalopods (*Sepia sp.*, *Octopus sp*., and *Loligo sp*.) and found the best sensitivities at 10 Hz and below. Other studies obtained perception thresholds (using reflex movements of antennae or legs as proxy) for underwater sound in species such as the brown shrimp (*C. crangon*) (Heinisch and Wiese 1987, Berghahn et al. 1995), hermit crab (*Pagurus bernhardus*) (Roberts et al. 2016), common littoral crab (*Carcinus maenas*) (Barth 1980), and northern prawn (*Pandalus borealis*) (Klages et al. 2002). These studies revealed these species are sensitive to acoustic or vibratory stimuli at frequencies below 400–500 Hz.

Moreover, detection of substrate-borne low-frequency vibration (<200 Hz) has been demonstrated to induce behavioural responses in some crustacean and bivalve species (Roberts et al. 2015, Roberts and Elliott 2017).

Most studies on marine invertebrates do not differentiate between pressure and particle motion. If conducted in tanks, the resulting thresholds and high-frequency ranges (e.g., Pye and Watson 2004, Lovell et al. 2005) may be artefacts, possibly resulting from acoustic interferences in the confines of the test environment (Sisneros et al. 2016, Carroll et al. 2017). The application of these experiment outcomes to impact assessments should be treated with caution due to the aspects regarding study design and representation of true hearing sensitivity (see above).

Mooney et al. (2010) quantify the acoustic sensitivity of the longfin squid (*Loligo pealeii*) using near-field acoustic and shaker-generated acceleration stimuli. Sound field pressure and particle motion components were measured from 30 to 10,000 Hz. Acceleration stimuli were measured from 20 to 1000 Hz. Their results suggest that squid detect the acceleration and particle motion components of a sound field up to frequencies of ~500 Hz.

Irrespective of the sensory modality for sound perception, marine invertebrates produce, detect, and respond to sound as shown in a review by Edmonds et al. (2016), thus indicating that these species are susceptible to effects from underwater sound. While research in this area is limited, the sensitivity of invertebrates to water borne particle motion and substrate vibration across a broad range of frequencies may potentially impact marine invertebrates through physical effects (Solé et al. 2017) and behaviour disruption (Solan et al. 2016).

5.1.2. Fishes

Although hearing ranges and sensitivities vary substantially between species (e.g., Ladich and Fay 2013), all fish species tested to date can hear (Dale et al. 2015). Fishes have developed two sensory mechanisms for detecting, localising, and interpreting underwater sounds and vibrations: the inner ear, which is tuned to sound detection, and the lateral line system, which allows them to detect vibration and water flow. Inter-specific variations in hearing range and sensitivity result from the different adaptations in these systems for perceiving sound pressure and particle motion information (Popper and Fay 2011).

The critical issue for understanding if an anthropogenic sound affects hearing is whether the sound is within the hearing (sound pressure) or detection (particle motion) frequency range of a fish and whether the sound is loud enough to be detected above its hearing threshold.

Sensitivity to sound pressure seems to be functionally correlated in fishes to the presence and absence of gas-filled chambers in the sound transduction system. These chambers enable fishes to detect sound pressure and to extend their hearing abilities to lower sound levels and higher frequencies (Ladich and Popper 2004, Braun and Grande 2008).

Based on their morphology, the Popper et al. (2014) classifications into three categories can be assigned to the following families or species of fish, common in Australian waters (see Figure 5 for hearing curves (‘audiograms’) of representatives of each group):

a. Fishes with swim bladders or other gas volumes, but whose hearing does not directly involve the swim bladder, e.g., snappers, emperors, groupers and rock cods (Lutjanids and Lethrinids such as *Pristipomoides spp*., *Lethrinus spp*., *Lutjanus spp*., and family Serranidae), and some species of tuna (*Thunnus sp*.) (Tavolga and Wodinsky 1963, Bertrand and Josse 2000, Higgs et al. 2006, Song et al. 2006, DoN US 2008, Braun and Grande 2008, Engineering-Environmental Management 2008, Caiger et al. 2012);

b. Fishes whose hearing does directly involve a swim bladder or other gas volume e.g., family Clupeidae (herrings, sardines, pilchards and shads), family Gadidae (true cods such as whiting), and potentially some nearshore/reef species relevant to tropical Australia, including some Pomacentridae (damsel fishes and clown fishes), some Holocentridae (soldierfishes and squirrelfishes) and some Haemulidae (grunters and sweetlips) (Nedwell et al. 2004, Braun and Grande 2008, Popper et al. 2014); and

c. Fishes without a swim bladder (e.g., mackerel, *Scomberomorus spp*., and sharks, including whale sharks, *Rhincodon typus*) (Casper et al. 2012, Popper et al. 2014, Carroll et al. 2017).

Most fishes are primarily sensitive to particle motion effects, while fishes with hearing that involves the swim bladder are also sensitive to sound pressure (Popper and Hawkins 2019, Popper et al. 2019). The most relevant metric for perceiving underwater sound for most fish species is, therefore, particle motion. However, with the exception of few species (Popper and Fay 2011, Popper et al. 2014) (Figure 5), there is an almost complete lack of relevant data on particle motion sensitivity in fishes (Popper and Hawkins 2018).

Most fish species investigated for sound pressure sensitivity can detect sounds from below 50 Hz up to 500–1500 Hz. A smaller number of species can detect sounds to over 3 kHz, while a very few species can detect sounds to well over 100 kHz; Mann et al. (1997, 1998) showed that the American shad (*Alosa sapidissima*, order: clupeiforms) can detect sounds up to 180 kHz. These species have two pairs of air bubbles in their inner ears that aid in sound detection. The authors subsequently investigated ultrasound hearing in other clupeid species and found that ultrasound detection may be limited to one subfamily of clupeiforms, the Alosinae (Mann et al. 2001). The hearing range in other clupeids such as the herring (*Clupea harengus*), however, is limited between 100–5000 Hz (Mann et al. 2005).

Ideally, auditory experiments in fishes should be conducted under conditions reflecting the acoustic conditions experienced by the animals in a free-field situation. For example, Dale et al. (2015) measured the auditory sensitivity of free-swimming Pacific bluefin tuna (*Thunnus orientalis*) in a tank and reported both sound components. Moreover, their approach to conducting a hearing test in swimming animals also takes the flow-noise created by the animals' own movement into account.

Elasmobranchs (sharks, rays, and skates) have no swim bladder or other gas bubble associated with their ears (category III), but they can detect and respond to sound (reviewed in Myrberg 1978, 1990, 2001, Casper and Mann 2009). Their range of best hearing sensitivity extends from below 50 Hz to over 500 Hz with relatively poor hearing sensitivity. While it is unclear what role sound plays in their life these species are less likely to be negatively affected by intense underwater sound.

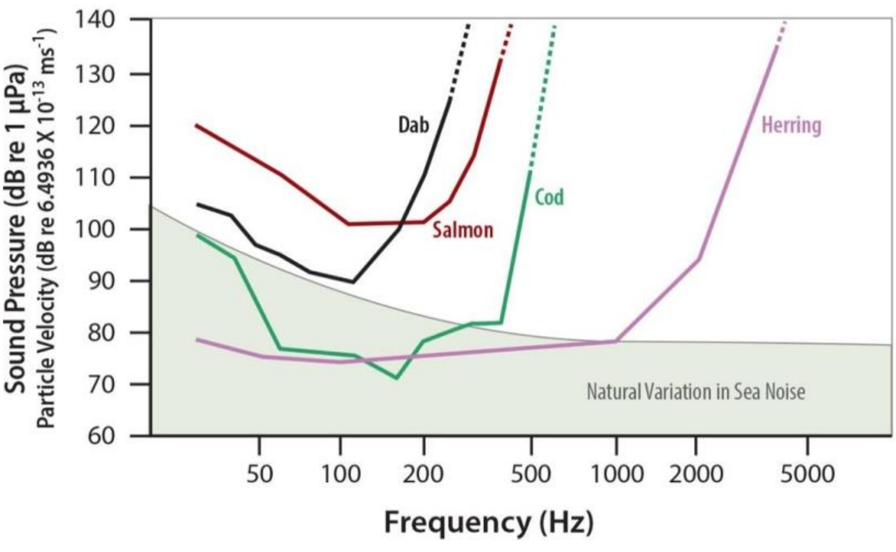

Figure 5. Fish audiograms obtained under open sea, free-field conditions; species representing different categories as classified by Popper et al. (2014) (source: Popper et al. 2019). Salmon (*Salmo salar*) have a swim bladder that does appear to play a role in hearing (category I), cod (*Gadus morhua*) and herring (*Clupea harengus*) have special structures mechanically linking the swim bladder to the ear (category II) and dab (*Limanda limanda*) are bottom-living fish with no swim bladder (category III).

5.1.3. Sea Turtles

In-air and underwater hearing studies in sea turtles indicate that all species tested have poor hearing sensitivity. Ridgway et al. (1969) measured cochlear potentials from green sea turtles (*Chelonia mydas*) in response to in-air acoustic stimuli and, while not measuring absolute hearing thresholds, detected responses over a limited frequency range (200–700 Hz) with best sensitivity at 400 Hz. Piniak et al. (2016) found that green turtles have maximum underwater sensitivity between 200 and 400 Hz.

Bartol et al. (1999) used vibratory stimuli to measure the hearing sensitivity of loggerhead turtles (*Caretta caretta*). The results show that this species has an in-air hearing sensitivity of up 1 kHz for tones and clicks. Underwater hearing sensitivity has been measured in the loggerhead turtle (Martin et al. 2012), demonstrating highest sensitivity at around 500 Hz (Willis 2016). Yudhana et al. (2010) measured auditory brainstem responses from two hawksbill turtles (*Eretmochelys imbricate)* in Malaysia and found that peak frequency sensitivity occurred at 457 Hz in one turtle and at 508 Hz in the other.

Ketten and Bartol (2005) conducted a series of electrophysiological studies establishing the hearing thresholds in three sea turtles species and documented age and species variations in response to underwater sound. Their data show that juvenile green turtles have a slightly broader hearing range (100–800 Hz; best sensitivity 600–700 Hz) than the range of sub-adults (100–500 Hz). Kemp's Ridley's sea turtles (*Lepidochelys kempi*) had a more restricted range (100–500 Hz) with most sensitive hearing at 100–200 Hz. Two-year old loggerhead turtles (*Dermochelys coriacea*) responded to sounds ranging from 100–700 Hz, while the three-year old animals responded to sounds between 100–400 Hz.

A small number of studies researching the effect of seismic noise on sea turtles focused on behavioural responses. Turtles avoid low-frequency sounds (Lenhardt 1994) and sounds from an airgun (O'Hara and Wilcox 1990), but these reports did not report received sound levels. Moein et al. (1995) found that penned loggerhead turtles initially reacted to seismic airgun stimuli but then showed little or no response to the sound (i.e., they likely habituated to it). Caged green and loggerhead sea turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB re 1 μPa, and they behaved erratically when the received SPL was ~175 dB re 1 μPa (McCauley et al. 2000a).

5.1.4. Marine Mammals

This taxonomic group comprises all aquatic or semi-aquatic mammalian species, including cetaceans, pinnipeds, sirenian, mustelids and the polar bears. Current data and predictions on hearing sensibility show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity, as well as their frequency band of hearing (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Southall et al. 2019). While hearing measurements are available for an increasing number of species, mainly based on captive animal studies, direct measurements of many odontocetes and all mysticetes do not exist. As a result, hearing ranges for many odontocetes are grouped with similar species into functional hearing groups, and predictions for mysticetes are based on other methods, such as anatomical studies and modelling (Houser et al. 2001, Parks et al. 2007b, Tubelli et al. 2012, Cranford and Krysl 2015), vocalisations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008b, Southall et al. 2019), taxonomy, and behavioural responses to sound (Dahlheim and Ljungblad 1990, Nowacek et al. 2007, Ellison et al. 2012).

5.1.4.1. Functional Hearing Groups

To better reflect the auditory similarities between phylogenetically closely related species, but also significant differences between species groups among the marine mammals, Southall et al. (2007) assigned the extant marine mammal species to functional hearing groups based on their hearing capabilities and sound production. This division into broad categories was intended to provide a realistic number of categories for which individual noise exposure criteria were developed. These groups were revised by NMFS (2018) and most recently by Southall et al. (2019). The categorisation as such has proven to be a scientifically justified and useful approach in developing auditory weighting functions and deriving noise exposure criteria for marine mammals. Based on the most recent information about similarities in hearing sensitivity between marine mammal species, Southall et al. (2019) proposed an updated new nomenclature and classification for the marine mammal functional hearing groups (Table 2).

Table 2. Functional marine mammal hearing groups and their generalised hearing range (Southall et al. 2019) and nomenclature used in the most recent underwater noise exposure regulation (NMFS 2018); N/A – not applicable, n.d. – no data provided.

Hearing group	Previously used classification and nomenclature (NMFS 2018)	Generalised hearing range*
Low-frequency (LF) cetaceans (mysticetes or baleen whales)	Low-frequency (LF) cetaceans (mysticetes or baleen whales)	7 Hz to 34 kHz
High-frequency (HF) cetaceans (other odontocetes)	Mid-frequency (MF) cetaceans (odontocetes: delphinids, beaked whales)	40 Hz to 160 kHz
Very-high frequency (VHF) cetaceans	N/A	300 Hz to 160 kHz
Phocid carnivores (PCW) (in water)	Phocid pinnipeds (PW) (underwater)	<75 Hz to 100 kHz
Phocid carnivores (PCA) (in air)	N/A	n.d.
Other marine carnivores (OCW) (in water)	Otariid pinnipeds (OW) (underwater)	100 Hz to 55 kHz
Other marine carnivores (OCA) (in air)	N/A	n.d.
Sirenia (SI)	N/A	<250 Hz to 72 kHz

* The generalised hearing range for all species within a group. Individual and species-specific hearing will vary.

The following sections provide an overview of hearing studies on marine mammals conducted following the comprehensive review by Southall et al. (2007).

5.1.4.1.1. Low-frequency (LF) Cetaceans

This functional hearing group comprises all baleen whale species (mysticetes). To this date, there has been no direct measurement of hearing sensitivity in any of these species. Instead, vocalisation frequency ranges have been used as a proxy to determine their hearing range. However, Houser et al. (2017) noted that vocalisation frequencies do not necessarily represent the full extent of their frequency range of best hearing and therefore vocalisation frequencies are a poor predictor of best hearing thresholds.

In the complete absence of direct data on auditory sensitivity in any baleen whale species, behavioural reactions provide some insight into the sound perception capabilities and sensitivities of mysticetes. Nowacek et al. (2007, 2015) reviewed previous studies and published new data on behavioural reactions of mysticetes . However, behavioural reactions are strongly context specific (Ellison et al. 2012) and are consequently also of limited use in delineating hearing ranges or even predicting hearing sensitivity.

The existing data so far suggest that some species (e.g., blue whales, *Balaenoptera musculus,* and fin whales, *Balaenoptera physalus*) have better low-frequency sensitivity while others (e.g., humpback whales, *Megaptera novaeangliae* and minke whales, *Balaenoperta acutorostrata*) have better sensitivity to higher frequencies.

In another approach, anatomical data have been used to predict hearing ranges in mysticetes (e.g., Parks et al. 2007b, Manoussaki et al. 2008). Most recently, functional models were developed focussing on different components of the hearing system (Tubelli et al. 2012, Ketten and Mountain 2014, Cranford and Krysl 2015). In combination with anatomical data on the hearing system, the audible frequency range of mysticetes—collectively treated as a single functional hearing group—is approximately between 7 Hz and 34 kHz (Southall et al. 2019).

5.1.4.1.2. High-frequency (HF) Cetaceans

Based on the frequency range of their vocal emissions as well as their known hearing ranges, most dolphin species, all beaked whale species, and sperm whales belong to this functional hearing group.

Following the initial review of existing information on marine mammal hearing by (Southall et al. 2007) hearing sensitivity has been directly measured recently for a number of species within this group; this includes several dolphin species (Pacific bottlenose dolphin (*Tursiops truncatus gilli*) (Houser et al. 2008), white-beaked dolphin (*Lagenorhynchus albirostris*) (Nachtigall et al. 2008), long-finned pilot whale (*Globicephala melas*) (Pacini et al. 2010), short-finned pilot whales (*Globicephala macrorhynchus*) (Schlundt et al. 2011), Indo-Pacific humpback dolphin (*Sousa chinensis*) (Li et al. 2012), beluga (*Delphinapterus leucas*) (Castellote et al. 2014), and killer whale (*Orcinus orca*) (Branstetter et al. 2017)) and two beaked whale species (Gervais' beaked whale (*Mesoplodon europaeus*) (Finneran et al. 2009), and Blainville's beaked whale (*Mesoplodon densirostris*) (Pacini et al. 2011)).

The white-beaked dolphins showed hearing sensitivity ranging from 16 to 181 kHz and showed the typical U-shaped curve for odontocetes. The thresholds for both animals tested demonstrated the most sensitive high-frequency hearing of any known dolphin and indicates that this species is as sensitive as the harbour porpoise. The long-finned pilot whale had relatively poor high-frequency hearing compared with other odontocete species and a region of best hearing between 11.2 and 50 kHz. Hearing in the killer whales was assessed as being generally similar to other delphinids, with the lowest threshold (49 dB re 1 µPa) at 34 kHz and a functional hearing range between 5 and 81 kHz.

The best hearing in beaked whales was determined at 40–60 kHz, with an upper functional hearing limit of ~80 kHz. There were indications for reduced overall hearing sensitivity in beaked whales as compared to other HF cetacean species, e.g., bottlenose dolphins.

Most of the audiograms measured in mid-frequency cetaceans follow the same general 'mammalian' U-shape and have a nominal hearing range starting at ~40 Hz up to 160 kHz. These frequencies were used as the lower and upper cut-off frequencies for the functional hearing limits by NMFS (2018).

5.1.4.1.3. Very high-frequency (VHF) Cetaceans

The VHF cetaceans are a group comprising porpoises [finless porpoise (*Neophocaena phocaenoides*), harbour porpoise (*Phocoena phocoena*), Vaquita (*Phocoena sinus*), Burmeister's porpoise (*Phocoena spinipinnis*), spectacled porpoise (*Phocoena dioptrica*) and Dall's porpoise (*Phocoenoides dalli*)]; river dolphins [La Plata river dolphin (Franciscana, *Pontoporia blainvillei*), Yangtze river dolphin (Baiji, *Lipotes vexillifer*, functionally extinct (Turvey et al. 2007)), Amazon river dolphin (Boto, *Inia geoffrensis*) and South Asian river dolphin (*Platanista gangetica*)]; Kogia species [Pygmy sperm whale (*Kogia breviceps*), Dwarf sperm whale (*Kogia sima*)]; Cephalorhynchus species [Commerson's dolphin (*Cephalorhynchus commersonii*), Chilean dolphin (*Cephalorhynchus eutropia*), Heaviside's dolphin (*Cephalorhynchus heavisidii*) and Hector's dolphin (*Cephalorhynchus hectori*)].

New information on the capabilities of the hearing system has been published for harbour porpoises (Kastelein et al. 2010, Kastelein et al. 2015c, Ruser et al. 2016, Kastelein et al. 2017a) and the Yangtze river dolphin (Popov et al. 2011). The audiograms measured in these species show the general 'mammalian' U-shape with a nominal hearing range between 300 Hz and 160 kHz that were subsequently used as lower and upper cut-off frequencies for the functional hearing limits for this animal group.

5.1.4.1.4. Phocid Carnivores in Water (PCW) and in Air (PCA)

Phocids comprise all 'true' seal species; their auditory system has special anatomical features (Wartzok and Ketten 1999, Reichmuth et al. 2013) that have led to the description of a unique 'phocid ear type' for this group (Nummela 2008). Reichmuth (2008) reviewed the available information on hearing in marine carnivores. Hearing sensitivity was investigated in comparative studies between phocid and otariid seals (Reichmuth et al. 2013, Cunningham and Reichmuth 2016), studies on specific aspects of underwater hearing in pinnipeds (Hemilä et al. 2006, Bowles et al. 2010, Cunningham et al. 2014, Stansbury et al. 2015) or species-specific studies on hearing sensitivity

(Kastelein et al. 2009, Reichmuth and Southall 2012, Sills et al. 2014, 2015). The results indicate that underwater hearing sensitivity in phocid seals extends from 75 Hz to 100 kHz (Southall et al. 2019).

5.1.4.1.5. Other Marine Carnivores in Water (OCW) and in Air (OCA)

This functional hearing group is comprised of otariids and odobenids as well as ursiids and mustelids.

Otariids include all eared seals (fur seals and sea lions). The walrus (*Odobenus rosmarus*) is an arctic species and the only extant odobenid species. Even though odobenids share the anatomical adaptations found in phocids to some extent, they are more similar to otariids in their hearing capabilities.

Besides the review by Reichmuth (2008) and comparative studies (Reichmuth et al. 2013, Cunningham and Reichmuth 2016), only two publications (Mulsow et al. 2012, Reichmuth and Southall 2012) provided new data on the underwater hearing of an otariid species, the California sea lions (*Zalophus californianus*). Based on all existing information, the otariid hearing limits are estimated to be 100 Hz to 55 kHz for underwater sound. There are no new data available for odobenids. With regard to the auditory parameters applied for deriving a weighting function and noise exposure criteria, the hearing limits defined for otariids were applied to walruses.

Hearing threshold measurements in polar bears (*Ursus maritimus*) have only been conducted in air (Nachtigall et al. 2007, Owen and Bowles 2011). These studies revealed auditory sensitivity to in-air sound stimuli up to ~20 kHz.

Ghoul and Reichmuth (2014) measured the hearing sensitivity of an individual sea otter (*Enhydra lutris*) in air and underwater. Their results show the aerial hearing sensitivity of the sea otter resembled that of sea lions; their best sensitivity was −1 dB re 20 µPa at 8 kHz. Under water, their hearing sensitivity was significantly reduced when compared to sea lions and other pinniped species, demonstrating that sea otter hearing is primarily adapted to receive airborne sounds.

5.1.4.1.6. Sirenia (SI)

This functional hearing group comprises three species of manatees (*Trichechus spp.*), which occupy warm latitudes of the coastal Atlantic Ocean and associated rivers, and the dugong (*Dugong dugon*), which inhabits the coastlines of the Indian and Pacific Oceans.

Behavioural and electrophysiological hearing data for manatees indicate some similarities to HF cetaceans and phocid pinnipeds (Southall et al. 2019). Assessments of Florida manatee (*Trichechus manatus latirostris*) hearing sensitivity indicate best hearing sensitivity between 8 and 32 kHz (Gerstein et al. 1999, Gaspard et al. 2012). Combined data suggest that sirenian have functional hearing between approximately 250 Hz and 80 kHz (Southall et al. 2019). However, extended hearing sensitivity has been measured for frequencies up to 90.5 kHz (Gaspard et al. 2012), suggesting that ultrasonic frequencies could play an important role in their lives.

5.1.4.2. Auditory Frequency Weighting Functions

The potential for anthropogenic sounds to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well, unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Auditory (frequency) weighting functions reflect an animal’s ability to hear a sound (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Houser et al (2017) provide an example illustrating the effect of applying a weighting function to a (hypothetical) sound (Figure 6).

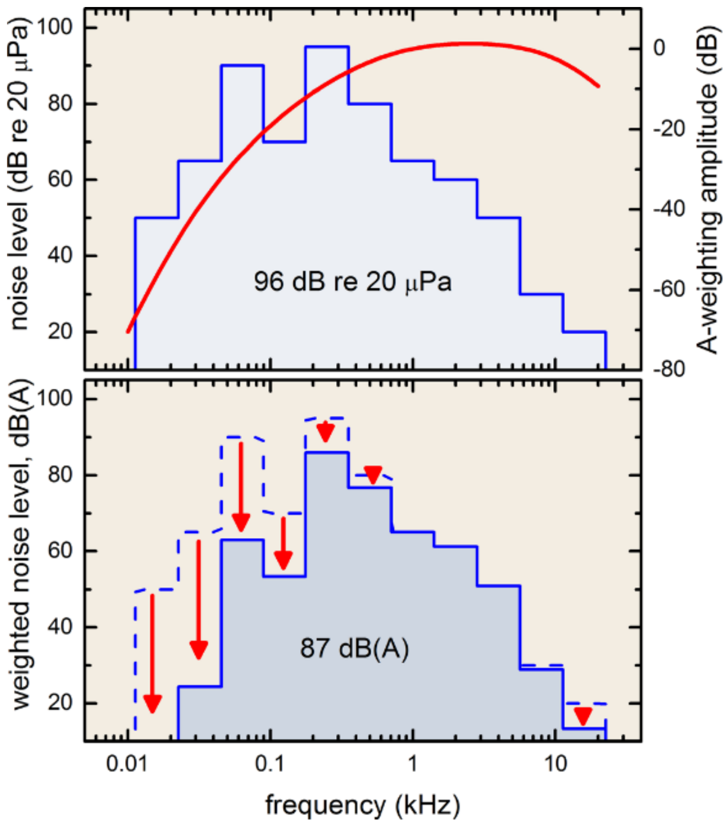

Figure 6. Application of an auditory weighting function. Blue line shows a hypothetical, octave-band sound pressure spectrum in air, with a total sound pressure level (integrated over all octave-bands) of 96 dB re 20 µPa (This example uses in air-noise levels; therefore, a different reference pressure (20 µPa) applies. The principle is identical to underwater sound where a reference pressure of 1 µPa applies). (Top) Red line shows the human A-weighting function amplitude (A-weighting applies only to human hearing). (Bottom) To determine the weighted exposure level, the A-weighting amplitude at each frequency is added to the sound pressure level at each frequency (red arrows). The weighted spectrum has lower amplitude at the frequencies where the A-weighting function amplitudes are negative. The values from 1–4 kHz do not change substantially, because the weighting function is flat (i.e., the weights are near zero). The weighted SPL is calculated by integrating the weighted spectrum across all octave-bands; the result is 87 dBA, meaning a sound pressure level of 87 dB re 20 µPa after applying the human A-weighting function (Source: Houser et al. 2017).

Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS thresholds expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL (L_E)) (Southall et al. 2007, Erbe et al. 2016a, Finneran 2016). Marine mammal auditory weighting functions published by Finneran (2016) are included in the NMFS (2018) Technical Guidance for use in conjunction with corresponding PTS (injury) onset acoustic criteria and Southall et al. (2019). Figure 7 shows the resulting frequency-weighting curves for marine mammals.

Applying marine mammal auditory weighting functions emphasizes the importance of making measurements and characterizing sound sources in terms of their overlap with biologically-important frequencies (e.g., frequencies of environmental signals, communication, or the detection of predators or prey), and not only the frequencies of interest or concern for the sound-producing activity such as a vessel (i.e., context of sound source; NMFS 2018).

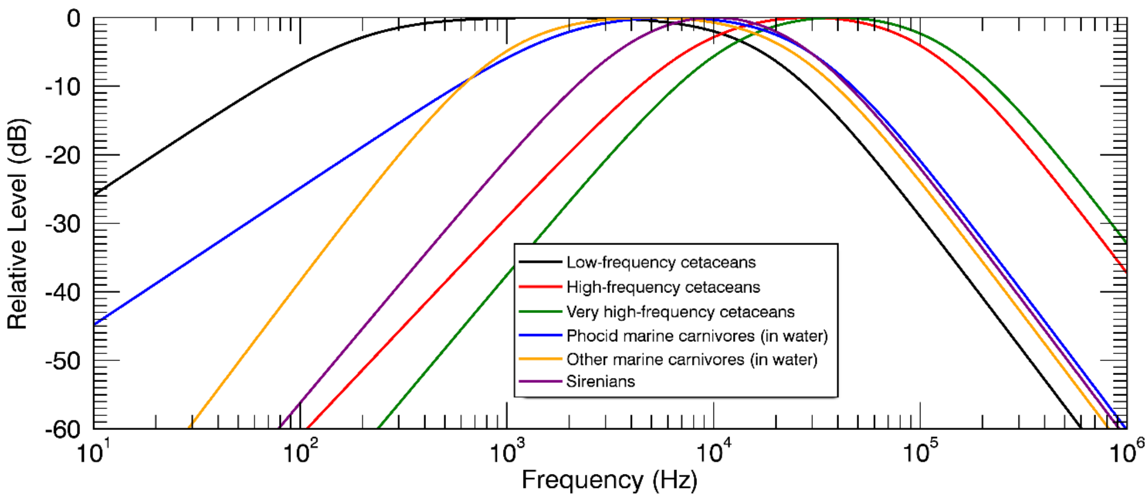

Figure 7. Auditory weighting functions for functional marine mammal hearing groups as proposed by NMFS (2018) and, with altered nomenclature (see Table 2), by Southall et al. (2019).

5.2. Noise Criteria and Rationale

To assess the potential impacts of noise exposure, criteria must first be established for which sound levels may be expected to negatively impact animals.

For marine mammals, NMFS issued a Technical Guidance document that provides acoustic thresholds for the onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) in marine mammal hearing for all sound sources (NMFS 2018). NMFS also provided guidance on the use of weighting functions when applying injury criteria. The NMFS Guidance recommends applying a dual criterion for assessing injurious exposures, including an unweighted (flat) peak sound pressure level metric PK (L_{pk}) and a sound exposure level SEL_{cum} ($L_{E,24h}$) metric with frequency weighting. Both acoustic criteria and weighting function application are different for the marine mammal functional hearing groups.

Southall et al. (2019) published an updated set of criteria for onset of TTS and PTS in marine mammals. While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups[1], the proposed thresholds and weighting functions for exposure to underwater sound do not differ in effect from those proposed by NMFS (2018).

Injurious effects caused by rapid pressure changes within the body are called 'barotrauma' (Stephenson et al. 2010, Halvorsen et al. 2011, 2012b). Popper et al. (2014) developed a set of criteria for fishes that are based on onset levels for barotrauma injury. These criteria are supported by data from Casper et al. (2013), who showed that less acoustic energy is required for the onset of barotrauma in fishes than for the onset of hair cell damage (the 'typical' cause for hearing impairment in mammals). Injuries include direct mortality, non-recoverable injury, and recoverable injury including TTS (Hawkins and Popper 2017). Criteria were chosen for all types of acoustic signals based on results from exposures to impulsive pile driving. This represents a conservative approach, as impulsive noise has a higher potential to cause deleterious effects than non-impulsive sounds. The guidelines suggested by Popper et al. (2014) then separated marine fishes into four classes according to available data on hearing sensitivity and onset of injury in relation to their developmental stage (e.g., eggs and larvae versus adult fishes) and the presence of morphological adaptations to their hearing system. The logic for choosing this indicator (injury), the baseline data (pile driving) and classification (animal groups) is reasonable and supported by the best available knowledge.

[1] The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NMFS.

5.2.1. Definitions of Sound Type

Underwater noise exposure criteria for marine fauna differ substantially for impulsive and non-impulsive sounds. However, there are some discrepancies in defining the impulsiveness of sound and, accordingly, classifying sounds in either of sound-type category.

A technical definition of impulsive noise is given by the International Standardisation Organisation, ISO: “Impulsive noise (ISO 2923:1996(en), 3.8): Noise of less than one-second duration which occurs as an isolated event or as one of a series of events with a repetition rate of fewer than 15 times per second. The presence of impulsive noise shall be determined by obtaining the difference between the equivalent continuous sound pressure level measured with time weighting I and F. If the difference is more than 2 dB, the presence of impulsive noise may be assumed.” (1996). Harris (1998) proposed a distinction between impulsive and non-impulsive sounds based on the different time constant used in sound level meters for measuring impulses (time constant: 35 ms) and non-impulsive sounds (time constants: 125 ms and 1,000 ms). A ≥3 dB difference in measurements between these settings constitutes an impulse while non-pulses sounds are characterised by <3 dB difference.

Based on these definitions, classifying most sounds into the two sound types seems straight forward and non-controversial. Problems arise with classifying commercial sonars and echosounders. Also, impulsive and non-impulsive sounds (Section 3.2) are typically determined based on their acoustic characteristics measured at the sound source. For distant receivers, however, pulsed sounds may lack the characteristics described above because long-distance underwater sound propagation attenuates at high frequencies more than at low frequencies (e.g., Martin et al. 2017). Over distance, this may change the structure of an impulsive sound to a non-impulsive sound, which would have regulatory implications as different thresholds apply to both types of sound under most jurisdictions.

5.2.2. Marine Invertebrates

5.2.2.1. Plankton

To assess impacts to plankton, there are only a few studies to base noise exposure threshold criteria on. Popper et al. (2014) published exposure guidelines for fish eggs and larvae that are based on exposure experiments using impact pile driving signals as test stimuli. Popper et al. (2014) proposed a threshold for mortality of fish eggs and larvae of >207 dB re 1 µPa PK (see Tables 3 and 4), which the authors note is likely to be conservative. There is no other official or widely accepted threshold for the onset of noise-induced effects for any planktonic species.

Results presented in Day et al. (2016b) for embryonic lobsters and Fields et al. (2019) for copepods align with those presented in Popper et al. (2014), which is that mortality and sub-lethal injury are limited to within tens of metres of seismic sources.

Other research has indicated the potential for effects at longer range: McCauley et al. (2017) reported changes in abundance and mortality in zooplankton over a range of 1.2 km after exposure to airgun sounds generated with a single airgun (150 in^3). Based on these results, a sound level of 178 dB re 1 µPa PK-PK in the water column has been proposed which could inform a highly conservative impact assessment but should not be regarded as an authoritative threshold. Fields et al. (2019) noted that it was difficult to reconcile the high mortality reported by McCauley et al. (2017) with the low mortalities reported in the previous body of earlier research and their experiment. They recommended further research into whether it is the sound pulse itself (i.e. the energy, peak pressures, or particle acceleration) or other factors not related to the sound impulse that might cause higher mortality.

5.2.2.2. Bivalves and Decapods

There are no guidelines or criteria regulating the underwater noise exposure of bivalves and decapods. There is not enough information to establish similar criteria and thresholds as was done for marine mammals and fish. Including recent research such as Day et al. (2016a), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes considering what particle motion levels lead to a behavioural response or to mortality.

Therefore, at this stage, authoritative thresholds to inform an impact assessment do not exist. However, levels can be determined for pressure metrics presented in the literature to assist impact assessment: Peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration at the seafloor can be used to help assess effects of noise on bivalves and decapods through comparing to results in Day et al. (2016a), (2019), (2016b), (2017), and Payne et al. (2008) (see Section 7.1.2 for more detail).

5.2.2.3. Cephalopods

There are no guidelines or criteria regulating the underwater noise exposure of cephalopods such as squid. In the absence of regulatory guidance, documented levels for onset of aversive behavioural reactions (Fewtrell and McCauley 2012) have been proposed for impulsive sound sources, such as seismic airguns (see detailed information in Section 7.1.3.1).

As with bivalves and decapods, there is not enough information to establish criteria and thresholds similar to those developed for marine mammals and fish. Moreover, current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes considering what particle motion levels lead to a behavioural response or to mortality.

5.2.2.4. Other Benthic Invertebrate Species

There are no guidelines or criteria regulating the underwater noise exposure of benthic species. As with the other marine invertebrate groups, there is not enough information to establish criteria and thresholds similar to those developed for marine mammals and fish. In the absence of authoritative thresholds, Heyward et al. (2018) reported a sound level of 226 dB re 1 µPa PK (L_{pk}) as a safe level of exposure for sponges and corals.

5.2.3. Fish

The Working Group on the Effects of Sound on Fish and Turtles undertook a review of experimental findings of sound effects on fishes (Popper et al. 2014). Previously, strong emphasis in assessing the effects of sounds had been placed on the hearing sensitivity of fishes. However, although hearing has to be taken into account, other effects also have to be considered (Hawkins et al. 2020). Popper et al. (2014) presented quantitative sound exposure guidelines for different groups of species and sound sources (Tables 3 and 4), for three types of immediate effects:

- Mortality, including injury leading to death;
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma; and
- TTS.

The onset level of behavioural responses in fishes varies greatly between and within species, including variables such as fish age and size, the behavioural and social context during exposure, and the motivation of the fishes. Existing data on behavioural responses do not provide a clear dose-response relationship. Consequently, it is currently impossible to determine single value thresholds for the onset of behavioural reactions.

In the absence of any qualitative scientific information on behavioural responses of fish and auditory masking, applying relative risk categories such as those proposed by Popper et al. (2014) seem most reasonable to apply rather than specific sound level thresholds.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, and for very long-lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move.

As discussed in Popper (2018), fish are mobile and some move over large distances. Popper suggests that it is reasonable to assume that if the sound of a seismic source becomes too loud, the fish will move away from the source because they are able to determine the direction of a sound source. If the fish moves away, the amount of energy to which it is exposed is likely to be one or a few seismic pulses, and these would not likely be loud enough to result in any effect because the fish would move away at a much lower level signal than could cause harm. Data on TTS for fish are limited to one study that examined recovery from seismic airgun impulses on caged fish (Popper et al. (2005b). Popper (2018) has since stated that if this study had been conducted on wild, free-swimming fish instead of caged ones, there would have been no effect whatsoever because they were likely to have moved away from the source as it approached them.

Table 3. Noise exposure criteria for pile driving and seismic noise exposure for fish, fish eggs and larvae, adapted from Popper et al. (2014).

Type of animal	**Mortality and Potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL_{24h} or > 213 dB PK	> 216 dB SEL_{24h} or > 213 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	186 dB SEL_{24h}	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL_{24h} or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 μPa; SEL_{24h} dB re 1μPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).

Table 4. Noise exposure criteria for shipping and other non-impulsive noise exposure for fish, fish eggs and larvae, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB for 48 h	158 dB for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

All criteria are presented as sound pressure level (SPL) even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).

5.2.4. Sea Turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles).

Finneran et al. (2017) presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol & Ketten, 2006; Dow Piniak et al. 2012; Martin et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

McCauley et al. (2000b) observed the behavioural response of caged sea turtles—green (*Chelonia mydas*) and loggerhead (*Caretta carett*a)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). In addition the 175 dB re 1 µPa level from McCauley et al. (2000b) this level has been recommended as a criterion for behavioural disturbance. In addition, the Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re1 µPa SPL reported by McCauley et al. (2000b) as the level that may result in a behavioural response to marine turtles.

The thresholds for impulsive noise suggested by Popper et al. (2014) shown in Table 5 is no longer recommended, and instead has been replaced by Finneran et al. (2017). The recommended criteria for PTS, TTS and behavioural response/disturbance are presented in Table 6.

The thresholds for vessel and non-impulsive noise suggested by Popper et al. (2014) and Finneran et al. (2017) are shown in Tables 7 and 8. The recommended criteria for PTS, TTS and behavioural response/disturbance is presented in Table 9.

Table 5. Noise exposure criteria for impulsive noise exposure for sea turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Turtles	> 210 dB SEL_{24h} or > 207 dB PK	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).

Table 6. Recommended criteria for assessing acoustic effects of impulsive noise on sea turtles: Unweighted SPL, SEL_{24h}, and PK thresholds.

Effect type	Criterion	SPL (L_p; dB re 1 μPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 μPa²·s)	PK (L_{pk}; dB re 1 μPa)
Behavioural response	NSF (2011)	166	NA	
Behavioural disturbance	McCauley et al. (2000a)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 μPa.
L_{pk}, flat denotes peak sound pressure that is flat weighted or unweighted and has a reference value of 1 μPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 μPa²s.

Table 7. Acoustic effects of vessel noise exposure on sea turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).

Table 8. Acoustic effects of non-impulsive noise exposure on sea turtles, weighted SEL_{24h}, adapted from Finneran et al. (2017).

PTS onset thresholds* (received level)	TTS onset thresholds* (received level)
220	200

Table 9. Recommended criteria for assessing acoustic effects of non-impulsive noise on sea turtles: Relative risk and SEL_{24h} thresholds.

Effect type	Criterion	Relative risk	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
Behaviour	Popper et al. (2014)	(N) High (I) Moderate (F) Low	NA
PTS onset thresholds (received level)	Finneran et al. (2017)	NA	220
TTS onset thresholds (received level)			200

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N, tens of meters), intermediate (I, hundreds of meters), and far (F, thousands of meters).
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.

5.2.5. Marine Mammals

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the most recent development of thresholds; however, this field remains an active research topic.

5.2.5.1. Auditory Impairment

There are two categories of auditory threshold shifts (also termed Noise Induced Threshold Shift, NITS): Permanent Threshold Shift (PTS), a physical injury to an animal's hearing system; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of physiological and mechanical processes in the inner ear. There are no PTS studies on marine mammals and the onset level of PTS is conventionally assumed to be at 40 dB TTS. While PTS undoubtedly constitutes an injury, TTS (as a temporary effect) was not considered in the same way. However, recent research clearly indicates that already moderate levels (<12 dB) of TTS produced an accelerated hearing loss (PTS) resulting from progressive neural degeneration with age (Kujawa and Liberman 2006, 2009, Maison et al. 2013, Kujawa and Liberman 2015). This relatively low level of TTS (12 dB) resulted in 22% neuronal loss in the inner ear; accumulated over multiple (low-level) TTS exposures this effect accumulates and leads to PTS.

The most recent criteria for assessing possible effects of impulsive sounds (such as pile driving or seismic impulses) noise and non-impulsive sound (such as vessel noise) on marine mammals are summarised in Tables 10 and 11 with frequency weighting explained in Section 5.1.4.2.

Table 10. Acoustic impairment effects of impulsive noise on marine mammals: SEL_{24h}, and PK thresholds

Hearing group	Southall et al. (2019)			
	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
LF cetaceans	183	219	168	213
HF cetaceans	185	230	170	224
VHF cetaceans	155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_{pk} denotes peak sound pressure and is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

Table 11. Acoustic impairment effects of non-impulsive noise on marine mammals: SEL_{24h} thresholds.

Hearing group	Southall et al. (2019)	
	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
LF cetaceans	199	179
HF cetaceans	198	178
VHF cetaceans	173	153

L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

5.2.5.2. Behavioural Responses

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For non-impulsive noise, NMFS currently uses step function (all-or-none) threshold of 120 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2019). The 120 dB re 1 µPa threshold is associated with continuous sources and was derived based on studies examining behavioural responses to drilling and dredging (NOAA 2018), referring to Malme et al. (1983), Malme et al. (1984), and Malme et al. (1986), which were considered in Southall et al. (2007). Malme et al. (1986) found that playback of drillship noise did not produce clear evidence of disturbance or avoidance for levels below 110 dB re 1 µPa (SPL), possible avoidance occurred for exposure levels approaching 119 dB re 1 µPa. Malme et al. (1984) determined that measurable reactions usually consisted of rather subtle short-term changes in speed and/or heading of the whale(s) under observation. It has been shown that both received level and proximity of the sound source is a contributing factor in eliciting behavioural reactions in humpback whales (Dunlop et al. 2017b, Dunlop et al. 2018).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic

Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

Because of the complexity and variability of marine mammal behavioural responses to acoustic exposure, NMFS has not yet released technical guidance on behaviour thresholds for use in calculating animal exposures (NMFS 2018)[2]. An US-based expert working group lead by Brandon Southall is in the process of developing an updated approach to assess noise-induced behavioural effects on marine mammals based on the latest research results and risk assessment frameworks (see below). The only alternative criteria addressing behavioural impacts for marine mammals (Germany (BMU 2013) and The Netherlands (de Jong et al. 2015)) are tailored specifically for harbour porpoises (*Phocoena phocoena*, a HF cetacean species), both promulgating a threshold level for the onset of behavioural responses of 140 dB re 1 µPa^2·s SEL.

[2] Contrary to their first publication of marine mammals noise exposure criteria (Southall et al. 2007), in their most recent update Southall et al. (2019) do not address the topic of behavioural effects.

6. Potential Impacts from noise – General

Underwater noise can impact marine fauna in six main ways:

- Inducing stress. Stress can be acute or chronic and affect health and behaviour (Section 6.1);
- Masking or interfering with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey) (Section 6.2);
- Disturbance leading to behavioural changes or displacement of fauna. The occurrence and intensity of disturbance is highly variable and depends on a range of factors relating to the animal and situation (Section 6.2);
- Injury to hearing or other organs. Hearing loss may be temporary threshold shift or permanent threshold shift (Section 6.4).
- Mortality and mortal injury – immediate or delayed death either due to injury or substantially reduced fitness (Section 6.5).
- Cumulative or chronic effects; repeated or long-term exposure to noise leading to additive severity of noise-induced effects (Section 6.6).

The most extensive research on the effects of noise has been conducted on humans where noise has been shown to have cardiovascular, endocrinological, neurological and auditory effects (Basner et al. 2014). Additionally, cognition is also impacted in humans (Lercher et al. 2013).

6.1. Stress

Stress is an integral, necessary part of the body's homeostasis, and certain stress levels are tolerable. At higher levels, if repeated too often, or continued over long durations stress can, however, become deleterious by creating an allostatic load to the body. This is expressed and can be measured as imbalances in the autonomic nervous system, central nervous system, neuroendocrine, and immune systems and/or result in changes in growth rate, disruption of diurnal rhythms and behavioural changes. Animals may not show overt signs of responding to an increase in noise but may nonetheless show physiological changes (e.g., Slabbekoorn et al. 2010, Kight and Swaddle 2011, Slabbekoorn et al. 2019). Symptomatic stress responses include changes in respiration rate, oxygen consumption, excretion, or food consumption rates or in chronic effects such as immune suppression. The effects of increased stress levels (acute or chronic) can be expressed through a variety of metabolic and/or physiological factors. The imbalance caused by stress in these factors can lead to immune suppression and/or result in changes in growth rate, disruption of diurnal rhythms, and behavioural changes. This cascade of effects may reduce the individual's fitness through alterations in reproduction (e.g.,Sierra-Flores et al. 2015) and, ultimately, survival (see review by Slabbekoorn et al. 2010).

Underwater sound is considered a stressor for marine animals; responses to sound exposure can range from an acute startle response to more chronic effects and can vary widely across individuals in type and magnitude according to a host of factors (see review by Busch and Hayward 2009). Direct measurements of noise-related stress responses in marine mammals from sound exposure are limited but increasing (Thomas et al. 1990, Miksis et al. 2001, Romano et al. 2004, Rolland et al. 2012). A greater amount of data are available for terrestrial mammals and other animals and, in some cases, may be useful where direct information is lacking (Wright et al. 2007). In a carefully controlled exposure experiment, Houser et al. (2020) exposed trained bottlenose dolphins to 1-s tones at different SPL. Their results show that stress-related hormones were either below detection limits (aldosterone) or levels did not show a consistent relationship with received levels (cortisol nor epinephrine). Stress responses may be species- and context-specific and depend on previous exposures (sensitisation/desensitisation, see Section 6.2, below) and the (lack of) results in the study by Houser et al. (2020) may reflect the fact that these animals have been exposed to artificial underwater sound before. However, it also gives reason to question if marine mammals interpret high-level anthropogenic sound as stressful and whether behavioural responses to sound can be equated to a physiological (endocrine) response.

6.2. Auditory Masking

Auditory masking is the process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound (Erbe and Farmer 1998, Erbe 2008, Erbe et al. 2016b). This describes the reduction in audibility for one sound (termed 'signal') caused by the simultaneous presence of another sound (termed 'noise'). For this to occur, the sound must be loud enough, have similar frequency content to the signal, and must happen at the same time.

Masking is a complex phenomenon and the onset levels and severity are difficult to predict for any particular combination of sender, environment, and receiver characteristics (Erbe et al. 2016b). Masking depends on the spectral and temporal characteristics of signal and noise and is reduced if the signal and noise (masker) are separated in time, frequency, or direction (space); it can occur if the noise happens shortly before or after the signal (forward and backward masking).

The severity and extent of auditory masking depends on the spectral and temporal characteristics of both the signal and the noise. The zone of auditory masking can maximally be as large as the zone of audibility, i.e., a faint noise might mask a faint signal. However, auditory masking ends immediately after the masking sound ceases.

Masking sound can interfere with the perception of communication between conspecifics and echolocation signals and the detection of environmental, predator and prey sounds; all of these acute masking effects can have cascading consequences for communities through altered species interactions (Francis et al. 2009). Auditory masking can lead to disruption of a behaviour, lack of appropriate behavioural reactions, increased vulnerability to predators, reduced access to prey, reduced communication or listening space (Clark et al. 2009, Pine et al. 2018a, Pine et al. 2018b), changes in vocal behaviour, disruption of spawning activities, and stress (Houser et al. 2020).

The masking effect can be reduced or remedied by various active or passive mechanisms for masking-release, such as spatial or temporal release from masking (for more information, see Erbe et al. 2016b, Popov et al. 2020). The masking effect can be reduced if the signal and noise are separated in time, frequency, or direction (space).

The biological significance of acoustic masking is directly linked to the duration of the masking sound. Both anthropogenic and natural marine sound can affect hearing and partially or completely reduce an individual's ability to effectively communicate. Auditory masking is likely occurring for all marine fauna; however, masking is most frequently associated with marine mammals. Masking in fishes or other taxa has not been studied in detail.

Repeating a signal or lengthening it may reduce the amount of masking because whales seem most reactive when the sound level is increasing and at the onset of a sound. Although limited, the data suggest that stationary industrial activities producing non-impulsive sounds (such as dredging, drilling, and oil-production-related activities) result in less dramatic vocal reactions by cetaceans than do moving sound sources, particularly ships (Richardson et al. 1995). Masking and the potential effects of masking on communication and listening space of marine mammals are not fully understood and remain an area of active research (Terhune et al. 1979, Cunningham and Mountain 2014, Tennessen and Parks 2016, Cholewiak et al. 2018, Dunlop 2018, Gabriele et al. 2018, Putland et al. 2018, Dunlop 2019).

Auditory masking was investigated in a number of studies in a wide range of marine mammal species (Lemonds et al. 2011, 2012; Branstetter et al. 2013), including harbour porpoises (Kastelein & Wensveen, 2008), manatees (Gaspard et al. 2012), spotted and ringed seals (Sills et al. 2014, 2015), California sea lions (Cunningham et al. 2014), and sea otters (Ghoul and Reichmuth 2014).

Some cetaceans are known to increase the source levels of their calls, shift their peak frequencies, or otherwise modify their vocal behaviour in response to increased noise (Dahlheim 1987, Au 1993, reviewed by Richardson et al. 1995, Lesage et al. 1999, Terhune 1999, Nieukirk et al. 2005, Scheifele et al. 2005, Parks et al. 2007a, Di Iorio and Clark 2009, Hanser et al. 2009, Holt et al. 2009, Parks et al. 2009, McKenna 2011, Parks et al. 2011, Castellote et al. 2012, Melcon et al. 2012, Parks et al. 2012, Risch et al. 2012, Tyack and Janik 2013, Luís et al. 2014, Sairanen 2014, Papale et al. 2015, Dahlheim and Castellote 2016, Gospić and Picciulin 2016, Heiler et al. 2016, Martins et al. 2016, O'Brien et al. 2016, Parks et al. 2016a, Parks et al. 2016b, also Bittencourt et al. 2017).

6.3. Behavioural Responses

The intensity of behavioural responses of marine fauna to sound exposure ranges from subtle responses, which may be difficult to observe and have little implication for the affected animal, to obvious responses, such as avoidance or panic reactions. Given that the sound is audible to the individual the behavioural responses include in approximate order of increasing severity but decreasing likelihood:

- Looking or increased alertness;
- Minor behavioural responses such as modifications associated with auditory masking (see Section 6.2);
- Cessation of feeding or social interactions;
- Temporary avoidance behaviour (emerging as one of the more common responses);
- Modification of group structure or activity state;
- Habitat abandonment; and
- Injury or death via direct response or possible exacerbated by physiological factors (see Section 6.5).

The context in which the sound is received by an animal affects the nature and extent of responses to a stimulus. The threshold for elicitation of behavioural responses depends on received sound level, as well as multiple contextual factors such as the activity state of animals exposed to different sounds, the type of sound, spatial relations between a sound source and receiving animals, the gender, age, and reproductive status of the receiving animal and the and novelty of or previous exposure to the sound (Ellison et al. 2012).

Previous exposure to a sound can influence the severity of a behavioural response, leading to an increased or decreased tolerance to the sound. A novel acoustic stimulus may initially provoke a substantial anti-predator response (Voellmy et al. 2016). Behavioural "habituation is the relative persistent waning of a response as a result of repeated stimulation to that novel stimulus" (Thorpe 1963, Bejder et al. 2009). Habituation is a process involving a reduction in response over time as individuals learn that there are neither adverse nor beneficial consequences of the occurrence of the stimulus. Sensitisation refers to the opposite phenomenon, an increasing "behavioural responsiveness over time when animals learn that a repeated or ongoing stimulus has significant consequences for the animal" (Richardson et al. 1995). Individuals that are sensitised to acoustic stimuli (such as emitted by anthropogenic activities) will thus exhibit a progressive intensification of their response to these stimuli, e.g., by fleeing farther and faster when they encounter the stimulus, or by exhibiting responses at progressively lower stimulus intensities. Since habituation and sensitisation constitute learning processes that are ongoing, they reflect an individual's cumulative experience with anthropogenic activities, including the number and outcome of its exposures to anthropogenic stimuli over the course of its lifetime (Knight and Temple 1995). Tolerance describes the "intensity of disturbance that an individual […] tolerates without responding in a defined way" (Nisbet 2000 p. 315).

Acoustic risk functions (or ''dose-response'' functions) relate an exposure to the probability of response. They are a useful approach for assessing the potential for behavioural responses to occur; they assume that the probability of a response depends first on the ''dose'' (in this case, the received level of sound) and that the probability of a response increases as the ''dose'' increases (e.g., Dunlop et al. 2017b). Based on observations of various animals the relationship represented by an acoustic risk function is a more robust predictor of the probable behavioural responses of marine mammals to noise exposure (NOAA 2018). However, no such function has yet been developed for exposure to noise from acoustic sources other than military sonar. Defining such a function is difficult due to the aforementioned complexity, resulting from the array of potential environmental and other contextual effects (Ellison et al. 2012).

This complexity and variability of marine mammal behavioural responses to acoustic exposure, along with missing relevant information resulted in lack of up-to-date guidance to regulate noise-induced behavioural responses by NMFS and other national regulators. Currently, NMFS still refers to SPL of 120 dB and 160 dB re 1 µPa (NOAA 2019) for non-impulsive and impulsive sounds, respectively (Section 5.2.5). Other regulatory guidelines include species-specific and/or sound-type specific criteria (e.g., BMU 2013). These behavioural criteria, however, are conservative estimates. Moreover, they will vary between functional hearing groups and species due to differences in hearing sensitivity and, as mentioned, they will vary with the behavioural context.

When measuring behavioural responses observed from captive marine animals held in an enclosure or tank it is important to realise that they do not necessarily reflect the full range of natural responses in the wild and conclusions should not be extrapolated to other contexts (Popper et al. 2014; Hawkins et al. 2015; Lucke et al. 2016). Erbe et al. (2019) provide an excellent literature review of behavioural effects of vessel noise on marine mammals.

6.4. Noise-Induced Threshold Shift (NITS)

Exposure to sufficiently intense sound may lead to an increased hearing threshold in any living animal capable of perceiving acoustic stimuli (Finneran 2015). If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift (TTS). The onset of TTS is often defined as threshold shift of 6 dB above the normal hearing threshold (Southall et al. 2019). If the threshold shift does not return to normal, the residual shift is called a permanent threshold shift (PTS).

Hearing loss occurs naturally in marine mammals, most likely explained by advancing age, diseases or congenital defects (Ridgway and Carder 1997, Mulsow et al. 2011). Threshold shifts can also be caused by acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser et al. 2017). Injury to the hearing apparatus of a marine animal may result from a fatiguing stimulus measured in terms of sound exposure level (SEL), which considers the sound level and duration of the exposure signal. Intense sounds may also damage the hearing apparatus independent of duration, so an additional metric of peak pressure (PK) is needed to assess acoustic exposure injury risk. Noise-induced effects mediated by particle motion have not been studied to date and it is unclear what the exposure thresholds for marine animals sensitive to particle motion are.

The severity of TTS is a function of recovery time and is expressed as the magnitude of the shift in hearing sensitivity relative to pre-exposure sensitivity and the duration of hearing impairment. TTS occurs at lower sound levels than PTS. Though the relationship between the onset levels of TTS and the onset levels of PTS is not fully understood for marine mammal species, PTS onset acoustic thresholds have been extrapolated from marine mammal TTS measurements using growth rates from terrestrial and marine mammal data (Finneran et al. 2017).

An important difference between marine fishes and marine mammals with regard to NITS is the fishes' apparent ability to regenerate their hair cells to a fully functional state within weeks after a detrimental exposure. The processes involved in the recovery are not fully understood yet and that there is conflicting evidence from sound exposure studies, such as McCauley et al. (2003). Noise-induced permanent threshold shift has not been reported for fishes yet, which may be explained by the apparent ability to recover hair cells. These findings could also suggest that the process of sensory hair cell death and regeneration is species-specific. Recovery from TTS takes a few days to a few weeks in fishes (Scholik and Yan 2001, Mackenzie and Raible 2012), and the time course for recovering from hearing loss likely depends on the species, its normal hearing sensitivity, the sound exposure intensity and duration, and the amount of sensory epithelial damage (Smith and Monroe 2016). Noise-induced PTS has not been reported for fishes yet, which may be explained by their apparent ability to recover hair cells.

As in other animal groups, NITS in fishes can result from mutations, treatment with ototoxic chemicals, and exposure to excessive levels of underwater noise. NITS has been demonstrated in a number of fish species (Popper and Clarke 1976, Scholik and Yan 2001, Amoser et al. 2004a, Smith et al. 2004, Popper et al. 2005a, Popper et al. 2007) after exposure to different types of sounds. Multiple exposures to very intense sounds (SPL well over 190 dB re 1 μPa) or long-term exposure to lower-level sounds were necessary to cause NITS. The onset thresholds for NITS, however, varied between individuals and species (Popper et al. 2005b, Popper et al. 2007, Hastings et al. 2008, Hastings and Miksis-Olds 2012). Not all experiments involving exposure to intense sound, however, caused NITS in the exposed fishes; some species exhibited no or minimal hearing threshold shifts following intense sound exposure (Smith and Monroe 2016).

The biological significance of NITS in fishes is mediated by the fact that perception of underwater sound for communication purposes is linked to the regulation of social and reproductive behaviours of fishes; fishes listen to other fishes (both conspecific and heterospecific) and other aquatic sound-producing organisms (Lagardère et al. 2005, Vasconcelos et al. 2011, McIver et al. 2014) such as their predators. With sound playing such a vital role in a variety of behaviours, fishes of all life stages face a higher risk of mortality and decreased fitness if their hearing is impaired.

In early life stages of reef fishes, impaired auditory or vibratory sensitivity has the potential to impair their orientation during homing phase (Montgomery et al. 2006, Munday et al. 2009, Vermeij et al. 2010, Radford et al. 2011, Simpson et al. 2011, Rossi et al. 2015). With sound as navigational cue for finding their new habitats, NITS has the potential of impacting these individuals in a sensitive life stage thus reducing their chance of survival.

6.5. Mortality

Exposure to excessive levels of impulsive sound or events characterised by rapid overpressure in water can kill and injure marine fauna (Carlson et al. 2011). Impulsive sounds, with rapid changes in pressure, are more damaging to tissues than gradual changes (Popper et al. 2014).

Mortality is either a direct effect of the exposure (in case of severe injury) or indirect if an animal is moderately injured. Data on sound-induced mortality has been documented for fish (Caltrans 2001), but is scarce for marine mammals (Ketten 1995, Landsberg 2000) and only hypothesised for other taxa (Guerra et al. 2004).

Exposure to intense underwater sound may not directly result in death or injury; however, it may be one of the indirect causative factors in death or injury to marine mammals. Marine mammal strandings of beaked whales (D'Amico et al. 2009) and common dolphin (Jepson et al. 2013), are thought to be a result of the animals' behavioural responses to acoustic exposure to military mid-frequency sonar. According to the US Navy's Atlantic Fleet Training and Testing Final Environmental impact Statement "Sonar use during exercises …… has been identified as a contributing factor in five species mass stranding events: Greece in 1996, the Bahamas in March 2000, Madeira Island, Portugal in 2000, the Canary Islands in 2002 and Spain in 2006. These five mass strandings resulted in approximately 40 known, scientifically verifiable sonar-related deaths among cetaceans consisting mostly of beaked whales." (US Dept. of the Navy, 2013).

Investigating the mass stranding of approximately 100 melon-headed whales in the Loza Lagoon system in Madagascar lead to the conclusion that the use of a 12 kHz multibeam echosounder (with SPL of 236 to 246 dB re 1 µPa and per pulse SEL of 218 to 224 dB re 1 $\mu Pa^2 \cdot s$) are "the most plausible and likely initial behavioral trigger of the stranding event, but that a variety of secondary factors contributed to or ultimately caused mortalities […]" (Southall et al. 2013).

6.6. Cumulative and Chronic Effects

Noise-induced effects can be acute (such as acoustic masking), or chronic (including altered distribution), lasting from the immediate duration of sound exposure to several days or weeks if animals are displaced from their preferred areas during an activity (Engås et al. 1996, Slotte et al. 2004, Løkkeborg et al. 2012b, 2012a, Streever et al. 2016) and can be permanent in case of PTS, for example.

Historically, most acoustic effects studies on marine animals have focused on short-term and acute effects from single, individual high-intensity sounds (e.g., the near-field sounds from seismic airguns, sonar, and impact pile driving). Recently there has been more interest in the effects of sound exposures received by marine mammals over larger spatial and temporal extents (Clark et al. 2009, Hatch et al. 2012). These long-term exposures, and the resulting chronic effects, may in some cases be more relevant to marine animals than short-term acute effects, especially for communications between conspecifics (see review by the National Academies of Sciences 2016).

Effects of a single exposure to a single stressor (such as noise) can be exacerbated by repeated exposures (cumulative – spatially and temporally) or through simultaneous exposure to multiple stressors (additive – e.g., noise and chemical pollution). The following scenarios can be considered:

- Acute effects following:

    - Single exposure to a single stressor
- Chronic effects following:
    - Continuous exposure to the same type of stressor
    - Continuous exposure to different types of stressors
- Cumulative effects following:
    - Repeated exposure to the same type of stressor
    - Repeated exposure to different types of stressors
- Additive/ aggregate effects following:
    - Simultaneous exposure to multiple variations of the same stressor
    - Simultaneous exposure to multiple variations of different stressors

Acute exposure and cumulative exposure to sound over time has been investigated in marine mammals and is reflected in the most recent set of noise exposure criteria (NMFS 2018; Southall et al. 2019) under the SEL criterion.

The simultaneous exposure to sounds from multiple sources is likely to induce stronger effects in marine animals that are currently not accurately represented by assessments of the most prevalent source alone (Wright and Robertson 2015). There may be, for example, an increased risk for TTS as well as for masking, stress and related effects. Differences in the frequency spectrum, temporal pattern and other acoustic parameters of the overlapping sounds and the complexity of the physiological and behavioural effects make it complicated, if not impossible to assess the cumulative and additive effects. Accordingly, the existing noise exposure criteria do not account for such combined exposure to different types of noise.

A cumulative effect may also exist with regard to the background noise level to which an animal is subjected to during exposures to intense sounds. Hamernik et al. (1974) exposed chinchillas to moderate levels of non-impulsive noise prior to exposure to intense impulsive noise. Their audiometric and histological findings show that the combination of two noise exposures, shown to be safe individually, cause NITS exceeding the additive effects of either component.

Marine species experience acoustic stimuli not in isolation from other environmental stressors such as chemical ocean pollution, habitat modification, food depletion and many other anthropogenic drivers with potentially detrimental effects (Kappel 2005, Halpern et al. 2008). These stressors can directly interact with each other in complex ways – they can be potentiating (i.e., being additive or multiplicative), counteracting (i.e., being subtractive or divisive) or non-interactive, and it should be noted that temporal separation is sufficient to remove any interaction effect.

Many of the drivers affecting marine animals are themselves affected by larger-scale ecological drivers. For example, global climate change is an ecological driver that changes the marine environment and exposes marine life to the stressors of warming and ocean acidification. Similarly, predators, prey, and competitors of marine mammals are potential stressors whose distributions are affected by ecological interactions of these stressors (National Academies of Sciences 2016).

With regard to marine animals, cumulative and additive effects from multiple sound sources as well as other stressors have been identified as important parameters for the assessment of human impacts (National Research Council, NRC 2005; Williams et al. 2015; Ellison et al. 2016).

The problem of assessing cumulative effects is exacerbated by limited data on relationships between stressors and vital functions in marine mammals, mainly owing to their cryptic lifestyle. This data deficiency makes it almost impossible to dissociate the assessment of effects caused by noise exposure from that of other stressors. There are no standards for assessment of cumulative exposure to underwater sound.

7. Species/Taxon-Specific Impacts

This section provides detailed information on documented effects of noise exposure on marine animals. Species are grouped at a high taxonomic level in each subsection, and information is differentiated by type of sound source and impact category if available.

7.1. Marine Invertebrates

Exposure to anthropogenic sound sources could have a direct consequence on the functionality and sensitivity of the sensory systems of marine invertebrates and affect their physiology, behaviour, and cause noise-induced trauma. For most species, however, the sensory sensitivity to underwater sound and susceptibility to noise-induced effects has not been investigated. Available scientific information is scarce and often derived from laboratory studies, in most cases with insufficient control over the particle motion field in the test environment. Lack of quantifying the most relevant input parameter for the sensory system of marine invertebrates, however, reduces the robustness of any conclusions drawn from such studies.

7.1.1. Plankton

7.1.1.1. Impulsive Sound Sources

7.1.1.1.1. Seismic Airguns

Parry et al. (2003) studied the abundance of plankton after exposure to airgun sounds but found no evidence of mortality or changes in catch-rate on a population level.

Contrary to other studies, McCauley et al. (2017) found that after exposure to airgun sounds generated with a single airgun (150 in^3) zooplankton abundance decreased and mortality in adult and larval zooplankton increased two- to threefold when compared with controls. In this first large-scale field experiment on the impact of seismic activity on zooplankton, they used a sonar and net tows to measure the effects on plankton. They determined a maximum effect-range of horizontal 1.2 km. Their findings contradicted the conventional idea of limited and very localised impact of intense sound in general, and seismic airgun signals, on zooplankton. Their results indicated that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity. The study was compromised by methodological design of the study (small sample sizes, large daily variability in the baseline and experimental data) and the statistical robustness of the data and conclusions (large number of speculative conclusions that appear inconsistent with the data collected over 2 days) (Richardson et al. 2017).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO, Richardson et al. 2017) simulated the large-scale impact of a seismic survey on zooplankton using the mortality rate inferred by McCauley et al. (2017). The CSIRO study aimed to estimate the spatial and temporal impact of seismic activity on zooplankton on the Northwest Shelf of Western Australian based on McCauley et al findings. The major findings of the CSIRO study were that seismic activity substantially impacted zooplankton populations on a local scale within or near the survey area; however, on a regional scale the impacts were minimal and were not discernible over the entire Northwest Shelf Bioregion. The study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relative quick recovery was due to the fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from inside and outside the impacted region (Richardson et al. 2017). Richardson et al. (2017) showed that zooplankton communities can begin to recover during the seismic survey in good oceanic circulation or they can “bottom out” at a maximum impact level (presumably where growth rates and/or zooplankton entering the survey area roughly approximate mortality rates) after 23–30 days of commencing survey operations.

Fields et al. (2019) exposed zooplankton (copepods) to seismic pulses at various distances up to 25 m from a seismic source. The source levels produced were estimated to be 221 dB re 1 μPa^{2}s, comparable to the far-field source levels associated with some commercial-scale seismic surveys. The study observed an increase in immediate mortality rates of up to 30% of copepods in samples at distances of 5 m or less from the airguns compared to controls. Mortality one week after exposure was significantly higher by 9% relative to controls in the copepods placed 10 m from the airguns. Fields et al. (2019) also reported that no sublethal effects occurred at any distance greater than 5 m from the seismic source. The findings of the study indicate that the potential effects of seismic pulses to zooplankton are limited to within ~10 m from the seismic source. Fields et al. (2019) also note that the findings of the McCauley et al. (2017) study are difficult to reconcile with the body of other available research and may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

Hawkins et al. (2014) generated synthetic impulse sounds (resembling pile driving or airgun impulses) in a behavioural response study in open water and documented the effects on fishes and zooplankton (such as copepods and larvae) using an echosounder. The typical reaction documented for zooplankton was a sudden “dent” in the top of the layer at the onset of the sound sequence, indicating that the animals either dispersed or changed depth, away from the source. The change did not persist for the whole duration of the exposure. The authors found that zooplankton aggregations within the ensonified area responded to received sound pressure levels ranging from 156 dB to 159 dB re 1 µPa peak-to-peak (PK-PK) while larger individuals (probably ctenophores and other coelenterates) did not respond to the sound exposure.

7.1.1.1.2. Offshore Pile Driving

The effects of impulsive sound on fish eggs and larvae were investigated in the context of offshore pile driving. Bolle et al. (2012) investigated the risk of mortality in common sole larvae by exposing them to impulsive stimuli in an acoustically well-controlled study. Even at the highest exposure level tested, at an SEL of 206 dB re 1 $\mu Pa^2 \cdot s$ (corresponding to 100 strikes at a distance of 100 m) no statistically significant differences in mortality was found between exposure and control groups.

7.1.1.2. Non-Impulsive Sound Sources

7.1.1.2.1. Offshore Drilling

Information specific for effects of sound emitted by offshore drilling activities on plankton is not available.

7.1.1.2.2. Vessels

Information specific for effects of sound emitted by vessel operations on plankton is not available.

7.1.2. Bivalves and decapods

7.1.2.1. Impulsive Sound Sources

7.1.2.1.1. Seismic Airguns

Aguilar de Soto et al. (2013) indicated that New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to extended periods of airgun signals during their ontogeny may be negatively affected. The authors found an increase in abnormality and mortality rates in scallop larvae after continued exposure to playbacks of intense airgun signals in a laboratory experiment. These results indicated that there may be species-specific differences in sensitivity of early life stages to sound exposure.

In a field study, Przeslawski et al. (2016) focused on potential short-term impacts of marine seismic surveys on scallops in the Gippsland Basin. Commercial scallops (*Pecten fumatus*) were not abundant in the study area, and there was no evidence of mortality or change in the condition of scallops two months after a marine seismic survey ended. Analysis of images and samples revealed site-specific variance in scallop abundance, size, condition, and assemblages were higher than the observed effects from exposure. The analysis of the acoustic parameters, however, is likely compromised by the erroneous use of acoustic modelling methods and no close range recordings.

Day et al. (2016a) conducted an open water study on the effects of exposures of rock lobster (*Jasus edwardsii*) and scallop to impulsive noise produced by an airgun. Their study used field and laboratory experimental approaches to investigate potential impacts of marine seismic surveys on these species. Their field study used a real airgun and had better control over the relevant experimental parameters than other reported studies. Accordingly, their results are more relevant than those obtained under laboratory conditions with animals exposed to simulated signals.

It is likely that particle motion and interface waves are the more relevant stimulus. Day et al. (2016a) provide a regression of particle acceleration versus range for the single 150 in^3 seismic airgun used in the study and showed that acceleration at the 10 and 100 m ranges were typically 26 and 5 ms^{-2}, respectively. The study also references an unpublished maximum particle acceleration measurement of 6.2 ms^{-2} from a 3130 in^3 seismic airgun array at 477 m range in 36 m of water.

Morris et al. (2018) assessed the effects of industry scale seismic exposure on catch rates of snow crab (*Chionoecetes opilio*) along the continental slope of the Grand Banks of Newfoundland. In a Before-After-Control-Impact study over two years they did not find evidence supporting the contention that seismic activity negatively affects catch rates in shorter term (i.e. within days) or longer time frames (weeks). However, significant differences in catches were observed across study areas and years. Their results suggest that if effects from exposure to seismic airgun impulses on snow crab harvests do exist, they are smaller than changes related to natural spatial and temporal variation.

Day et al. (2019) tested the impact of seismic surveys on the righting reflex and statocyst morphology of the rock lobster. Their results show that exposure to seismic airgun impulses with calculated received PK levels of up to 205 dB re 1 µPa and maximum SEL of 191 dB re 1 $\mu Pa^2 \cdot s$ can cause morphological damage to the sensory organ of rock lobster. Two reflex behaviours, tail tonicity or extension and righting behaviour, were assessed. These reflexes have been used in lobster fishery industries in grading animals for their likelihood of survival. While results for tail tonicity were inconclusive, there was a significant response to exposure in the righting response, which is a more complex reflex requiring neurological control and muscle coordination. The lobsters showed impaired righting and significant damage to the sensory hairs of the statocyst. Reflex impairment and statocyst damage persisted over the course of the experiments and did not improve following moulting.

Consistent with other studies of high-intensity, low-frequency sound exposure of crustaceans and molluscs (reviewed by Edmonds et al. 2016, Carroll et al. 2017), the study found no evidence of mass mortality directly following airgun exposure. Consequently, the authors rejected the hypothesis that exposure to seismic airguns causes immediate mass mortality.

Day et al. (2017) investigated the effect of exposure to airgun impulses on scallops (*Pecten fumatus*). The authors conclude that exposure to seismic signals significantly increases mortality, particularly over a chronic (months post-exposure) time scale, though not beyond naturally occurring rates of mortality. The calculated maximum PK levels at the position of the bivalves reached 213 dB re 1 µPa and maximum SEL of 198 dB re 1 $\mu Pa^2 \cdot s$.

Studies on the impacts of underwater explosions on several species of bivalve, including two pearl oyster species, indicated strong resilience to the shock waves created by the detonation of explosives underwater. Chalmer (1986) found that no mortality occurred in the exposed animals over a 13-week period and at a minimum exposure range of 1 m from the blast centre. These studies do not offer any insights as to the distances at which sub-lethal effects (such as morphological, biochemical and physiological changes being indicators of some level of stress in an animal) could occur.

7.1.2.1.2. Offshore Pile Driving

Information specific for effects of sound emitted by offshore pile driving activities on bivalves and decapods is not available.

7.1.2.2. Non-Impulsive Sound Sources

7.1.2.2.1. Offshore Drilling

Information specific for effects of sound emitted by offshore drilling activities on bivalves and decapods is not available.

7.1.2.2.2. Vessels

Shore crabs (*Carcinus maenas*) experiencing repeated ship noise playback showed initial stress responses (Wale et al. 2013). On first exposure, the animals consumed more oxygen, indicating a higher metabolic rate. Filicotto et al. (2016) examined the effects of recorded boat noise on the behaviour and biochemistry of the common prawn (*Palaemon serratus*). The exposure elicited changes in locomotor patterns and caused physiological and behavioural effects that the authors identified as stress-related responses.

7.1.2.2.3. Other Non-Impulsive Sound Sources

Two tank-based experiments investigated the physiological and behavioural effects of sound exposure on marine invertebrates. The sound generated by tidal and wind turbines was found to delay the time to metamorphosis between larval stages in estuarine crabs (Pine et al. 2012). Celi et al. (2013) documented statistically significant variations in haemato-immunological parameters as well as a reduction in agonistic behaviour in red swamp crayfish (*Procambarus clarkii*) after constant exposure to frequency sweeps over a duration of 30 min. The signals covered a frequency range between 0.1–25 kHz and reached a peak amplitude 148 dB re 1 µPa at 12 kHz.

7.1.3. Cephalopods

7.1.3.1. Impulsive Sound Sources

7.1.3.1.1. Seismic Airguns

Guerra et al. (2004) found statocyst and organ damage in seven stranded giant squids and considered these findings as circumstantial evidence for noise-induced effects caused by nearby seismic surveys. McCauley et al. (2000a) and Fewtrell and McCauley (2012) conducted controlled exposure experiments with caged squid (*Sepioteuthis australis*) using a single seismic airgun as the sound source. They found that in one trial, where the received level of the first seismic air gun impulse was 162 dB re 1 $\mu Pa^2 \cdot s$, the squid inked (an alarm response). This response was not observed again within this trial, however the authors stated that it was unknown if this was due to depleted ink reserves or habituation. In two other trials, the initial received levels were lower (132 and 146 dB re 1 $\mu Pa^2 \cdot s$ per-pulse SEL), and although the received levels did exceed 162 dB re 1 $\mu Pa^2 s$, no inking behaviour was observed. Exposure to airgun impulses at sound levels greater than 147 dB re 1 $\mu Pa^2 \cdot s$ induced the caged squid to start jetting away from the sound source (i.e., an avoidance behaviour). The authors hypothesised that the results also suggest that a gradual increase in received levels and prior exposure to seismic air gun impulses decreases the severity of the alarm responses in this species, i.e. the animals likely habituated to the sound exposure. This aligns with findings of general habituation in response to predators in squid (Long et al. 1989). While Fewtrell and McCauley (2012) stated that their results were preliminary, the level associated with inking (162 dB re 1 $\mu Pa^2 \cdot s$ per-pulse SEL) has been considered as a startle response threshold[3] for both squid and octopus.

[3] It is worth noting that perception of sound impulses in squid are most likely mediated by particle motion and that the relevant levels were not reported by the authors.

7.1.3.1.2. Offshore Pile Driving

No scientific information is available on the potential of noise-induced effects on cephalopods following exposure to impact pile driving impulses.

7.1.3.2. Non-Impulsive Sound Sources

7.1.3.2.1. Offshore Drilling

Information specific for effects of sound emitted by offshore drilling activities on cephalopods is not available.

7.1.3.2.2. Vessels

Information specific for effects of sound emitted by vessel operations on cephalopods is not available.

7.1.3.2.3. Other Non-Impulsive Sound Sources

Mooney et al. (2016) tested unconditioned behavioural responses to tonal signals in squid (*Doryteuthis pealeii*). The reactions elicited by sound exposure from 80 Hz to 1 kHz ranged from inking and jetting to body pattern changes and fin movements. Animals responded to the lowest sound levels in the 200–400 Hz range.

André et al. (2011) and Solé et al. (2013) provide evidence of acoustic trauma in different cephalopod species (*Sepia officinalis*, *Octopus vulgaris*, *Loligo vulgaris*, and *Illex condietii*) that they exposed (underwater) for 2 h to low-frequency sweeps between 50–400 Hz (1 s duration) generated by an in-air speaker. The received level at the animals' position was 157 dB re 1 µPa with peak levels (unspecified) up to 175 dB re 1 µPa. Both studies report permanent and substantial morphological and structural alterations of the sensory hair cells of the statocysts following noise exposure with no indication of recovery. In a more recent experiment, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) to tonal sweeps between 100–400 Hz in a controlled exposure experiments in open water. Their results show a clear statistical relationship between the cellular damage detected in the sensory cells of the individuals exposed to the sound sweeps and the distance to the sound source. The authors measured the particle motion and pressure of the signals received by the animals. Due to the signal type (frequency sweep), they could only provide the maximum received levels or an estimate thereof, respectively; the maximal particle motion level was 0.7 ms^{-2} observed at 1 m depth, the pressure reached levels of 139–142 dB re $1µPa^2$. The sound pressure levels reported are only slightly higher than the hearing threshold determined for longfin squid (*Loligo pealeii*), another decapodiforme cephalopod, measured by Mooney et al. (2010). The maximum particle motion (reported in terms of particle acceleration) reported by Solé et al. (2017) is in the same order of magnitude as the behavioural thresholds measured at 100 Hz by (Packard et al. 1990) using a standing wave acoustic tube.

7.1.4. Other Benthic Invertebrate Species

Many marine invertebrates are permanently, or at least sporadically, in contact with bottom sediment. The sediment, however, does not follow exactly, or at all, the movement of the surrounding water. Therefore, exposure to underwater sound will result in a relative movement between the body of these animals and the oscillating water column. Accordingly, marine benthic invertebrates face a different situation and perception from free-swimming or neutrally buoyant animals such as demersal or pelagic fish or marine mammals. In a discussion of the pressure-related as well as the particle motion-related sensitivity in marine invertebrates, it is therefore important to also consider the propagation of vibration through the ground. For benthic organisms, it is likely that this type of vibration is of similar if not greater importance than the water-borne vibration or even the compressional component of a sound (Roberts and Elliott 2017). The published scientific information on vibration sensitivity in marine invertebrates is extremely scarce (Roberts et al. 2015, Roberts et al. 2016). Most information on vibration sensitivity has been derived from semi-terrestrial species known to use vibration in mating behaviour (Aicher and Tautz 1990). Only a small number of studies have indicated reception of vibration and behavioural responses in bivalves, which include closing syphons and, in more active molluscs, moving away from the substrate (Mosher 1972, Ellers 1995, Kastelein 2008). Nevertheless, to date, there is no convincing evidence for any significant effects induced by non-impulsive noise in benthic invertebrates.

Moreover, given the rapid attenuation of vibrational signals beyond the near field of a sound source (Morley et al. 2014), it is unlikely that these stimuli are causing more than behavioural effects (such as flight or retraction) or physiological (e.g., stress) responses.

In a field experiment, Nedelec et al. (2014) investigated the effect of long-term exposure to non-impulsive noise on the development and survival of the early life stages of the sea hare (*Stylocheilus striatus*). They found that in comparison to a control experiment with ambient-noise playback, the exposure to 12-h playbacks of small boat noise stopped development of nudibranch embryos by 21% and increased the mortality of the remaining nudibranch larvae by 22%.

Heyward et al. (2018) monitored different types of corals *in situ* before, during and after a four-day 3-D seismic survey. They found no detectable effect on soft tissues or skeletal integrity of the corals after exposure to seismic airgun signals at levels of up to 204 dB re 1 $\mu Pa^2 \cdot s$ SEL and 226 dB re 1 µPa PK. There is no further information available on noise-induced effects on benthic organisms (other than bivalves and decapods, see Section 7.1.2) specific to a particular type of sound source.

7.2. Fish

Studies on noise-induced effects on fish are mainly focused on behavioural and auditory effects.

The onset level of behavioural responses in fishes varies greatly between and within species, including between fishes of different ages and sizes, the behavioural and social context, and the motivation of the fishes. Existing data on behavioural responses do not provide a clear dose-response relationship. Consequently, it is currently impossible to determine single value thresholds for the onset of behavioural reactions. Instead, broad response and effect categories such as those proposed by Popper et al. (2014) (see Section 5.2.3) seem most reasonable and may guide regulatory decisions in this context.

Contrary to marine mammals, TTS and PTS have less ecological relevance for fishes as they can regenerate their hearing sensitivity sensory cells, therefore, affecting their fitness (i.e., including ability to communicate and mate) only temporarily. Moreover, the detection of acoustic signals is mostly mediated in fishes through particle motion rather than sound pressure, which reduces the ecological relevance of auditory impairment in fishes even further.

The fact that some fish species, however, have also the ability to detect sound pressure indicates that this sensory system has a functional role for these species and cannot be completely ignored. More information about the role of the hearing system and the particle motion sensitivity of fishes is required to allow for a more comprehensive assessment of noise-induced effects. In the absence of such information, behavioural responses and non-auditory injury are better descriptors for noise-induced effects. The susceptibility for all types of effects seems directly related to the existence, form, and function of a swim bladder, which lead to division of fish species in three categories (see Section 5.2.3 and Popper et al. (2014)).

Extreme levels of particle motion may also have the potential to injure tissues although this has not been demonstrated for any source yet (Popper et al. 2014).

7.2.1.1. Impulsive Sound Sources

7.2.1.1.1. Seismic Airguns

<u>Stress</u>

Stress effects caused by exposure to seismic signals was investigated in an *in situ* experiment on caged sea bass (*Dicentrarchus labrax*) by Santulli et al. (1999). The animals showed increased levels of various biochemical parameters as primary and secondary stress markers in their tissues after exposure to airgun emissions, while no physical trauma or mortality was observed. The physiological responses disappeared within 72 h, indicating a recovery of homeostasis following the exposure. McCauley et al. (2003) conducted a similar study in caged pink snapper (*Pagrus auratus*) but did not find any significant biochemical indicators of stress in the exposed animals.

Behavioural Responses

Pearson et al. (1992) showed that exposure to airgun sound can cause changes in schooling patterns and distribution of captive rockfish (*Sebastes* spp.). Strong 'startle' responses have been observed in some fish species at received sound levels of 200–205 dB re 1 µPa, indicating that sounds at or above this level may cause more severe behavioural reaction such as avoidance. Sound levels of this intensity are likely to occur 100 to 300 m from a seismic array (McCauley 1994). Based on this, an approximate range of 200 m was estimated as the minimum distance at which fish may start avoiding an approaching seismic source.

Santulli et al. (1999) exposed caged European sea bass (*Dicentrarchus labrax*, a demersal species) to a 2,500 in^3 seismic source. Limited response was observed at 2.5 km distance. A startle response was observed when the array was at a distance of approximately 800 m, but after passing within 180 m, fish behaviour appeared to return to normal within 1 hour. Exposures of fish in the wild would likely result in avoidance of high sound levels prior to the seismic source approaching to as close a range and to as high sound levels as the captive fish in the experiment were exposed to. Wardle et al. (2001) studied the behavioural reaction of reef-associated fishes in their natural environment in response to emissions from a single seismic airgun using underwater video and an acoustic tracking system. They observed startle responses and some changes in the movement patterns of fish. Similar to this, Hassel et al. (2004) observed startle responses in fish species exposed to airgun sounds.

Most work on the effect of airgun signals on free-swimming fishes has been conducted on demersal species. Peña et al. (2013) used an omnidirectional fisheries sonar to study the response of free-ranging herring schools to the approach of a full-scale seismic airgun survey. Throughout the study period, the herring swam slowly against the predominant northeast current, with a net displacement along with the current. The mean swimming speed after subtracting the drift velocities was 0.35 m/s, and the mean response speed in the direction away from the airgun array was 0.22 m/s. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to the transmitting seismic vessel as it approached from a distance of 27 to 2 km, over a 6-hour period. The unexpected lack of a response to the seismic survey was interpreted as a combination of a strong motivation for feeding, a lack of suddenness of the airgun stimulus, and an increased level of habituation to the repeated presentation of the same seismic signal.

Several studies in Norwegian waters found that the horizontal and vertical distributions of both pelagic and demersal fishes were altered during and after airgun operations (Skalski et al. 1992, Engås et al. 1996, Engås and Løkkeborg 2002, Slotte et al. 2004). The researchers were unable to observe the behaviour of fishes in response to the sound exposure. Instead, they measured catch rate of fishes as an indicator of fish behaviour. These studies reported pronounced reductions (up to 70% in longline fishing) in commercial catches from trawls and longlines and the wide-ranging displacement (up to 50 km, Slotte et al. 2004) of fish from fishing grounds.

Contradicting findings were made by Løkkeborg et al. (2012b, 2012a). They found changes in catch rates of all species studied, indicating that these species all responded to airgun sounds. However, they also showed that gillnet catches were doubled for some fish species during seismic shooting and only longline catch rates fell slightly. They explain these contradictory results by greater swimming activity versus lowered food search behaviour in fishes exposed to airgun sound emissions. Except for one species, they did not find any changes in abundance or displacement from fishing grounds. This may be correlated to less intense sound exposure compared with previous studies and strong habitat preference in some species. These findings are in general corroborated by the finding of Hawkins et al. (2014). The synthetic signals they used in their playback experiment contained generic impulsive signal characteristics that make the results applicable also to the behavioural effects of airgun sounds. The sprat and mackerel they investigated generally reacted to the impulsive sound exposure by dispersing and changing depths, which would make it difficult to detect the true scope of effects in a study relying on fisheries technology.

Free-swimming fishes were exposed to noise from seismic airguns in Mackenzie River (Northwest Territories, Canada), but no apparent change in their swimming direction or speed was observed as revealed by using a sonar (Cott et al. 2012). The received sound exposure levels reached 175 dB re 1 $\mu Pa^2 \cdot s$ and zero-to-peak sound pressure levels (PK) of over 200 dB re 1 µPa.

Behavioural observations of free-swimming fish conducted during a 3-D seismic survey at Scott Reef (Miller and Cripps 2013) show that seismic airgun emissions did not cause lethal or sub-lethal effects on fish near the operating array. At close range, the vessel approach caused fishes to cease their behaviours and move towards the seabed, but the effect was short-lived. Fishes began to feed and behave normally again within 20 minutes after the seismic survey vessel passed. Caged fishes displayed startle responses too infrequently to analyse. However, agitation levels increased with increasing received sound exposure level for the three holocentrid species (squirrelfishes and soldierfishes, Holocentroidei) but were not detectable for the blue-stripe sea perch (*Lutjanus kasmira*). Sonar observations of free-swimming fishes indicated that individual animals tended to move towards the seabed on approach of the operating airgun array, consistently out to 400 m either side of the survey test line. Schools of fishes moved towards the seabed within 200 m of the survey test line in response to the passage of the operating seismic source and stayed significantly closer to the seabed up to 63 minutes post-exposure. The vocal behaviour of fishes was unaffected during the seismic activity. Fish choruses remained unchanged with regards to timing and chorus level (at daily, lunar, and seasonal scales). These findings suggest that in the long term, the survey had little effect on the fish that produced the choruses. Visual census revealed that diversity and abundance of Pomacentridae (damselfishes and clownfishes) and non-Pomacentridae fish species (inhabiting shallow-slope regions) showed no significant changes after the seismic survey compared to the long-term temporal trend before the survey. Analysis of recordings from baited remote underwater video stations showed no detectable effects of the seismic survey on the diversity and abundance of deeper water fish communities at the spatial and temporal scales examined. Also, there were no signs of loss of individuals or of systematic re-distribution of individuals and species at any of the time scales examined.

The findings from the research at Scott Reef support those by Wardle et al. (2001), who exposed free ranging marine fish inhabiting an inshore reef to sounds from a seismic source (maximum received levels (RL) of 195–218 dB re 1 µPa PK). The study found that fishes exhibited a startle response to all received levels, but no avoidance behaviour were observed. They showed no signs of moving away from the reef, and exposure to the seismic noise did not interrupt a diurnal rhythm of fish gathering at dusk. Slight changes were recorded to the long-term day-to-night movements of two tagged pollack (*Pollachius sp.*), particularly when positioned within 10 m of their normal living positions. However, the seismic sound had little effect on the day-to-day behaviour of the resident fishes and invertebrates. Fewtrell and McCauley (2012) showed that fishes tended to remain lower in the water column and/or swim faster and form tighter schools during periods of close air-gun emissions.

Fish populations can be further impacted if behavioural responses result in deflection from migration paths, feeding grounds, or disturbance of spawning, thereby affecting recruitment of fish stocks. Available evidence suggested that behavioural changes for some fish species are insignificant and short-lived. The duration of effect is less than or equal to the duration of exposure and is expected to vary between species and individuals and be dependent on the properties of received sound (DFO 2004). Such a temporary short-range displacement of pelagic or migratory fish populations would have insignificant repercussions at a population level (McCauley 1994). For site-attached reef fish, spatial patterns of species richness, abundance, and diversity did not change after airgun noise emissions (Miller and Cripps 2013). The ecological significance of such effects is expected to be low, except where they may influence reproductive activity. However, researchers have observed that once acoustic disturbances are removed, fish return to normal behaviour within about 1 hour (Pearson et al. 1992, McCauley et al. 2000b, Wardle et al. 2001). In conclusion, it is evident that behavioural reactions can occur to impulsive signals such as seismic airgun impulses, but at this point there are no data that can be applied to develop guidelines regulating noise-induced behavioural effects on fishes.

TTS

McCauley et al. (2003) demonstrated that exposure to repeated emissions of a single airgun with a source level of 222.6 dB re 1µPa PK-PK from 5 to 15 m at the closest approach caused extensive damage to the sensory hair cells in the inner ear of caged pink snapper (*Pagrus auratus*). Although no mortality was observed, they found that an increased amount of epithelial damage occurred 58 days compared to 18 days post-exposure (i.e., no evidence of sensory cell regeneration). No hearing tests were performed to quantify hearing loss. The authors of the study acknowledged that the impact of exposure on ultimate survival of the fish was unclear.

Popper et al. (2005b) exposed three species of freshwater fish in a river to airgun signals at received SPL of up to 209 dB re 1 μPa (PK) and a mean SEL of up to 180 dB re 1 $\mu Pa^2 \cdot s$ and subsequently tested the animals for auditory threshold shifts. The amount of NITS induced by the noise exposure differed among the three species. Northern pike (*Esox lucius*) showed the largest shifts, broad whitefish (*Coregonus nasus*) intermediate levels of threshold shift, and lake chub (*Couesius plumbeus*) being least affected. Hearing loss increased with the number of seismic signals that the fish were exposed to, but in all cases hearing thresholds recovered within 18 hours. These same individuals were subsequently examined for sensory hair cell loss, but none was detected (Song et al. 2008). This suggests that any damage to the fishes may have occurred at an individual hair cell level but could not be detected by the methods employed in their study. Furthermore, the authors concluded that for airgun surveys conducted in rivers, the risk for fishes to be substantially affected by exposure is low as individuals would be exposed to only a few seismic impulses.

A study of auditory sensitivity in four species of tropical reef fishes following exposure to emissions from a 2,055 in^3 seismic airgun array showed that none of the four species, including the pinecone soldierfish (a species expected to have good hearing sensitivity) experienced any hearing sensitivity loss (i.e., TTS) following exposure to SEL up to 190 dB re 1 $\mu Pa^2 \cdot s$ (Hastings et al. 2008, Hastings and Miksis-Olds 2012). No detectable gross physiological damage was found in individuals from any of the seven species (McCauley and Kent 2012). The results of the hearing tests are consistent with the sound exposure guidelines proposed in Popper et al. (2014), which indicated that TTS may occur at SEL levels >186 dB re 1 $\mu Pa^2 \cdot s$, while other studies (Song et al. 2008, Popper and Hastings 2009a) indicate that TTS may occur at levels as high as SPL 205–210 dB re 1μPa (PK).

<u>Mortality</u>

There is no documented evidence that exposure to seismic airgun impulses causes mortality in fishes (Boeger et al. 2006, Normandeau Associates Inc 2012). Popper et al. (2016) investigated the possible levels of impulsive seismic airgun sound to which adult fish can be exposed without immediate mortality. They found that the two fish species in their study, with body masses in the 200–400 g range, exposed to a single-impulse of a maximum received level of either 231 dB re 1 μPa (PK) or 205 dB re 1 $\mu Pa^2 \cdot s$ (SEL), remained alive for 7 days after exposure and that the probability of mortal injury did not differ between exposed and control fish.

7.2.1.1.2. Offshore Pile Driving

<u>Stress</u>

In a comparative study by Radford et al. (2016), European seabass (*Dicentrarchus labrax*) showed heightened stress levels (indicated by elevated ventilation rates) in response to playbacks of recordings of pile driving and seismic surveys. This response diminished over time and animals were obviously desensitised after 12 weeks as they no longer showed signs of increased stress. Interestingly, no changes in growth or mortality were found in animals exposed to noise over long-term as compared to those reared with exposure to ambient-noise playback. The relevance of these findings may, however, be compromised by the fact that these experiments were conducted under laboratory conditions (Carroll et al. 2017).

In an *in situ* experiment, Debusschere et al. (2016) exposed juvenile European sea bass to offshore pile driving impulses. Their results demonstrated acute stress responses expressed by significant changes in secondary stress indicators (oxygen consumption rate and body lactate concentrations), which resulted in a temporary reduction of fitness.

<u>Behavioural Responses</u>

The published information on behavioural responses of fishes to pile driving sound is relatively scarce. Ruggerone et al. (2008) conducted a behavioural response study in juvenile Coho salmon (*Oncorhynchus kisutch*) that were held in cages next to a pile driving operation in a harbour. No apparent change in behaviour during the pile driving was reported, as less than 10% of the fish exhibited a startle response during the first or subsequent hammer strikes of each pile.

In controlled exposure experiment, Mueller-Blenkle et al. (2010) exposed Atlantic cod and sole (*Solea solea*) held in two large (40 m) net pens located in a quiet bay to playbacks of pile driving noise. They tracked their movements visually and quantified both the received sound pressure level and particle motion. Sole showed an increase in swimming speed at received peak sound pressure levels (PK) of 144–156 dB re 1µPa, and cod exhibited significant freezing response at onset and cessation of playback at received peak sound pressure levels of 140–161 dB re 1 µPa (particle motion was determined to be between 6.51×10^{-3} m/s² peak and 8.62×10^{-4} m/s² peak). The authors report a high variability in behavioural reactions across individuals and a decrease of response with multiple exposures.

In a sound playback experiment in an enclosed, quiet, coastal sea lough, Hawkins et al. (2014) exposed free-living pelagic fish to sound playback of synthetic, low-frequency, impulsive sounds, mimicking some of the features of sounds produced by pile drivers and seismic airguns. Behavioural responses of fishes were observed with a sonar/echo sounder. The fishes they encountered were predominantly sprat and Atlantic mackerel (*Scomber scombrus*) and were not accustomed to heavy disturbance from shipping and other intense sound sources. Following a short latency, sprat schools reacted to sound exposure with lateral dispersal, taking them outside the sonar beam. The fish often then reappeared at a greater depth recombined into a school. Mackerels responded by dispersing and/or a rapid depth change. The lowest received sound pressure level (PK-PK) eliciting a response in free-living sprat was 140 dB re 1 µPa, while mackerel responded to a received sound pressure level of 143 dB re 1 µPa. There was an increase in the proportion of sprat and mackerel schools responding to sound playback with increasing sound levels. The 50% response level for sprat was at a received sound pressure level (PK-PK) of 163.2 dB re 1 µPa, for mackerel schools the 50% level was reached at a peak-to-peak sound pressure level (PK-PK) of 163.3 dB re 1 µPa.

TTS

Casper et al. (2013) used a specially designed wave tube to expose hybrid striped bass (white bass *Morone chrysops* × striped bass *Morone saxatilis*) and Mozambique tilapia (*Oreochromis mossambicus*) to pile driving sounds and investigated the effects on hair cells. Exposure to 960 pile driving strikes at SEL_{24h} levels of 210–216 dB re 1 µPa²·s caused barotraumas in both species. Hair cells loss, in contrast, was only found at significant levels after exposure to the highest sound level in some striped bass and in a single tilapia.

Injury and Mortality

Casper et al. (2012) showed that fishes can recover from less severe injuries under laboratory conditions, suggesting that minor injuries do not inevitably lead to mortality. Nevertheless, in open waters, minor injuries have the potential to reduce the animal's fitness to the extent that its ability to find food decreases and its risk of being predated increases (Halvorsen et al. 2011, 2012b).

Mortality is either a direct effect of barotrauma (in the case of severe injury) or indirect if an animal is moderately injured. Halvorsen et al. (2011, 2012a, 2012b) exposed different fish species in a well-controlled acoustic environment (using a wave tube) to signals replicated from actual pile driving operations and found that the extent of injury increased with sound exposure levels and number of pile driving strikes. Their results demonstrated that an appropriate metric for guidelines may be a combination of the single strike SEL (SEL_{ss}) and the number of strikes that are used to yield the SEL value, with the understanding that at the same SEL value, higher SEL_{ss} and fewer strikes can result in the same onset of effects as a lower SEL_{ss} and more strikes (Popper et al. 2014).

Data on sound-induced direct mortality in fishes are scarce and mainly related to underwater explosions (Popper and Hastings 2009b). Observations conducted during pile driving activities showed that fish within a few metres of driving a large pile were killed (Caltrans 2001, 2004), but no data from these studies document the sound levels to which the fish were exposed or the extent of exposure before mortality occurred. At greater distances from pile driving activities, data from caged fish show no mortality and no damage that can be clearly associated with pile driving activities (Abbott et al. 2005, Nedwell et al. 2006, Ruggerone et al. 2008, Caltrans 2010b, 2010a, Houghton et al. 2010).

7.2.1.2. Non-Impulsive Sound Sources

7.2.1.2.1. Offshore Drilling

No scientific information is available on the potential of noise-induced effects on fishes following exposure to sound emitted by offshore drilling.

7.2.1.2.2. Vessels

Boat noise represents a chronic source of harassment for fish species (Popper 2003), whose communication is mainly based on low-frequency sound signals (Ladich and Myrberg 2006, Myrberg and Lugli 2006).

Stress

Wysocki et al. (2006) showed that boat noise can induce endocrine stress response in fish. Radford et al. (2016) compared the reaction of European seabass (*Dicentrarchus labrax*) to various types of sound, but found no signs of elevated stress in response to playbacks of recordings of ship passes. Nedelec et al. (2016) showed the same physiological responses in reef-associated fish after exposure to short-term exposure to vessel noise. Interestingly, these responses were diminished when the exposure continued (up to 2 weeks of repeated exposure). This desensitisation effect indicates that extrapolating results from short-term studies may lead to overestimating effects. Purser et al. (2016) exposed European eels (*Anguilla anguilla*) to playbacks of ambient coastal noise and coastal noise with passing ships. They found that juveniles in good condition do not respond differently to playbacks of ambient coastal noise and coastal noise with passing ships. In those individuals with poor body condition, by contrast, the additional noise of ship passes caused an increase in ventilation rate and a decrease in startling response to a looming predatory stimulus, thus providing evidence that noise effects can be condition-dependent.

Recent studies show that boat noise can induce endocrine stress response (Wysocki et al. 2006), diminish hearing ability, and mask intra-specific relevant signals in exposed fish species (Scholik and Yan 2002, Amoser et al. 2004b, Vasconcelos et al. 2007, Codarin et al. 2009). In addition, vessel noise can provoke short-term changes in the spatial position and group structure of pelagic fish in the water column (Buerkle 1973, Olsen et al. 1983, Schwarz and Greer 1984, Engås et al. 1995, Soria et al. 1996, Vabø et al. 2002, Mitson and Knudsen 2003, Ona et al. 2007, Sarà et al. 2007).

Auditory Masking

Scholik and Yan (2001), Vasconcelos et al. (2007), and Codarin et al. (2009) demonstrated masking effects due to vessel noise in several marine fish families. They measured decreased hearing sensitivities between 10 dB and more than 30 dB in the presence of vessel noise.

Codarin et al. (2009) investigated the effects of ambient and ship noise on representatives of three vocal fish families with different hearing abilities. In their laboratory study, they found that the noise emanating from recreational shipping substantially masked the auditory perception in these fish species, with a pronounced effect on the frequencies used for communication.

Stanley et al. (2017) modelled the effective communication range in Atlantic cod and haddock at three spawning locations. These areas are characterised by elevated levels of anthropogenic underwater sound, particularly due to commercial shipping. They found near constant high levels of low-frequency sound and consequentially a reduction in the communication space during times of high vocalisation activity for these fish species.

Behavioural Responses

Fish can respond to approaching vessels by diving towards the seafloor or by moving horizontally out of the vessel’s path, with reactions often initiated well before the vessel reaches the fish (Ona et al. 2007, Berthe and Lecchini 2016). The avoidance of vessels by fish has been linked to the high levels of infrasonic and low-frequency noise (>10 to 1000 Hz) emitted by the ships. Accordingly, it was suggested that silent ships have a higher chance of encountering more fish than noisier ones (De Robertis et al. 2010). This assumption was initially contradicted when two research vessels were compared with regard to their effect on schooling herring (Ona et al. 2007). The authors found that the reaction initiated by the silent vessel was stronger and more prolonged than the one initiated by the conventional vessel. In a comment to this publication, Sand et al. (2008) pointed out that fish are highly sensitive to particle acceleration and that the cue, in this case, may have been low-frequency particle acceleration caused by displacement of water by the moving hull in the near field of the vessel. This fact would explain the stronger response to the larger noise-reduced vessel in the study by Ona et al. (2007), which would have displaced more water as it approached.

Nedelec et al. (2016) investigated the response of reef-associated fish by exposing them in their natural environment to playback of motorboat noise. They found that juvenile fish increased hiding and ventilation rate after a short-term boat noise playback, but responses diminished after long-term playback thus indicating habituation to sound exposure over longer durations. These results were corroborated by Holmes et al. (2017) who also observed short-term behavioural changes in juvenile reef fish after exposure to boat noise as well as desensitisation over longer exposure periods.

TTS

A single study reported temporary threshold shift caused by exposure to vessel noise: Scholik and Yan (2001) exposed fathead minnows (*Pimephales promelas*) for two hours to sound playback recorded from small boats at a level of 142 dB re 1 μPa. They measured noise-induced threshold shift (NITS) of 7.8–13.5 dB at frequencies between 1–2 kHz, the most sensitive hearing range of this species.

7.3. Sea Turtles

7.3.1.1. Impulsive Sound Sources

Based on physiology, it is likely that TTS can occur in sea turtles as it does in other vertebrates. However, there is no robust information on the susceptibility of sea turtles to noise-induced effects to confirm this hypothesis. Injury or mortality have not been reported to have occurred in turtles as a result of noise emissions during seismic surveys. Because of their rigid external anatomy, it is possible that sea turtles are highly protected from impulsive sound effects (Popper et al. 2014).

7.3.1.1.1. Seismic Airguns

Few data exist on the effects of seismic airgun activity on sea turtles. Avoidance responses of sea turtles to low frequency tones have been demonstrated in caged animals (Lenhardt 1994). O'Hara and Wilcox (1990) found that sea turtles in a canal would avoid an area with an airgun, although the received level at the sea turtles was not measured. Moein et al. (1995) monitored the behaviour of penned loggerhead turtles to airguns firing at 175–179 dB re 1 μPa at 1 m. Avoidance to the airguns was observed at first exposure, but the sea turtles habituated to the sound over time. Behavioural responses by sea turtles, including rising to the surface and altered swimming patterns, have been elicited in caged animals exposed to an airgun at received levels of 166 dB (rms) re 1 μPa (McCauley et al. 2000). Weir (2007) reported no obvious behavioural avoidance by several species of sea turtle at the sea surface to a seismic survey as recorded by ship-based observers, although fewer turtles were seen at the surface when the airguns were firing.

There is not information on onset levels for TTS, injury or mortality of sea turtles from exposure to seismic airgun signals. It is likely that sea turtles would be subject to recoverable injury or TTS from exposure to seismic airgun signals; it is also possible that these signals could lead to direct or indirect mortality in sea turtles that are very close to the source, although preliminary data suggest that sea turtles are highly resistant to high intensity explosives (Ketten et al. 2005), making it likely that they would also be resistant to damage from seismic airguns. Accordingly, Popper et al. (2014) adopted onset levels for fish that do not hear well assuming that these would be conservative for sea turtles.

7.3.1.1.2. Offshore Pile Driving

No scientific information is available on the potential of noise-induced effects on sea turtles following exposure to sound emitted by offshore pile driving.

7.3.1.2. Non-Impulsive Sound Sources

No scientific information is available on the potential of noise-induced effects on sea turtles following exposure to non-impulsive sounds such as emitted by vessel operations or offshore drilling.

7.4. Marine Mammals

Marine mammals in general and cetaceans (whales, dolphins and porpoises) in particular received most scientific attention of all marine taxonomic groups with regard to the potential noise-induced effects. This is reflected in the larger volume of scientific literature on the various relevant aspects. However, due to the complexity of cause-effect relationships in this context, the elusive lifestyle of cetaceans and the relative difficulty for conducting well controlled experiments on (most of) these species the overall assessment remains difficult and incomplete. The following sections provide an overview of the existing knowledge and understanding of the potential noise-induced effects in cetaceans. Like for the other marine taxa, this is a quickly evolving field of ongoing research.

7.4.1. Stress

The available literature indicates that marine mammals increase the secretion of endocrine hormones and alter their cardiovascular function following relatively intense noise exposure in some cases.

7.4.1.1. Impulsive Sound Sources

7.4.1.1.1. Seismic Airguns

Non-auditory physiological effects do include changes in stress-related hormone levels and blood cell count (aldosterone and monocytes) levels in bottlenose dolphins; epinephrine, norepinephrine, and dopamine levels in beluga exposed to sounds from a seismic watergun (e.g., studies of beluga exposed to sounds from a seismic watergun in Romano et al. 2004).

7.4.1.1.2. Offshore Pile Driving

No scientific information is available specific for stress responses to exposure to sound from impact pile driving.

7.4.1.2. Non-Impulsive Sound Sources

No scientific information is available specific for stress responses to exposure to non-impulsive sounds as generated by vessel operations and offshore drilling.

7.4.2. Behaviour

7.4.2.1. Impulsive Sound Sources

7.4.2.1.1. Seismic Airguns

For exposure to pulsed sounds specifically, there is evidence that the behavioural state of baleen whales combined with their proximity to seismic sources affects how the whales react to the sounds (McCauley et al. 1998a, McCauley et al. 1998b, Gordon et al. 2003). Several species of baleen whales have exhibited avoidance behaviour to sounds from seismic surveys (Richardson et al. 1995), including bowhead whales (*Balaena mysticetus*) avoiding distant seismic airguns at received levels of SPL of 120–130 dB re 1 µPa during fall migration (Richardson et al. 1999). Feeding bowhead whales in the summer were more tolerant to airgun sounds—avoiding airguns only when received levels reached 152–178 dB re 1 µPa, about 40 dB higher than avoidance levels of the same population of migrating whales (Richardson et al. 1995). McDonald et al. (1995) observed that a blue whale stopped vocalising when within 10 km of an active seismic vessel.

Humpback whales tended to avoid seismic surveys with resting females diverting to remain 7–12 km away, though males were occasionally attracted to the sounds (McCauley et al. 2000b). During the first 72 h of a 10-day seismic survey, fin whales appeared to move away from the airgun array, with apparent displacement persisting at least 14 days beyond the 10-day duration of seismic airgun activity (Castellote et al. 2012). Migrating humpback whales avoided a 3130 in^3 commercial seismic airgun array and responded with decreased dive time, elevated respiration rates, increased breaching rates, decreased tail and pectoral fin slapping (Dunlop 2016), and reduced swim speed (Dunlop et al. 2017a). These behavioural responses were lessened or absent with smaller array volumes, though the migrating humpback whales avoided the vessels and their associated seismic sources (Dunlop et al. 2015, Dunlop et al. 2016). The behavioural response studies conducted by Dunlop et al. (2017b, 2018) suggest that proximity of the seismic airgun vessel and received level are important factors in triggering a response in humpback whales. Their results indicate that the size of the source is not a significant factor in predicting an avoidance response, nor the received level alone. Instead, it seems to be a combination of received level and proximity to the airgun source, in that for both aspects a threshold must be exceeded to trigger a greater magnitude of response. Similar to these findings, DeRuiter et al. (2013) reported that a beaked whale (*Ziphius cavirostris*) responded to nearby playback of naval sonar but not to signals from a distant real source.

Sperm whales in the Gulf of Mexico (GoM), where seismic surveys have been conducted nearly continuously for decades, were found to maintain their behaviour state when subjected to seismic sound sources, suggesting habituation to this relatively loud sound source (Miller et al. 2009). Similar results have been observed in the Arctic, where no changes were recorded in typical sperm whale vocal patterns during feeding dives in proximity to seismic survey noise (Madsen et al. 2002). Conversely, sensitization to sound exposure can occur and would lead to an increased behavioural responsiveness. The Sperm Whale Seismic Study (SWSS) conducted controlled exposure experiments in the GoM to determine the direction of movement in eight tagged sperm whales over a series of 30 min intervals during pre-exposure, ramp-up, and full-array firing (Jochens et al. 2008). Results showed no horizontal avoidance to received airgun sounds of <150 dB re 1 µPa (SPL) and diving and foraging rates were affected only in one individual (longer resting period at the surface and diving immediately following the final airgun transmission).

In response to seismic airgun sounds, small toothed whales showed the strongest lateral spatial avoidance, baleen whales and killer whales showed more localised spatial avoidance, long-finned pilot whales (*Globicephala melas*) only showed a change in orientation, and sperm whales did not show any significant avoidance response (Stone and Tasker 2006). A report from US Bureau of Ocean Energy Management (BOEM; Barkaszi et al. 2012) showed each species group (all cetaceans, baleen whales, delphinids, and sperm whales) was sighted at significantly greater distances from the seismic vessel when the source was operating at full power compared with times when the source was turned off, suggesting spatial avoidance to the seismic source. Pirotta et al. (2014) found that the acoustic activity of harbour porpoises in the northeast of Scotland was positively related to distance from a seismic source vessel. Probable avoidance of active seismic sources by odontocetes is also suggested by analysis of the reports of observers on seismic vessels off the UK collated by the UK Joint Nature Conservation Committee (Stone 2003). In contrast to these reports of avoidance in some whales, other observations suggest that sperm whales show little response and are not excluded from habitat by seismic surveys (e.g., Rankin and Evans 1998).

7.4.2.1.2. Offshore Pile Driving

<u>Cetaceans</u>

Kastelein et al. (2013) documented behavioural responses of a captive harbour porpoise to playbacks of pile driving sounds in a controlled experiment. Their results showed that above a received SPL of 136 dB re 1 µPa the porpoise's respiration rate increased in response to the pile driving sounds. At higher levels, the porpoise also jumped out of the water more often. In another study on a captive harbour porpoise (Kastelein et al. 2018) documented that these animals are capable of maintaining an increased swim speed of 2 m^{s-1} throughout 30 min, when exposed to pile driving playbacks with an SEL_{ss} of 145 dB re 1 $\mu Pa^2 \cdot s$.

There is evidence to suggest that harbour porpoises can habituate and/or adapt to impulsive anthropogenic sound in their environment (Cox et al. 2001). Dähne et al. (2013) and Brandt et al. (2011), however, demonstrated avoidance of offshore pile driving activities by harbour porpoises over a distance of 20 km.

Pinnipeds

A study on the effects of pile driving on ringed seals (*Phoca hispida*) at Northstar Island, Alaska, did not show dramatic reactions to underwater pile driving impulses with received SPL of at least 150 dB re 1 µPa (Blackwell et al. 2004). A study conducted in the North Sea, however, shows that offshore pile driving can cause temporary, localized displacement of marine mammals; during construction of offshore wind farms, harbour seals (*Phoca vitulina*) have demonstrated displacement of up to 25 km from the centre of the pile driving site (Russell et al. 2016).

7.4.2.1.3. Other impulsive sources

A recent report by Southall et al. (2013) concluded that multibeam echosounders used in offshore energy development projects may have played a significant role in a mass stranding of melon-headed whales, most likely by affecting their behaviour (see Section 6.5). Behavioural responses by toothed whales are also documented for higher frequency (>10 kHz) sonar such as multibeam echosounders (Vires 2011, Quick et al. 2016, Cholewiak et al. 2017). Controlled behavioural response studies documented reduced foraging effort in response to pulsed 1–2 kHz sonar (Isojunno et al. 2016). Similar responses were also observed following playbacks of killer whale (i.e., potential predator) sounds (Curé et al. 2016, Isojunno et al. 2016).

7.4.2.2. Non-Impulsive Sound Sources

7.4.2.2.1. Offshore Drilling

There is limited information on behavioural responses of marine mammals to sound emitted from offshore drilling activities. Malme et al. (1984) exposed migrating grey whales (*Eschrichtius robustus*) to playbacks of sounds recorded from a drillship and a drilling platform. They documented onset of behavioural reactions (deflection from migration route, i.e. avoidance) for 10% of the observed animals at received SPL of 110 dB and 114 dB re 1 µPa, respectively; 50% of the animals reacted at received SPL of 117 dB re 1 µPa and 90% reacted at received SPL of 122 and >128 dB re 1 µPa, respectively.

Richardson et al. (1991) documented behavioural reactions of spring-migrating bowhead whales (*Balaena mysticetes*) to playback of recorded drilling sound near the arctic ice. The whales showed an increased turning frequency at a received SPL of 114 dB re 1 µPa and strong behavioural changes (without turning away from the projector) at received SPL of 124 dB re 1 µPa. The received SPL at their typical closest point of approach to the sound projector was 131 dB re 1 µPa.

Blackwell et al. (2017) recorded the underwater sound of offshore drilling with six arrays of directional recorders and identified and localised bowhead whale calls produced within 2 km of each recorder array using triangulation. The analysis showed that with increasing tone levels, bowhead whale calling rates initially increased, peaked, and then decreased. Increasing call repetition rates can be a viable anti-masking strategy, i.e. to compensate for decreased detectability of signals arising due to increased background noise. Meanwhile, as noise levels increase further, the benefits likely decreases because information transfer (i.e. communication) becomes increasingly less efficient and eventually impossible.

7.4.2.2.2. Vessels

Mysticetes

With regard to non-impulsive sounds such as those produced by ships, the review by Southall et al. (2007) found no or limited responses by low-frequency cetaceans to non-impulsive sound at received levels up to 120 dB re 1 µPa, but an increasing probability of avoidance and other behavioural responses.

Humpback whales off the Australian east coast exhibited great variation in behavioural responses to seismic survey vessels with the airguns turned off. While no behavioural change was seen in some trials, others revealed a decrease in dive duration, travel speed, and the number of breaches (Dunlop et al. 2015, Dunlop 2016, Dunlop et al. 2017a, Dunlop et al. 2017b, Dunlop et al. 2018). As pointed out above, their results indicate a combined factor of received sound level and proximity of sound sources (seismic airguns and vessel) influencing the onset and strength of the animals responses. Tsujii et al. (2018) found that humpback whales moved away from large vessels, while others noted changes in respiratory behaviour (Baker and Herman 1989, Frankel and Clark 2002) and a cessation of foraging activities (Blair et al. 2016). However, in a controlled exposure experiment using a tactical sonar as sound source, most humpback whales did not respond to sonar vessels with the sonar turned off (Sivle et al. 2016, Wensveen et al. 2017). The large number of studies on humpback whales and the resulting variety of documented responses demonstrate that context affects behaviour and cause-effect relationships are not fully understood yet.

North Atlantic right whales (*Eubalaena glacialis*) show no behavioural response to ship noise at all, or at least not to received SPL of 132–142 dB 1 µPa from large ships passing within 1 nm distance, nor to received SPL of 129–139 dB re 1 µPa (main energy between 50 and 500 Hz) from ship noise playback (Nowacek et al. 2004a).

Blair et al. (2016) found a reduced foraging effort (slower descent rates and fewer side-roll feeding events on sand lance fish per dive) in humpback whales with increasing received levels (RL) from ship traffic. A general connection between noise and foraging effort was established but no thresholds for onset of behavioural responses could be deduced from their results. In the Western Mediterranean Sea Campana et al. (2015) documented a much higher sightings rate of cetaceans in areas of low vessel density compared to heavily trafficked areas with one general exception, that is, fin whales and deep sea diving cetaceans generally avoided ships except for an area in the central Ligurian Sea.

<u>Odontocetes</u>

In the case of beaked whales, much effort has been spent on understanding the potential effects of ship-based sonar transmissions given coincident strandings and naval exercises (e.g., DeRuiter et al. 2013, Sivle et al. 2015, Kvadsheim et al. 2017). The effects of ship noise without sonars have been investigated less. Using passive acoustic monitoring and acoustic tags, ship noise at received SPL of approximately 135 dB re 1 µPa (0.1–45 kHz) affected beaked whale foraging by reducing both the horizontal area in which animals foraged and the number of successful prey captures (as indicated by the number of feeding buzzes recorded), with foraging efficiency reduced by >50% (Aguilar Soto et al. 2006, Pirotta et al. 2012). Similarly, fewer clicks were recorded of sperm whales (*Physeter macrocephalus*) during vessel passes (Azzara et al. 2013), and decreases in surface time, respiration interval, and the number of ventilations were reported in the presence of whale-watching boats (Gordon et al. 1992). A different study found no decrease of sperm whale acoustic detections in ship noise (André et al. 2017). Rather, an increase in sperm whale acoustic and visual detections was found near longline fishing vessels, and propeller cavitation noise (to be exact, changes in that noise corresponding to typical operational changes in longline fishing vessel speeds) was identified as the ‘dinner bell’ attracting sperm whales to depredate (Thode et al. 2007). Such diverse responses (avoidance, no response, and attraction) highlight the importance of context in assessments of underwater noise.

Lesage et al. (1999) revealed that belugas reduced their overall call rate in the presence of vessels but increased the emission and repetition of specific calls and shifted to higher frequency bands.

Killer whales (*Orcinus orca*) in British Columbia, Canada, and Washington State, USA, have recently received much attention with regards to impacts from ships, given the steady decline in their population size. Changes in behaviour (i.e., less foraging and increased surface-active behaviour), respiration, and swim speed and direction occurred at received SPL above 130 dB re 1 µPa (0.01–50 kHz), and the Lombard effect (i.e., increased source level and vocalization duration) has been reported in ship noise levels above 98 dB re 1 µPa (1–40 kHz) (Williams et al. 2002, Foote et al. 2004, Holt et al. 2009, Lusseau et al. 2009, Noren et al. 2009, Holt et al. 2011, Williams et al. 2014). This geographic area has seen a lot of ship noise recording, quantification, and impact modelling studies (e.g. Erbe 2002, Erbe et al. 2012, Erbe et al. 2014, Williams et al. 2015, Cominelli et al. 2018, Joy et al. 2019).

Beluga whales lost pod integrity in response to icebreakers, commenced rapid movement, asynchronous and shallow dives, and changed their vocal behaviour (i.e., vocalisation types) at received SPL of 94–105 dB re 1 µPa (20–1000 Hz), while narwhals changed their locomotion (i.e., exhibited more directed and slower movement, became motionless, and sank) and fell silent at received SPL of about 124 dB re 1 µPa (20–1000 Hz) (Cosens and Dueck 1988, Finley et al. 1990). Since the 1990s, beluga whale responses to boats and ships have been studied more extensively in the St. Lawrence Estuary, Canada. Here, beluga whales have shown increasing avoidance (i.e., increased dive duration and swim speed) with the number of boats, as well as other changes in both physical and acoustic behaviour (Blane and Jaakson 1994, Lesage et al. 1999). The Lombard effect has been demonstrated as an increase in source level, vocalisation rate, and frequency (i.e., shift to higher frequencies; Lesage et al. 1999, Scheifele et al. 2005).

Dolphins were displaced or changed their site occupancy in response to vessel traffic (Lusseau 2005, Bejder et al. 2006, Rako et al. 2013, Pirotta et al. 2015, Pérez-Jorge et al. 2016). They altered their movement patterns within an area in response to vessel traffic, with animals changing their direction of travel, beginning to travel erratically, or significantly increasing traveling speeds when approached by vessels (Au and Perryman 1982, Nowacek et al. 2001, Mattson et al. 2005, Lemon et al. 2006, Lusseau 2006, Christiansen et al. 2010, Marley et al. 2017b).

Groups of Pacific humpback dolphins (*Sousa chinensis*) that contained mother-calf pairs increased their rate of whistling after a boat transited the area (Van Parijs and Corkeron 2001). The authors postulated that vessel sounds disrupted group cohesion, especially between mother-calf pairs, requiring them to re-establish by vocal contact after boat noise masked their communication.

Marley et al. (2017a) found that Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Fremantle Inner Harbour (WA) significantly increased their average movement speeds in high vessel densities but only for some activity states. Behavioural budgets also changed in the presence of vessels, with animals spending more time travelling and less time resting or socialising.

Watercrafts can cause a shift in dolphin behavioural budgets, generally increasing time spent travelling whilst decreasing time spent resting and socializing (Lusseau 2003, Constantine et al. 2004, Stensland and Berggren 2007, Arcangeli and Crosti 2009, Steckenreuter et al. 2012, Marley et al. 2017b). Other changes in behaviour can include alterations to dive patterns, displays of breathing synchrony, and changes in inter-animal distances (Janik and Thompson 1996, Nowacek et al. 2001, Hastie et al. 2003, Kreb and Rahadi 2004, Stensland and Berggren 2007).

Polacheck and Thorpe (1990) noted that harbour porpoises tended to swim away from approaching vessels. Off the western coast of North America, Barlow (1988) observed that harbour porpoises within 1 km of a survey vessel moved rapidly out of its path. Teilmann et al. (2013) reported on a single observation of a fast ferry passing apparently very close to a harbour porpoise at high speed. When the vessel appeared in the recording, the animal ascended to the surface and ceased echolocation. When the received levels were above approximately 115 dB re 1µPa (SPL), the animal dove and speeded up.

Pinnipeds

A study using acoustic tags (DTAGs) that record sound and behaviour concurrently showed that harbour and grey seals (*Halichoerus grypus*) were exposed to vessel noise 2.2–20.5% of their time at sea (Mikkelsen et al. 2019). In response to vessel noise, a tagged seal changed its diving behaviour, switching quickly from a dive ascent to descent (Mikkelsen et al. 2019). This observation agrees with descriptions of changes in diving reported from a juvenile northern elephant seal (*Mirounga angustirostris*) (Fletcher et al. 1996, Burgess et al. 1998).

Sirenia

Manatees (*Trichechus spp*.) respond to approaching boats by often changing their orientation (heading or roll), depth, diving behaviour, behavioural state, and swimming speed (Nowacek et al. 2004b, Miksis-Olds et al. 2007b, Rycyk et al. 2018). Such responses to vessels were more pronounced for vessels in close proximity and travelling at speed (Nowacek et al. 2004b). Dugongs were also affected by close boat approaches and less likely to continue feeding when vessels travelled within 50 m (Hodgson and Marsh 2007). Manatees foraged in habitat with lower ambient noise (that included vessel noise below 1 kHz), particularly at times with less boat density (Miksis-Olds et al. 2007a). Playback experiments simulating different boats at different speeds approaching to within 10 m supported earlier behavioural response studies that manatees swam to deeper waters in the presence of boat noise (Nowacek et al. 2004b).

7.4.3. Masking

Masking reduces the communication space of marine mammals (Clark et al. 2009, Hatch et al. 2012). A calculation of reductions in communication range can be a useful proxy for impact. So far, a direct assessment and quantification of masking effects in wild animals has proven impossible (Tougaard et al. 2015). It depends on the positions of the signalling and the receiving animal relative to the sound source and to each other. In humpback whales, tonal and grunting sounds acting as contact calls between a mother and its calf were recorded at comparatively low levels (Videsen et al. 2017). While there is controversy about the validity of conclusions, such low levels would create a small communication space (<100 m) that, in turn, would be sensitive to increases in ambient noise.

Most studies related to masking effects in marine mammals have investigated the auditory parameters that are most relevant in this context, such as auditory sensitivity, frequency-tuning (critical bandwidth and critical ratio), auditory integration time, and critical interval.

Marine mammals employ various methods to compensate for masking sounds to a limited degree. They may increase the amplitude of their calls (referred to as the Lombard effect) or change spectral and temporal properties of vocalisations such as frequency content (Parks et al. 2011, Hotchkin and Parks 2013).

As ambient noise levels increase, killer whales have been known to increase the amplitude of their calls (Holt et al. 2009). Right whales increase the amplitude of their calls or react to the presence of noise by changing vocalisation properties such as frequency content (Parks et al. 2011, Hotchkin and Parks 2013). North Atlantic right whales produced calls with a higher average fundamental frequency and lowered their call rates in high noise conditions (Parks et al. 2007a, 2009).

Erbe et al. (2016b) reviewed the current knowledge on masking in marine mammals, summarising data on marine mammal hearing as they relate to masking and discussing masking release processes of receivers. The variability seen in auditory sensitivity (Section 5.1.4) indicates the variability seen with respect to auditory masking.

7.4.3.1. Impulsive Sound Sources

7.4.3.1.1. Seismic Airguns

Studies show North Atlantic right whales produced calls with a higher average fundamental frequency and lowered their call rate in high noise conditions (Parks et al. 2007a, 2009), whereas blue whales have been recorded increasing their rate of social calling in the presence of signals emitted during a seismic exploration survey (Di Iorio and Clark 2009).

Bowhead whales were found to increase their calling rate in response to seismic airgun signals at low levels (approximately 94 dB re 1 $\mu Pa^2 \cdot s$ SEL, integrated over 10 minutes) (Di Iorio and Clark 2009). However, when those signals exceeded approximately 127 dB re 1 $\mu Pa^2 \cdot s$ SEL, their calling rate began to decrease, and when it reached approximately 160 dB re 1 $\mu Pa^2 \cdot s$ SEL the whales stopped calling completely (Blackwell et al. 2015). Note that the levels were measured with a receiver within 2 km of the whales; therefore, the received levels at the whales are approximations.

Castellote et al. (2012) reported that male fin whales from two different subpopulations not only modified their song characteristics during increased ambient noise conditions but also left the area for an extended period during seismic airgun activity, not returning for 14 days.

Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (Richardson et al. 1986, McDonald et al. 1995, Greene et al. 1999a, 1999b, Smultea et al. 2004, Holst et al. 2005b, 2005a, Holst et al. 2006, Dunn and Hernandez 2009, Holst et al. 2011, Nieukirk et al. 2012, Thode et al. 2012, e.g., Bröker et al. 2013, Cerchio et al. 2014, Sciacca et al. 2016).

Sperm whales ceased vocalising when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies of sperm whales found that they continued vocalising in the presence of seismic pulses (Madsen et al. 2002, Tyack et al. 2003, Smultea et al. 2004, Holst et al. 2006, Jochens et al. 2008, Holst et al. 2011, Nieukirk et al. 2012). Madsen et al. (2006a) noted that airgun sounds would not be expected to cause significant masking of sperm whale calls given the intermittent nature of airgun pulses. Dolphins and porpoises are also commonly heard vocalising while airguns are operating (Gordon et al. 2003, Smultea et al. 2004, Holst et al. 2005a, 2005b, Potter et al. 2007, Holst et al. 2011).

7.4.3.1.2. Offshore Pile Driving

Madsen et al. (2006b) concluded that impact pile driving impulses have little potential to mask the auditory perception of marine mammals (cetaceans and pinnipeds) due to the short duration and low duty cycle of individual pile driving impulses. The masking potential of impulsive sound can gradually increase over distance due to dispersion while SPL are decreasing due to spreading loss, thus reducing a potential masking effect.

7.4.3.2. Non-Impulsive Sound Sources

7.4.3.2.1. Offshore Drilling

There is no information on auditory masking effects of sound emitted from offshore drilling activities for marine mammals. Studies reporting masking effects caused by vessels noise (below) may provide insight into the potential masking effects caused by offshore drilling; however, extrapolating from one source to another can be done but dissimilarities in sound spectra have to be taken into account.

7.4.3.2.2. Vessels

<u>Mysticetes</u>

Studies show North Atlantic right whales produced calls with a higher average fundamental frequency and lowered their call rate in high noise conditions (Parks et al. 2007a, Parks et al. 2009), whereas blue whales have been recorded increasing their discrete audible calls during a seismic survey (Di Iorio and Clark 2009) and when ship sounds were nearby (Melcon et al. 2012).

Grey whales (*Eschrichtius robustus*) have a limited repertoire of low-frequency (40–4000 Hz) vocalisations, which overlap with vessel noise (Dahlheim et al. 1984, Moore and Ljungblad 2012, Dahlheim and Castellote 2016, Burnham et al. 2018). In the presence of ships and boats, grey whales increased their vocalisation rate, and at times of increased outboard engine noise, received levels from grey whales were higher (interpreted as an increase in source levels; Dahlheim 1987, Dahlheim and Castellote 2016).

Humpback whales in Glacier Bay National Park, AK, United States of America, are prone to high noise exposures from tourism vessels. They have been shown to increase the amplitude of their vocalizations by 0.8 dB for every 1.0 dB increase in ambient noise, while also vocalising less frequently (Frankel and Gabriele 2017, Fournet et al. 2018). Similarly, singing individuals near Chichi-jima Island ceased singing after a passenger-cargo vessel passed within 1400 m (Tsujii et al. 2018).

Blue whales increased the frequency of their discrete, audible calls if ships were nearby (Melcon et al. 2012).

<u>Odontocetes</u>

Bottlenose dolphins (*Tursiops truncatus*) produced more whistles when boats approached (Buckstaff 2004) and emitted lower frequency and longer whistles when interacting with dolphin-watching boats, particularly during foraging activities (May-Collado and Quiñones-Lebrón 2014). Furthermore, Luís et al. (2014) discovered that the mean overall call rates decreased significantly in the presence of operating vessels. These changes in call emission rates and temporary shifts in whistles characteristics may be a vocal response to the proximity of operating vessels, facilitating communication in this busy noisy estuary. Similarly, high-speed ferry noise has been demonstrated to have implications for harbour porpoise (Hermannsen et al. 2014). For killer whales (*Orcinus orca*), an increased source level and vocalization duration has been reported in the presence of ship noise levels above 98 dB re 1 µPa rms (1–40 kHz) (Foote et al. 2004, Holt et al. 2009, Holt et al. 2011).

Dolphins have been observed to alter their whistle characteristics, such as their frequency range, in elevated noise conditions or in the presence of vessels (Morisaka et al. 2005, May-Collado and Wartzok 2008, Papale et al. 2015, Heiler et al. 2016, Marley et al. 2017b). Changes to whistle duration have also been reported (May-Collado and Wartzok 2008, May-Collado and Quiñones-Lebrón 2014), as have increases in whistle production rates (Scarpaci et al. 2000, Van Parijs and Corkeron 2001, Buckstaff 2004); Guerra et al. 2014; Martins et al. 2018).

Aguilar-Soto et al. (2006) reported that noise from a passing vessel masked the ultrasonic vocalisations of a Cuvier's beaked whale and reduced the maximum communication range by 82% when exposed to a 15-dB increase in ambient sound levels at the vocalisation frequencies; the effective detection distance of the Cuvier's beaked whale's echolocation clicks was reduced by 58%.

Pinnipeds

Underwater noise from watercraft has the potential to mask or alter the communication of pinnipeds. Bagočius (2014) showed that grey seal vocalizations recorded underwater in captivity overlapped with the noise spectrum of a vehicle/passenger ship. Terhune et al. (1979) reported a decrease in the loudness of underwater harp seal (*Pagophilus groenlandicus*) vocalizations after the presence of a vessel was recorded acoustically near whelping sites in the Gulf of St. Lawrence. This may have reflected a change in seal vocalizations or the movement of seals away from the recording area (Terhune et al. 1979).

7.4.4. TTS/PTS

Noise-induced physical impacts from exposure to non-impulsive sound have not been directly observed or measured in free-ranging marine mammals. A number of studies have been conducted on marine mammals in controlled conditions to investigate noise-induced threshold shift phenomena. The experiments have focused on measuring TTS[4] exposed to intense tones and band-limited noise with various sound pressure levels, frequencies, durations, and temporal patterns. These studies have been performed with dolphins and belugas, and a harbour porpoise exposed to tones with durations ranging from 1 s to 1 h. Most of these studies employed non-impulsive exposures, though four studies used intermittent tones (Mooney et al. 2009, Finneran et al. 2010, Kastelein et al. 2014, Kastelein et al. 2015b). Tonal signals may be used to represent the effects of military sonars, fish finders, depth sounders, and other sources emitting steady-state, narrowband signals. The studies showed that the temporal pattern of noise exposure affects the resulting threshold shift and for intermittent noise, the quiet periods between noise exposures allow some recovery of hearing compared to noise that is continuously present with the same total SEL (Ward 1997, Finneran et al. 2007). For continuous exposures with the same SEL but different durations, the exposure with the longer duration will tend to produce higher levels of TTS.

Finneran (2015) and Finneran et al. (2017) provide reviews and a comprehensive assessment of the existing information on noise-induced TTS in marine mammals. These publications provided the basis for the most recent set of underwater noise regulations in the US (NMFS 2018).

7.4.4.1. Impulsive Sound Sources

In marine mammals, the onset level and growth of TTS (i.e. the increase of TTS with increasing sound exposure levels) is frequency specific, depends on the temporal pattern, duty cycle, and the hearing test frequency of the fatiguing stimuli (Finneran 2015, Finneran et al. 2017). Exposure to intense impulsive noise might be more hazardous to hearing than non-impulsive noise, and there is a positive relationship between exposure duration and the amount of TTS induced. TTS can accumulate across multiple exposures, but the resulting TTS will be less than the TTS from a single, continuous exposure with the same total SEL. Sounds generated by seismic airguns, pile driving and mid-frequency sonars have directly been tested and proven to cause noise-induced threshold shifts in marine mammals at high received levels. Finneran (2015) reviewed the current state of knowledge on TTS and PTS. TTS typically decreases in marine mammals relative to the logarithm of the increasing recovery time. There is, however, considerable individual difference in all TTS-related parameters between subjects and species tested so far.

PTS is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in marine mammals. Regeneration of sensory cells, as known to occur in fishes, has

[4] No PTS has been performed on marine mammals.

not been documented for any marine or terrestrial mammal. Onset levels of PTS onset are typically extrapolated from TTS onset levels and assumed growth functions (Southall et al. 2007).

The role of the temporal pattern of sound on TTS in marine mammals has been studied in MF and HF cetaceans (Mooney et al. 2009, Finneran et al. 2010, Kastelein et al. 2014, Kastelein et al. 2015b).

7.4.4.1.1. Seismic Airguns

Cetaceans

Only a few studies have investigated TTS in marine mammals in response to exposure to impulsive sounds such as airgun impulses. Lucke et al. (2009) tested the effect of a single airgun on a male harbour porpoise. They documented onset of TTS at received (unweighted) SEL of 164 dB re 1 µPa^2·s. This equates to a (HF) weighted SEL_{24h} of 140 dB re 1 µPa^2·s (NMFS 2018). The main energy of the fatiguing stimulus (airgun pulse) was centred below 500 Hz, but a substantial amount of energy was also present at higher frequencies.

Kastelein et al. (2017b) exposed a harbour porpoise to 10 and 20 consecutive airgun impulses at received SEL_{24h} of 188–191 dB re 1 µPa^2·s with a mean shot intervals of around 17 seconds. TTS of ~4.4 dB was measured at 4 kHz.

Finneran (2015) tested the exposed three bottlenose dolphins to 10 impulses produced by a seismic airgun. The highest exposures were conducted at peak sound pressure levels (PK) of 210 dB re 1 µPa, peak-peak sound pressure levels (PK-PK) of 212 dB re 1 µPa, and cumulative (unweighted) SEL_{24h} of 195 dB re 1 µPa^2·s. This exposure induced 9 dB TTS in one animal at 8 kHz.

In other studies, bottlenose dolphins exposed to multiple airgun impulses up to 195 dB SEL did not experience any TTS (Finneran et al. 2015). Two of the three test animals were observed turning their heads away from the sound source, suggesting that they might be anticipating the next impulse and potentially self-mitigating the received levels (Finneran et al. 2015).

Pinnipeds

Two previously untested, pinniped species from the Arctic, a spotted seal (*Phoca largha*) and a ringed seals (*Pusa hispida*) were exposed to impulsive noise from a seismic airgun before their hearing sensitivity was measured with a psychoacoustic method at 100 Hz (Reichmuth et al. 2016). Even at a received unweighted SEL of up to 181 dB re 1 µPa^{2}s and peak-to-peak pressure level (PK-PK) of up to 207 dB re 1 µPa no evidence for TTS was found. The authors conclude that their findings confirm that existing regulatory guidelines in the US for single impulse noise exposures are conservative for seals.

7.4.4.1.2. Offshore Pile Driving

Cetaceans

In a study using playbacks of pile driving sounds, Kastelein et al. (2016) exposed harbour porpoises to a maximum single-strike unweighted broadband SEL of 145 dB re 1 µPa^{2}s and a cumulative SEL_{24h} of up to 187 dB re 1 µPa^2·s. TTS increased from 0 dB after 15 min exposure to 5 dB after 360 min exposure. Based on their results, they calculated an onset of TTS for this type of sound at a SEL_{24h} of ~175 dB re 1 µPa^2·s.

Kastelein et al. (2015a) tested the auditory tolerance of a harbour porpoise to playbacks of pile driving sounds. Using a psychoacoustic technique, they measured the animal’s hearing sensitivity at frequencies between 0.5 and 125 kHz for TTS. After one hour of exposure (2760 strikes) at single strike unweighted SEL 146 dB re 1 µPa^{2}s and a SEL_{24h} of 180 dB re 1 µPa^{2}s, TTS of 2.3 dB and 3.6 dB occurred at 4 kHz and 8 kHz, respectively, but at no other frequency tested. The recovery occurred within 48 min. The average cumulative, weighted SEL_{24h} from these exposures is approximately 144 dB re 1 µPa^2·s.

Pinnipeds

Kastelein et al. (2018) exposed harbour seals in a controlled study to low received playback levels of pile driving impulses and documented TTS of 3.9 dB at 4 kHz after exposure over 360 minutes. The TTS onset level was found at an SEL of 192 dB re 1 µPa^{2}s.

7.4.4.2. Non-Impulsive Sound Sources

Acoustic emissions from offshore drilling and vessel operations have not been tested for their potential for causing TTS in marine mammals. In the absence of information for these types of acoustic signatures, conclusions on potential effects and thresholds can be drawn from research on TTS effects of other non-impulsive sounds such as (military) sonar signals, or from studies using tones or band-limited signals as acoustic stimuli.

7.4.5. Mortality

7.4.5.1. Impulsive Sound Sources

There is no direct evidence for the potential of seismic airgun and impact pile driving impulses to cause mortality in marine mammals. Exposure to noise from seismic surveys has been implicated in the deaths of two beaked whales in the Gulf of California in 2002 (Lamont-Doherty Earth Observatory survey); although no direct correlation has been proven it was considered to be the indirect cause of death of the marine mammals (Cox et al. 2006).

7.4.5.1.1. Other Sound Sources

The only evident case of an injury to a marine mammal caused by what can clearly be considered an impulsive underwater sound source was reported by Ketten et al. (1993). However, as the most likely sound source in this case was an underwater explosion of undefined charge weight and distance to the animals, the physical cause of the injury may have been the shock wave created by the explosion.

7.4.5.2. Non-Impulsive Sound Sources

There is no scientific information available on the potential of sound emitted by offshore drilling or vessel operations to cause mortality in marine mammals.

Abbreviations

Abbreviation	Definition
AEP	auditory evoked potentials
AIS	Automatic Identification System
ANSI	American National Standards Institute
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
Caltrans	California Department of Transportation
DoC	Department of Commerce (US)
DoN	Department of the Navy (US)
DP	Dynamic Positioning
FPSO	Floating Production Storage and Offload
HESS	High Energy Seismic Survey
HF	High frequency (cetacean)
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
JASCO	JASCO Applied Sciences (Australia) Pty Ltd.
LF	Low frequency (cetacean)
MF	Mid frequency (cetacean)
MODU	Mobile Offshore Drilling Unit
NITS	Noise-induced threshold shift
nm	Nautical mile
NIOSH	National Institute for Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
ONR	Office of Naval Research
OCA	Other marine carnivores (in air)
OCW	Other marine carnivores (in water)
OW	Otariids (water)
PCA	Phocid Carnivores (in air)
PCoD	Population Consequences of Disturbance
PCW	Phocid Carnivores (in water)
PK	Peak

Abbreviation	Definition
PL	Propagation loss
PSD	Power spectral density
PW	Phocid (water)
PTS	Permanent Threshold Shift
RAF	risk assessment framework
RMS	Root Mean Square
SEL	Sound Exposure Level
SI	Sirenia
SL	Source Level
SWSS	Sperm Whale Seismic Study
SPL	Sound Pressure Level
TL	Transmission loss
TTS	Temporary Threshold Shift
US	United States (of America)
VHF	Very high-frequency
VSP	Vertical Seismic Profiling
WHP	Well Head Drilling Platform

Glossary

Term	Definition
1/3-octave	One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).
1/3-octave-band	Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.
90%-energy time window	The time interval over which the cumulative energy rises from 5 to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.
90% sound pressure level (90% SPL)	The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.
A-weighting	Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.
Absorption	The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.
Acoustic masking	Obscuring of sounds of interest by sounds at similar frequencies.
Ambient noise	All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.
Attenuation	The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.
Audiogram	A graph of hearing threshold level (sound pressure levels) as a function of frequency, which describes the hearing sensitivity of an animal over its hearing range.
Auditory frequency weighting (auditory weighting function, frequency-weighting function)	The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017).
Azimuth	A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.
Background noise	Total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal (ANSI S1.1-1994 R2004). Ambient noise detected, measured, or recorded with a signal is part of the background noise.
Bandwidth	The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).
Bar	Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 105 Pa or 1011 µPa.
Decibel (dB)	One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).
Frequency	The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.
Functional hearing group	Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, phocid pinnipeds (in air and water) and otariid pinnipeds (in air and water).
Hearing threshold	The sound pressure level for any frequency of the hearing group that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

Term	Definition
High-frequency cetacean	The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.
Hertz (Hz)	A unit of frequency defined as one cycle per second.
Impulsive sound	Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.
Intermittent sound	A level of sound that abruptly drops to the background noise level several times during the observation period.
Kurtosis	A measure of the outliers in given distribution (or time-series) relative to their occurrence in a normal distribution.
Lombard effect	The Lombard effect (response) is an increase in the subject's vocal levels in response to increased noise levels. This functions to maintain an adequate signal-to-noise ratio at the position of the receiver when noise levels vary (Lombard 1911).
Low-frequency cetacean	The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.
Mid-frequency cetacean	The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.
Non-impulsive sound	Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).
Odontocete	The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.
Otariid	A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids (true seals) and odobenids (walrus).
Particle motion, sound	The magnitude and direction of movement of particles making up the media due to presence of a sound wave. Particle motion is expressed as a vector quantifying movement such as displacement, velocity, or acceleration
Peak pressure level (PK)	The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).
Permanent threshold shift (PTS)	A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.
Phocid	A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.
Pinniped	A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and odobenids (walrus).
Pressure, acoustic	The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: ρ.
Scholte wave	An acoustic wave propagating at a fluid–solid interface (such as water-sediment) and decaying exponentially in both directions along the normal to its interface (Vinh 2013).

Term	Definition
Sound exposure level (SEL)	A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 μPa²·s. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).
Sound pressure level (SPL)	The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004). For sound in water, the reference sound pressure is one micropascal (p_0 = 1 μPa) and the unit for SPL is dB re 1 μPa²: $L_p = 10 \log_{10}(p^2/p_0^2) = 20 \log_{10}(p/p_0)$ Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.
Source level	The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 μPa·m (pressure level) or dB re 1 μPa²·s·m (exposure level).
Temporary threshold shift (TTS)	Temporary loss of hearing sensitivity caused by excessive noise exposure.

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Appendix A. Physical Characteristics of Underwater Sound

The following section provides a brief overview of the most important aspects and introduces the most relevant terms and metrics.

A.1. Sound Characteristics

Sound is a physical phenomenon consisting of minute vibrations that travel through a supporting medium, such as air or water. When the surface of a vibrating object (sound source) moves forward into the medium, it compresses the surrounding molecules, thereby creating a region of higher pressure. As the surface then moves back toward and past its neutral position, the molecules of the surrounding medium expand back and a region of lower pressure results. These cycles are called compressions and rarefactions, respectively (Figure A-1).

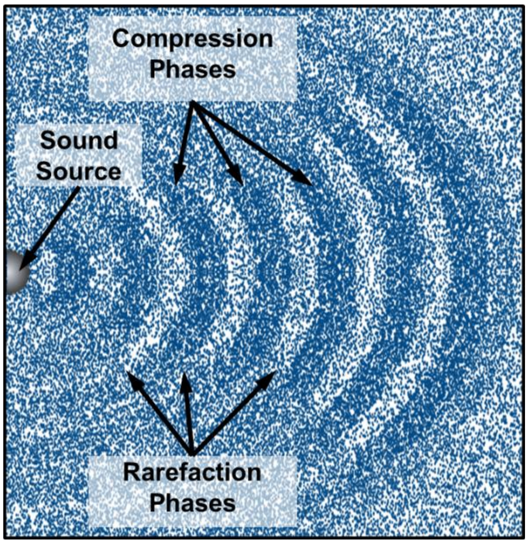

Figure A-1. Compression and rarefaction phases of a travelling sound wave.

The successive compressions and rarefactions result in sound waves. The speed at which these compressions and rarefactions travel away from the source depends on the compressibility and density of the medium and defines the speed of sound in that medium. Sound waves travel much faster in water than in air.

Sound is generally described in terms of frequency (or pitch), intensity, and temporal properties (e.g., short or long in duration, impulsive and non-impulsive). The following text provides a general description of these terms. For more details, there are several publications and books that provide detailed overviews of underwater acoustics, such as Richardson et al. (1995) and Au and Hastings (2008a), and some internet sources such as the Discovery of Sound in the Sea (DOSITS 2019), which is a highly recommended source of information on the subject.

Frequency is a measure of how many times the crest of a sound pressure wave passes a fixed point over the duration of a second; it is measured in Hertz (Hz). Some mysticetes (baleen whales) produce and may hear sounds below 20 Hz, while odontocetes (toothed whales) produce and hear sounds at frequencies much higher (up to 180 kHz for some species).

Sound intensity is defined as the acoustic power per unit area. The intensity, power, and energy of a sound wave are proportional to the average of the squared pressure. Measurement instruments and most receivers (humans, animals) sense changes in pressure, which is measured in Pascals (Pa). While pressure changes due to sound waves can be measured in Pascals, they are more commonly expressed in decibels (dB). The decibel is a logarithmic scale that is based on the ratio of the sound pressure relative to a standard reference pressure. The logarithmic decibel scale is used to allow comparison of extremely large sound pressure differences between sources.

Different standard reference pressures are used for airborne sounds and underwater sounds. The airborne standard pressure reference is $p_{ref(air)}$ = 20 micropascals (µPa), while the underwater standard reference pressure is $p_{ref(water)}$ = 1 µPa. The formula used to convert a pressure p measured in micropascals to sound pressure level *P* measured in dB is *P* = 20 log10 [p/p_{ref}]. Because of the logarithmic nature of the decibel scale, sound levels cannot be added or subtracted directly. If a sound's pressure is doubled, its sound level increases by 6 dB, regardless of the initial sound level.

A.2. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (ISO 2017, e.g., ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,\mathrm{pk}}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \qquad \text{(A-1)}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,\mathrm{pk\text{-}pk}}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{\mathrm{p,pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \qquad \text{(A-2)}$$

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure:

$$L_{\mathrm{p}} = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right) \qquad \text{(A-3)}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,\mathrm{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\mathrm{boxcar\ 125ms}}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \quad \text{(A-5)}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \quad \text{(A-6)}$$

$$L_{p90} = L_\text{E} - 10\log_{10}(T_{90}) - 0.458 \quad \text{(A-7)}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (L_eq; dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, $p(t)$, over the same time period, T:

$$L_\text{eq} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \Big/ p_0^2\right) \quad \text{(A-8)}$$

The equations for SPL and the energy-equivalent SPL are numerically identical. Conceptually, the difference between the two metrics is that the SPL is typically computed over short periods (typically of one second or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the L_eq reflects the average SPL of an acoustic signal over time periods typically of one minute to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,\text{LF,24h}}$) or auditory-weighted SPL ($L_{p,\text{ht}}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

In the present report, audiogram-weighted, fast-averaged SPL ($L_{p,\text{ht,F}}$) is defined by the exponential function from Plomp and Bouman (1959):

$$L_{p,\text{ht}} = L_{E,\text{ht,per-pulse}} - 10\log_{10}(d/0.9)\,,$$
$$L_{p,\text{ht,F}} = L_{p,\text{ht}} + 10\log_{10}\frac{1-e^{-d/\tau}}{1-e^{-T/\tau}} \quad \text{(A-9)}$$

where d is the duration in seconds, τ is the time constant of 0.125 s representing marine mammal auditory integration time, $L_{p,\text{ht}}$ is the audiogram-weighted SPL over pulse duration, and T is the pulse repetition period. This metric accounts for the hearing sensitivity of specific species through frequency weighting, and results in reduced perceived loudness (i.e., sensation level) for pulses shorter than auditory integration time (τ).

A.3. Kurtosis

Popper and Hawkins (2019) proposed kurtosis[5] as a metric to distinguish impulsive sounds in the studies of fish and invertebrates. Martin et al. (2020) compared various types of impulsive and non-impulsive sounds in terms of their kurtosis, and the results strongly support using kurtosis for quantifying impulsiveness for future assessments and revised underwater noise regulations. The results also show that by applying this metric, it becomes irrelevant for assessing hearing impairment if impulsive signals seemingly merge into non-impulsive signals over distance due to dispersion as their kurtosis remains high (i.e., an indicator for impulsiveness). However, this aspect is a field of ongoing research, and while kurtosis is an established criterion in human audiometry, no studies have applied it to date to marine species; it therefore remains unclear if kurtosis is the ultimate criterion for determining the impulsiveness of acoustic signals for these taxa.

A.4. Particle Motion

Since sound is a mechanical wave, it can also be measured in terms of the vibratory motion of fluid particles. Particle motion can be measured in terms of three different (but related) quantities: displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. The most relevant particle motion metrics with regard to potential effects on marine fauna are acceleration and velocity.

The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. It can be derived from the pressure gradient and Euler's linearized momentum equation where ρ_0 is the density of the medium:

$$v = -\int \nabla p(t) dt / \rho_0 \,. \qquad \text{(A-10)}$$

The particle acceleration (a) is the rate of change of the velocity with respect to time, and it can be obtained from A-10 as

$$a = \frac{dv}{dt} = -\frac{\nabla p(t)}{\rho_0} \qquad \text{(A-11)}$$

Unlike sound pressure, particle motion is a vector quantity, meaning that it has both magnitude and direction: at any given point in space, acoustic particle motion has three different time-varying components (x, y, and z). Given the particle velocity in the x, y, and z, directions, v_x, v_y, and v_z, the particle velocity magnitude $|v|$ is computed per the Pythagorean equation:

$$|v| = \sqrt{v_x + v_y + v_z} \qquad \text{(A-12)}$$

The magnitude of particle acceleration is calculated similarly from the particle acceleration in the x, y, and z directions.

[5] Kurtosis is a measure of the outliers in given distribution (or time-series) relative to their occurrence in a normal distribution. Kurtosis is not a measure of sharpness or roughness of an acoustic signal.

Attachment 12 Greenhouse Gas Emissions Quantification

Santos Dorado Development Projected Emissions Inventory

Revised final report

Santos WA Energy Ltd

3 March 2022 | 125908 | v3

Executive summary

Santos' proposed Dorado Development will be located in the Bedout Basin offshore of north-west Western Australia. The proposed Dorado Development includes a 16 slot well head platform with a floating production storage and offloading (FPSO) facility handling oil and condensate stabilisation, storage and offloading, water treatment for disposal, gas dehydration, gas compression and reinjection. Full production is anticipated in 2026 and covers a 20-year period. Our assessment is based on a total production volume of 350 million barrels (MMbbl) of oil from the Dorado Development which includes future tiebacks[1] from nearby fields (Project Area).

As part of the regulatory requirements, and to improve the understanding of the associated environmental impacts and risks, Santos has prepared an Offshore Project Proposal (OPP) for assessment by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). Energetics has assisted Santos with quantifying the atmospheric emissions from the Dorado Development, as an input to the OPP. This report sets out the key findings of the projected emissions inventory of the proposed Dorado Development.

Scope of our assessment

The boundary of our assessment is limited to the production and onshore processing and use of 350 MMbbl of oil from the Dorado Development including future tiebacks from neighbouring fields from currently identified prospects in the Project Area. The assessment assumes that the oil is processed onboard an FPSO installation operating for 20 years at full capacity and includes emissions from drilling and installation of wellhead platforms (WHPs) and facilities, as well as commissioning and decommissioning of the FPSO. It is assumed that 100% of the oil product will be shipped to Kobe, Japan for refining. Transport from the receiving Kobe port to the refinery is assumed to be negligible. The final products from the refining process were assumed to follow the typical slate from the processing of Cossack crude (given that there are currently no estimates of the refining slate for Dorado fluids), and 100% of the final product is assumed to be combusted.[2]

Dorado Development's atmospheric emissions profile

Emissions from the Dorado Development will include greenhouse gases (GHGs) and other atmospheric emissions. To assess GHG emissions, Energetics relied on guidance from the GHG Protocol (GHGP) Corporate Accounting and Reporting Standard.[3] The GHGP classifies GHG emissions into three 'scopes'. For this assessment, and aligned with the GHGP, Scope 1 emissions include all direct emissions from sources owned or controlled by Santos (i.e. within Santos' operational control). For the Dorado Development, this includes a normally unmanned WHP, hydrocarbon processing on the FPSO and any transport occurring to and from these facilities that fall within Santos' operational control over a 20-year period. It also incorporates any supporting activities for the commissioning and decommissioning of facilities including those installed for future tiebacks.

Scope 2 emissions cover emissions from purchased electricity, steam, heating and cooling. Santos has identified that due to fuel gas and purchased diesel meeting on site energy requirements, there are no likely sources of Scope 2 emissions for the Dorado Development.

[1] Dorado Development is used in the remainder of the report to include oil from potential future tiebacks currently identified as prospects within the Project Area.
[2] This assumption was selected in consultation with Santos and represents a conservative approach.
[3] GHG Protocol, 'A Corporate Accounting and Reporting Standard: Revised Edition' <*https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf*>.

Scope 3 GHG emissions are indirect emissions for the Dorado Development from assets that are not owned or controlled by Santos. In assessing the Dorado Development's Scope 3 inventory, 15 emissions categories detailed by the GHGP were reviewed for relevance and materiality. Categories included in this assessment were: purchased goods and services, capital goods, fuel and energy related activities (not included in Scope 1 or 2 emissions), business travel, downstream transport and distribution of sold product, processing of sold products, and the use of sold products. Scope 3 emissions are based on operating the Dorado Development for 20 years, with a maximum export volume of 350 MMbbl, produced from up to 38 wells from the Dorado field and future tiebacks within the Project Area.

Direct (Scope 1) GHG emissions over the lifetime of the Dorado Development[4] were calculated as approximately 15.6 $MtCO_2e$ and total indirect (Scope 3) emissions as 153 $MtCO_2e$. As illustrated in Figure ES1 below, the vast majority of Scope 1 GHG emissions occur in the operations and maintenance stage (94% of total Scope 1 emissions).

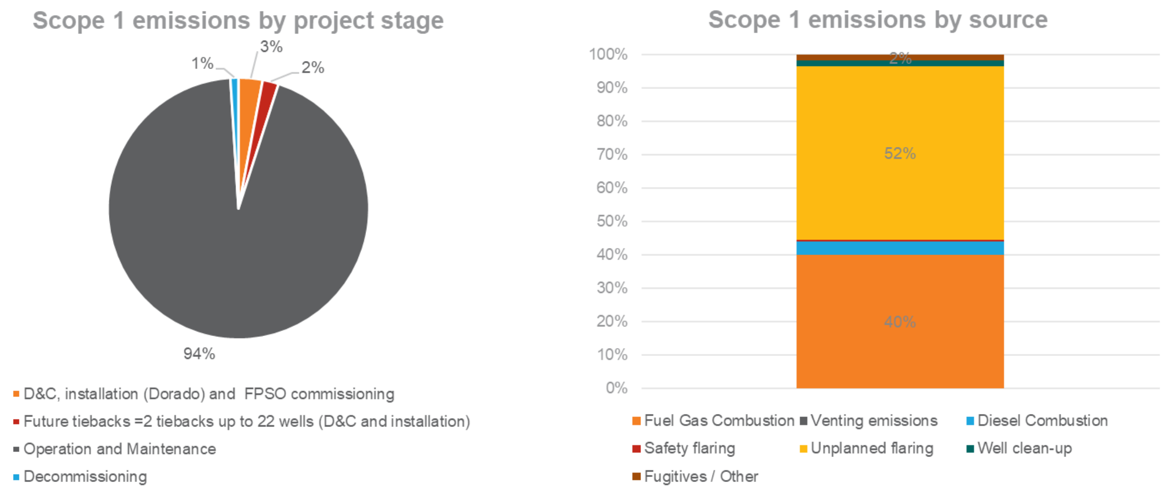

Figure ES1. Breakdown of Scope 1 GHG emissions by project stage and source

Figure ES2 shows that the final combustion of sold products makes up the majority of the Scope 3 emissions inventory (87%) followed by emissions from the refining process (9%).

[4] A 20-year period is used in our assessment.

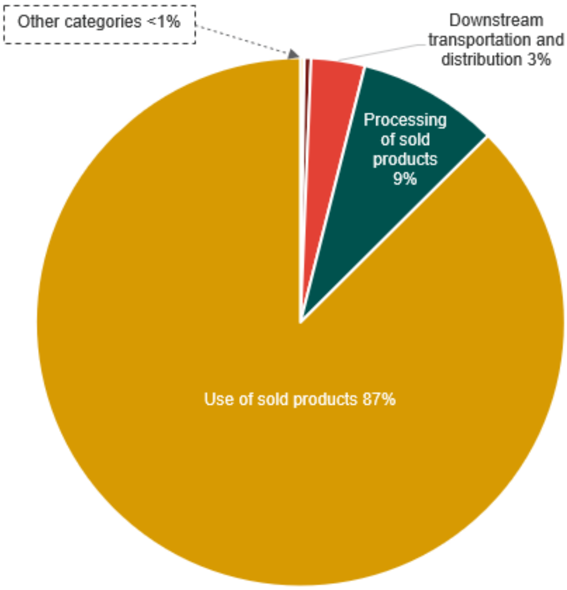

Figure ES2. Breakdown of Scope 3 GHG emissions by category

Emissions from the combustion of the sold product were conservatively estimated by assuming 100% combustion of the oil product.[5] The calculated emissions intensity for Cossack crude[6] (0.38 tCO_2e/bbl) falls within range of the average emissions intensity for oil combustion identified by the International Energy Agency (IEA).[7] However, the significance of this category to total Scope 3 emissions underscores the importance of understanding the final processing and market placement of the oil from the Dorado Development.

Other atmospheric emissions including sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs) and particulate matter (PM) were also assessed, using the National Pollutant Inventory (NPI) guidelines. Over a 20-year period, the Dorado Development will emit approximately 82,100 t of other atmospheric emissions.

Parties agree that this report may be reprinted in accordance with the purposes of the project for which it has been commissioned.

[5] This is a conservative approach as it assumes that the carbon in the oil is most rapidly released to the atmosphere as a GHG as these products are combusted in use.
[6] Used as a proxy for Dorado fluids.
[7] International Energy Agency, 'The Oil and Gas Industry in Energy Transitions' (2020) <*https://webstore.iea.org/download/direct/2935*>.

List of acronyms and units

Acronym/unit	Meaning
bbl	Barrel
bopd	Barrels of oil per day
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
D&C	Drilling and completions
DISER	Australian Federal Department of Industry, Science, Energy and Resources
EET	Emission Estimation Technique as defined under the National Pollutant Inventory
EF	Emissions Factor
FEED	Front End Engineering Design
FPSO	Floating production storage and offloading
GHG	Greenhouse gas
GHGP	Greenhouse Gas Protocol
IEA	International Energy Agency
kt	kiloton
LCI	life cycle inventory
LHV	Lower Heating Value
LPG	Liquefied petroleum gas
MMbbl	Million barrels
MMscfd	Million standard cubic feet per day
MODU	Mobile offshore drilling unit
Mt	Million tonnes
N_2O	Nitrous oxide
NGA	National Greenhouse Accounts
NGER Determination	*National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NO_x	Nitrogen oxides
NPI	National Pollutant Inventory
OPP	Offshore project proposal
PMs	Particulate matter(s)

Acronym/unit	Meaning
ppm	Parts per million
SO_X	Sulphur oxides
tCO_2e	Tonnes carbon dioxide equivalent
VOCs	Volatile organic compounds
WHP	Wellhead platform

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1. Introduction

Santos is planning Phase 1 of the Dorado Development in the Bedout Basin, which is offshore of north-west Western Australia and approximately 130 km north of Port Hedland. Full production is expected from 2026.[8] The Dorado Development, including oil production from the Dorado reservoir and future tiebacks (if commercially viable), currently identified as prospects, is anticipated to produce 350 million barrels (MMbbl) of oil over a 20-year life. Reservoir fluid from the Dorado Development reservoirs will be collected on a wellhead platform (WHP) and pumped by subsea infrastructure (flowlines) for processing on a floating production storage and offloading (FPSO) facility. The FPSOs headline liquids and oil processing capacity is 100,000 bopd[9] and a gas re-injection (excluding fuel gas requirements) rate of 235 MMscfd.

The Dorado Development is subject to regulatory assessment in accordance with the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (Cth), administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). Santos is required to develop an Offshore Project Proposal (OPP) detailing environmental impacts and risks arising from planned and unplanned activities associated with the project.

As an input to the OPP, Santos has requested that Energetics quantify key sources of atmospheric emissions, consistent with good industry practice and aligned with contemporary published emissions estimation methodologies. This report sets out the key findings relating to the projected emissions inventory of the proposed Dorado Development.

2. Dorado Development's emissions profile

2.1. Emissions overview

Emissions from the Dorado Development will include both greenhouse gases (GHGs) and other atmospheric emissions. GHGs are defined as gases that reradiate heat back onto the earth's surface. For our assessment, and in line with the GHG Protocol (GHGP), the quantification of GHGs included carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The assessment of other atmospheric emissions was based on the National Pollutant Inventory (NPI) guidelines. In addition to GHG emissions, our report also assessed sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs) and particulate matter (PM) as the most significant sources of atmospheric emissions.

The GHGP Corporate Accounting and Reporting Standard classifies a company's GHG emissions into three 'scopes'.[10] Scope 1 emissions include all direct emissions from sources owned or controlled by Santos (i.e. within Santos' operational control). Scope 2 emissions cover emissions from purchased electricity, steam, heating and cooling by Santos. Scope 3 GHG emissions are indirect emissions for the Dorado Development and are from assets not owned or controlled by Santos. These include the emissions associated with the refining and use of products from the Dorado Development. Santos has identified that due to fuel gas and purchased diesel meeting on

[8] First oil targeted in December 2025.
[9] Headline capacities expressed in units as provided by Santos to provide continuity across the project.
[10] GHG Protocol, 'A Corporate Accounting and Reporting Standard: Revised Edition' <https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf>. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

site energy requirements, there are no likely sources of Scope 2 emissions for the Dorado Development.

The following sections describe the emissions boundary applied to Phase 1 of the Dorado Development, the methodology for calculating atmospheric emissions and Scope 1 and 3 GHG emissions, and a summary of the resulting emissions inventories.

2.2. Emissions boundary

The boundary of assessment of the Dorado Development is defined by two key operational aspects:

- The operation of the FPSO for a 20-year period
- The production, processing, and sale of 350 MMbbl of oil from the Dorado reservoir and potential future tiebacks yet to be appraised.

Figure 1 presents a high-level overview of processing steps to occur on the FPSO and the downstream activities related to the processing and sale of the oil.

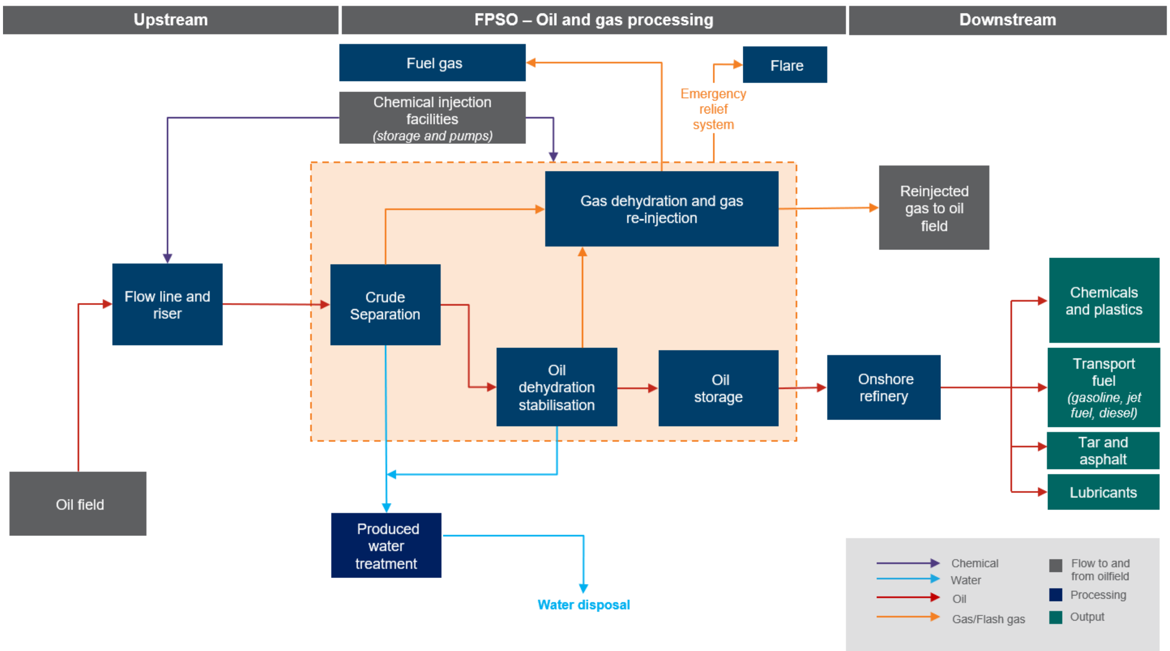

Figure 1. Flowsheet of Dorado operations highlighting Scope 1 and 3 emissions sources

In assessing atmospheric and Scope 1 GHG emissions, most parameters related to processing oil on the FPSO have been defined on the assumption that the FPSO runs at full (100%) capacity and are independent of the total oil processed. Given that the FPSO will have scheduled maintenance shutdowns, as well as the potential for emergency shutdowns or unplanned events resulting in "down time", this assumption is considered conservative. Fugitive emissions from the FPSO are dependent on the quantity of oil produced and contributes less than 1% to the Scope 1 GHG emissions profile.

Calculations of Scope 3 emissions are based on the assumption that 350 MMbbl of oil will be produced by the Dorado reservoir and future tiebacks. Any changes in the quantity of oil produced from the FPSO will result in changes in Scope 3 emissions, particularly for emissions from the transport, processing and end use of the sold product. Consequently, the boundary of our assessment includes the production, onshore processing and use of 350 MMbbl of oil from the Dorado Development with future tiebacks.

The characteristics of the oil from the Dorado field and future tiebacks targeting similar geological formations, have largely been approximated by Caley crude oil. As no estimates for the refining slate of Caley crude were readily available, we considered public sources of similar light, sweet condensates. Cossack crude was identified as the closest to these in terms of geographic location and API. Cossack crude is extracted from the North West shelf and exhibits an API of 48.8, comparable with Caley, and adopted as the proxy for this inventory assessment.

Our assessment assumes that the oil is processed onboard a FPSO operating for 20 years at full capacity and includes emissions from the commissioning and decommissioning of the WHP and FPSO. In consultation with Santos, Energetics has assumed that 100% of the Dorado Development's product will be shipped to Kobe, Japan for refining.[11] The final products from the refining process were assumed to follow the typical slate from the processing of Cossack crude. Energetics has conservatively assumed that all of the final refining products are combusted.[12] Figure 2 provides a summary of these boundaries with key assumptions described in further detail in Section 2.3.4 and 2.4.2.

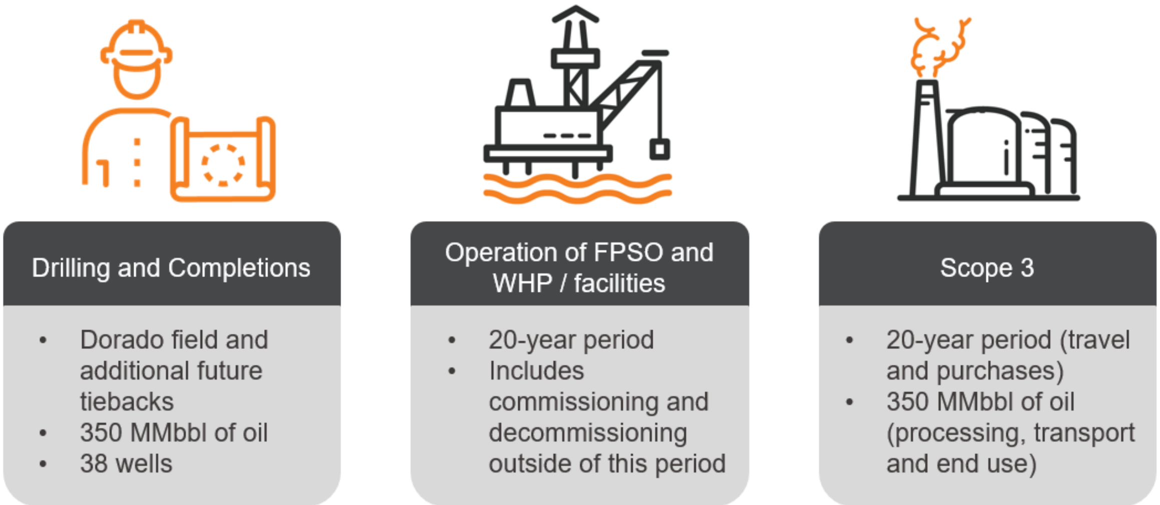

Figure 2. Defined boundaries for the Dorado Development

2.3. Direct emissions (Scope 1)

2.3.1. Calculating direct emissions

Greenhouse gas emissions

To calculate Scope 1 GHG emissions, Energetics adopted the methodology outlined in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth) (NGER Determination) together with emissions factors outlined in the federal Department of Industry,

[11] Japan was identified as one of the likely end customer countries and therefore was assumed to be the location of the port to which oil would be shipped, reflecting a conservative approach since shipping to Japan represents the farthest distance from the Dorado location that is likely to be travelled.
[12] This assumption was selected in consultation with Santos and represents a conservative approach.

Science, Energy and Resources' (DISER)[13] National Greenhouse Accounts (NGA) factors (August 2021).[14] The NGA factors draws on the NGER Determination and uses the National Greenhouse and Energy Reporting (Measurement) Amendment (2020 Update) Determination 2020.[15]

For each activity, an appropriate methodology for calculating emissions was selected from the NGER Determination. Data was converted into the appropriate units and multiplied by the required emissions factor to determine the carbon dioxide equivalent (CO_2e) amounts of CO_2, CH_4, and N_2O emissions. This allows the direct comparison of emissions sources and is aligned with global best practice in GHG accounting.

Other atmospheric emissions

To calculate other atmospheric emissions, guidance manuals developed for the NPI were used. These were primarily:

- Emission Estimation Technique (EET) Manual for Oil and Gas Extraction and Production (Version 2.0)
- EET Manual for Combustion Engines (Version 3.0)
- EET Manual for Fuel and Organic Liquid Storage (Version 3.3).

Similar to the method applied for GHG emissions, the manuals were used for both the method and emissions factors. A summary of the activities and the corresponding estimation method and emissions factor for both GHGs and other atmospheric emissions are presented in Appendix A.

2.3.2. Direct emissions boundary

Scope 1 emissions include all direct emissions from sources owned or controlled by Santos (i.e. within Santos' operational control). For the Dorado development, this includes operations occurring within the Dorado WHP and the FPSO and any transport occurring to and from these sites, that falls within Santos' operational control over a 20-year period. It also incorporates any supporting activities for the commissioning and decommissioning of the WHP and FPSO and associated activities or infrastructure installation for future tiebacks, such as additional wells, WHP or subsea facilities or pipelay.

The assessment of Scope 1 emissions covered the following stages of the Dorado Development:

- ***Drilling and completions (D&C), installation and commissioning***: includes the installation of infrastructure such as WHPs and flowlines, drilling of the production wells (including tiebacks) and commissioning of WHP and the FPSO
- ***Operations and maintenance (O&M)***: includes all activities which occur during a 20-year operation of the FPSO assuming 350 MMbbl of oil from the Dorado field and future tiebacks
- ***Decommissioning***: includes all activities related to well plugging and abandonment, and the removal of the WHPs and any supporting infrastructure.

Key assumptions for each operating stage are described in the following sections.

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[13] Formerly Department of Environment and Energy.

[14] Department of Industry, Science, Energy and Resources, 'National Greenhouse Accounts Factors: 2021' (2021) <***https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-factors-2021***>. Current at the date of the revised version of this report (February 2022).

[15] Compiled on 1 July 2021. Current at the date of the revised version of this report (February 2022).

2.3.3. Operations breakdown and sources of emissions

In conjunction with Santos' engineers, Energetics identified the key activities which could release GHGs and/or atmospheric emissions within each project stage.

D&C, installation and commissioning

During this phase, key activities identified include the use of diesel for the mobile offshore drilling unit (MODU), support vessels servicing the MODU, diesel use for power generation and the flaring of liquid and gas produced during the unloading and clean-up of each well. Up to 38 wells have been assumed for the Dorado Development.

Operations and maintenance

Fuel gas

Fuel gas is used on the FPSO for powering generation turbines and to drive turbines associated with gas compression which may include re-injection compressors or low-pressure flash gas compressors. The fuel gas used in this equipment will be sourced from the process and originates from the reservoir. The majority of process gas is reinjected back into the reservoir as standard operational procedure. This is required to enhance and maximise the liquids recovery.

Flaring

During the operations and maintenance stage, the possible requirement for the flaring of gas can be separated into safety and unplanned flaring events associated with non-routine events:

- Safety flaring accounts for the pilot flame
- Unplanned flaring occurs during process trips which could be triggered by unforeseen events, including intermittent blanket gas flaring and maintenance activities. This accounts for unplanned flaring which also includes blowdown events, pressure relief events, process upsets which lead to flaring, flaring due to equipment down time and flaring for maintenance purposes.

Unplanned flaring activities may occur and further emissions reduction methods may also be defined and applied during Front End Engineering Design (FEED) and detailed engineering design yet to commence. For example, off gas from flaring may be sent to the vapour recovery system and reinjected into the reservoir. However, to apply a conservative approach, the emissions assessment has been based on the upper bound of safety and unplanned flaring to occur in the 20 year period (36.5 MMscfd of safety and 3,750 MMscf per year of unplanned flaring) inclusive of all potential flaring sources.

Diesel combustion

During this stage, diesel combustion will be limited to diesel used for power generation when the FPSO is not on station (assumed as approximately 15 days of the year) and diesel use associated with testing equipment such as the fire pump. While there may be other sources of miscellaneous diesel use on the FPSO and WHP (i.e. use by the lifeboat, emergency generators and fast rescue craft) this was deemed to be negligible relative to the aforementioned sources.[16] This is a fair assumption based on our understanding of similar inventories and the magnitude of these emissions sources. Diesel use in support vessels and helicopters for the transport of personnel to

[16] It was noted that the FPSO may utilise additional diesel in the case that the FPSO is required to sail away due to a cyclone or other adverse weather conditions. However, as the frequency and sail away distances in such events can be difficult to predict and is expected to have a marginal impact, this is excluded from the emissions inventory.

and from the WHP/FPSO is excluded from Scope 1 GHG emissions as these activities are operated by a third party; they are therefore included in the Scope 3 GHG assessment (see Section 2.4).

Fugitive emissions

Fugitive emissions occur as a result of minor leaks from equipment. Sources of fugitive emissions from the Dorado Development include emissions during the transfer of gas and oil through equipment, the storage of diesel and oil in the FPSO and the offloading of oil. To minimise these emissions during production and offloading operations, the Dorado Development will include a vapour recovery system which supplies a blanket gas for all cargo and slops tank. A blanket gas fills the vapour space of the tanks preventing the formation of an explosive vapour-air mixture. However, to adopt a conservative approach in estimating emissions, Energetics has included unmitigated fugitive emissions from storage tanks in the emissions inventory.

Decommissioning

During the decommissioning stage, emissions will primarily result from the combustion of diesel in the MODU, generators and support vessels. Based on Santos' prior experience, the activities in this stage are likely to be similar to those in the drilling stage (with the exception of flaring as well clean-up is not anticipated). To estimate emissions from this stage, daily diesel usage from drilling has been applied to the time frame of the decommissioning stage (152 weeks based on 38 wells and four weeks to decommission each well). Table 1 summarises the activities in each project stage.

Table 1. Activities resulting in Scope 1 emissions from the Dorado Development

Activities	D&C, installation and commissioning	Operations and maintenance	Decommissioning
Fuel gas combustion for compressors and electricity generation		✓	
Flaring (well clean-up and FPSO commissioning)	✓	✓	
Fugitive emissions –oil and gas throughput		✓	
Fugitive emissions –oil and diesel storage		✓	
Diesel combustion – gensets	✓	✓	
Diesel combustion – support vessels and jack up MODU*	✓		✓
Produced water		✓	
Acetylene combustion		✓	

Activities	D&C, installation and commissioning	Operations and maintenance	Decommissioning
Lubricant oils		✓	
Oil loading		✓	

** the use of support vessels in other stages will be third party operated and are quantified as Scope 3 GHG emissions*

2.3.4. Key assumptions

Key assumptions regarding start dates, duration and activities for each operating stage are listed in Table 2. These assumptions are based on information provided by Santos in response to Energetics' requests. Assumptions were based on the best data available at the time of the assessment. Where data or activities are yet to be defined, Santos' assumptions have been derived from data from similar operations or prior experience.

Table 2. Key assumptions applied in developing the Scope 1 emissions inventory

Stage	Activity	Assumption
General	Oil production	350 MMbbl of oil produced in the 20-year period.
	Oil composition	Crude condensate assay results indicate the Dorado well will produce a mixed condensate product from multiple reservoir members (Archer Formation). Caley PS-E (51.4° API, 189 ppm wt sulphur) will form the majority of the condensate (80%) followed Baxter condensate (51.0° API, 133 ppm wt sulphur) (20%). Assay results representing the BoD analysis of the condensate from these two sources were used to estimate the speciation of VOC components which would be released upon the flaring of condensate (in the drilling stage) and related in the form of fugitive emissions during the loading/offloading of condensate (O&M).
	Oil properties	Specific gravity of condensate is 0.779.
	D&C, commissioning and decommissioning	No use of acetylene and lubricant oils in the drilling & completions, commissioning, and decommissioning stage.
	General	Heat rate of Solar Titan[17] = 10,160 kJ/kWhr Heat rate of Solar Taurus = 11,265 kJ/kWhr LHV of gas = 46.3 GJ/tonne LHV of diesel = 43 GJ/tonne Gas – specific gravity = 0.82 Gas density = 1.0 kg/m^3 Annual run hours = 8,760 hours (based on operating 365 days at 24 hours per day) Diesel energy content = 38.6 GJ/kL[18] Specific gravity of diesel = 0.84 Density of lubricant oil = 950 kg/m^3[19]

[17] Assumed industry standard compressors given concept engineering phase of the Dorado Development (as provided by Santos).
[18] NGER Determination.
[19] ***https://www.neste.com/companies/products/lubricants/basic-consepts-lubricants***

Stage	Activity	Assumption
D&C, installation and commissioning	**Start date**	**Drilling (Dorado):** 1 January 2024[20] **Drilling (Dorado infill wells):** approx. year 6 of O&M **Drilling (future tieback 1):** approx. year 6 of O&M **Drilling (future tieback 2):** approx. year 10 of O&M **Commissioning:** 1 October 2025
	Duration	**Drilling (Dorado and future tiebacks):** duration of drilling and completions is 1.75 years for Dorado, future tieback 1 and future tieback 2 **Installation:** 4 months prior to the commencement of drilling activities of each field **Drilling (Dorado infill wells):** Four infill wells to be drilled in year 6 of O&M for the Dorado field only, which is assumed to take a period of 140 days **Commissioning:** 3 months following the completion of drilling the Dorado wells and before full production
	Drilling activities	Primary drilling activities consist of diesel use for support vessels and flaring. All other activities likely to be immaterial.
	Diesel use	Primary diesel use during drilling activities is for support vessels. Each support vessel is assumed to use 12m^3 of diesel per day. All other activities likely to be immaterial. Key assumptions for each stage: **Drilling and completions**: • **Dorado (16 wells) and infill wells (4 wells)**: 3 support vessels per day for the duration of the drilling period of Dorado and infill wells (1 support vessel assumed to only operate for 6 months of the drilling period) • **Future tieback 1 (12 wells) and future tieback 2 (10 wells)**: 3 support vessels per day for the duration of the drilling period, with 1 support vessel assumed to only operate for 6 months of the drilling period. The volume of fuel use per vessel per day has been scaled according to the number of wells that need to be drilled relative to the Dorado field (e.g, with 12 wells at future tieback 1, support vessels are assumed to only be required 75% of

[20] Start date of the MODU assumed to be 1st January 2024, with the installation activities for the WHP occurring in Q4 2023. The dates for the purpose of this assessment are nominal, with durations assumed based on historical project activity experience and historical drilling activities undertaken in the Bedout Basin.

Stage	Activity	Assumption
		the time relative to the Dorado field which has 16 wells). **Installation (Dorado and future tiebacks)**: 5 support vessels required per day for the duration for 4 months for each field. **Commissioning**: 5 support vessels required per day for the duration of 4 months.[21]
	Flaring	**Drilling and installation**: Includes well clean-up for wells drilled for the Dorado Development (including tiebacks) over the 2-year period. Clean up occurs periodically over the 2-year period of drilling activities. • **Gas flaring volumes**: 25,000t (Dorado and infill wells: 10,542 t, future tiebacks: 14,470 t) • **Hydrocarbon flaring:** 54,247t (Dorado and infill wells: 27,331 t, future tiebacks: 26,916 t) **Commissioning:** Includes any excess gas flared during commissioning. To account for this, the flare (based on concept design) is assumed to operate at its peak design rate for a period of 72 hours (assumed to flare 21,434 tonnes) as advised by Santos. Flare destruction of all gas flaring activities at 98-99% of total VOCs.
Operations and maintenance	**Start date**	**Full production assumed at 1 January 2026**
	Duration	20 years
	Safety flaring	0.1MMScfd, accounts for the pilot flame
	Unplanned flaring	3,750 MMscf per year assuming 15 extended flaring events at 48 hours per event and half flare rates. Given the Dorado Development is still in concept engineering, this assumption is highly conservative and will be more defined during FEED and detailed engineering. The assumption assumes one "unplanned" flaring event per month, along with up to three shutdowns for cyclone avoidance per year. These unplanned events may be associated with process upsets, gas

[21] Conservative estimate as commissioning is assumed to take 3 to 4 months, only one commissioning period associated with the FSPO itself.

Stage	Activity	Assumption
		compressor downtime and cyclone avoidance. The basis of the volume is estimated as a worst case at half of the potential reservoir gas (i.e. production has been ramped down) and a period of 48 hours to allow for repairs.
	Gas reinjection	Annual gas reinjection assumed constant through the 20 years period independent of crude production (235 MMscfd).
	Compressors	The maximum power of the compressors has been used for all calculations with the assumption that the FPSO operates at 100% capacity for 20 years Equipment: • Reinjection compressors – Solar Titan 130 (11.7 MW, 15.7 MW maximum power) • HP (Flash Gas compressor) – Solar Taurus 60 (5.75 MW)
	Diesel use	Includes diesel use in gensets, fire water pumps and diesel used for testing. All other activities likely to be immaterial. Diesel engine efficiency assumed to be 26%.
	Fugitive emissions	While there is a vapour recovery system in place to reduce emissions from crude tanks, to be conservative all fugitive emissions are accounted for in this inventory and are based on the total throughput of gas through the facility.[22]
	Venting emissions	Any vented emissions will be captured via the vapour recovery system. There are no emissions expected to be vented during operation.
	Fuel gas	Fuel gas composition applied to all fuel gas compressor activities, generator activities and flaring activities. Ethane is excluded from the VOCs calculation. While not specifically excluded under the NPI definition of VOCs[23] it has minimal photochemical activity so would likely be excluded. For comparison, it is excluded from the US definition of VOCs.[24]

[22] Throughput has been assumed to be the total volume of gas extracted from the wells (i.e. the sum of the volume of gas reinjected, flared, and used as fuel gas).
[23] http://www.npi.gov.au/resource/npi-definition-volatile-organic-compounds

Stage	Activity	Assumption
	Produced water	Table 7-13 of OPP states maximum design rate for produced water is 4,350 m^3/day; this is the value used in the calculations; tCO_2-e/ML, is equivalent to $kgCO_2$-e/m^3.
	Tank cleaning	While the crude oil tanks are planned to be cleaned every five years, given the nature of the hydrocarbon, i.e., a light condensate, Santos does not expect be measurable additional emissions associated with the tank cleaning process for the five-yearly inspections. This is because it is unlikely that much residue/sludge would accumulate in the tank bottoms.
Decommissioning	**Start date**	**1 January 2046**. For the purpose of inventory assessment, it is assumed that decommissioning commences at end of 20-year operations life.
	Duration	Approximately 3 years (4 weeks per well for plug and abandonment activities, approximately 38 wells including future tie backs).
	General	Activities in the decommissioning stage are estimated to be the same as the drilling stage (diesel use for the MODU and support vessels only) but adjusted for a 3-year period. This assumption is based on prior experience by the team. No flaring expected in this stage.

[24] https://www.epa.gov/air-emissions-inventories/what-definition-voc

A summary of the volume of gas released, combusted, and reinjected by the facility is summarised in Table 3.

Table 3. Breakdown of total gas flows according to project activity[25]

Stage	Activity	Location	Unprocessed gas (tonnes)	Contribution to total gas flows in project lifetime[26]
Drilling and installation	Flaring	Dorado wells (12)	10,500	0.0195%
Drilling and installation	Flaring	Dorado infill wells (4)	0.00189	<1%
Drilling and installation	Flaring	Tie backs (up to 22)	14,500	0.0269%
Commissioning	Flaring	FPSO	21,400	0.0398%
O&M	Safety flaring	FPSO	20,900	0.0387%
O&M	Unplanned flaring	FPSO	2,140,000	3.98%
O&M	Compressor fuel gas	FPSO	2,600,000	4.83%
O&M	Gas reinjected	FPSO	49,100,000	91.1%
O&M	Gas vented	FPSO	0	0.00%
O&M	Fugitives	FPSO	3,650	0.00678%

The assumed oil production timeline for the purpose of this inventory assessment is illustrated in Figure 3. Drilling for future tiebacks may take place following the first year of full production from the primary Dorado field. All D&C, installation and commissioning activities related to future tiebacks are assumed to be completed by 2035 for this assessment. Based on the oil production profile including the future tiebacks, the year of maximum production is anticipated in 2030. All wells are assumed to commence being decommissioned from 2046 onwards.

[25] To 3 significant figures
[26] Includes D&C and installation

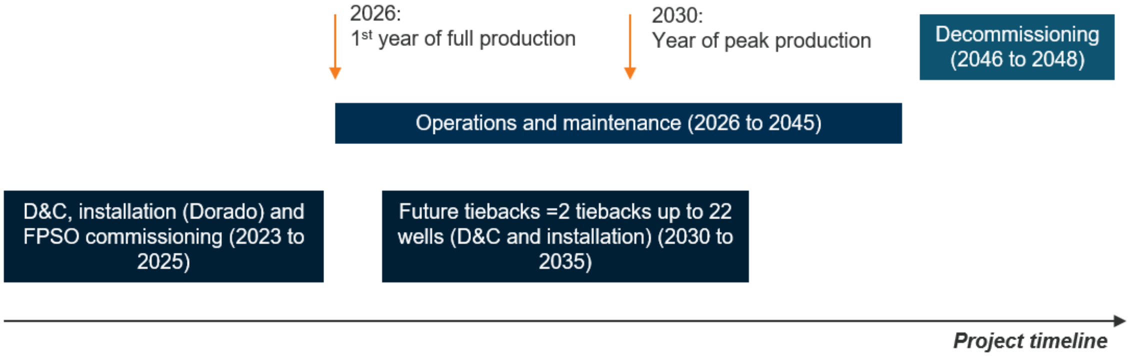

Figure 3. Assumed oil production schedule (for the purpose of this inventory assessment) from Dorado field and future tiebacks

2.3.5. Scope 1 GHG inventory

Scope 1 GHG emissions from the Dorado Development were calculated to be approximately 15.6 $MtCO_2e$. This is equivalent to 732 $ktCO_2e$ per year based on total emissions over the 20-year period and 767 $ktCO_2e$ per year based on the year of highest production.[27] Of Scope 1 emissions, 85% is CO_2 followed by 15% CH_4 with minimal N_2O. A detailed breakdown of direct GHG emissions and sources is presented in Appendix B.

The emissions breakdown by project stage and emissions source is included in Figure 4. The majority of emissions occur in the O&M stage (94% of total emissions), with flaring activities contributing to 53% of total lifetime emissions. This is followed by the combustion of fuel gas (40% of total emissions). It should be reiterated that fugitive emissions calculated in this inventory have likely been overestimated and are expected to be minimised by the vapour recovery unit in place on the FPSO.

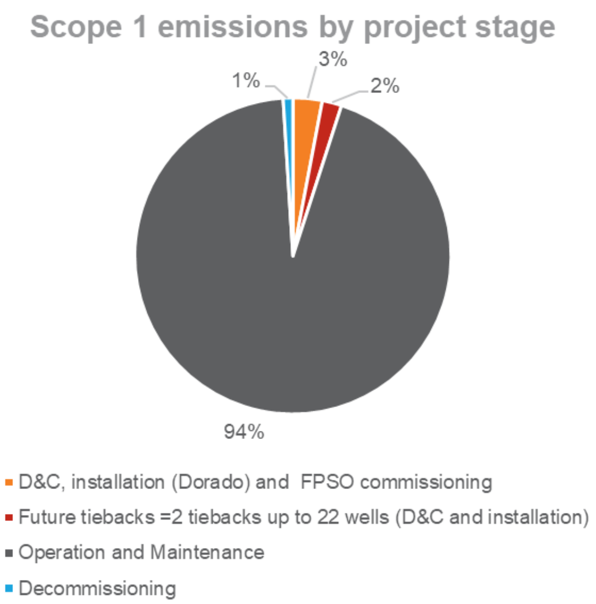

Figure 4. Scope 1 emissions breakdown by project stage

[27] Annualised emissions apply only to the O&M stage and exclude D&C, installation and commissioning.

2.3.6. Atmospheric emissions

Key atmospheric emissions identified include NO_x (45% of other atmospheric emissions), followed by CO (35% of other atmospheric emissions) and VOCs (19%) (see Figure 5). Emissions of SO_x and PMs, while present, are less than 1% of key atmospheric emissions. Due to the high volume of flaring in the O&M stage relative to other stages, this phase is the most significant contributor of atmospheric emissions during the project.

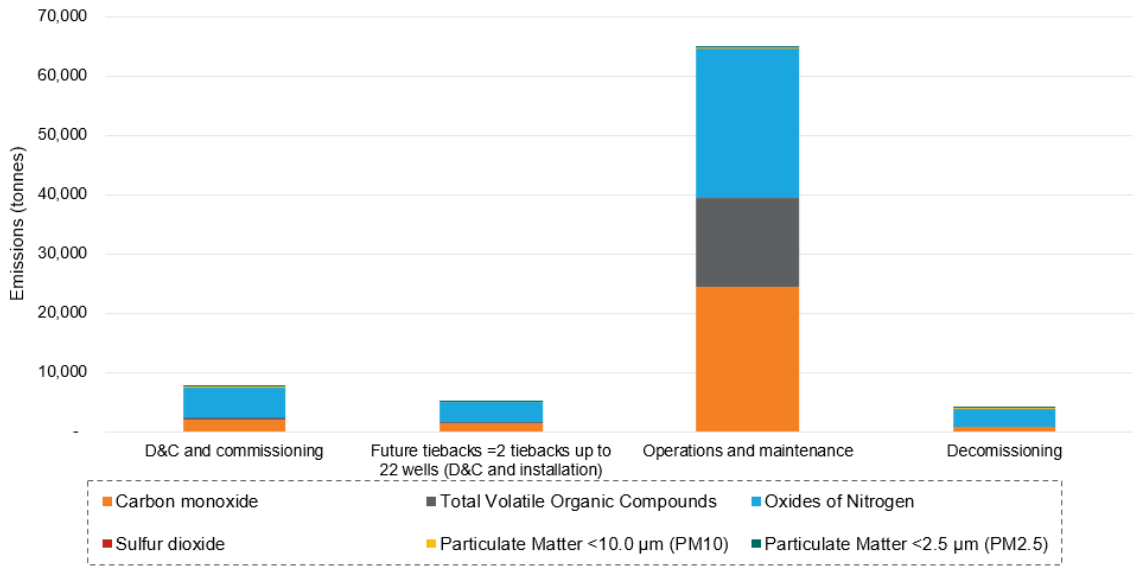

Figure 5. Other atmospheric emissions from the Dorado Development

2.4. Indirect emissions (Scope 3)

2.4.1. Scope 3 boundary

In assessing the Dorado Development's Scope 3 inventory, Energetics used the guidance provided in the GHGP Corporate Value Chain (Scope 3) Accounting and Reporting Standard[28] to identify, categorise and quantify value chain emissions. Together with Santos, the 15 emissions categories detailed by the GHGP were reviewed for relevance and materiality to the Dorado Development's value chain. Table 4 provides a summary of these categories together with explanations for their inclusion or exclusion from the Scope 3 inventory.

[28] Greenhouse Gas Protocol, 'Corporate Value Chain (Scope 3) Accounting and Reporting Standard' < ***https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf***>.

Table 4. Scope 3 emissions categories and their relevance to the Dorado Development

GHGP Category	Description	Inclusion	Relevance to the Dorado Development's emissions boundary
1. Purchased goods and services	Extraction, production, and transportation of goods and services purchased or acquired by the reporting company in the reporting year, not otherwise included in GHGP Categories 2 to 8	✓	• Limited to chemicals purchased for the Dorado processing facility including the flowlines, risers, WHP, and FPSO and infrastructure for future tiebacks • The purchase of fuel is included in GHGP category 3 • At this stage of the project development, there is limited information available on any other goods and services
2. Capital goods	Extraction, production, and transportation of capital goods purchased or acquired by the reporting company in the reporting year	✓	• Limited to Dorado processing facility including the risers, WHP, and FPSO and infrastructure for future tiebacks • The mass of the steel which makes up the structure of the WHP and FPSO were used to quantify this category
3. Fuel- and energy-related activities (not included in Scope 1 or Scope 2)	Extraction, production, and transportation of fuels and energy purchased or acquired by the reporting company in the reporting year, not already accounted for in Scope 1 or Scope 2	✓	• Limited to Dorado processing facility including the risers, WHP and FPSO and infrastructure for future tiebacks • Fuel sources identified in Scope 1 emissions inventory were used to quantify this category
4. Upstream transportation and distribution	Transportation and distribution of products purchased by the reporting company in the reporting year between a company's tier 1 suppliers and its own operations (in vehicles and facilities not owned or controlled by the reporting company)	×	This category will be excluded as: • The development forms part of the upstream sector of oil and gas value chain • The transportation and distribution of goods upstream is likely to be immaterial noting that the transport of raw materials like diesel to the FPSO will be covered in GHGP category 3 (fuel and energy related activities) and Scope 1 transport related emissions. • Other related emissions to upstream transport (i.e. transport of diesel from supplier to barge) are outside the scope of Santos' sphere of influence The exclusion of this category is in accordance with the size and influence criteria Table 6.1 of the Protocol

GHGP Category	Description	Inclusion	Relevance to the Dorado Development's emissions boundary
5. Waste generated in operations	Disposal and treatment of waste generated in the reporting company's operations in the reporting year (in facilities not owned or controlled by the reporting company)	×	This category is excluded on the basis that: • Water waste is proposed to be overboarded, and no solid waste is produced • There is a lack of standardised emissions factor for this waste source together with limited data availability on the organic content of the liquid waste • The emissions source is unlikely to be material relative to the whole Scope 3 inventory
6. Business travel	Transportation of employees for business-related activities during the reporting year (in vehicles not owned or operated by the reporting company)	✓	• Limited to travel associated with the workforce during project preparation, installation activities and travel of workforce to and from site during the operations and maintenance phase of the project • Specifically includes flights of team from head office (Perth) to Dampier and transport from Dampier to FPSO (via helicopter and support vessels)
7. Employee commuting	Transportation of employees between their homes and their worksites during the reporting year (in vehicles not owned or operated by the reporting company)	×	This category will be excluded from the emissions inventory on the basis that material emissions associated with the movement of people are included in Category 6
8. Upstream leased assets	Operation of assets leased by the reporting company (lessee) in the reporting year and not included in Scope 1 and Scope 2 – reported by lessee	×	This category will be excluded due to: • Lack of clarity at this stage of development on the potential use of leased assets, based on project concept, and not yet in FEED and detailed design phase • The emissions source is unlikely to be material relative to the whole inventory

GHGP Category	Description	Inclusion	Relevance to the Dorado Development's emissions boundary
9. Downstream transportation and distribution	Transportation and distribution of products sold by the reporting company in the reporting year between the reporting company's operations and the end consumer (if not paid for by the reporting company), including retail and storage (in vehicles and facilities not owned or controlled by the reporting company)	✓	Limited to transport from the FPSO to the facility at which crude will be processed
10. Processing of sold products	Processing of intermediate products sold in the reporting year by downstream companies (e.g., manufacturers)	✓	Limited to the processing that occurs to produce the immediate outputs from the oil refinery
11. Use of sold products	End use of goods and services sold by the reporting company in the reporting year	✓	Limited to the combustion of fuels as a conservative assumption
12. End-of-life treatment of sold products	Waste disposal and treatment of products sold by the reporting company (in the reporting year) at the end of their life	×	Excluded as this category is limited to the combustion of fuels and excludes any downstream emissions related to the production and use of plastics and chemicals. The combustion of fuels is covered in GHG category 11 - Use of sold products
13. Downstream leased assets	Operation of assets owned by the reporting company (lessor) and leased to other entities in the reporting year, not included in Scope 1 and Scope 2 – reported by lessor	×	Excluded as downstream leased assets will fall under the company-wide emissions reporting and are not specific and/or significant to the Dorado Development
14. Franchises	Operation of franchises in the reporting year, not included in Scope 1 and Scope 2 – reported by franchisor	×	Excluded as downstream leased assets will fall under the company-wide emissions reporting and are not specific and/or significant to the Dorado Development

GHGP Category	Description	Inclusion	Relevance to the Dorado Development's emissions boundary
15. Investments	Operation of investments (including equity and debt investments and project finance) in the reporting year, not included in Scope 1 or Scope 2	×	Excluded as downstream leased assets will fall under the companywide emissions reporting and are not specific and/or significant to the Dorado Development

2.4.2. Key assumptions

The Protocol categories 1, 2, 3, 6, 9, 10 and 11 were identified as relevant to the Dorado Development's Scope 3 inventory. However, as the Dorado Development is at an early stage of development, there is limited information on where the oil will be sold, how it will be processed and who the end user will be. As such, Energetics has applied a series of assumptions, aiming to maintain a conservative approach in estimating emissions. These key assumptions are detailed below.

Category 1, 2, 3 and 6: Purchased goods and services, capital goods, fuel use and business travel

Table 5 summarises the key assumptions for Category 1, 2, 3 and 6.

Table 5. Assumptions used in the calculation of emissions from Category 1, 2, 3 and 6

Category	Assumptions
Category 1: Purchased goods and services	• Purchased goods limited to chemical use • Chemicals purchased based on use during the 20-year operational period[29] • While other purchased goods are not included, primarily due to a lack of data, other emissions from purchased goods are likely to be immaterial
Category 2: Capital goods	• Includes the mass of major capital goods (FPSO, WHP and future tieback infrastructure) only • Assumes the WHP, FPSO and materials required for drilling/ wells are primarily steel. To account for any other materials and construction of the capital goods, an uplift factor of 30% is applied to the emissions factor • Assumes the installation of 3 WHPs (allowance for WHPs to support future tiebacks) • Excludes any equipment on the FPSO and the any equipment related to the risers

[29] Underlying operational assumptions defined by Santos.

Category	Assumptions
Category 3: Fuel- and energy related activities (not included in scope 1 or scope 2)	• Diesel purchased is the only fuel included in this category. Other fuel used for the FPSO is supplied from fuel gas from the reservoirs.
Category 6: Business travel	• Assumes travel via helicopters (three flights per week) and support vessels (one per week) occurs from Dampier to Dorado field for the operational period of 20 years • Assumes flights from Perth to Dampier for personnel (five flights per week)

Category 9: Downstream transportation and distribution

Energetics has assumed that 100% of the Dorado Development's product will be shipped to Kobe, Japan for refining (this is the furthest potential port that the Dorado crude is likely to be shipped to). To maintain a conservative approach, we have also assumed that the return trip of the cargo ship from the final destination port to the loading port is included in this category (the ship returns empty).

Category 10: Processing of sold products

Santos has indicated that the oil produced from the Dorado Development (Dorado reservoir and potential future tiebacks) can be approximated to Caley crude oil. Crude condensate assay results indicate the Dorado well will produce a mixed condensate product from multiple reservoir members. Caley PS-E (51.4° API, 189 ppm wt sulphur) will form the majority of the condensate (80%) followed Baxter condensate (51.0° API, 133 ppm wt sulphur) (20%). As no estimates for the refining slate of Caley or Baxter crude were readily available to be used in this assessment, we considered public sources of similar light, sweet condensates. Cossack crude was identified as the closest to these in terms of geographic location and API and adopted as the proxy for the purpose of this assessment. Cossack crude is extracted from the North West shelf and exhibits an API of 48.8, comparable with Caley and Baxter.

Category 11: Use of sold products

The distillation yields of Cossack crude are shown in Table 6. Following a conservative approach, 100% of the oil product was assumed to be combusted. While Energetics recognises that vacuum residues are commonly used to produce non-fuel products, we have applied a conservative assumption that this fraction is combusted using the emissions factor for fuel oil based on the categorisation of this heavy residue product as low sulfur waxy residue.

Table 6. Typical yield output from the distillation of Cossack crude[30]

Substance	Yield through distillation (%)
LPG	3%
Light naphtha	36%
Heavy naphtha	0%
Kerosene	21%
Diesel	0%
Gasoline	26%
Light vacuum gas oil	13%
Heavy vacuum gas oil	0%
Vacuum residue	2%

2.4.3. Method

Wherever possible, emissions factors were sourced from the DISER's compilation of NGA factors. This specifically applied to Category 11, where the emissions related to the combustion of fuel products were sourced from Table 3 of the DISER's NGA factors, the regulated data set for this type of calculation should emissions occur as Scope 1 emissions. For the calculation of emissions related to Category 1, the Ecoinvent Database (v3) was used as the source of life cycle emissions factors.[31] Ecoinvent v3 is the most recent iteration of the globally used Ecoinvent life cycle inventory (LCI) database. While an Australian implementation of the Ecoinvent database, AusLCI (based on Ecoinvent v2.2) is available, this version does not contain all the required LCI data. For consistency, we have used Ecoinvent v3 throughout. Detailed assumptions used to calculate emissions are outlined in Appendix A.

2.4.4. Scope 3 GHG inventory

Scope 3 GHG emissions from the Dorado Development (on the basis of the initial Dorado field, and future tiebacks yielding 350 MMbbl) were calculated to be approximately 153 $MtCO_2e$. This is equivalent to 7.59 $MtCO_2e$ per year based on total emissions over the 20-year period and 20 $MtCO_2e$ per year based on the year of highest production.[32]

The summary of GHG emissions from activities in the Dorado Development's value chain is provided in Figure 6. Total Scope 3 emissions were 153 $MtCO_2e$ with the final combustion of sold products making up the majority of the Scope 3 emissions inventory (87%), followed by emissions from the refining process (9%). Downstream distribution is just over 3% of the inventory with the remaining categories making up less than 1% of emissions.

[30] BP Crude assays - Cossack Crude, ***https://www.bp.com/en/global/bp-global-energy-trading/features-and-updates/technical-downloads/crudes-assays.html***.
[31] Gregor Wernet et al, 'The Ecoinvent Database Version 3 (Part I): Overview and Methodology' (2016) 21 *International Journal of Life Cycle Assessment* 1218-30.
[32] Based on GHGP categories 9, 10 and 11.

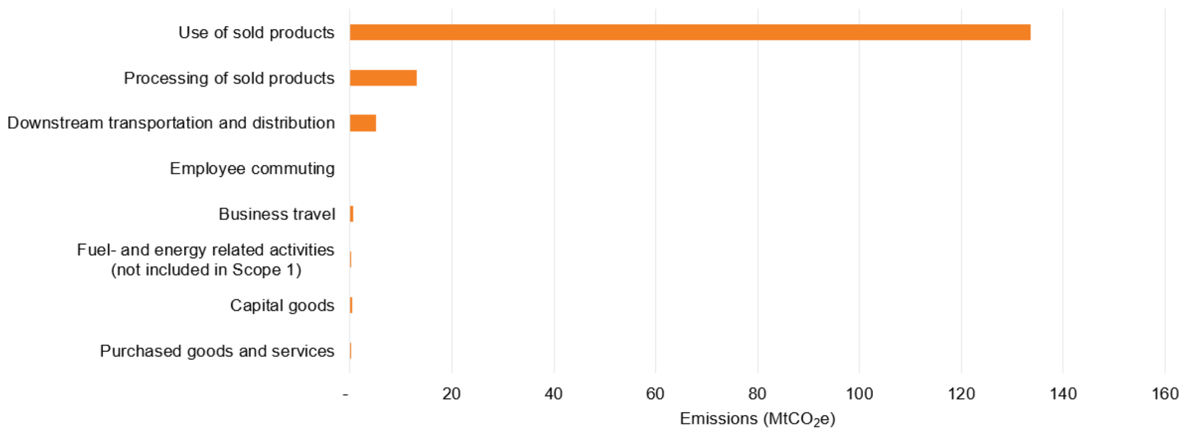

Figure 6. Scope 3 emissions in the project's value chain

2.5. Benchmarking Dorado Development's emissions

2.5.1. Benchmarking against global estimates

The total GHG emissions produced during the 20-year operation of the Dorado Development were found to be approximately 168.6 $MtCO_2e$ with direct emissions (Scope 1) and indirect emissions (Scope 3) contributing to 9% and 91% of total emissions respectively.

The product life cycle emissions were assigned to the following life cycle phases and normalised on a per barrel basis[33] as shown in Table 7 and benchmarked against global averages in Table 8.

Table 7. Emissions intensity of each stage of the Dorado Development's value chain

Phase	Categories included	Total emissions ($MtCO_2e$)	Emissions per barrel (tCO_2e/bbl)
Oil production	Scope 1 emissions Scope 3 emissions: GHGP categories 1, 2, 3 and 6	15.6	0.045
Oil transport	Scope 3 emissions: GHGP Category 9	5	0.0143
Refining	Scope 3 emissions: GHGP Category 10	13	0.0376
Final combustion	Scope 3 emissions: GHGP Category 11	134	0.382
Total		**168.6**	**0.48**

[33] Based on a lifetime production of approximately 350 Mbbl.

Table 8. Benchmarking the Dorado Development against global averages

Phase	Dorado Development (tCO_2e/bbl)	IEA Benchmark (tCO_2e/bbl)[34]
Combustion of sold products	0.38	0.41
Oil development lifecycle (flaring, transport, extraction, refining and methane emissions)	0.098	0.05-0.25

Table 8 indicates that the emissions intensity associated with the combustion of sold products from the Dorado Development is within range of the average emissions intensity identified by the International Energy Agency (IEA)[35] for oil combustion. Differences in the final intensity are likely to be driven by the assumed product slate from the refining process that is sold to end users. The end use of the oil will be driven by demand for combustible fuels. This will be influenced by technology, policy and market conditions which could shift in the lifetime of the Dorado Development. The emissions intensity for the development lifecycle activities projected for the Dorado Development are within the benchmark range.

It should be noted that as the engineering design of the Dorado Development matures, the accuracy of the emissions estimates will improve. Any significant changes to the engineering design or production profile from the assumptions presented in this report will require the emissions profile to be reviewed.

3. Conclusions

Over a 20-year period, the Dorado Development is projected to produce 350 MMbbl of oil from the Dorado field and future tiebacks. Although the final placement of the product is still under consideration, it is anticipated that Asia will be an important market for the oil.

Emissions from the Dorado Development will include GHGs and other atmospheric emissions. Over a 20-year period, the Dorado Development will emit approximately 82,100 t of other atmospheric emissions. Scope 1 GHG emissions were calculated as approximately 15.6 $MtCO_2e$ and Scope 3 emissions as 153 $MtCO_2e$. The majority of Scope 1 emissions occur in the O&M stage (94% of total Scope 1 emissions). The final combustion of sold products makes up the majority of the Scope 3 emissions inventory (87%) followed by emissions from the refining process (9%).

Based on high-level benchmarking, GHG emissions intensities from flaring at the Dorado Development and the use of the sold product are within anticipated industry ranges. However, limited publicly available data on Scope 3 emissions from oil developments makes it challenging to provide a benchmark for the overall GHG emissions intensity. We have based our assessment on best available data at the time and this may be refined as the development progresses.

[34] International Energy Agency, 'The Oil and Gas Industry in Energy Transitions' (2020) <*https://webstore.iea.org/download/direct/2935*>.
[35] International Energy Agency, 'The Oil and Gas Industry in Energy Transitions' (2020) <*https://webstore.iea.org/download/direct/2935*>.

Appendix A Scope 1 and 3 methods

The tables below summarise the source of the estimation method and emissions factors used in the calculation of Scope 1 and 3 emissions for the Dorado Development.

Table 9. Method and emissions factors used for Scope 1 calculations[36]

Activity	Emission method*	NGA factors used**	Data input (over the total duration of each stage)		
			D&C, installation and commissioning	O&M	Decommissioning
Oil production – gas flaring	NGER Determination Section 3.44, Method 1 NPI EET Manual for Oil & Gas v2.0, Table 8	3,759 kg CO_2e/t gas flared	D&C: 25,000 t Commissioning[37] 21,400 t	Safety flaring = 20,900 t Unplanned flaring = 2,140,000 t	N/A
Oil production – liquid flaring	NGER Determination Section 3.44, Method 1 NPI EET Manual for Oil & Gas v2.0, Table 8	3,269 kg CO_2e/t liquid flared	D&C: 54,200 t	N/A	N/A
Diesel combustion (for use in a stationary engine >450kW)	NGER Determination Division 2.4.2, Method 1 NPI EET Manual for Combustion Engines v3.0, Table 43 - Stationary Large Diesel Engines (> 450 kW)	70.2 kg CO_2e/GJ diesel	D&C: 98,700 m^3 Installation: 21,900 m^3 Commissioning: 35,400 m^3	19,000 m^3	57,400 m^3

[36] Data inputs have been provided to 3 significant figures.
[37] Unplanned flaring only.

Activity	Emission method*	NGA factors used**	Data input (over the total duration of each stage)		
			D&C, installation and commissioning	O&M	Decommissioning
Fuel gas combustion (electricity generation)	NGER Determination Division 2.3.2, Method 1 NPI EET Manual for Combustion Engines, Table 52 - Uncontrolled gas turbines natural gas engines	51.53 kg CO_2e/GJ fuel gas Energy content (Project specific): 46.7 GJ/m3 ***		1,740,000,000 m^3	
Fuel gas combustion (compressors)	NGER Determination Division 2.3.2, Method 1 NPI EET Manual for Combustion Engines, Table 52 - Uncontrolled gas turbines natural gas engines	51.53 kg CO_2e/GJ fuel gas		841,000,000 m^3	
Crude oil storage: fixed roof	NGER Determination Division 3.3.3, Section 3.49, Method 1 NPI EET Manual for Fuel and Organic Liquid Storage v3.3, Appendix F1 - Fuel storage-vertical fixed roof tank (Central WA)	0.0056 kg CO_2e/t crude oil		43,300,000 t	

Activity	Emission method*	NGA factors used**	Data input (over the total duration of each stage)		
			D&C, installation and commissioning	O&M	Decommissioning
Light crude oil loading	N/A NPI EET Manual for Oil & Gas EET Manual v2.0, Table 7, Emissions factors for condensate loading operations - total VOC	N/A		43,300,000 t	
Diesel storage (vertical fixed roof)	N/A NPI EET Manual for Fuel and Organic Liquid Storage v3.3, Appendix F1 - Fuel storage-vertical fixed roof tank (Central WA)	N/A		93,800 t	
Fugitive emissions – crude throughput	NGER Determination Division 3.3.3, Section 3.49, Method 1 NPI EET Manual for Oil & Gas EET Manual v2.0, Section 5.1.2, Method 1	1.60 kg CO_2e/t crude oil		43,300,000 t	

Activity	Emission method*	NGA factors used**	Data input (over the total duration of each stage)		
			D&C, installation and commissioning	O&M	Decommissioning
Fugitive emissions – gas throughput	NGER Determination, Division 3.3.6, Section 3.73Q, Method 1 NPI EET Manual for Oil & Gas EET Manual v2.0, Section 5.1.2, Method 1	17.5523 kg CO_2e/t gas		53,800,000 t	
Produced water - Produced water (other than emissions that are vented or flared)	NGER Determination section 3.73NA, Method 1. NGA p33[38]	7.86192 tCO_2-e/ML		363,256 ML[39]	
Acetylene	NGER Determination Division 2.4.2, Method 1, Gaseous fossil fuels other than those mentioned in items 17 to 26	51.53 kg CO_2e/GJ		1,680 m^3	

[38] We have chosen to use 3.73NA Method 1 – produced water (other than emissions that are vented or flared) is it best reflects the situation and the information available
[39] Table 7-13 of OPP states maximum design rate for produced water production is 4,350 m^3/day; tCO_2-e/ML, is equivalent to kgCO_2-e/m^3

Activity	Emission method*	NGA factors used**	Data input (over the total duration of each stage)		
			D&C, installation and commissioning	O&M	Decommissioning
Oils – combusted	NGER Determination, Division 2.4.5A, Section 2.48 A, Method 1	13.9 kg CO_2e/GJ		400 kL	

** Source of NPI and NGER method listed for each activity. If an activity does not have an NGER or NPI method listed this indicates no emissions were calculated for the absent guideline*
*** NGA factors listed as sourced from the NGA factors (August 2021) which draws on the National Greenhouse and Energy Reporting (Measurement) Determinations 2008 and incorporates the National Greenhouse and Energy Reporting (Measurement) Amendment (2020 Update) Determination 2020 (No. 1). NPI factors not listed due to number of discrete factors but can be sourced from the cited NPI guidelines*

Table 10. Method and emissions factors used for Scope 3 calculations

GHGP category	Input	Emissions factor (EF) used	Source
Category 1: Purchased goods and services	Mass of chemicals utilised: • Acetylene • Lubricant oil • Reverse emulsion breaker (water clarifier) • Scale inhibitor • Corrosion inhibitor • Oxygen scavenger	• Acetylene: 5.90 kg CO_2e/kg • Lubricant oil: 1.20 kg CO_2e/kg • Reverse emulsion breaker (water clarifier) (assume epoxy resin): 3.70 kg CO_2e/kg • Scale inhibitor (assume sodium triopolyphosphate): 5.10 kg CO_2e/kg • Corrosion inhibitor (assume 1,2,3-Benzotriazole):13.9 kg CO_2e/kg • Oxygen scavenger (assume sodium sulphite): 1.50 kg CO_2e/kg	Ecoinvent Database (v3).
Category 2: Capital goods	Mass of FPSO, WHP and materials for drilling/wells (t) Assumes majority of capital goods are made up of steel	EF for steel: 1.85 tCO_2e/t steel Uplift factor: 30% (to account for other materials and the construction of capital goods)	World Steel Association position paper[40]
Category 3: Fuel- and energy-related activities (not included in Scope 1 or Scope 2)	Diesel used in direct activities (Scope 1 inventory) (GJ)	Scope 3 EF for diesel: 3.60 kg CO_2e/GJ	Table 43, NGA factors (August 2019)

[40] World Steel Association, 'Steel's Contribution to a Low Carbon Future and Climate Resilient Societies: World Steel Position Paper (2020) <*https://www.worldsteel.org/publications/position-papers/steel-s contribution-to-a-low-carbon-future.html*>.

GHGP category	Input	Emissions factor (EF) used	Source
Category 6: Business travel	• Distance travelled (km) • Mode of travel • Fuel type – for support vessels • Engine rating – for support vessels (kW) • Number of passengers – for helicopters and flights	• Scope 1 EF for diesel in support vessels: 70.2 kg CO_2e/GJ • Scope 3 EF for diesel: 3.60 kg CO_2e/GJ • EF for flight emissions intensity (economy class): 0.173 kg CO_2e/passenger km • EF for helicopters: 0.447 kg CO_2e/passenger km	• Scope 1 EF for diesel in support vessels: Table 3, NGA factors (August 2019) • Scope 3 EF for diesel: Table 43, NGA factors (August 2019) • EF for flight emissions intensity (economy class): UK Government GHG Conversion Factors for Company Reporting[41] • EF for helicopters: Chapter D4, Sunshine Coast Airport Expansion project EIS[42]

[41] Department for Business, Energy and Industrial Strategy, 'Greenhouse Gas Reporting: Conversion Factors 2019' (2019), <***https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019***>.
[42] Sunshine Coast Airport, 'Sunshine Coast Airport Expansion Project, Environmental Impact Statement' (2018), <***http://eisdocs.dsdip.qld.gov.au/Sunshine%20Coast%20Airport%20Expansion/EIS/Volume%20D%20chapters/Chapter%20D4%20-%20Air%20quality%20and%20greenhouse%20gas%20emissions%2018Sep14.pdf***>.

GHGP category	Input	Emissions factor (EF) used	Source
Category 9: Downstream transportation and distribution	• Total crude production (t) • Distance travelled from FPSO to refinery (domestically and internationally) (km) • Tanker type and weight	EF for a crude tanker (80,000 to 119,999 dwt): 0.007 kg CO_2e/t.km	UK Government GHG Conversion Factors for Company Reporting[43]
Category 10: Processing of sold product	• Crude oil input into refinery • Crude oil type (heavy, light)	EF for a refinery processing Cossack crude: 304 kg CO_2e/t crude	Jing et al. (2020)[44]
Category 11: Use of sold product	Product slate (% product yield)	Scope 1 EF for the combustion of stationary fuels	Table 3, NGA factors (August 2019)

[43] Department for Business, Energy and Industrial Strategy, 'Greenhouse Gas Reporting: Conversion Factors 2019' (2019), <***https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019***>.
[44] Jing et al, Carbon intensity of global crude oil refining and mitigation potential, *Nature Climate Change* 10, 526-532 (2020).

Appendix B Dorado Development emissions summary[45]

Table 11. Summary of direct GHG emissions from Dorado Development

Emissions	Units	D&C, installation (Dorado) and commissioning	Future tiebacks[46] (D&C and installation)	Operations and maintenance	Decommissioning
		2023 to 2025	**2030 to 2035**	**2026 to 2045**	**2046 to 2048**
Total carbon dioxide equivalent	tCO_2e	464,736	309,780	14,647,993	155,504
Carbon dioxide (CO_2)	tCO_2e	431,112	293,330	12,303,325	154,840
Methane (CH_4)	tCO_2e	30,426	13,981	2,284,636	222
Nitrous oxide (N_2O)	tCO_2e	3,198	2,468	60,031	443

Table 12. Direct GHG emissions from Dorado Development attributed to source

Emissions category	Units	D&C, installation (Dorado) and commissioning	Future tiebacks (D&C and installation)	Operations and maintenance	Decommissioning
		2023 to 2025	**2030 to 2035**	**2026 to 2045**	**2046 to 2048**
Fuel Gas Combustion	tCO_2-e	0	0	6,207,527	0
Venting emissions	tCO_2-e	0	0	0	0
Diesel Combustion	tCO_2-e	255,262	167,396	51,462	155,504
Safety flaring	tCO_2-e	0	0	78,422	0

[45] Where possible, values have been provided to 3 significant figures.
[46] Two tiebacks, up to 22 wells.

Emissions category	Units	D&C, installation (Dorado) and commissioning	Future tiebacks (D&C and installation)	Operations and maintenance	Decommissioning
Unplanned flaring	tCO_2-e	80,571	0	8,057,055	0
Well clean-up	tCO_2-e	128,904	142,383	0	0
Fugitives / Other	tCO_2-e	0	0	253,527	0

Table 13. Direct atmospheric emissions from Dorado Development

Emissions	Units	D&C, installation (Dorado) and commissioning	Future tiebacks (D&C and installation)	Operations and maintenance	Decommissioning
		2023 to 2025	**2030 to 2035**	**2026 to 2045**	**2046 to 2048**
Carbon monoxide	t	2,090	1,480	24,400	803
Volatile Organic Compounds	t	301	205	15,100	75.8
Oxides of Nitrogen	t	5,100	3,370	25,100	3,020
Sulphur dioxide	t			33.0	
Particulate Matter <10.0 µm (PM10)	t	154	101	155	94.1
Particulate Matter <2.5 µm (PM2.5)	t	151	98.8	154	91.8

Table 14. Summary of Scope 3 GHG emissions

GHGP	Category	Emissions ($ktCO_2e$)	Proportion of Scope 3 inventory	Boundary
1	Purchased goods and services	3.75	0.00244%	Limited to spend on chemicals and diesel
2	Capital goods	319	0.209%	Limited to WHP and FPSO
3	Fuel- and energy related activities (not included in Scope 1)	44.3	0.0290%	Limited to use of diesel on the FPSO
4	Upstream transportation and distribution		N/A	
5	Waste generated in operations		N/A	
6	Business travel	617	0.404%	Limited to use of helicopter and support vessels
7	Employee commuting		N/A	
8	Upstream leased assets		N/A	
9	Downstream transportation and distribution	5,010	3.28%	Limited to sea transport from the FPSO to the relevant port
10	Processing of sold products	13,200	8.61%	Limited to activities which occur at the refining facility
11	Use of sold products	134,000	87.5%	Limited to the combustion of fuel products
12	End-of-life treatment of sold products		N/A	
13	Downstream leased assets		N/A	
14	Franchises		N/A	
15	Investments		N/A	
	Scope 3 total emissions	153,000	100%	

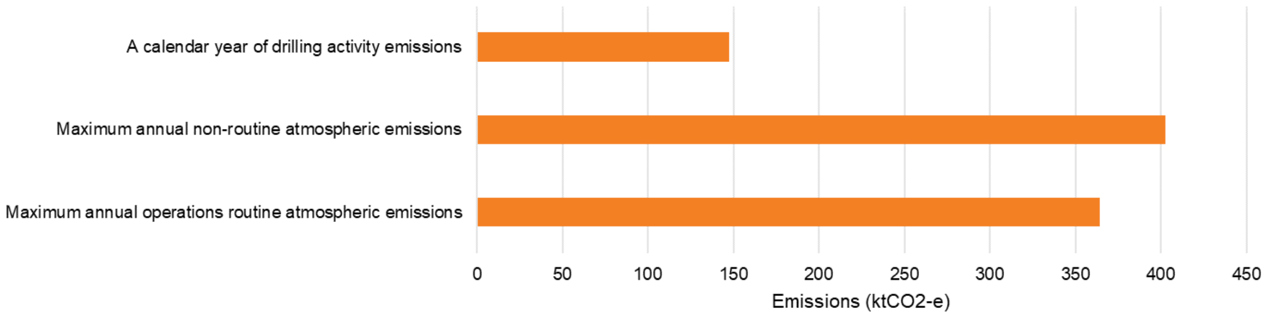

Figure 7. Selected indicators of emissions

Document control

Description	Prepared by	Reviewed by	Approved by	Approval date
2821330_5	SS, GP	MS	MS	27/4/2021
Updated post the NOPSEMA letter 1/2/2022 e.g., GHG factors, produced water NGER method	JH	MS	MS	25/02/2022
Updated with revised produced water formula. Based on Excel inventory doc ref 2963074	JH	RH, MS	JH	03/03/2022

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In June 2008, Energetics became one of Australia's first consulting firms to achieve carbon neutrality through the Australian Government's Greenhouse Friendly Program.

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Contact us

www.energetics.com.au

Sydney

Level 7, 5 Blue St, North Sydney NSW 2060

PO Box 294 North Sydney NSW 2059

P: +61 2 9929 3911

F: +61 2 8089 1144

Perth

Level 3, 182 St Georges Tce, Perth WA 6000

P: +61 8 9429 6400

F: +61 2 8089 1144

Melbourne

Level 14, 356 Collins St, Melbourne VIC 3000

PO Box 652, CSW Melbourne VIC 8007

P: +61 3 9691 5500

F: +61 2 8089 1144

Brisbane

Level 12, 410 Queen St, Brisbane Qld 4000

P: +61 7 3230 8800

F: +61 2 8089 1144

Adelaide

The Hub

5 Peel St, Adelaide SA 5000

P: +61 2 9929 3911

F: +61 2 8089 1144

abn 67 001 204 039

acn 001 204 039

afsl 329935

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Attachment 13 Dorado Development – Public Comment Report

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
1.0		They key issues are summarised below according to the submission.	Subsections of the submission are addressed below	Subsection of the submission are addressed below.
1.1	Commentor # 1	Consideration from the DISER as to why a project such as this is even being tabled.	DISER is responsible for management of offshore acreage for petroleum exploration and production. DISER releases acreage annually, following a stakeholder consultation process, for companies to bid for exploration permits (Offshore petroleum exploration acreage release process). Queries related to DISER's decision to release acreage for the Bedout sub-basin, which has subsequently resulted in the Dorado development proposal by Santos, should be directed to DISER.	Santos considers that no modification to the document is necessary.
1.2		There is a medium risk of accidental release of hydrocarbons and chemical spills. Why is a medium risk considered ok for this project.	The object of the *OPGGS (Environment) Regulations* is to ensure that petroleum activities in Commonwealth waters are carried out in a manner: + consistent with the principles of Ecologically Sustainable Development set out in section 3A of the EPBC Act; + by which the environmental impacts and risks of the activity will be reduced to as low as reasonably practicable (ALARP); and + by which the environmental impacts and risks of the activity will be at an acceptable level. For the Dorado Development, while an unplanned release event is unlikely, the potential environmental risks and impacts of a credible spill event need to be assessed and mitigated to acceptable levels. When considering environmental risk and impact from unplanned spill events, Santos considers the Environment that May Be Affected (EMBA) for each credible spill scenario (see OPP Section 7.3.1). Acceptable levels of environmental risk and impact are demonstrated through the application of control measures to mitigate environmental impacts (see OPP Section 7.1.4) and assessment against acceptability criteria (see OPP Section 7.3.1.4). Santos have reviewed and further detailed the consequence rankings for each of the environmental receptors and sensitivities impacted from an Accidental Release of Hydrocarbon or Chemical Spill. In re-evaluating the risk per receptor, the most sensitive receptors were Marine Mammals, Protected Areas and Heritage, bringing the overall consequence to Major (IV). Through this process the consequence ranking for this risk has been revised from Severe (V) to Major (IV) leading to a reduction in residual risk from Medium to Low. In accordance with the OPGGS (Environment) regulations, Santos considers the likelihood of large hydrocarbon releases and the reduction in impacts should one occur from Dorado Phase 1 to be acceptable.	A consequence ranking was applied to each environmental sensitivity for the Accidental Release – Hydrocarbon and Chemical Spill sections, including: + **Section 7.3.1.2.1** – Water Quality + **Section 7.3.1.2.2** – Sediment Quality + **Section 7.3.1.2.3** – Air Quality + **Section 7.3.1.2.4** – Benthic Habitats + **Section 7.3.1.2.5** – Coastal Habitats + **Section 7.3.1.2.7** – Key Ecological Features + **Section 7.3.1.2.8** – Marine Mammals + **Section 7.3.1.2.10** – Birds + **Section 7.3.1.2.11** – Fish + **Section 7.3.1.2.12** – Protected Areas + **Section 7.3.1.2.13** – Heritage + **Section 7.3.1.2.14** -Fisheries + **Section 7.3.1.2.15** – Tourism + **Section 7.3.1.2.16** – Maritime Industry. The Summary of Risk evaluation in **Section 7.3.1.3** was also updated.
1.3		If water movement in the area is dominated by 'strong tidal regimes' why isn't Santos exploring tidal energy?	The premise of the Dorado Development, as assessed in the OPP, is to extract and produce liquid hydrocarbon fuels from petroleum resources within the Bedout sub-basin. An alternative development concept, such as development of tidal energy resources, is outside the scope of the Dorado OPP. Please note that in accordance with the *OPGGS (Environment) Regulations*, information that is irrelevant to NOPSEMA's decision making criteria such as fundamental objection to oil and gas projects, cannot be considered (NOPSEMA Information Paper # A473111 - Public comment on offshore project proposals).	Santos considers that no modification to the document is necessary.

[65] EPO, control measures and section references were valid for the OPP version submitted at the start of the stage 2 assessment.

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
1.4		There are "no protected areas of overlap" from an accidental release of hydrocarbons and chemical spills. Comment provider disagreed with this statement, expressing that protected areas will be impacted.	Santos confirms that no protected areas overlap the Dorado Project area, however several protected areas do overlap the Environment that May be Affected (EMBA) from the worst-case credible unplanned hydrocarbon release events. Further explanation of the difference between the Dorado Project area and EMBA are described below: *Project Area (further described in **Section 6.3.1** of the OPP):* The Dorado Development Project Area defines the geographic extent where petroleum activities are planned to take place. The current Project Area is 3,443 km². The Project Area has been designed to avoid potential overlap with any KEFs (such as ancient coastline at 125 m depth contour) and fishing sensitivities (such as pearl oyster). *EMBA (further described in **Section 3.1.1** of the OPP)* The EMBA is determined by the combined spatial extent of impacts and risks of Dorado Phase 1 planned activities and unplanned events. For the Dorado OPP the EMBA represents the largest possible spatial extent for the worst-case credible spill events modelled. The protected areas that occur within the EMBA are detailed in section 3.4.2 of the OPP and risk assessed in Section 7.3 of the OPP. As a summary protected areas in the EMBA include: + 18 Commonwealth Australian marine marks (AMPs); + 14 Western Australian marine protected areas; + 14 Western Australian terrestrial protected areas; and + six wetlands of international importance (Ramsar wetlands).	Santos considers that no modification to the document is necessary.
1.5		The impacts to a number of threatened and migrator species are not adequately mitigated, with no effort to explain the mitigation. The project will have significant environmental impact on these species whether passing through the project boundary or reside within it.	A suite of controls have been included in the OPP to mitigate the risk of an accidental release of hydrocarbons to the environment and matters of MNES, examples include: + The WHP, FPSO and MODU(s) will maintain navigation aids to facilitate identification by other users (e.g. radar response beacons). + Source control emergency response plans in place for all drilling activities. + Accepted Oil Pollution Emergency Plans in place for all Dorado Development activities. A full list of controls is listed in **Section 8.2** of the OPP. While the first priority is always to implement measures to prevent an accidental release of hydrocarbons, there are a range of mitigations that can be applied in the event of an unplanned hydrocarbon spill that can greatly reduce the impacts of the spill, and may eliminate impacts to key environmental receptors. The level of impact reduction achieved through effective mitigation for an accidental release of hydrocarbons from Dorado Phase 1 is described in the demonstration of acceptability in **Section 7.3.1.4** of the OPP.	Santos considers that no modification to the document is necessary.
1.6		With endangered animals listed as breeding in the project area, combined with known science behind global warming, this project should not proceed.	The project area is not within any Biologically Important Areas (BIA) for the Humpback whale, with the closest calving BIA 380 kilometres from the project area, so breeding in the project area is unlikely. This assertion is supported by migration data presented in Thums et al. (2018), which shows only a small number of migrating individuals will traverse the Project Area (Figure 13-4 of the OPP). This migration data, collected over 2008, 2009 and 2011 for tagged humpback whales, shows there are no migration paths that overlap with the Project Area.	Santos considers that no modification to the document is necessary.

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
			Seabirds are common around the islands and Pilbara coast beyond the Project Area. There are two seabird breeding BIAs which intersect the Project Area: + lesser frigatebird (overlaps the WHP); and + brown booby (19 km from the WHP). Both of these species, along with other seabird species, are expected to forage within the Project Area. The lesser frigatebird, and brown bobby which are known to breed on small remote tropical islands (Bedout Island), are very unlikely to interact with the Well Head Platform. As per Table 8-1 of the OPP, controls will be applied to reduce the likelihood of interaction of birds with the project (for example lighting design). When considering the limited interaction of protected animals designated as endangered MNES within the Project Area, combined with the application of control measures (Table 8-1 of the OPP) to mitigate environmental impacts, Santos considers the impacts to be acceptable.	
			Regarding impacts from warming to 1.5 degrees, Dorado Phase 1 will be developed in a manner that is compliant with Australia's NDC emissions reduction targets as a party to the Paris Agreement. Demonstration that impacts from Dorado Phase 1 GHG emissions are acceptable is addressed in Section 7.2.6.8 of the OPP.	
1.7		Mitigation such as reporting a vessel strike with an endangered Southern Right Whale is not mitigation. Mitigation should not be developed after the incident.	The assessment of impacts and risks from vessel interactions with marine fauna predicts the risk to be very low (Section 7.4 of the OPP), with no adverse effect on species populations. Management of the risk of vessel interactions with marine fauna is consistent with conservation advice and recovery plans that identify vessel strike as a threat. As per the management controls specified in Table 8-1 of the OPP, all vessels will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans, (except in emergency conditions or when manoeuvring is not possible), which include: + Implement a caution zone of 150 m for dolphins and 300 m for whales, + Vessels will not knowingly approach closer than 50 m to a dolphin 100 m to a whale (i.e. no approach zone), + Make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale, + Vessels will not knowingly travel more than 6 knots within the caution zone of a dolphin or whale, and + There will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone). Outside of the above mitigations, the requirement to report a marine-fauna vessel strike incident is an incident reporting requirement, not a mitigation.	Santos considers that no modification to the document is necessary.
1.8		We know that noise in the ocean is impacting marine life and their ability to survive. Commentor provided several links to articles relating to Noise impacts on MNES. The most	Noise modelling has been used to quantify the environmental impacts anticipated from the Dorado Project in OPP Attachment 10. Potential noise-related impacts will be concentrated around the WHP and FPSO	Santos considers that no modification to the document is necessary.

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
		obvious impact is the link between military sonar and seismic survey detonations and deafness, mass strandings, and deaths of marine mammals.	locations during the installation and operations stages, which will be temporary and of short duration. The Project area does not include critical habitat (Biologically Important Areas) for threatened or migratory EPBC listed species that may be impacted by underwater noise, such as cetaceans and marine turtles (see OPP Section 7.5.2). Permanent Threshold Shift (PTS) impacts to threatened and migratory fauna could only credibly occur during piling and vertical seismic profiling. Potential PTS impacts will be limited to the area in the immediate vicinity of the piling or vertical seismic profiling source. Temporary Threshold Shift (TTS) and behavioural disturbance may occur at greater distances, but have much lower potential for significant impacts to MNES. Santos' management of underwater noise emissions is aligned to industry practices and relevant requirements, for example the adaptive management of piling and vertical seismic profiling activities aligns with EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales (full controls for acoustic emissions are specified in Table 8-1 of the OPP). Santos has experience in effectively implementing these controls for other petroleum developments. These management practices are aligned to relevant conservation advice and recovery plans for threatened and migratory species. While impacts to individual fish may occur, these are expected to consist of TTS and behavioural responses that are temporary. The referenced publications and articles on underwater noise impacts on marine life are noted. Santos consults a wide range of peer-reviewed published literature on noise impacts to marine life to ensure underwater noise environmental impact assessment are informed by peer-reviewed, published science. The Underwater Noise Impacts on Marine Fauna technical appendix captured in **Appendix 12** of the OPP reviews a considerable range of literature relevant to the noise impacts from the Dorado Project (VSP, piling, drilling and vessel operations), to support the acceptability assessment.	
2	Commentor # 2	Regarding gas lift and flash gas compression system for Dorado FPSO; it would be more environmental friendly to have an electrical motor driven compressors. This however will require a larger capacity of power generation system.	During the early engineering phase, Santos did consider electric motors as alternative to gas turbines for the reinjection compressors and flash gas compressors. Electric motor drives were selected for flash gas compressors (*3) and gas driven turbines were selected for the reinjection compressors (*2). The assessment concluded that the electric motor drive for the reinjection compressors would require an additional gas-fired power generation turbine, which would pose unacceptable inefficiencies associated with converting turbine power into electricity and electricity back into rotating power. The reinjection compressor power load requirement closely equates to the available power of a single turbine, therefore it is a good match with regard to efficiency.	Santos considers that no modification to the document is necessary.
3.1	Commentor # 3	EPO4 and other relevant EPO's which refer to 'substantial' are not specific enough, It allows for impact beyond 95%, but does not say to what extent - e.g. 80% species protection limit or 50% species protection limit for example. This should be bounded to a reasonable extent.	+ EPO 4 is considered appropriate, and specific enough. The EPO is bounded by physical extent (i.e. 1 km from the discharge source), and the definition of "substantial" resides in the footnote, describing: - Substantial impacts are defined as an exceedance of the 95% species protection levels for water quality or the default guideline value (high) value for sediments for contaminants in the PW derived from either Australian and New Zealand	+ EPO 7 has been updated in **Section ES-8, Section 7.2.5.3** and **Section 8.2.2** of the OPP.

Santos

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
			guidelines for fresh and marine water quality (Commonwealth of Australia and New Zealand Government 2018) or discharge-specific whole effluent toxicity testing result using methodology aligned with the guidelines. + EPO 7 has been updated as follows: No impacts from Dorado Phase 1 to commercial fish stocks that occur within the Project Area and are important to the following fisheries: - Pilbara Trap Managed Fishery; - Pilbara Fish Trawl Interim Managed Fishery; - Pilbara Line Fishery; - Mackerel Managed Fishery (Area 2)	
3.2		EPO8 is not specific enough.	EPO 8 is worded intentionally to ensure there is a broad link between management and regulation of Dorado Phase 1 Scope 1 emissions and Australia's commitment and emissions reduction targets as a party to the Paris Agreement. By design, the Paris Agreement incorporate adaptive management provisions to evolve over time as progress is made against emissions reduction targets and temperature reduction objectives, which may mean that the Australian Government's regulation of Dorado Phase 1 GHG emissions may also evolve over time.	Santos considers that no modification to the document is necessary
3.3		EPO9 is not specific enough.	EPO 9 is considered appropriate by committing to reduce direct (Scope 1) GHG emissions to ALARP and acceptable levels because this approach drives facility design and operations to reduce emissions to as low as reasonably practicable, rather than adhering to a prescribed limit. It also allows adoption of future advances in emissions reduction technologies, that may not be considered if the EPO is limited to a prescribed emissions performance limit.	Santos considers that no modification to the document is necessary
3.4		EPO10 is not specific enough nor do CM20, 21, 22, 34 to demonstrate impacts from GHG will be reduced to acceptable levels.	+ EPO10 has been updated to better articulate intent, as follows: Dorado Development oil sale agreements require that the product is sold into a country that has ratified the Paris Agreement and is implementing controls to reduce national emissions in line with Paris Agreement climate change objectives. + CM20 has been removed as the economic viability of the Dorado Project is not relevant to management of environmental risk and outside the scope of OPP decision criteria under the *OPGGS (Environment) Regulations* Demonstration that GHG emissions have been reduced to acceptable levels is addressed in Section 7.2.6.8. CM21 is linked to acceptability through 'internal context' acceptability criteria, and CM22 is linked to 'other relevant requirements' acceptability criteria. CM34 has been deleted due to duplication with CM21 and CM38.	+ EPO 10 has been updated in **Section ES-8, Section 7.2.6** and **Section 8.2.2** of the OPP. + CM 20 and CM34 have been removed from **Section ES-8, Section 7.2.6 and Section 8.2.2** of the OPP.
3.5		CM15 is not acceptable - it should meet the no flaring during routine operations principle. Ref: https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030	+ CM15 has been updated as follows: Limit planned flaring to operation of the flare pilot during routine operations.	CM15 has been updated in **Section ES-8, Section 7.2.4, Section 7.2.6, Section 7.2.7** and **Section 8.2.2** of the OPP.
3.6		CM38 does not show a continuous improvement process which will reduce GHG emissions to ALARP or acceptable levels on an ongoing basis.	+ CM38 has been further strengthened to include a clear commitment to establish a GHG management plan for operation of the facilities, that includes a continuous cycle for monitoring, evaluating, and	CM38 has been replaced by CM35 in the revised OPP, refer to updates in **Section ES-8, Section 7.2.4, Section 7.2.6, Section 7.3.7** and **Section 8.2.2** of the OPP.

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
			implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations, as follows: - Dorado Phase 1 will implement a GHG management plan that incorporates an adaptive management approach that facilitates a continuous cycle of monitoring, evaluating, and implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations including: o Evaluation of emissions monitoring data and ensuring the implemented controls deliver predicted emission reductions, o Seeking new and relevant data/information from external sources relevant to GHG emission management including Commonwealth legislation or policy, o Ensuring effectiveness of internal processes and procedures to reduce and manage GHG emissions, o Responding to changes from detailed engineering outcomes or Paris Agreement updates, o Implementing corrective actions identified from the above.	
3.8		CM39 does not achieve either NZE by 2040 or show how scope 1,2 and 3 emissions reach NZE by 2040. CCS alone can not achieve this. 21MTpa CO2-e emissions are outlined within the Santos 2020 climate change report. Please demonstrate how the Dorado scope 3 emissions will be reduced to net zero by 2040 as a part of this development impact assessment.	+ Elements of CM39 have been incorporated into CM21. CM39 has been deleted. CM21 includes a clear commitment by Santos to achieve NZE by 2040 for scope 1 and 2. As outlined in Santos' 2021 Climate Change report, Santos' credible roadmap to NZE 2040 does not rely on CCS alone and includes a combination of nature based offsets, energy efficiency improvements, CCS, electrification and transition to cleaner fuels such as hydrogen. As discussed in Section 7.2.6.7.1, Scope 3 emissions are outside the control of Santos, as further confirmed by a recent ruling in the NSW Land and Environment Court for the Santos Narrabri Project (Mullaley Gas and Pipeline Accord Inc v Santos NSW (Eastern) Pty Ltd, 2021). Notwithstanding that Scope 3 are outside the direct control of Santos, Santos has committed to only sell Dorado product into a country that has ratified the Paris Agreement and is implementing controls to reduce national emissions in line with Paris Agreement climate change objectives (see EPO10), with the Paris Agreement being the established international framework to manage each countries scope 1 and 2 emissions in line with NDC emissions reduction targets. As such Scope 3 emissions are not within the scope of Santos' NZE by 2040 commitment.	+ CM21 has been replaced by CM20 in the revised OPP, refer to updates in **Section ES-8, Section 7.2.6** and **Section 8.2.2** + CM39 has been removed from **Section ES-8, Section 7.2.6** and **Section 8.2.2**.
3.8		There are material residual impacts to MNES and there supporting habitats which will occur as a result of this development (including indirect impacts from climate change). In addition, the project does not meet the principles of ecologically sustainable development at the moment. It is clearly inconsistent with these as demonstrated by the 153 (not 150 as stated in the OPP main text) MtCO2-e (about 30% Australians total annual emissions) scope 3 emissions alone emitted during this first phase of the project (not even contemplating emissions from a potential future gas project).	Residual impacts to MNES from the Projects contribution to climate change have been assessed at a species and ecological community level in 7.2.6.6, and further assessed within consideration for principles of ESD in 7.2.6.7. In broad terms, the Project will be developed in manner that is compliant with Australia's NDC emissions reduction targets as a party to the Paris Agreement to limit global temperature increase to less than 2°C, thereby ensuring that residual impacts to MNES are limited to acceptable levels. It is misleading to represent the Project's Scope 3 emissions as ~30% of Australia's global emissions when Scope 3 emissions represent emissions	Santos considers that no modification to the document is necessary

#	Name/Organisation	Key Summarised comments on the OPP, including any objections or claims	Santos Assessment of Merit of comment; and response to comment	Changes made to the OPP in response to the comment[65]
			from end use that will occur internationally outside of Australia. Section 7.2.6.5.2. presents a more meaningful comparison of Dorado's Scope 1 and Scope 3 emissions as follows: the estimated total annual average scope 1 and scope 3 CO_{2-e} emissions from all stages of Dorado Phase 1 equate to 0.022% of the 2019 global emissions from fossil fuels, and 0.024% and 0.056% of the predicted 2040 world energy-related CO_{2-e} emissions under the IEA Stated Policies Scenario and the Sustainable Development Scenario respectively.	
3.9		On this basis, I believe it it unacceptable for this development to proceed without a clear demonstrated net positive impact on biodiversity in line with UN sustainable development goals (13, 14 and 15). This should be measured through independent methods such as accounting for nature or other recognised standards and have an appropriate level of independent oversight accordingly.	Comments about the Project demonstrating a net positive biodiversity impact in line with UN Sustainable Development Goals are noted, but not relevant to OPP decision or acceptance criteria under the *OPGGS (Environment) Regulations* or are otherwise already addressed via the *EPBC Act*, and are not considered any further.	Santos considers that no modification to the document is necessary
3.10		Santos as a part of this project should commit to actions which demonstrate how Santos will achieve net zero by 2040 and probably interim targets for Dorado specially as well - such as 2030 or 2035.	As outlined in a response to an earlier comment, Santos has outlined a roadmap to NZE 2040 in its 2021 Climate Change report which includes a combination of measures such as nature based offsets, energy efficiency improvements, CCS, electrification and transition to cleaner fuels such as hydrogen. In 2021, Santos also set three new 2030 emissions reduction targets: + reducing absolute scope 1 and scope 2 emissions and emissions intensity from 2019-2020 levels by 26% to 30% by 2030*, in keeping with Australia's Paris Agreement 2030 emissions reduction target; + carbon capture and storage technology used to accelerate the economic feasibility of clean hydrogen and delivering step change in emissions reduction by 2030; and + actively working with customers to reduce their scope 1 and scope 2 emissions by more than one million tonnes of CO2-e/a by 2030 through direct switching to cleaner fuels. * Baseline is defined as Santos' net share of Scope 1 and 2 emissions, in mtCO2e, from financial year 19/20 production volumes, adjusted to include Bayu-Undan and DLNG at 68.4% for full baseline year.	Santos considers that no modification to the document is necessary
3.11		The project scope reinjects gas from the reservoir. But makes no assessment at this point for potential cumulative impacts of GHG emissions in the eventuality from additional scope 1 and 3 emissions from this potential future development. Confirmation now as to potential cumulative impacts through strategic impact assessment should be carried out now. Will gas recovery occur in future or not?	The Dorado OPP clearly states the development premise is for liquids production and gas reinjection only (with potential for future tie-backs). A potential future Stage 2 gas development is out of scope for this OPP.	Santos considers that no modification to the document is necessary

Attachment 14 Underwater Noise Modelling - VSP

Dorado Walk-Away VSP Acoustic Modelling

Assessing Marine Fauna Sound Exposures

Submitted to:

Norman Scott
Santos WA Northwest Pty Ltd

Contract: PO 4800001487

Authors:

Matthew Koessler
Craig McPherson

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JASCO Applied Sciences (Australia) Pty Ltd
Unit 1, 14 Hook Street
Capalaba, Queensland, 4157
Tel: +61 7 3823 2620
www.jasco.com

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

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Executive Summary

Santos WA Northwest Pty Ltd (referred to herein as Santos) are proposing to develop the Dorado oil field, on the North West Shelf of Western Australia. Referred to as the Dorado Development, the project will include a Well Head Platform (WHP) and a Floating Production Storage and Offloading (FPSO) facility.

During the life of the field, Santos may be required to conduct a walk-away Vertical Seismic Profiling (VSP) survey centred on the WHP. This modelling study provides the basis to assess the effects of noise on marine mammals, sea turtles, fish (adults, larvae, eggs), plankton, sponges and corals. The modelling scenarios for the walk-away VSP considered a single 1200 in^3 array suspended at 5 m from the sea surface and towed in a spiral pattern increasing in distance from the WHP. Modelling assessed both individual impulses and multiple impulses within two 24 h periods to determine SEL_{24h}.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. A conservative sound speed profile that would be most supportive of sound propagation conditions for any time of year was defined and applied to all modelling.

The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. Where the corresponding SEL_{24h} radii are larger than those for peak pressure criteria, they often represent an unlikely worst-case scenario. More realistically, marine mammals, fish and sea turtles would not stay in the same location for 24 hours (especially in the absence of location-specific habitat, such as reef), but rather a shorter period, depending upon their behaviour and the proximity and movements of the source. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either permanent threshold shift (PTS) or temporary threshold shift (TTS)) if it remained in that location for 24 hours.

The analysis considered the distances away from the VSP source at which several effects criteria or relevant sound levels were reached. The results are summarised for the representative single-impulse site and accumulated SEL scenarios in Tables 1–4. The impact criteria for impairment of marine mammals, fish and sea turtles use dual metrics (PK and SEL_{24h}), and the longest distance associated with either metric is required to be applied, and thus is presented in this summary.

Marine mammals

Table 1. Maximum (R_{max}) horizontal distances (in km) from modelled site or within SEL_{24h} modelled scenario to behavioural response, TTS and PTS thresholds for marine mammals.

Hearing group	**Modelled distance (in km) to effect threshold (R_{max})**		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
Low-frequency (LF) cetaceans	3.78	15.0	3.4
High-frequency (HF) cetaceans		-	-
Very-high-frequency (VHF) cetaceans		1.95	-

[1] Noise exposure criteria: NOAA (2019)
[2] Noise exposure criteria: Southall et al. (2019)
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles

Table 2. Maximum (R_{max}) horizontal distances (in km) from modelled site or within SEL_{24h} modelled scenario to behavioural response, TTS and PTS thresholds for sea turtles.

Hearing group	Modelled distance (in km) to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[2]	Impairment: TTS[3]	Impairment: PTS[3]
Turtles	1.99	0.72	2.92	0.03

[1] Noise exposure criteria: NSF (2011)
[2] Noise exposure criteria: McCauley et al. (2000b)
[3] Noise exposure criteria: Finneran et al. (2017)

Fish, fish eggs, and fish larvae

This modelling study assessed the ranges for the quantitative guidelines based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- Fish with a swim bladder that do not use it for hearing
- Fish that use their swim bladders for hearing
- Fish eggs and fish larvae

Table 3. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios, maximum-over-depth.

Relevant hearing group	Effect criteria	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.03
	TTS	SEL_{24h}	4.65
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.07
	TTS	SEL_{24h}	4.65
Fish eggs, and larvae	Injury	PK	0.07

Table 4. Summary of maximum fish TTS onset distances for SEL_{24h} modelled scenarios, seafloor receptors.

Relevant hearing group	Effect criteria	Scenario 1	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	TTS	SEL_{24h}	4.55

Relevant hearing group	Effect criteria	Scenario 1	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing			
Fish eggs, and larvae			

Sponges and Coral

To assist with assessing the potential effects on these receptors, the following have been determined:

- Sponges and coral: The PK sound level at the seafloor directly underneath the VSP source was estimated at the single impulse modelling site and did not reach the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018);

1. Introduction

JASCO Applied Sciences (JASCO) performed a modelling study of underwater sound levels associated with the development of the Dorado oil field, on the North West Shelf of Western Australia. The Dorado Development will include a Well Head Platform (WHP) and a Floating Production Storage and Offloading (FPSO) facility.

During the life of the field, Santos may be required to conduct a walk-away Vertical Seismic Profiling (VSP) survey centred on the WHP, which could take up to 10 days to complete. The modelling scenarios for the walk-away VSP considered a single 1200 in^3 array suspended at 5 m from the sea surface and towed in a spiral pattern increasing in distance from the WHP. Modelling assessed both individual impulses and multiple impulses within two 24 h periods to determine SEL24h. The scenarios included tight spirals close to the WHP, and larger spirals further away from the WHP An overview of the modelled area is shown in Figure 1. The geographic coordinates for the single impulse modelled site are provided in Table 5.

This study specifically assessed distances from the considered operations to where underwater sound levels reached thresholds corresponding to various levels of impact to marine fauna. The fauna considered in this study included marine mammals, sea turtles, fish (including fish eggs and larvae), plankton, sponges and corals. Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance.

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), and either single-impulse (i.e., per-strike) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria for impulsive noise sources.

As the walk-away VSP survey could take place at any time in the year, a conservative water column sound speed profile (i.e., the profile leading to the longest acoustic propagation) was selected for modelling (July, Appendix D.4.2). The seabed vicinity of the modelled sites consists of a layer of unconsolidated fine sandy sediment underlain by a package of carbonate rock with various degrees of lithification, but likely increasing in cementation/lithification with depth.

Table 5. Location details for the single impulse modelled site.

Site	Location Description	Latitude (S)	Longitude (E)	MGA (GDA94), Zone 50		Water depth (m)
				X (m)	*Y* (m)	
1	WHP	19° 01' 38.0010"	118° 44' 36.7440"	683500	7895250	91

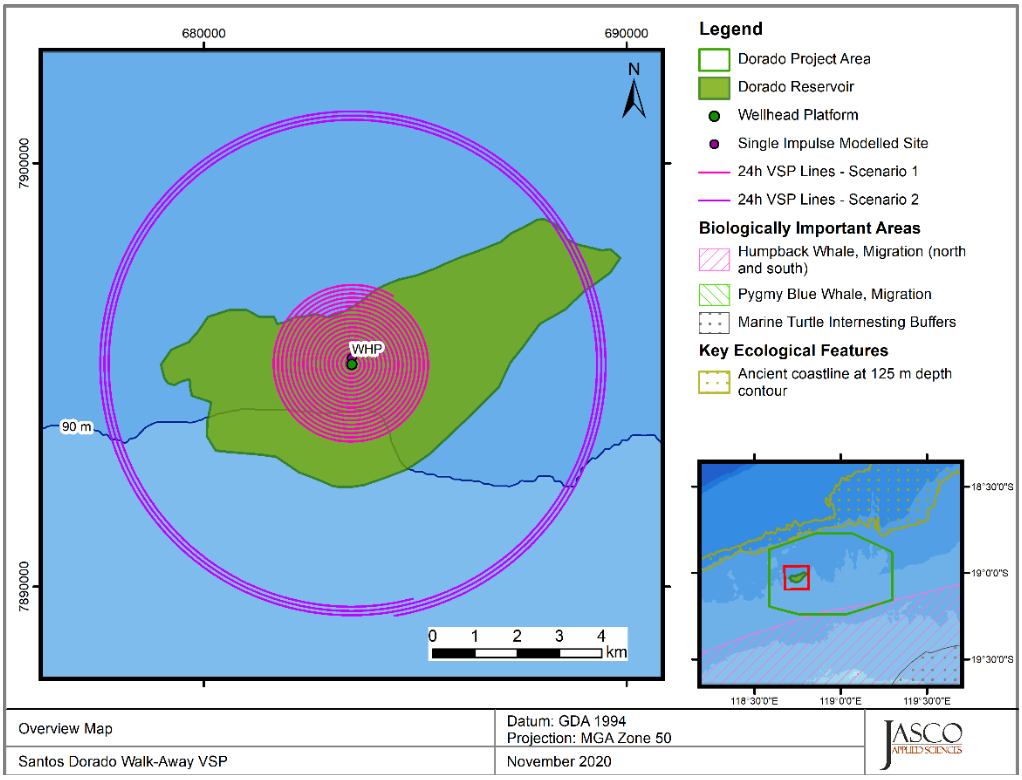

Figure 1. Project overview map showing single impulse site and 24 h SEL modelling scenarios

2. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as from seismic airguns, is not generally proportional to the instantaneous acoustic pressure. Rather, perceived loudness depends on the pulse rise-time and duration, and the frequency content. Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A.1). The period of accumulation associated with SEL is defined, with this report referencing either a “per pulse” assessment or over 24 h. Appropriate subscripts indicate any applied frequency weighting; unweighted SEL is defined as required. The acoustic metrics in this report reflect the updated ISO standard for acoustic terminology, ISO/DIS 18405:2017 (2017).

Whether acoustic exposure levels might injure, impair or disturb marine fauna is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury and impairment, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), United States National Marine Fisheries Service (NMFS 2018) and Southall et al. (2019). The number of studies that have investigated the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

The following thresholds, guidelines and sound levels for this study were chosen because they represent the best available science, and sound levels presented in literature for fauna with no defined thresholds:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Southall et al. (2019) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals (low-frequency (LF), high-frequency (HF), and very-high-frequency (VHF) cetaceans).
2. Marine mammal behavioural threshold based on the current NOAA (2019) criterion for marine mammals of 160 dB re 1 µPa (SPL; L_p) for impulsive sound sources.
3. Sound exposure guidelines for fish, fish eggs and larvae (including plankton) (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of PTS and TTS in turtles.
5. Sea turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_p) (NSF 2011), as applied by the US NMFS, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000a, 2000b).
6. Additionally, for comparison to published literature, a no effect sound level for sponges and corals of 226 dB re 1 µPa (PK; L_{pk}), is reported for comparing to Heyward et al. (2018).

The following sections (Sections 2.1–2.2 and Appendix A.1), expand on the thresholds, guidelines and sound levels for marine mammals, fish, fish eggs, fish larvae, sea turtles, benthic invertebrates and humans.

A detailed description of the criteria and the background literature is provided in Lucke and McPherson (2020).

2.1. Marine Mammals

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal’s hearing organs; and Temporary Threshold Shift (TTS), a temporary reduction in an animal’s hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To help assess the potential for the possible injury and hearing sensitivity changes in marine mammals, this report applies the criteria recommended by Southall et al. (2019), considering both PTS and TTS. These criteria, along with the applied behavioural criteria (NOAA 2019), are summarised in Tables 6 with descriptions included in Appendix A.3.1 (auditory impairment) and Appendix A.3.2 (behavioural response), with frequency weighting explained in Appendix A.4.

Table 6. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL_{24h}, and PK thresholds

Hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans		183	219	168	213
High-frequency cetaceans	160	185	230	170	224
Very-high-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

2.2. Fish, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Sea Turtles was formed to continue developing noise exposure criteria for fish and sea turtles, work begun by a NOAA panel two years earlier. The Working Group developed guidelines with specific thresholds for different levels of effects for several species groups (Popper et al. 2014). The guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. However, as these depend upon activity-based subjective ranges, these effects are not addressed in this report and are included in Table 7 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Sea turtles, fish eggs, and fish larvae are considered separately.

Impulsive noise from airguns (VSP) is assessed in this study, the relevant effects thresholds from Popper et al. (2014) are listed in Table 7. In general, whether an impulsive sound adversely effects fish behaviour depends on the species, the state of the individual exposed, and other factors.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move. The integration time for VSP operations it is over the total number of impulses per day.

Table 7. Guidelines for seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	>219 dB SEL_{24h} or >213 dB PK	>216 dB SEL_{24h} or >213 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae (relevant to plankton)	>210 dB SEL_{24h} or >207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Peak sound pressure level dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.3. Sea turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles).

Finneran et al. (2017) presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol and Ketten 2006, Dow Piniak et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

McCauley et al. (2000a) observed the behavioural response of caged sea turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). In addition the 175 dB re 1 µPa level from McCauley et al. (2000a) is recommended as a criterion for behavioural disturbance. The Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re1 µPa SPL reported by McCauley et al. (2000a) as the level that may result in a behavioural response to marine turtles. These thresholds are shown in Table 8.

Table 8. Acoustic effects of impulsive noise on sea turtles: Unweighted SPL, SEL_{24h}, and PK thresholds

Effect type	Criterion	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behavioural response	NSF (2011)	166	NA	
Behavioural disturbance	McCauley et al. (2000b)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

3. Methods

This section describes the methods used to characterise the VSP acoustic sources as well as the acoustic propagation models and frequency ranges considered for estimation of acoustic fields.

The pressure signature of the individual airguns and the composite decidecade-band point-source equivalent directional levels (i.e., source levels) of the 1200 in^3 VSP source suspended at 5 m were modelled with JASCO's Airgun Array Source Model (AASM; Appendix B.1).

Three sound propagation models were used to predict the acoustic field around the VSP source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz; Appendix C.3).
- FWRAM (5 Hz to 1024 Hz; Appendix C.2).
- Wavenumber integration model (VSTACK, 10 Hz to 1024 Hz).

The models were combined to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix C details each model. MONM was used to calculate SEL of a 360° area around the source location. To account for the change in the source orientation as the spiral survey progresses, the orientation of the VSP source was modelled at tow angles encompassing 360° around the source location incremented at 5º.

VSTACK was used to calculate PK and PK-PK transects at the seafloor at close range from the seismic source. FWRAM was used to calculate PK and PK-PK in the entire water column along four selected transects, and to obtain a range dependent conversion factor to estimate SPL from the MONM-BELLHOP SEL results.

3.1. Acoustic Source Model

AASM accounts for the notional pressure signatures of each source element with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

The VSP source considered was modelled over AASM's full frequency range, up to 25 kHz; Appendix B.1 details this model.

3.2. Sound Propagation Models

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances at least 80 km from the source, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta = 2.5°$ for a total of $N = 144$ radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 350 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using Bellhop for frequencies from 1.6 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

FWRAM was run to 80 km along only four radials for computational efficiency from 5 to 1024 Hz in 1 Hz steps. In the context of VSP source geometry (see Appendix B.2) the along four radials (fore and aft endfire, and port and starboard broadside) for computational efficiency. This was done to compute

SEL-to-SPL conversions (Appendix D.2) but also to quantify water column PK and PK-PK. The horizontal range step was dependent on frequency and ranged from 50 m at lower frequencies to 10 m above 800 Hz.

The maximum modelled range for VSTACK was 1000 m and a variable receiver range increment that increased away from the source, from 10 to 25 m, was used. Received levels were computed at the seafloor.

During a seismic survey, new sound energy is introduced into the environment with each pulse from the seismic source. The vessel towing the airgun was modelled travelling at 2.5 knots, with an overall inter-pulse-interval of 25 m. The modelling for Scenario 1 and Scenario 2 each included 4448 seismic impulses. While some impact criteria are based on the per-pulse energy released, others, such as the marine mammal, turtle and fish SEL criteria used in this report (Section 2) account for the total acoustic energy marine fauna is subjected to over a specified period of time, defined in this report as 24 h. An accurate assessment of the accumulated sound energy depends not only on the parameters of each seismic pulse impulse, but also on the number of impulses delivered in a period and the relative positions of the impulses. Appendix D.3 provides additional details on the methods used to calculate the accumulated sound energy for the considered scenarios.

4. Results

For the results and tables presented below where a dash is used in place of a horizontal distance, these thresholds may or may not be reached due to the discretely sampled radial increments of the modelled sound fields. A dash therefore is an indication that effect levels for the associated metric may only be reached within a very close proximity to a given source.

4.1. Acoustic Source Levels and Directivity

AASM (Section 3.1) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic source, with results provided in Appendix B.2 along with the horizontal directivity plots.

Table 9 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the tow direction), endfire (along the tow direction), and vertical directions. The vertical source level that accounts for the “surface ghost” (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Figure B-2 shows overpressure signatures and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 300 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 9. Far-field source level specifications for the 1200 in^3 source, for a 5 m source depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 μPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 $μPa^2m^2s$)	
		10–2000 Hz	2000–25000 Hz
Broadside	244.7	218.5	174.8
Endfire	232.6	217.8	169.5
Vertical	244.7	218.5	178.8
Vertical (surface affected source level)	244.7	220.5	181.9

4.2. Per-Pulse Sound Fields

This section presents the per-pulse sound fields in terms of maximum-over-depth SPL, SEL, PK, and seafloor PK and PK-PK. The different metrics are presented for the following reasons:

- SPL sound fields were used to determine the distances to marine mammal and turtle behavioural thresholds (see Sections 2.1 and 2.3).
- Per-pulse SEL sound fields are used as inputs into the 24 h SEL scenarios, and to place in context the range to 160 dB re 1 µPa^2·s, relevant for the EPBC Act Policy Statement 2.1 (DEWHA 2008).
- PK metrics within the water column are relevant to thresholds and guidelines for marine mammals, sea turtles, fish, fish eggs and larvae (as well as plankton) (Sections 2.1–2.3).
- PK metrics at the seafloor are relevant to guidelines for fish, fish eggs and larvae (Section 2.2) and the sound level for no effect on corals and sponges.

The maximum and 95% distances (calculated as detailed in Appendix D.1) for per-pulse SEL and SPL metrics are presented in Tables 10 and 11. The SPL sound fields, and distances to relevant isopleths can be visualised on the contour map presented in Figure 2. The SPL sound fields are also presented as a vertical slice along the endfire and broadside directions out to 15 km, with the airgun array in the centre (Figure 3).

Maximum distances to PK and PK-PK thresholds were calculated with maximum-over-depth results presented in Table 12, whilst maximum distances to PK thresholds were also calculated at the seafloor (Table 13).

Table 10. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 1200 in^3 source to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the modelled single impulse site at the WHP.

Per-pulse SEL (L_E; dB re 1 µPa^2·s)	R_{max} (km)	$R_{95\%}$ (km)
190	–	–
180	0.08	0.08
170	0.43	0.39
160†	1.84	1.52
150	4.74	4.16
140	11.0	9.51
130	27.5	22.9
120	756.0	60.5

† Low power zone assessment criteria DEWHA (2008).
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 11. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 1200 in^3 source to modelled maximum-over-depth SPL isopleths from the modelled single impulse site at the WHP.

SPL (L_p; dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–
190	0.06	0.06
180	0.37	0.34
175#	0.72	0.67
170	1.27	1.18
166†	1.99	1.85
160‡	3.78	3.31
150	9.26	8.06
140	23.5	19.5
130	68.5	54.4

Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 12. Maximum (R_{max}) horizontal distances (m) from the 1200 in^3 VSP array to modelled maximum-over-depth peak pressure level (PK) PTS and TTS thresholds for marine mammals (Southall et al. 2019), sea turtles (Finneran et al. 2017) and guidelines for fish (Popper et al. 2014).

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)
Low-frequency cetaceans (PTS)	219	–
Low-frequency cetaceans (TTS)	213	0.03
High-frequency cetaceans (PTS)	230	–
High-frequency cetaceans (TTS)	224	–
Very-high-frequency cetaceans (PTS)	202	0.23
Very-high-frequency cetaceans (TTS)	196	0.41
Fish (Recoverable injury): No swim bladder (also applied to sharks)	213	0.03
Fish (Recoverable injury): Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	0.07
Sea turtles (PTS)	232	–
Sea turtles (TTS)	226	–

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 13. Maximum (R_{max}) horizontal distances (in m) from the 1200 in^3 VSP array to modelled seafloor peak pressure level thresholds (Popper et al. 2014) (PK) from the modelled single impulse site at the WHP.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)
Sound levels for sponges and corals†	226	Not Reached
Fish (Recoverable injury): No swim bladder (also applied to sharks)	213	
Fish (Recoverable injury): Swim bladder not involved in hearing; Swim bladder involved in hearing Fish eggs, and larvae	207	45

† Heyward et al. (2018)

4.2.1. Sound field maps and graphs

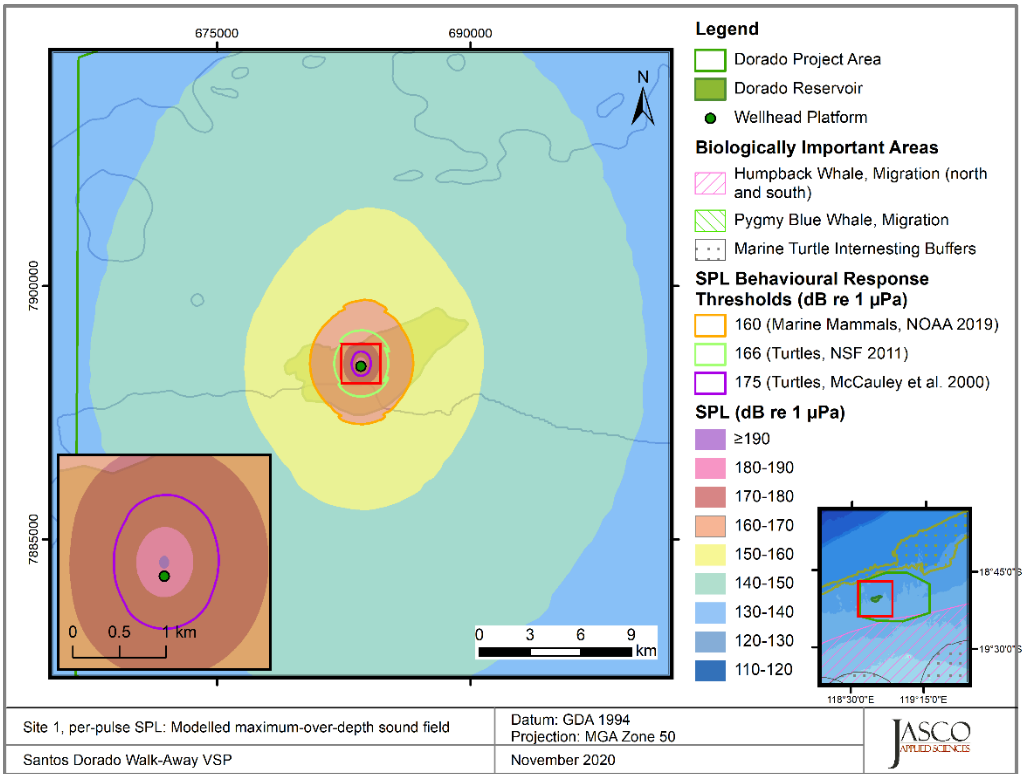

Figure 2. *SPL:* Sound level contour map showing unweighted maximum-over-depth results.

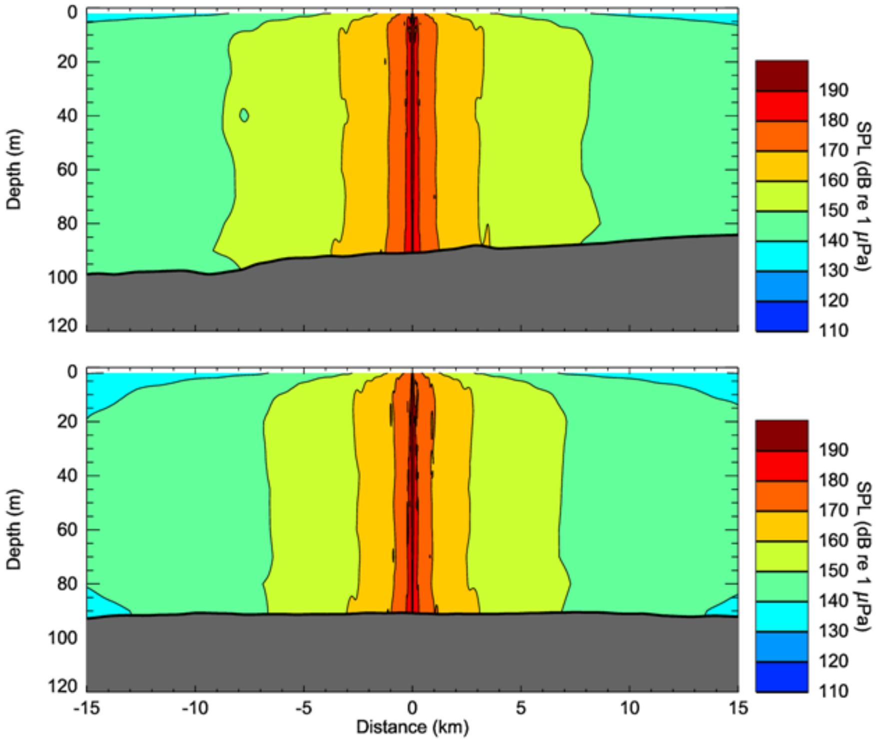

Figure 3. *SPL*: *Vertical sound field slice,* broadside (top) and endfire (bottom).

4.3. Multiple Pulses Sound Fields

This section presents the sound fields in terms of SEL accumulated over 24 hours of survey, for the two modelled SEL_{24h} scenarios. Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum and 95% distances (R_{max} and $R_{95\%}$; calculated as detailed in Appendix D.1) to marine mammals and turtle PTS and TTS thresholds (listed in Table 14), and to estimate maximum distance and the area to injury and TTS thresholds for fish over the entire water column and at the seafloor (Table 15).

The SEL_{24h} sound fields are presented as contour maps in Figures 4 to 7. These figures present the unweighted SEL_{24h} in 10 dB steps, as well as the isopleths corresponding to criteria thresholds. Only contours at ranges larger than the nearfield of the seismic source are rendered.

Table 14. *Marine Mammal and sea turtles*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the survey lines to permanent threshold shift (PTS) and temporary threshold shift (TTS) thresholds considering 24 h of survey activity.

Hearing group	Weighted SEL thresholds ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1[A]		Scenario 2[B]	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS					
Low-frequency cetaceans	183	3.4	34.8	0.96	57.0
Mid-frequency cetaceans	185	–	–	–	–
High-frequency cetaceans	155	–	–	–	–
Sea Turtles	204	0.03[C]	1.8	0.03[C]	1.8
TTS					
Low-frequency cetaceans	168	13.6	523.6	15.0	661.8
High-frequency cetaceans	170	–	–	–	–
Very High-frequency cetaceans	140	1.95	11.5	0.20	5.8
Sea Turtles	189	2.92	25.9	0.63	37.3

[A] Radial distance reported from the centre of the WHP unless indicated otherwise.
[B] Radial distance reported from the centre of a 24 h scenario track unless indicated otherwise.
[C] Radial distance estimated from the centre impulse point.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 15. *Fish guidelines*: Maximum horizontal distances (R_{max}, in km) from the survey lines and area (km²) to injury and temporary threshold shift (TTS) thresholds considering 24 h of survey activity.

Marine fauna group	**Threshold for SEL_{24h}** ($L_{E,24h}$; dB re 1 µPa²·s)	**Scenario 1**[A]		**Scenario 2**[A]	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
Maximum-over-depth					
I	219	–	0.003	–	0.003
II, fish eggs and fish larvae	210	<0.02	1.78	<0.02	1.78
III	207	0.02	1.78	0.02	1.78
Seafloor					
I	219	*	*	*	*
II, fish eggs and fish larvae	210	*	*	*	*
III	207	*	*	*	*
Fish recoverable injury					
Maximum-over-depth					
I	216	<0.02	1.78	<0.02	1.78
II, III	203	0.03	1.78	0.03	1.78
Seafloor					
I	216	*	*	*	*
II, III	203	*	*	*	*
Fish TTS					
Maximum-over-depth					
I, II, III	186	4.65[B]	65.4	2.48[C]	140.6
Seafloor					
I, II, III	186	4.55[B]	63.9	2.4[C]	137.0

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
[A] Radial distance estimated from a shot point unless indicated otherwise.
[B] Radial distance reported from the centre of the WHP.
[C] Radial distance reported from the centre of a set of 24 h scenario tracks unless indicated otherwise.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
An asterisk indicates that the sound level was not reached.

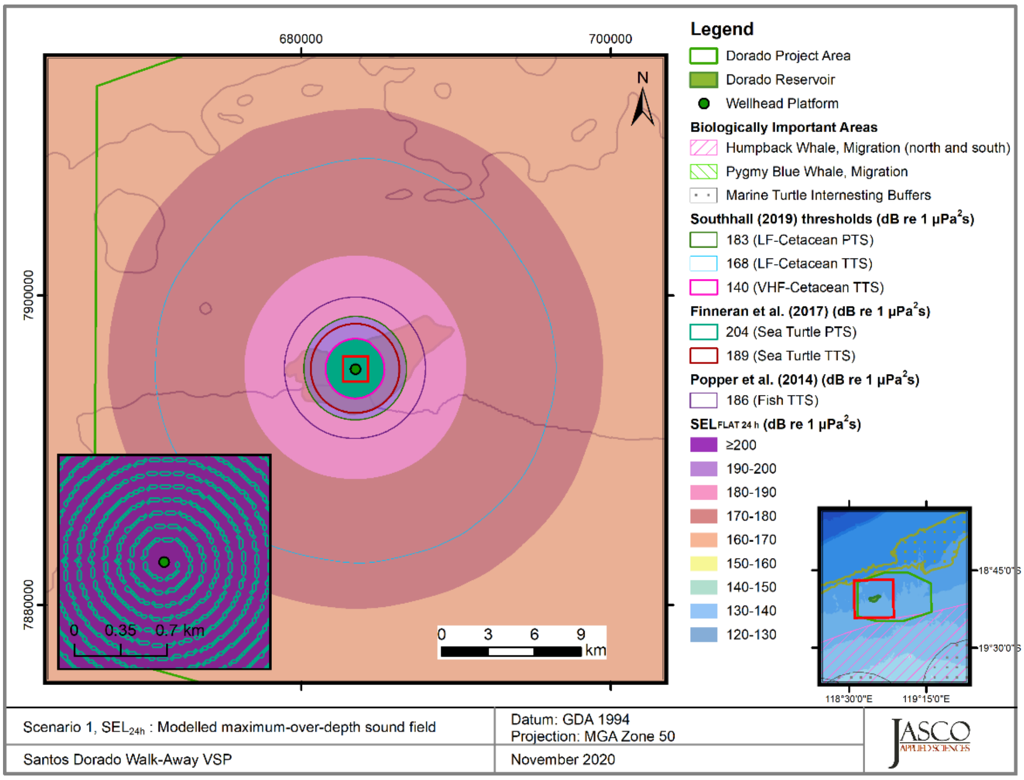

Figure 4. *Scenario 1*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-, and very-high-frequency cetaceans and sea turtles and fish.Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 14 and 15 for tabulated radii.

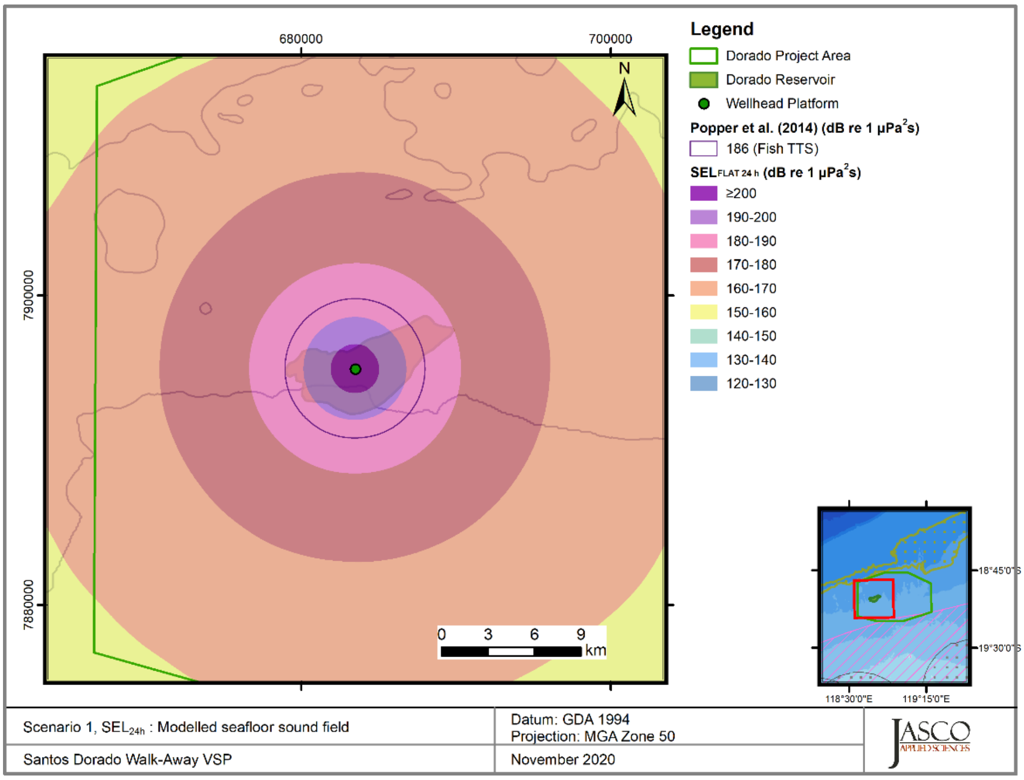

Figure 5. *Scenario 1*: Sound level contour map showing unweighted seafloor SEL_{24h} results, along with isopleths for fish. Where contours are too small to identify on the map refer to the radii in Table 15 for distances. Mortality and recoverable injury thresholds for Fish I were not reached.

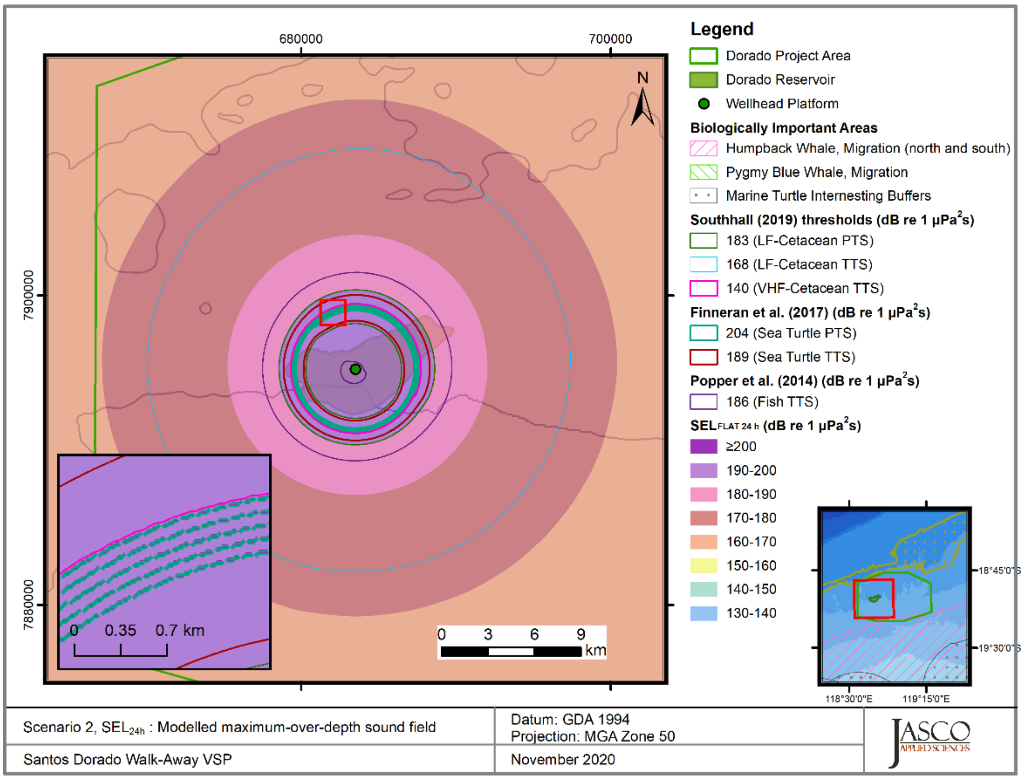

Figure 6. *Scenario 2*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-, and very-high-frequency cetaceans and sea turtles and fish.Thresholds omitted here were not reached or not large enough to display graphically. Refer to Tables 14 and 15 for tabulated radii.

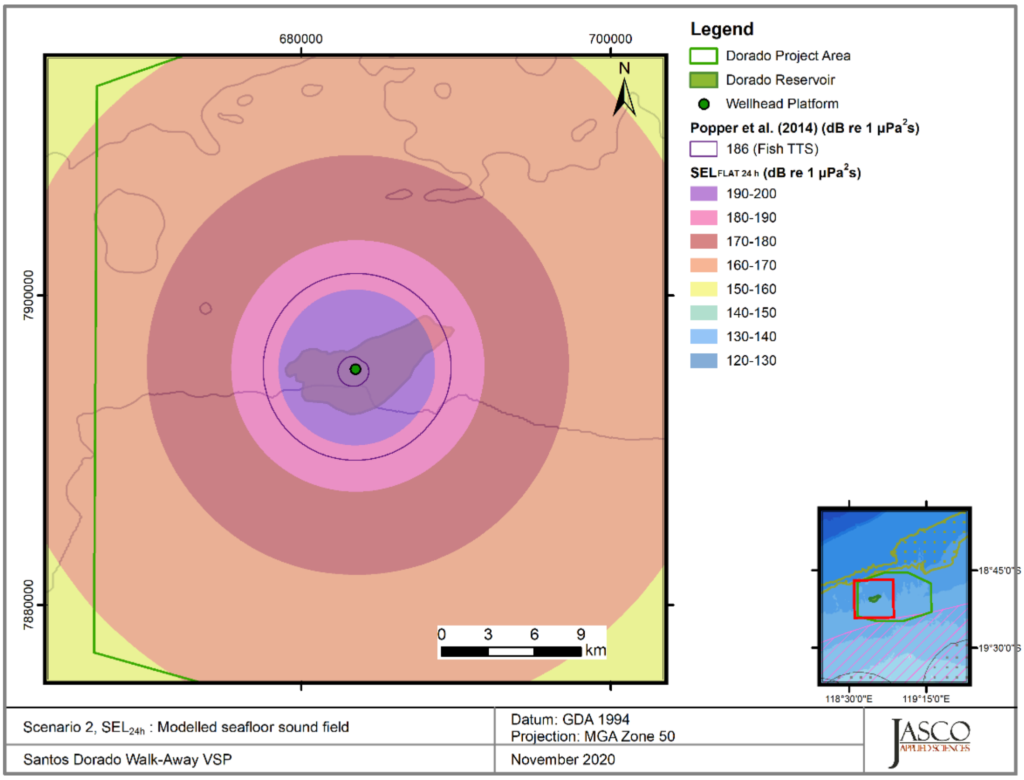

Figure 7. *Scenario 2*: Sound level contour map showing unweighted seafloor SEL_{24h} results, along with isopleths for fish. Where contours are too small to identify on the map refer to the radii in Table 15 for distances. Mortality and recoverable injury thresholds for Fish I were not reached.

5. Discussion and Summary

An analysis of seasonal sound speed profiles, the results of which are presented in Appendix D.4.2, indicated that July was the month most conducive to sound propagation due to the presence of an upward refracting layer near the sea surface; as such it was selected to ensure a conservative estimation of distances to received sound level thresholds. Modelling also accounted for site-specific bathymetric variations (Appendix D.4.1) and local seabed geoacoustic properties (Appendix D.4.3).

As the VSP modelled site was situated on the central North West Shelf, variations in bathymetry were generally gradual within the modelled area. Any variations in the bathymetry had a small effect on the predicted sound field footprints as manifested in the generally symmetric single pulse sound field footprints.

5.1. Ranges to exposure thresholds

For the results and summary tables presented above and below where a dash is used in place of a horizontal distance, these thresholds may or may not be reached. Due to the discretely sampled 20 m radial increments of the modelled sound fields, distances to those levels could not be estimated to the computational resolution of the closest step to the source. It is likely that in the case of per-pulse SPL, SEL, and PK, some thresholds would be reached at distances between the source and the modelled horizontal resolution (20 m); the injury thresholds based on accumulated SEL on the other hand may not be reached at any range due the species specific frequency weighing functions. A dash therefore is an indication that effect levels for the associated metric may only be reached within a very close proximity to a given source, if at all.

This study predicted underwater sound levels associated with the VSP source at the WHP. The underwater sound field was modelled for a 1200 in^3 seismic source array deployed at depth 5 m (Appendix B). The VSP source exhibits minor directivity (Figure 2), with higher levels in the broadside direction.

The accumulated SEL over 24 hours of seismic source operation was modelled considering two representative scenarios with a realistic acquisition pattern for the walk-away VSP – either close to the MODU or further out on the spiral. The modelling predicted the accumulation of sound energy, considering the change in location and the azimuth of the source at each pulse point, which were used to assess distances to the SEL_{24h} based thresholds and guidelines. The results were presented as maps of the accumulated exposure levels and tabulated values of ranges to threshold levels and exposure areas for the given effects criteria (Section 4.3).

5.2. Summary

This section summarises the distances to the noise effect criteria applied in this study (Section 2) for the various fauna groups. The effect criteria for impairment of marine mammals, fish and sea turtles use dual metrics (PK and SEL_{24h}), and the longest distance associated with either metric is required to be applied, and thus is presented in this summary.

The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. Where the corresponding SEL_{24h} effect radii are larger than those for peak pressure criteria, they often represent an unlikely worst-case scenario. More realistically, marine mammals, fish and sea turtles would not stay in the same location for 24 hours, but rather a shorter period, depending upon their behaviour and the proximity and movements of the source. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained in that location for 24 hours.

Marine mammals

Table 16 summarises the distances to effect criteria for marine mammals.

Table 16. Maximum (R_{max}) horizontal distances (in km) from modelled site or within SEL_{24h} modelled scenario to behavioural response, TTS and PTS thresholds for marine mammals (PK values from Table 12 and SEL_{24h} values from Table 14).

Hearing group	Modelled distance (in km) to effect threshold (R_{max})		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
Low-frequency (LF) cetaceans	3.78	15.0	3.4
High-frequency cetaceans		–	–
Very-high-frequency cetaceans		1.95	–

[1] Noise exposure criteria: NOAA (2019)
[2] Noise exposure criteria: Southall et al. (2019)
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles

Table 17 summarises the distances to effect criteria for sea turtles.

Table 17. Maximum (R_{max}) horizontal distances (in km) from modelled sites or scenarios to behavioural response thresholds and PTS and TTS thresholds for sea turtles (PK values from Table 12 and SEL_{24h} values from Table 14).

Hearing group	Modelled distance (in km) to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[2]	Impairment: TTS[3]	Impairment: PTS[3]
Turtles	1.99	0.72	2.92	0.03[C]

[1] Noise exposure criteria: NSF (2011)
[2] Noise exposure criteria: McCauley et al. (2000b)
[3] Noise exposure criteria: Finneran et al. (2017)
[C] Radial distance estimated from the centre impulse point.

Fish, fish eggs, and fish larvae

This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information).
- Fish with a swim bladder that do not use it for hearing.
- Fish that use their swim bladders for hearing.
- Fish eggs and fish larvae.

Tables 18 and 19 summarise the distances to injury criteria for fish, fish eggs and fish larvae along with the relevant metric and the location of the information within this report.

Table 18. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Table 12 and SEL_{24h} values from Table 15).

Relevant hearing group	Effect criteria	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.03
	TTS	SEL_{24h}	4.65
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.07
	TTS	SEL_{24h}	4.65
Fish eggs, and larvae	Injury	PK	0.07

Table 19. Summary of maximum fish TTS onset distances for SEL_{24h} modelled scenarios, seafloor receptors , values from Table 15.

Relevant hearing group	Effect criteria	Scenario 1	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	TTS	SEL_{24h}	4.55
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing			
Fish eggs, and larvae			

Sponges and Coral

To assist with assessing the potential effects on sponges and coral, the PK sound level at the seafloor directly underneath the VSP source was estimated and compared to the no effect sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); it was not reached (Table 13).

6. Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

absorption
The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

acoustic impedance
The ratio of the sound pressure in a medium to the rate of alternating flow of the medium through a specified surface due to the sound wave.

ambient noise
All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

Auditory frequency weighting (auditory weighting function, frequency-weighting function)
The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017). One example is M-weighting introduced by Southall et al. (2007) to describe "Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterising auditory effects of strong sounds".

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 10^5 Pa or 10^{11} µPa.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decade
Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 2006).

decidecade
One tenth of a decade (ISO 2017). Note: An alternative name for decidecade (symbol ddec) is "one-tenth decade". A decidecade is approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a "one-third octave".

decidecade band
Frequency band whose bandwidth is one decidecade. Note: The bandwidth of a decidecade band increases with increasing centre frequency.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

fast-average sound pressure level
The time-averaged sound pressure levels calculated over the duration of a pulse (e.g., 90%-energy time window), using the leaky time integrator from Plomp and Bouman (1959) and a time constant of 125 ms. Typically used only for pulsed sounds.

fast Fourier transform (FFT)
A computationally efficiently algorithm for computing the discrete Fourier transform.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, high-, and very-high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level for any frequency of the hearing group that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialised for high-frequency hearing. Mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019).

intermittent sound
A level of sound that abruptly drops to the background noise level several times during the observation period.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialised for hearing low frequencies.

masking
Obscuring of sounds of interest by sounds at similar frequencies.

median
The 50th percentile of a statistical distribution.

Monte Carlo simulation
The method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but they use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of

toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

peak-to-peak pressure level (PK-PK)
The difference between the maximum and minimum instantaneous pressure levels. Unit: decibel (dB).

percentile level, exceedance
The sound level exceeded *n*% of the time during a measurement.

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

pressure, hydrostatic
The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2·s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 µPa²·s. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: µPa²·s/Hz.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa²:

$$L_p = 10\log_{10}(p^2/p_0^2) = 20\log_{10}(p/p_0)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 µPa·m (pressure level) or dB re 1 µPa²·s·m (exposure level).

spectrogram
A visual representation of acoustic amplitude compared with time and frequency.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

very-high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialised for very-high-frequency hearing. High-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019).

wavelength
Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,pk}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\text{pk}} = 10\log_{10}\left(\frac{\max|p^2(t)|}{p_0^2}\right) = 20\log_{10}\left(\frac{\max|p(t)|}{p_0}\right) \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,pk\text{-}pk}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{p,\text{pk-pk}} = 10\log_{10}\left(\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2}\right) \tag{A-2}$$

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right) \tag{A-3}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,fast}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,boxcar\ 125ms}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$). In this report, SPL refers to $L_{p,boxcar\ 125ms}$.

The sound exposure level (SEL or L_E; dB re 1 µPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \quad \text{(A-5)}$$

Because the SPL and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \quad \text{(A-6)}$$

When applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., *LE,LF,24h*; see Appendix A.4).

A.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analysing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are one tenth of a decade wide. They are approximately one third of an octave (base 2) wide and are therefore often referred to as 1/3-octave-bands. Each octave represents a doubling in sound frequency. The centre frequency of the ith band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}}\,\text{kHz} \quad \text{(A-7)}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i) \quad \text{(A-8)}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-3). The acoustic modelling spans from band 7 (f_c (7) = 5 Hz) to band 44 ($f_c(44)$ = 25 kHz).

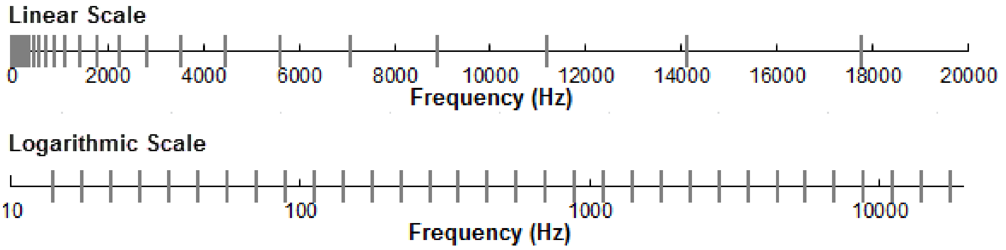


Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{\text{lo},i}$ and $f_{\text{hi},i}$:

$$L_{p,i} = 10 \log_{10} \int_{f_{\text{lo},i}}^{f_{\text{hi},i}} S(f)\, df \qquad \text{(A-9)}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}} \qquad \text{(A-10)}$$

Figure A-4 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the spectral levels at higher frequencies. Acoustic modelling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

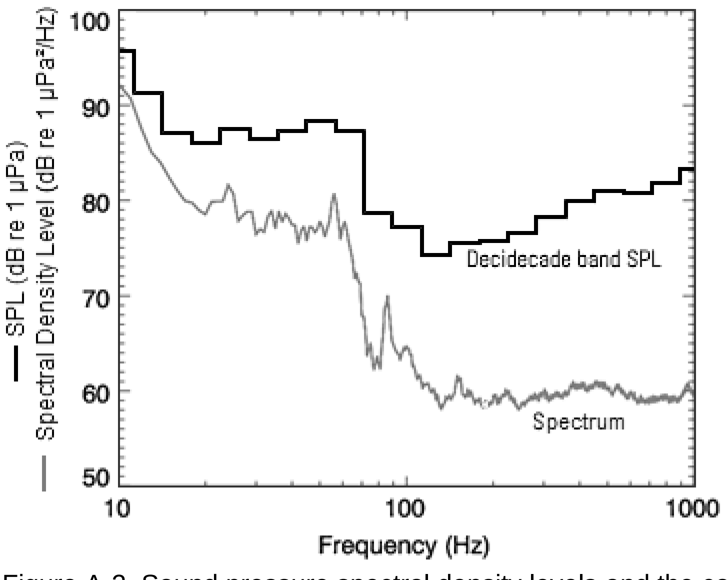


Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

$$f_c(i) = 10^{\frac{i}{10}} \text{ kHz} \qquad \text{(A-11)}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{\text{lo},i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{\text{hi},i} = 10^{\frac{1}{20}} f_c(i) \qquad \text{(A-12)}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-3). The acoustic modelling spans from band 7 (f_c (7) = 5 Hz) to band 44 ($f_c(44)$ = 25 kHz).

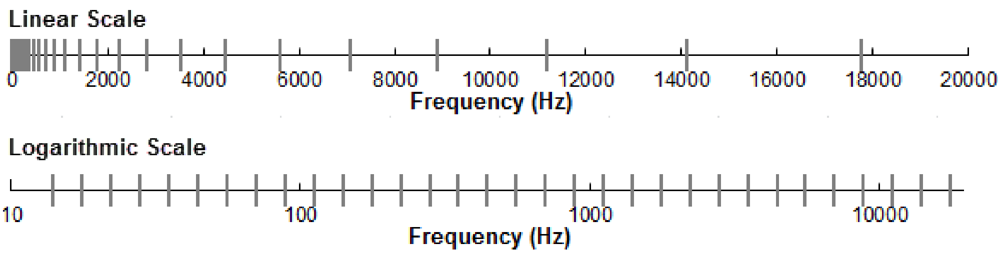


Figure A-3. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{\mathrm{lo},i}$ and $f_{\mathrm{hi},i}$:

$$L_{p,i} = 10 \log_{10} \int_{f_{\mathrm{lo},i}}^{f_{\mathrm{hi},i}} S(f)\, df \tag{A-13}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}} \tag{A-14}$$

Figure A-4 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the spectral levels at higher frequencies. Acoustic modelling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

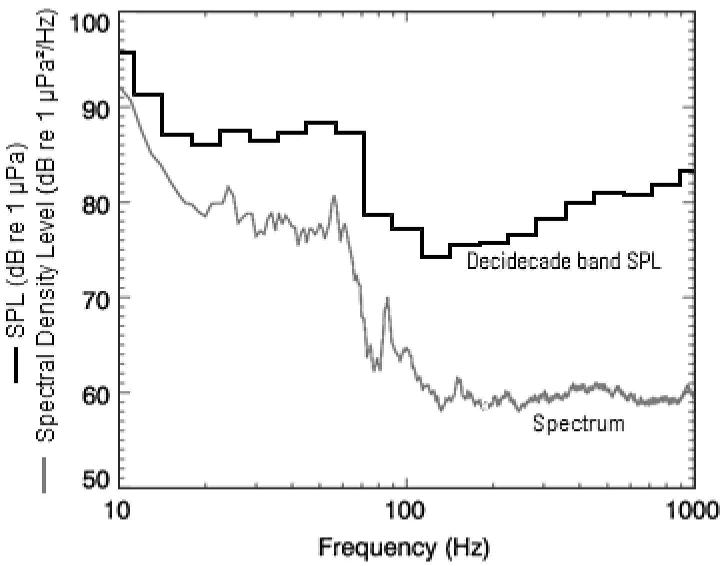


Figure A-4. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

A.3. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources–primarily airguns used in seismic surveys–could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Auditory Impairment

There are two categories of auditory threshold shifts (also termed Noise Induced Threshold Shift, NITS): Permanent Threshold Shift (PTS), a physical injury to an animal's hearing system; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of physiological and mechanical processes in the inner ear. While PTS undoubtedly constitutes an injury, TTS (as a temporary effect) was not considered in the same way. However, recent research clearly indicates that already moderate levels (<12 dB) of TTS produced an accelerated hearing loss (PTS) resulting from progressive neural degeneration with age (Kujawa and Liberman 2006, 2009, Maison et al. 2013, Kujawa and Liberman 2015).

The most recent criteria for assessing possible effects of impulsive sounds (such as pile driving or seismic impulses) noise and non-impulsive sound (such as vessel noise) on marine mammals, Southall et al. (2019), was applied in this study.

A.3.2. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.4. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \tag{A-15}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans, but the weighting functions remain the same. Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-5 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
High-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
Very-high-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

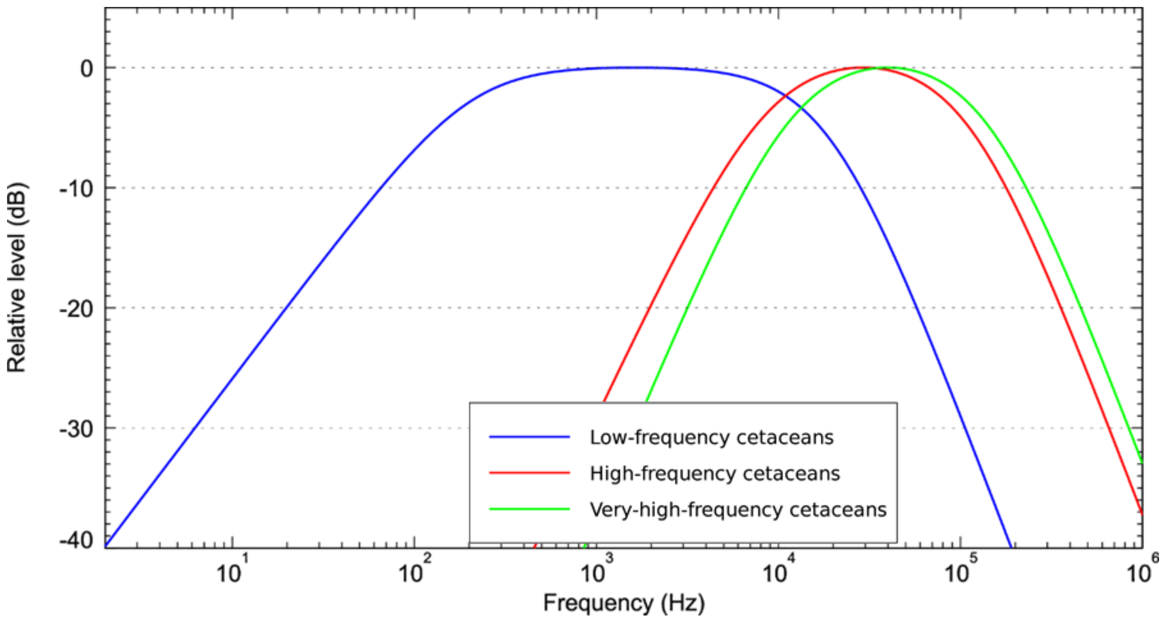


Figure A-5. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2019).

Appendix B. VSP Source

B.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landrø (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, operating depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda} \quad \text{(B-1)}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

B.2. VSP Source Parameters

The layout of the seismic source is provided in Figure D-1. Details of the airgun parameters are provided in Table B-1. The right panel of Figure D-1 should the layout of the array with depth and offset, in the context of this source geometry the broadside direction is perpendicular to the sagittal plane of the array and the endfire direction is parallel to the sagittal plane of the array.

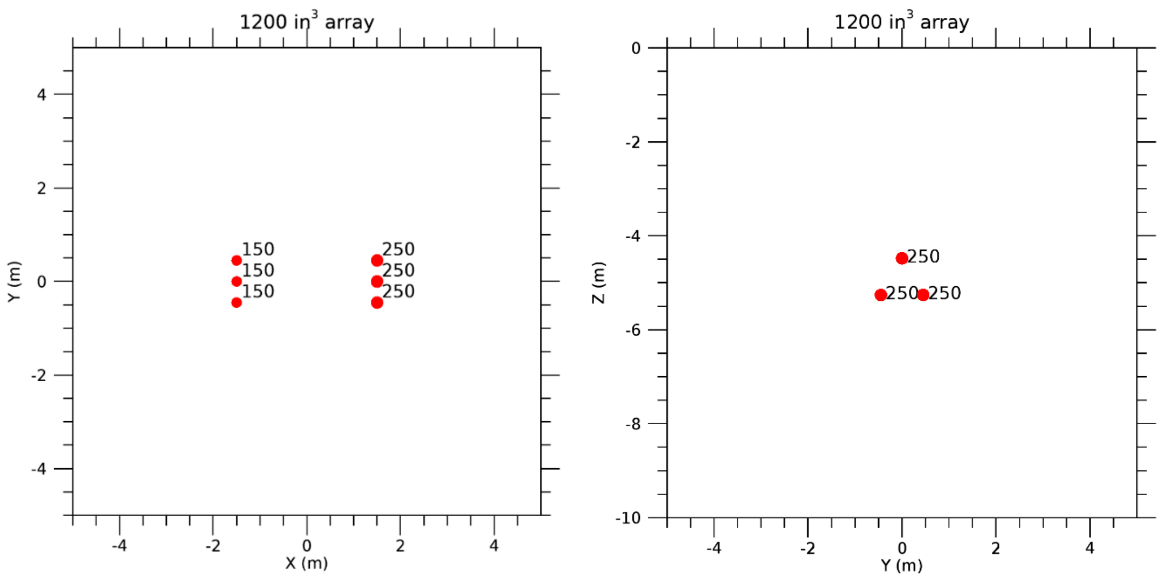


Figure B-1. Layout in plan view (left) and cross-section view (right) of the modelled 1200 in^3 VSP source array. Operational depth is 5 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table B-1.

Table B-1. Layout of the modelled 1200 in^3 seismic source array. Operational depth is 5 m. Firing pressure for all guns is 2000 psi. Also see Figure B-1.

Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	1.5	0	4.48	250
2	1.5	-0.45	5.26	250
3	1.5	0.45	5.26	250
4	-1.5	0	4.48	150
5	-1.5	-0.45	5.26	150
6	-1.5	0.45	5.26	150

B.3. Array Source Levels and Directivity

Figure B-2 shows the broadside (perpendicular to the sagittal plane), endfire (parallel to the sagittal plane), and vertical overpressure signature and corresponding power spectrum levels for the 1200 in^3 array (Appendix B.2). Horizontal decidecade-band source levels shown as a function of band centre frequency and azimuth (Figure B-3) indicate that this array is mainly isotropic.

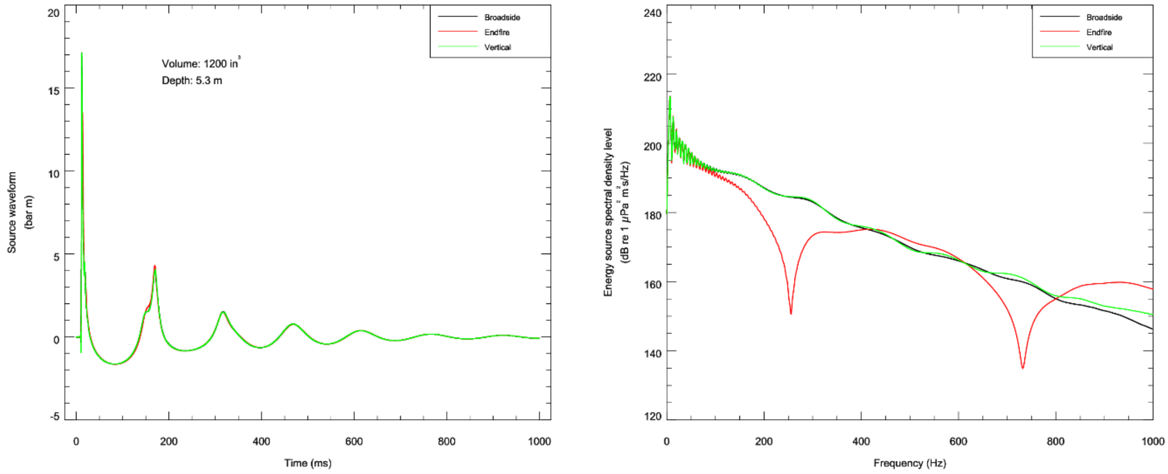


Figure B-2. Predicted source level details for the 1200 in^3 array at a 5 m operational depth.(Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

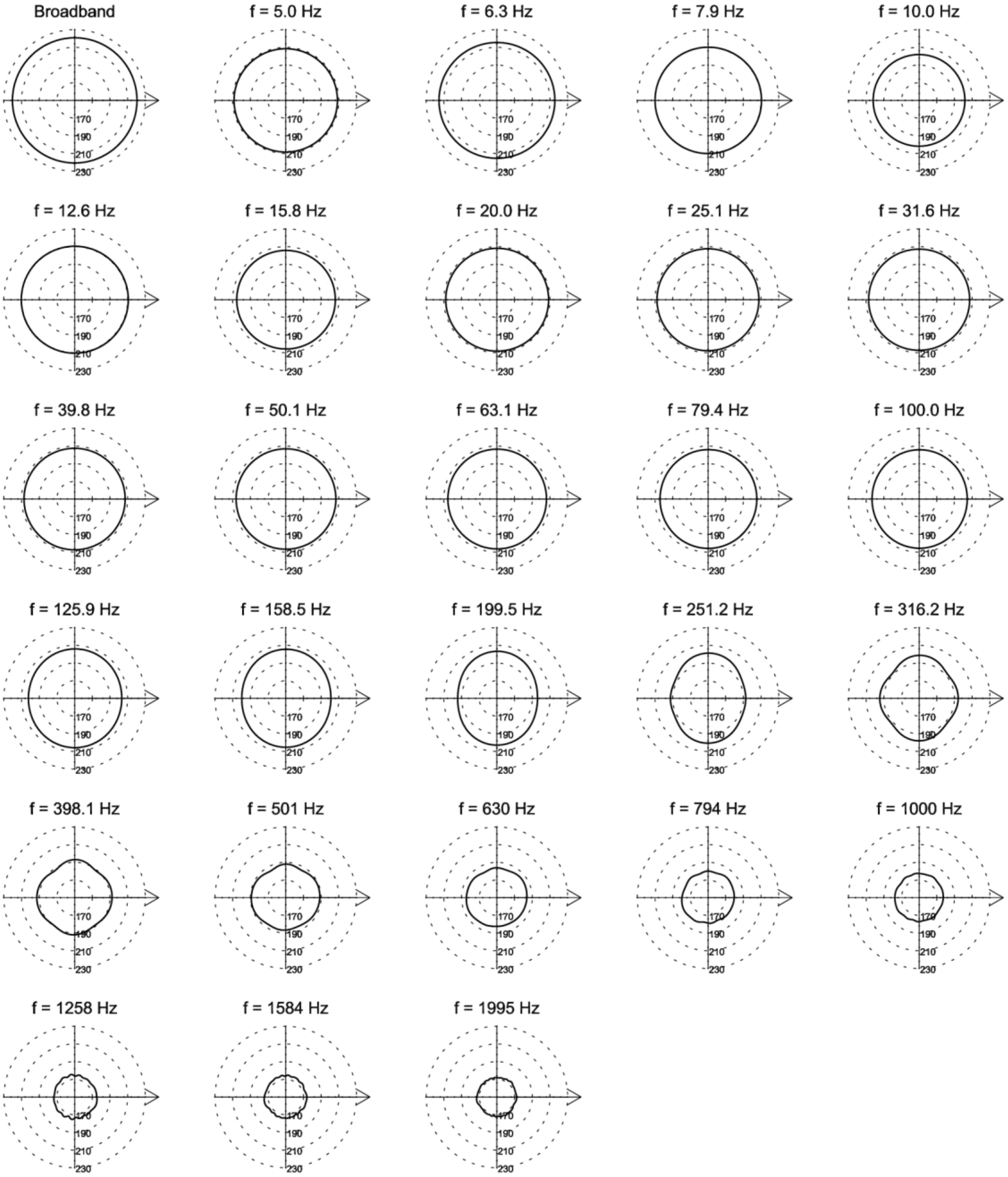


Figure B-3. Directionality of the predicted horizontal source levels for the 1200 in^3 seismic source array, 5 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the decidecade-bands modelled; frequencies are shown above the plots. The endfire axis is to the right. Operational depth is 5 m.

Appendix C. Sound Propagation Models

C.1. Transmission Loss

The propagation of sound through the environment was modelled by predicting the acoustic transmission loss–a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs. Transmission loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Transmission loss depends on the acoustic properties of the ocean and seabed, its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 µPa^{2}m^2, and transmission loss (TL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 µPa by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{TL} \tag{C-1}$$

C.2. Noise Propagation with FWRAM

For impulsive sounds from the seismic source, time-domain representations of the pressure waves generated in the water are required to calculate SPL and PK. Furthermore, the seismic source must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seafloor geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

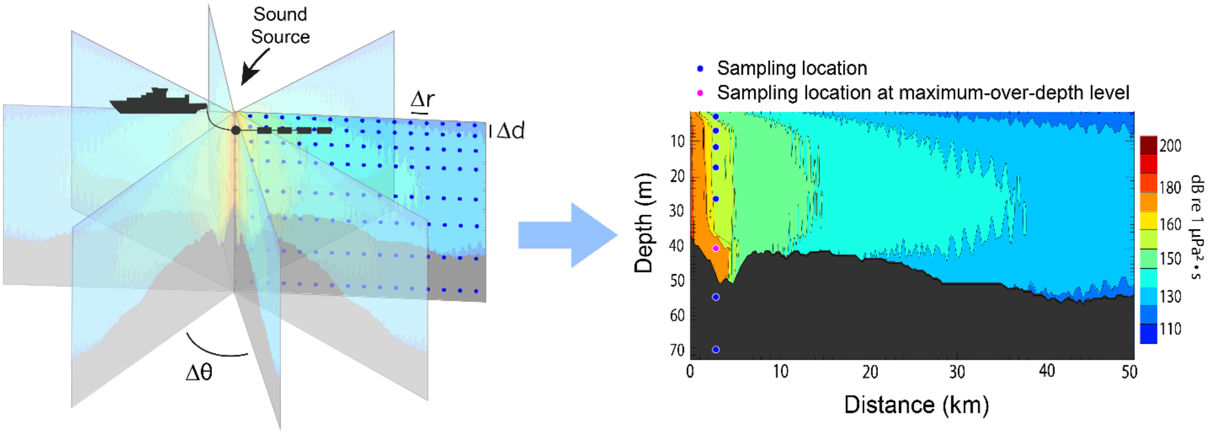
Besides providing direct calculations of the PK and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

C.3. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed but is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1.6 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1.6 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes.



MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of decidecade bands. Sufficiently many frequency bands, starting at 5 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The decidecade-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received decidecade-band levels.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as colour contours around the source.

C.4. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

Appendix D. Methods and Parameters

This section describes the specifications of the seismic source that was used at all sites and the environmental parameters used in the propagation models.

D.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure D-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure D-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure D-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

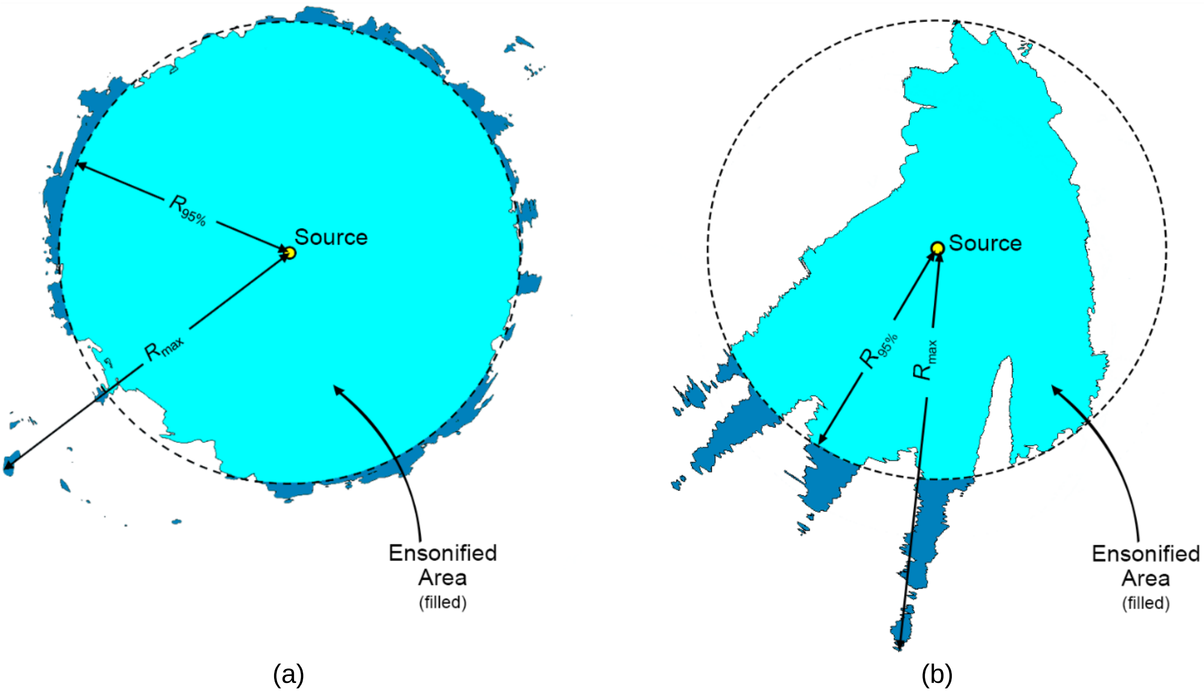


Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

D.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at modelled site 1. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. A 125 ms fixed time window positioned to maximise the SPL over the pulse duration was applied. The resulting SEL-to-SPL offsets were averaged in 0.01 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for the site. The range-dependent conversion function was then applied to predicted per-pulse SEL results from MONM to model and map SPL values. Figure D-2 shows the conversion offsets for the WHP site; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source

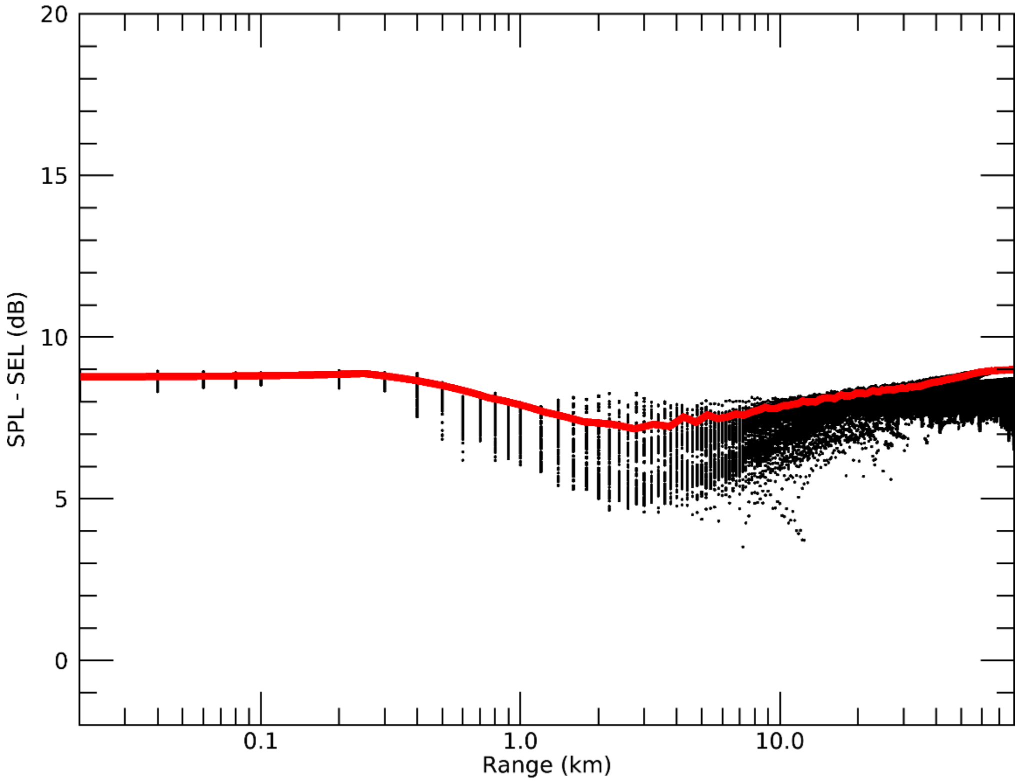


Figure D-2. Range-and-depth-dependent conversion offsets for converting SEL to SPL for VSP pulses at the Dorado WHP site. Black dots are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Accumulated SEL Calculation

When there are many seismic pulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The distance between the consecutive seismic impulses is small enough, however, that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse location(s) are calculated, they are adjusted to account for the source position for nearby impulses.

Although estimating the cumulative sound field with the described approach is not as precise as modelling sound propagation at every impulse location, small-scale, site-specific sound propagation features tend to blur and become less relevant when sound fields from adjacent impulses are summed. Larger scale sound propagation features, primarily dependent on water depth, dominate the cumulative field. The accuracy of the present method acceptably reflects those large-scale features, thus providing a meaningful estimate of a wide area SEL field in a computationally feasible framework.

To produce the map of accumulated received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth level was calculated at the single impulse modelled site(s) within the modelled region. The radial grids of maximum-over-depth and seafloor sound levels for each impulse were then resampled (by linear triangulation) to produce a regular Cartesian grid. The sound field grids from all impulses were summed (Equation A-5) to produce the cumulative sound field grid with cell sizes of 20 m. The contours and threshold ranges were calculated from these flat Cartesian projections of the modelled acoustic fields. The single-impulse SEL fields were computed over model grids approximately 80 × 80 km in range, which encompasses the full area of the cumulative grid (the entire survey area).

D.4. Environmental Parameters

D.4.1. Bathymetry

Water depths throughout the modelled areas were extracted from a dataset provided by the client (Berry 2019) and these data were re-gridded from several overlapping sub dataset using bathymetry acquired during recent surveys in the area of the dorado development project. The Australian Bathymetry and Topography Grid, a 9 arc-second grid data (Whiteway 2009) was used as a base layer for re-gridding. Bathymetry data were re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 54) with a regular grid spacing of 100 × 100 m. For large the scale overview inset maps in the report, Australian Bathymetry and Topography Grid, a 9 arc-second grid data (Whiteway 2009) was used to supplement client supplied data.

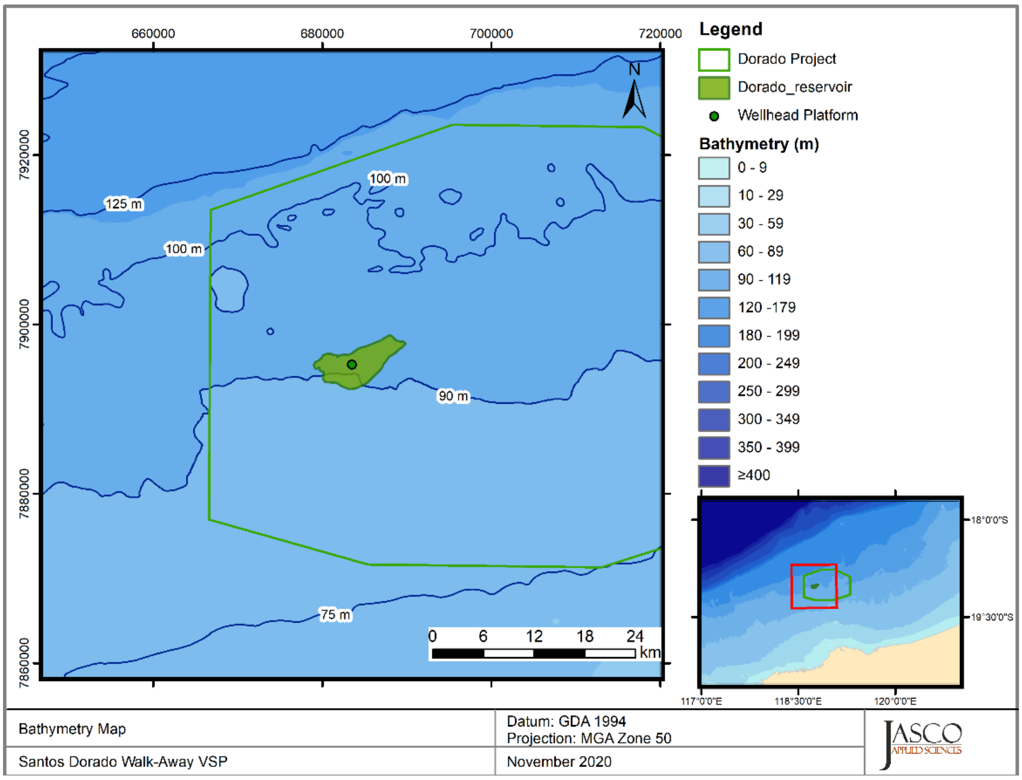


Figure D-3. Bathymetry in the modelled area.

D.4.2. Sound speed profile

The sound speed profile in the area was derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles within a 100 km box radius encompassing all modelled sites. The July sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, July was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-4 shows the resulting profile used as input to the sound propagation modelling.

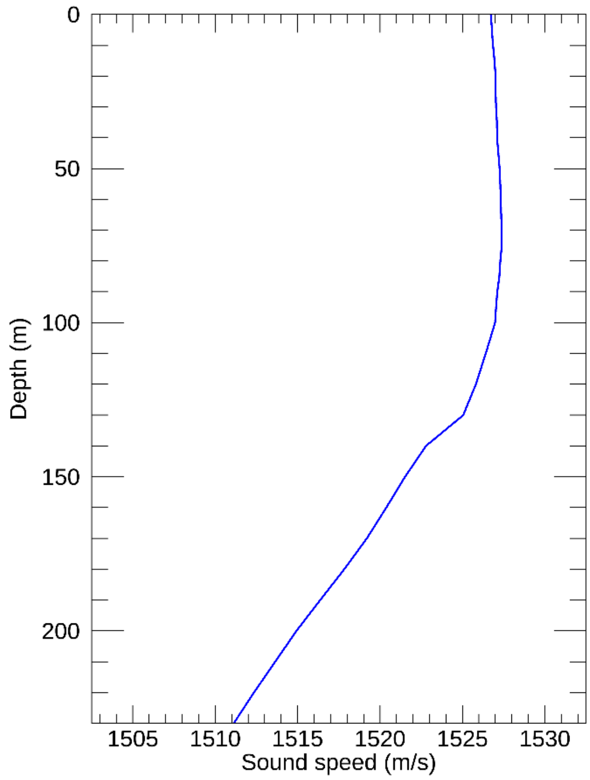


Figure D-4. The modelling sound speed profile corresponding to July Profiles are calculated from temperature and salinity profiles from *Generalized Digital Environmental Model* V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.4.3. Geoacoustics

For the modelled sites the seabed in the area has been described as a calcarenite substrate overlain with a layer of sand (NGI 2017). This is very similar to a profile described in association with measurement data (McCauley et al. 2016), and other modelling studies in the region (AIMS 2018). The geoacoustic parameters used for modelling (Table D-1) are based on Duncan et al. (2009).

Table D-1. Geoacoustic profile for the modelled site

Depth below seafloor (m)	Predicted lithology	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–10	Medium carbonate sand	1.8	1700	0.8	350	2.5
>10	Calcarenite	2.4	2800	0.1		

D.5. Model Validation Information

Predictions from JASCO's propagation models (MONM, FWRAM, and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).