

gorgon gas development
backfill fields offshore project proposal

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executive summary

introduction

overview

Chevron Australia Pty Ltd (CAPL) is the operator of the Gorgon Gas Development, one of Australia's largest natural gas projects located off the northwest coast of Western Australia (WA). The first stage of the Gorgon Gas Development was the Gorgon Foundation Project (GFP), which included constructing the Gorgon Gas Treatment Plant (GTP) for both liquefied natural gas (LNG) and domestic gas processing on Barrow Island, and developing the Gorgon and Jansz–Io offshore fields (the first of the Greater Gorgon Area fields).

CAPL is proposing to undertake the Gorgon Gas Development: Backfill Fields (the Development), which represents the next phase of the Gorgon Gas Development. A backfill field is a supply of natural gas that is required to maintain the throughput to an operating facility. The intent of the Development is to maintain gas supply to the existing GTP on Barrow Island to sustain current production rates of LNG and domestic gas.

The proposed Development comprises the construction, installation, and operation of drill centres (DCs), flowlines, and subsea tiebacks to access seven backfill gas fields in the Greater Gorgon Area. The development of Greater Gorgon Area fields was outlined in the original two-train Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) (Ref. 1; Ref. 2), which stated that the other fields of the Greater Gorgon Area would be developed once production from the Gorgon and Jansz–Io fields began their natural decline. The *Barrow Island Act 2003* (WA) also refers to the Greater Gorgon Area, which includes the backfill fields.

All seven backfill fields are located in Commonwealth (Cth) waters off the north-west coast of WA; and comprise Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR).

The Geryon and Eurytion (G&E) fields will be co-developed and fed into a single flowline. The Chrysaor and Dionysus (C&D) fields are anticipated to be co-developed in a similar manner. Consequently, while the OPP covers the seven fields, activities, impacts, and risks associated with each set of co-developed fields are considered jointly.

The earliest the first stage of the Development is likely to be ready for activities to commence is in 2026.

document purpose

This Offshore Project Proposal (OPP) has been submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) in accordance with the requirements of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) (OPGGS Act) and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth) (OPGGS(E)R).

location

The Development fields are located in Commonwealth waters offshore north-west WA. The fields and proposed subsea infrastructure lie to the north-west of Barrow Island, in the vicinity of the GFP fields. Water depths in the area range from ~100–1,400 m.

The closest infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow.

All planned petroleum activities within this OPP will occur in the development area (DA), which lies in Commonwealth waters (Figure ES-1).

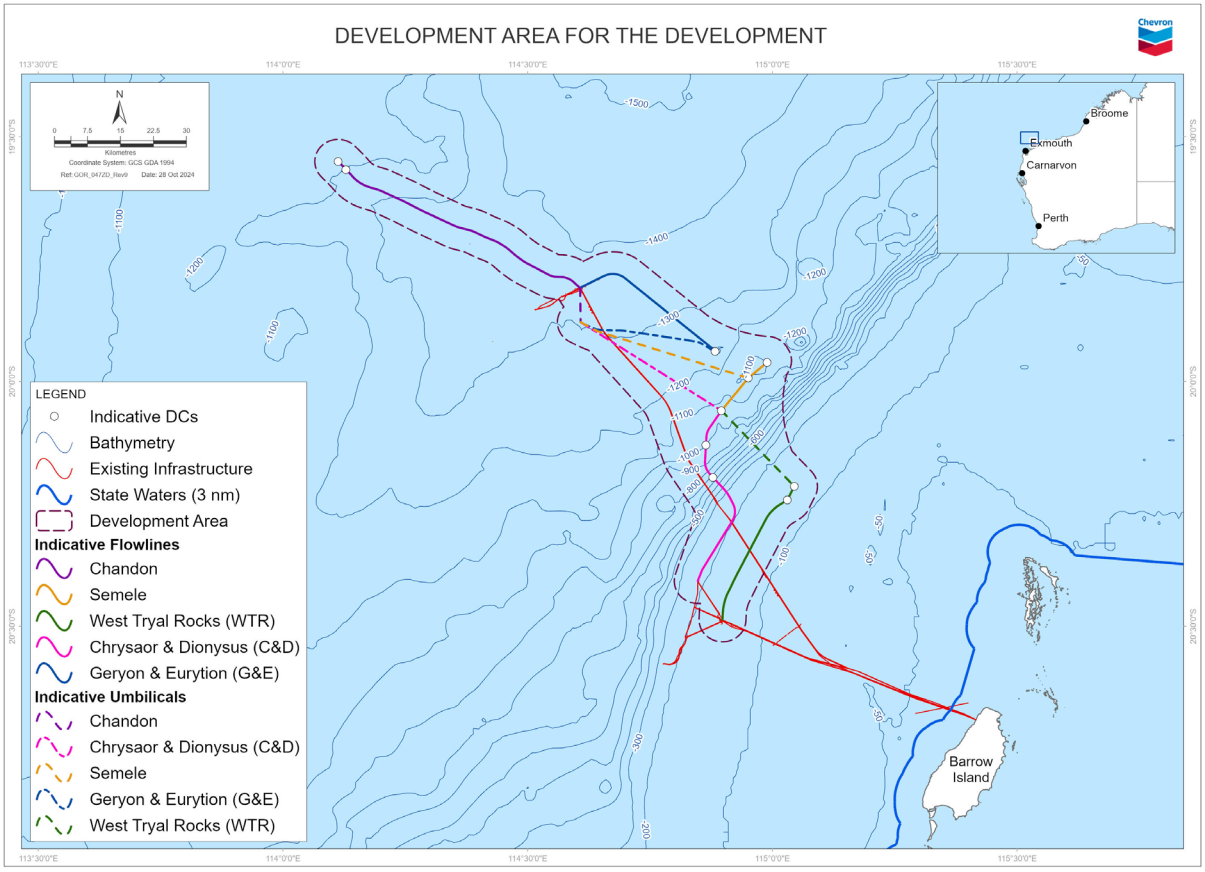


Figure ES-1: Development area for the Development

scope

The OPP addresses site surveys, drilling, installation and commissioning, operations, and decommissioning phases; and support activities associated with the Development.

GFP developments currently in operation are not within the scope of the OPP. Activities associated with GFP developments that are currently being implemented or which are to be implemented at a later date, including Gorgon Stage 2 (GS2), and Jansz-Io Compression (J-IC) and other GFP power supply options, are excluded from the scope of the OPP.

proponent details

CAPL is the proponent for the Development. The company has been operating in Australia since 1952 and is the operator for the Gorgon Gas Development and Wheatstone Project in the north-west of WA.

CAPL is one of the major suppliers of domestic gas in WA.

requirements

The Development is located entirely in Commonwealth waters and therefore triggers two key Commonwealth acts: the OPGGS Act and *Environmental Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

offshore petroleum and greenhouse gas storage act 2006

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration and production activities occurring in Commonwealth waters. The OPGGS(E)R were created

under the Act, and the OPP is required under these regulations. In addition to the OPP, the OPGGS(E)R require CAPL to have in place environment plans (EPs) for the petroleum activities within the scope of the Development.

environment protection and biodiversity conservation act 1999

The EPBC Act and the supporting Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations) provide for the protection and management of nationally and internationally important flora, fauna, ecological communities, and heritage places, including matters of national environmental significance (MNES). If there is potential for any MNES to be impacted by offshore petroleum activities, an assessment of the impacts must be presented in the OPP.

Other environmental requirements that apply to the Development include relevant:

- additional Commonwealth legislation
- Commonwealth and international policies and guidelines
- Western Australian legislation
- international agreements and conventions.

stakeholder consultation

CAPL is committed to building and maintaining relationships and conducting meaningful consultation with external stakeholders, including governments, Traditional Owners, and the communities where CAPL operates. Early consultation (Phase 1) with key stakeholders has been undertaken during the preparation of the OPP. This early consultation is the first phase in the stakeholder consultation that will occur throughout the lifecycle of environmental approvals for the Development. The full stakeholder consultation strategy consists of:

- phase 1—early consultation with key stakeholders (including relevant Traditional Owners) undertaken during the preparation of the OPP
- phase 2—public consultation under NOPSEMA's public comment process
- phase 3—relevant persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance.

Phase 2 consultation has also been undertaken, with a 12-week public comment period between 9 August to 1 November 2024. During this period the full OPP was made publicly available on NOSPEMA's website. Eight submissions were received during the public comment period.

description of the project

The Development will develop and operate seven gas fields and associated flowlines and tie-ins. The fields will feed into the Gorgon GTP on Barrow Island.

The C&D fields are anticipated to be co-developed and will feed into a single in-field flowline. Similarly, the G&E fields will be co-developed and feed into a single flowline.

Chandon and G&E will be tied-in to the existing Jansz Feed Gas Pipeline. C&D, Semele (via C&D) and WTR will be tied-in to the existing Gorgon Feed Gas Pipeline. Figure ES-2 shows the indicative DC locations, flowline routes and umbilical routes proposed for the Development and the existing pipelines.

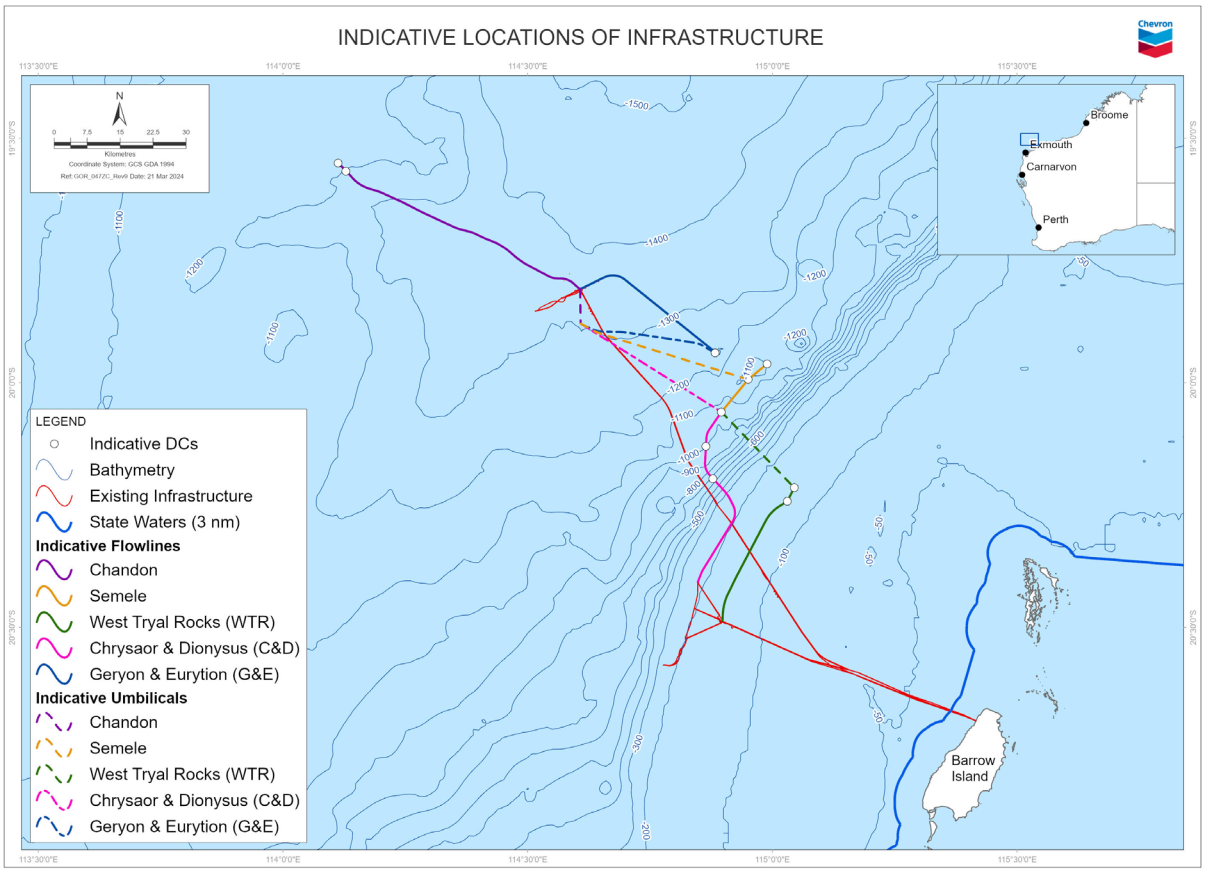


Figure ES-2: Indicative locations of infrastructure.

timing

The Development will be staged (i.e. the fields will be developed over multiple campaigns), with the G&E co-development earmarked as the first stage. The indicative durations of the Development phases have been estimated for each field (or co-developed field) and are ~24 months for drilling, ~12–15 months for installation and commissioning, and ~10–30 years for operations for each field. Actual durations will vary depending on factors including final flowline routes, reservoir performance, weather events, and vessel availability.

As the Development will be staged, some phases may occur concurrently (e.g. drilling may be occurring at one location while production operations have already begun at another). In addition, multiple activities may occur at the same time within a single field (e.g. drilling and pipelay). The sequence in which the fields will be developed has not yet been finalised.

The earliest the first stage of the Development is likely to be ready for activities to commence is in 2026. The end of life for the Development is notionally ~2070, with each field identified in the Development having its own end of life.

Activities covered by this OPP can occur 24 hours a day, 7 days a week and at any time of the year.

hydrocarbon system

The Development will comprise a new subsea hydrocarbon system which is summarised in Table ES-1.

Table ES-1: Key elements of the hydrocarbon system

System element	Key descriptions
Production wells	A maximum total of 40 wells will be located across 10 DCs. Each well will be fitted with a subsea tree.
Subsea structures	Manifolds and other structures (e.g. slug catchers, overpressure protection system) will be located at DCs and tie-in locations.
Flowlines, MEG pipelines, jumpers and spools PLETs and PLEMs	In-field production flowlines, MEG pipelines, jumpers and spools will be installed. Pipeline end terminations (PLETs) or pipeline end manifolds (PLEMs) will be installed on the flowlines and pipelines. In-line tees will be installed.
Umbilicals and power supply	Umbilicals, control distribution units (CDUs) and flying leads will be installed.

development phases

The Development activities are grouped in phases as shown in Table ES-2.

Table ES-2: Phases and activities of the Development

Phase	Key activities
Surveys	Geophysical survey Geotechnical survey
Drilling	MODU positioning Drilling top- and bottom-holes Drilling fluids and cuttings handling Cementing operations Pressure-control equipment installation Well suspension Completions installation Production tree installation Well clean-up and testing Well evaluation
Installation and commissioning	Pre-lay works Excavation and trenching Installation of flowlines, MEG pipelines and PLETs/PLEMs Installation of subsea structures Post-lay works Hydrotest and pre-commissioning Commissioning (verification and pre-start-up testing) Start-up (introduction of hydrocarbons)
Operations	Operation of the hydrocarbon system Inspection Maintenance and repairs Major repairs Well intervention
Decommissioning	Flush and clean Flowline and MEG pipeline decommissioning Umbilical decommissioning Other subsea structures decommissioning Well plug and abandonment

alternatives analysis

A number of development concepts are feasible for developing the resources in the backfill fields of the Greater Gorgon Area. Development concepts can be implemented using a range of design and activity elements. All these alternatives have relative advantages and disadvantages. CAPL performed an alternatives analysis to consider the range of options and determine the preferred concept and design elements.

Analysis of the development concept, design and activity alternatives was based on the following focus areas: environment, technical feasibility, safety, commercial and social. Each focus area was further divided into categories and assessment criteria. A comparative assessment was carried out for the design concept, with the preferred option then carried through to a comparative assessment for the design and activity elements.

The development concept determined to be the most favourable was subsea tiebacks to existing pipelines. This concept scored significantly better than the other options on environmental criteria, and marginally better on all other focus areas. This option maximises the use of existing infrastructure and does not entail an additional shore crossing or pipeline installation.

Design and activity elements assessed included MODU type, hydrotest discharge and decommissioning activities. For MODU type, flowline retrieval and umbilical retrieval, it was determined that more than one option should be carried in the OPP. This allows for these elements to be finalised much closer to implementation to ensure the most favourable environmental option is selected.

description of the environment

The OPP describes the environment that may be affected (EMBA) by the planned activities and unplanned events associated with the Development.

CAPL defined sub-areas of the EMBA based on oil spill modelling to support the description of the environment and the impact and risk assessment. The Hydrocarbon Ecological EMBA has been determined based on the spatial extent of stochastic modelling of hydrocarbon exposure at thresholds relevant to ecological receptors. The Hydrocarbon Social EMBA has been determined based on lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil but are below concentrations at which ecological impacts are expected.

The DA is the area in which all petroleum activities will be undertaken.

ecosystems and their constituent parts including people and communities

The EMBA occurs in the North-west Marine Region (NWMR), which is characterised by shallow-water tropical marine ecosystems and high species richness (Ref. 102; Ref. 103). The DA occurs within the Northwest Province and Northwest Shelf Province bioregions.

To support understanding of the existing environment within the DA and inform impact and risk assessment, CAPL commissioned a benthic survey by Advisian (Ref 104; appendix a). The benthic survey targeted a range of sites, including predicted geomorphic features, indicative infrastructure locations and DCs, identified data gaps and areas within key ecological features (KEFs). Overall, the distribution of benthic habitat within the DA comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 108; Ref. 111; Ref 104). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed.

A number of threatened and/or migratory species listed under the EPBC Act may be present within the Hydrocarbon Ecological and Social EMBAs, including:

- 14 marine mammals (12 within the DA)
- eight marine reptiles (seven within the DA)
- 19 fishes, sharks, or rays (14 within the DA)
- 48 seabirds and shorebirds (16 within the DA).

Biologically important areas (BIAs) for humpback and pygmy blue whales, flatback turtles, whale sharks and wedge-tailed shearwaters overlap the DA. Habitat critical to the survival of flatback turtles overlaps the DA.

Water clarity on the North West Shelf (NWS) is variable according to movement, depth, and sediment (Ref. 196). Water and sediment quality data collected during the benthic survey indicate the quality is consistent with the Australian and New Zealand Guidelines (Ref. 66), except for copper and cobalt in water samples, and nickel in sediment at one location. Air quality in the EMBA is expected to be typical of the pristine air quality found in offshore areas.

The NWMR supports a range of economic, social, and cultural activities. Islands and waters within the Hydrocarbon Ecological and Social EMBAs are used for recreational activities. The land adjacent to the NWMR has been inhabited by Traditional Owners for at least 50,000 years and they continue to use the NWMR and adjacent coastal resources for their cultural identity, health, and economy.

Three KEFs have been identified as overlapping the DA:

- ancient coastline at 125 m depth contour
- continental slope demersal fish communities
- Exmouth Plateau.

natural and physical resources

Natural and physical resources include fishing stocks, petroleum reservoirs, or values of the Commonwealth marine area.

Three Commonwealth-managed fisheries with management areas and with recorded fishing effort between 2013–2022 intersect the Hydrocarbon Ecological and Social EMBAs; two of these fisheries intersect with the DA. Fifteen State-managed fisheries with management areas and with recorded fishing effort between 2014–2023 intersect the Hydrocarbon Ecological and Social EMBAs; four of these fisheries intersect with the DA. Recreational and traditional fishing is not expected to occur in the DA, but shore-based fishing may occur within the Hydrocarbon Ecological and Social EMBAs.

The DA overlaps part of the NWS shipping fairway system.

No tourism or recreational activities are expected within the DA. However, the Hydrocarbon Ecological and Social EMBAs connect with some coastal areas where nature-based tourism may occur.

The DA is located in the Northern Carnarvon Basin, which is Australia’s premier hydrocarbon-producing province. As a result, the basin contains an established network of oil, condensate, and gas production infrastructure. Several oil and gas projects are located within the vicinity of the DA, including some production wells and pipeline present within the DA.

qualities and characteristics of locations, places, and areas

Several locations in the vicinity of the Development are protected via legislation as a result of their natural values.

There are no Australian Marine Parks (AMPs) within the DA, however Gascoyne, Montebello, Shark Bay, Ningaloo, and Argo-Rowley Terrace Marine Parks overlap the Hydrocarbon Ecological and Social EMBAs.

No State marine protected areas or terrestrial protected areas overlap the DA. Several State marine or terrestrial protected areas intersect with the Hydrocarbon Ecological and Social EMBAs.

heritage value of places

The Ningaloo Coast and Murujuga Cultural Landscape are listed as World Heritage properties, and the Ningaloo Coast and Dampier Archipelago are listed as a National Heritage places. The Hydrocarbon Ecological and/or Social EMBAs intersect with these heritage places.

Multiple shipwrecks have been identified within the Hydrocarbon and Social EMBAs; none are known to be present within the DA.

At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known underwater cultural heritage sites within the DA or Hydrocarbon Ecological and Social EMBAs. Consultation with Traditional Owner groups and individuals has identified that Sea Country is of importance to their people.

environmental impact and risk assessment methodology

The OPGGS(E)R require that CAPL demonstrate the environmental risks and impacts arising from the Development are acceptable. CAPL evaluated the impacts and risks according to the following methodology.

The petroleum activity was identified and described, environmental values and sensitivities were identified, and aspects of the activity that may interact with the environment were identified. The credible interactions between aspects, impacts and risks, and receptors were then mapped.

The impacts and risks were then evaluated by determining the source and consequence level for each impact and risk, and then for risks identifying the likelihood of the consequence occurring and corresponding residual risk level. The consequence, likelihood and residual risk levels were determined using CAPL's Integrated Risk Prioritization Matrix.

CAPL defined acceptable levels specific to receptors based on relevant contexts, including principles of ecologically sustainable development (ESD), internal and external context, and legislative requirements.

environmental risk assessment and management strategy

The environmental impact and risk assessment, consequence and/or residual risk, environmental performance outcomes (EPOs) and adopted control measures are shown for each aspect in Table ES-3.

Table ES-3: Summary of the assessment of environmental impacts and risks from the Development

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
Seabed disturbance	Seabed disturbance may result in: • localised and temporary reduction in water quality.	6	Seabed disturbance within a KEF may result in: • change to values and sensitivities of KEFs.	4	4	Low (7)	**EPO-01**: Planned seabed disturbance within the Development Area will not cause lasting changes to water quality (total suspended solids). Water quality will return to ambient state within seven days following the cessation of the disturbance. **EPO-02**: Undertake seabed surveys of proposed wells and subsea infrastructure locations prior to final field layout design to ensure that: • infrastructure design footprints will be positioned to minimise disturbance to key ecological features • any emergent seabed features or other obstacles are avoided wherever practicable within technical and safety constraints. **EPO-03**: No planned seabed disturbance from the Development to any previously undisturbed exposed hard substrate within the 'ancient coastline at 125 m depth contour' key ecological feature. **EPO-04**: Long-term direct disturbance from the	**CM-01**: Visual seabed inspections conducted prior to drilling, pipelay, or subsea installation ensures no previously undisturbed exposed hard substrate within the 'ancient coastline at 125 m depth contour' key ecological feature is within the proposed disturbance footprint. **CM-02**: Develop and maintain an inventory of subsea assets for the Development. **CM-03**: Remove all property above the mudline unless an alternative decommissioning approach has been accepted by NOPSEMA. **CM-04**: If property is accepted to be decommissioned in situ, a sea dumping permit will be acquired in accordance with the *Environmental Protection (Sea Dumping) Act 1981* (Cth).
	Seabed disturbance may result in: • alteration of benthic habitats and associated communities.	4						
			Seabed disturbance may result in: • temporary changes in fish behaviour.	6	4	Very Low (9)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							Development is limited to 18.85 km^2 within the Development Area. **EPO-05**: Short-term direct disturbance from the Development is limited to 0.98 km^2 within the Development Area. **EPO-06**: Decommissioning of subsea infrastructure will not be inconsistent with obligations under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) and/or other relevant legislation in place at the time.	
			Seabed disturbance may result in: • change to cultural heritage values: underwater cultural heritage.	–	–	–	**EPO-07**: Undertake an underwater cultural heritage assessment of proposed wells and subsea infrastructure locations prior to final field layout design to identify and report any suspected underwater cultural heritage and to ensure these areas are avoided (unless a permit under section 23 of the *Underwater Cultural Heritage Act 2018* (Cth) is granted). **EPO-08:** No adverse impacts to declared underwater cultural heritage without a permit[1] from planned activities associated with the Development.	**CM-05**: Implement CAPL's Inadvertent Underwater Cultural Heritage Discovery Procedures (Ref. 691), including processes for notification and response to suspected discoveries. **CM-06**: Discovery of suspected underwater cultural heritage is reported to the Minister within 21 days of discovery as per section 40 of the *Underwater Cultural Heritage Act 2018* (Cth).

[1] Where a permit under section 23 of the *Underwater Cultural Heritage Act 2018* (Cth) has been granted.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Seabed disturbance may result in: • change to cultural heritage values: Traditional Owners.	4	4	Low (7)	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.
Air emissions	Air emissions may result in: • localised and temporary reduction in air quality.	6	N/A	–	–	–	**EPO-10**: Planned air emissions within the Development Area will not cause lasting changes to air quality. Air quality will return to ambient state within seven days following the cessation of the emission.	**CM-09**: Vessels operating within the Development Area will comply with requirements within Marine Order 97—Marine pollution—air pollution.
Greenhouse gas emissions	GHG emissions from the Development may result in: • a potential reduction to IPCC's estimated 'remaining carbon budget' to limit	6	N/A	–	–	–	**EPO-11**: Manage GHG emissions from the 'Gorgon Operations Facility'[2] in accordance with requirements under the Commonwealth Safeguard Mechanism and from the 'Gorgon GTP'[3] in accordance with requirements under any in-force State or	**CM-10:** Chevron Australia will implement GHG emissions management, reductions, and reporting aligned with any applicable requirements under the Commonwealth Safeguard Mechanism as well as approvals under the EP Act (WA) and EPBC Act (Cth), to

[2] The 'Gorgon Operations Facility' is registered with the CER as a facility under both the NGER and Safeguard Mechanism schemes (Section 8.3.5.3). The reporting boundary of the Gorgon Operations Facility includes direct (Scope 1) emissions from the 'Gorgon GTP' as well as direct (Scope 1) emissions from any activities or facilities in Commonwealth waters.

[3] The 'Gorgon GTP' includes all direct (Scope 1) GHG emissions from the current operational Gorgon Gas Development facilities (as outlined in MS 800) (Section 8.3.6.1).

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
	global warming to 1.5–2.0°C.						Commonwealth approval conditions for the Gorgon Gas Development.	the extent such requirements remain in-force and as amended from time to time, including: • implementation of measures that are necessary to achieve the injection underground of at least 80% of Reservoir Carbon Dioxide[4] – offsetting the quantity of Reservoir Carbon Dioxide not injected underground • Net GHG Emissions[4] from the Gorgon GTP are within the limits set in condition 27.1 of MS 1198 • the Safeguard Mechanism baseline for the Gorgon Operations Facility declines each financial year at rates as defined within the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 – responsible emitters of facilities that exceed or expect to exceed their baselines must manage their excess emissions through various means including the surrender of Australian Carbon Credit Units or Safeguard Mechanism credit units.

[4] Reservoir Carbon Dioxide and Net GHG Emissions are defined within MS 1198.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								Note: These requirements under **CM-10** may be amended from time to time, and this control measure will be revised to reflect any contemporary requirements. **CM-09**: Vessels operating within the Development Area will comply with requirements within Marine Order 97—Marine pollution—air pollution. **CM-11:** Vessel and MODU fuel usage will be recorded during the Development. **CM-12:** Chevron Australia will develop activity-specific GHG emissions estimate for use in Environment Plans based on contemporary information (e.g. specific petroleum activity scopes, emission calculation methodologies, emission factors, etc.) as available at the time.
							EPO-12: Net GHG emissions associated with the transport and third-party end use of products from the Development do not represent a significant proportion of cumulative global GHG emissions[5] and would be managed under the laws of the	**CM-13:** Chevron Australia will undertake routine reviews (5-yearly to align with in-force periods of Environment Plans) of the projected domestic and global energy trends, including the role of Gorgon Gas Development's product types (domestic gas, LNG,

[5] Refer to Table 7-6.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							respective customer countries', which reflect among other things the countries' GHG emissions reduction ambitions and international commitments.	condensate) in these projections. If required, Chevron Australia will consider the application of additional control measures within Environment Plans to demonstrate that net 'secondary GHG emissions' remain at an acceptable level. **CM-14:** Chevron Australia will develop a transport and third-party end use GHG emissions estimate (e.g. 5-yearly to align with in-force periods of Environment Plans) based on contemporary information (e.g. production forecasts for the Gorgon Gas Development, emission calculation methodologies, emission factors, etc.) as available at the time. **CM-15:** Petroleum recovery will not be inconsistent with petroleum production licence obligations (i.e. approved Rate of Recovery and Field Development Plans) under the OPGGS Act and Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 and/or other relevant legislation in place at the time.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	**C**	**Risks**	**C**	**L**	**RR**		
Light emissions	Light emissions may result in: • localised and temporary change in ambient light.	6	A localised and temporary change in ambient light may result in: • change to behaviour in marine reptiles.	6	5	Very Low (10)	**EPO-13**: Artificial light emissions from planned Development activities do not prevent light sensitive marine fauna[6] from undertaking biological important behaviours[7]. **EPO-14**: Artificial light within or adjacent to habitat critical to the survival of marine turtles[8] will be managed such that marine turtles are not displaced from these habitats. **EPO-15**: Manage artificial light from offshore sources to ensure biologically important behaviours of: • nesting adults and emerging/dispersing hatchlings of the flatback turtle Pilbara stock (F-Pil) can continue • nesting adults and dispersing hatchlings of the hawksbill turtle WA (H-WA) can continue. **EPO-16**: Implement an adaptive management approach (**CM-17**) for artificial light emissions from the Development such that it can be demonstrated that risks	**CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-17**: Where there is a risk of behavioural effects on marine fauna from artificial light emissions, CAPL will adopt an adaptive management approach which identifies activity-specific preventative mitigation measures such that the potential risks from artificial light emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will include: • lighting requirements for safe navigation and operations • seasonal presence and behaviour of marine fauna within indicative activity windows
			A localised and temporary change in ambient light may: • change to behaviour in birds.	5	5	Very Low (9)		
			A localised and temporary change in ambient light may: • change to behaviour in fish.	6	5	Very Low (10)		
			A localised and temporary change in ambient light may result in: • change to values and sensitivities of Australian Marine Parks.	5	5	Very Low (9)		

[6] Where light sensitive marine fauna includes marine turtles, seabirds and migratory shorebirds.

[7] Where biologically important behaviours are defined as behaviour associated with critical life functions (e.g. reproduction, foraging, migration, and resting) (Ref. 719).

[8] Where habitat critical to the survival of marine turtle species is defined in Table 6 of the Recovery Plan for Marine Turtles in Australia (Ref. 24).

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							have been reduced to as low as reasonably practicable and can be managed to meet acceptable levels. The outcomes of this adaptive management approach will be incorporated into Environment Plans for the petroleum activities associated with this Development.	• location(s) of the petroleum activity in relation to sensitive fauna receptors • type, location, and duration of any concurrent activities • existing (e.g. Recovery Plan for Marine Turtles in Australia 2017–2027 [Ref. 24]) or contemporary regulatory requirements as available at the time. Mitigation options may include those as described within existing (e.g. National Light Pollution Guidelines [(Ref. 37)]) or contemporary guidance as available at the time.
			A localised and temporary change in ambient light may result in: • change to cultural heritage values: Traditional Owners.	5	5	Very Low (9)	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
Underwater sound emissions	Sound emissions may result in: • localised and temporary change in ambient underwater sound.	5	A localised and temporary change in ambient underwater sound may result in: • behavioural disturbance to benthic invertebrates.	6	5	Very Low (10)	**EPO-17**: Sound emissions from planned Development activities will be managed such that EPBC Act listed species continue undertaking biological important behaviours[9]. **EPO-18**: Sound emissions from planned Development activities will be managed to prevent TTS or AUD-INJ onset to EPBC Act listed species. **EPO-19**: Any blue whale continues to utilise the biologically important area without injury[10], and is not displaced from a foraging area[11,12].	**CM-18**: Vessels under transit[14] within the Development Area will implement caution and no approach zones as described in sections 8.05 and 8.06 of the EPBC Regulations 2000 (Cth). **CM-19**: Helicopters under transit within the Development Area will operate in alignment with section 8.07 of the EPBC Regulations 2000 (Cth). **CM-20**: Where there is a risk of behavioural, or auditory impairment or injury[15] to marine fauna from impulsive sound, CAPL will adopt an adaptive management approach which identifies activity-specific
			A localised and temporary change in ambient underwater sound may result in: • change to behaviour in fishes, including sharks and rays.	6	2	Low (7)		
			A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine reptiles.	6	2	Low (7)		

[9] Where biologically important behaviours are defined as behaviour associated with critical life functions (e.g. reproduction, foraging, migration, and resting) (Ref. 719).

[10] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'injury to blue whales' is considered both PTS and TTS and any other form of physical harm arising from anthropogenic sources of underwater sound (Ref. 369).

[11] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'displaced from a foraging area' applies in relation to BIAs (Ref. 369); and these BIAs correspond to a 'Foraging Area', 'Possible Foraging Area', and 'Known Foraging Area' as illustrated in Figure 1 of the Conservation Management Plan for the Blue Whale (Ref. 20; Ref. 369). There are no Foraging Area BIAs within or adjacent to the Development Area.

[12] In accordance with Australian Government guidance, activities outside designated Foraging Areas should adopt adaptive management approaches in the event that indicators (e.g. aggregation in a particular area) of whale foraging are evident to ensure that impacts are not unacceptable (e.g. no injury or biologically significant disturbance) (Ref. 369). EPO-17 incorporates foraging as one of the biologically important behaviours of marine fauna, and EPO-23 applies adaptive management.

[14] For safety reasons this control measure is not applied to vessels holding station or with limited manoeuvrability (e.g. during lifts, bunkering, etc.) or during emergency situations.

[15] Where 'auditory impairment or injury' includes physical or physiological changes to the auditory system that may be either recoverable or permanent (e.g. TTS, AUD-INJ).

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine mammals.	5	2	Moderate (6)	**EPO-20**: Any marine turtle is not displaced from identified habitat critical to the survival of the species[13]. **EPO-21**: Any marine turtle continues to undertake biologically important behaviour within biologically important areas. **EPO-22**: Undertake underwater sound assessments based on acoustic modelling (or equivalent, as appropriate to the nature and scale of the sound source) and predictions of ensonified areas that consider effect criteria based on contemporary guidance as available at the time. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development. **EPO-23**: Implement an adaptive management approach (**CM-20**, **CM-21**) for underwater sound emissions from the Development such that it can be demonstrated that risks have been reduced to as low as reasonably practicable and can be managed to meet acceptable	preventative mitigation measures such that the potential risks from impulsive sound emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will include: • sound source characteristics of selected (or indicative) equipment • seasonal presence and biologically important behaviours of marine fauna (e.g. Table 6-18) within indicative activity windows • location(s) of petroleum activity in relation to sensitive marine fauna habitats • type, location, and duration of any concurrent activities • existing (e.g. Conservation Management Plan for the Blue Whale 2015–2025 [Ref. 20]) or contemporary regulatory requirements as available at the time.
			A localised and temporary change in ambient underwater sound may result in: • mortality or auditory impairment to marine fauna.	5	3	Low (7)		
			A localised and temporary change in ambient underwater sound may result in: • change to values and sensitivities of Australian Marine Parks.	5	3	Low (7)		

[13] Where habitat critical to the survival of marine turtle species is defined in Table 6 of the Recovery Plan for Marine Turtles in Australia (Ref. 24).

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							levels. The outcomes of this adaptive management approach will be incorporated into Environment Plans for the petroleum activities associated with this Development.	Mitigation options may include use of visual surveillance (e.g. prior to starting an activity), temporal or spatial based modifications to activities (e.g. restricting use of VSP within BIAs/HCTS during peak seasonal periods). Noting that seismic surveys are not within scope of the OPP, the types of mitigation measures described within existing (e.g. EPBC Act Policy Statement 2.1) or contemporary guidance as available at the time for the management of impulsive underwater sound would also be considered. To further ensure the potential risks from impulsive underwater sound emissions on pygmy blue whales can be managed such that the risk is consistent with the relevant acceptable levels and EPOs, the adaptive management framework described in Section 10.4 will be applied. **CM-21**: Where there is a risk of behavioural or auditory impairment or injury to marine fauna from non-impulsive sound, CAPL will adopt an adaptive management approach which identifies activity-specific preventative mitigation measures such that the potential risks from non-

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								impulsive sound emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will include: • sound source characteristics of selected (or indicative) vessels and equipment • seasonal presence and biologically important behaviours of marine fauna (e.g. Table 6-18) within indicative activity windows • location(s) of petroleum activity in relation to sensitive marine fauna habitats • type, location, and duration of any concurrent activities • existing (e.g. Conservation Management Plan for the Blue Whale 2015–2025 [Ref. 20]) or contemporary regulatory requirements as available at the time. Mitigation options may include use of visual surveillance (e.g. prior to starting an

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								activity), temporal or spatial based modifications to activities (e.g. reducing the number or types of activities occurring within peak seasonal migration periods), or in-field adaptive management (e.g. positioning support vessels further away from main construction/drilling vessel; pause or stop an activity when operationally safe and viable to do so). To further ensure the potential risks from non-impulsive underwater sound emissions on pygmy blue whales can be managed such that the risk is consistent with the relevant acceptable levels and EPOs, the adaptive management framework described in Section 10.4 will be applied.
			A localised and temporary change in ambient underwater sound may result in: • change to cultural heritage values: Traditional Owners.	5	3	Low (7)	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
Planned discharges – MODU and vessels	Planned discharges from the MODU and vessels may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • changes to predator–prey dynamics.	6	6	Very Low (10)	**EPO-24**: Planned discharges from general MODU and vessels operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge. **EPO-25:** Planned discharges from general MODU and vessels operations within the Development Area will not cause lasting changes to marine fauna behaviour. Predator-prey dynamics will return to ambient state within seven days following the cessation of the discharge.	**CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-23**: Vessels operating within the Development Area will comply with requirements within Marine Order 95—Marine pollution—garbage. **CM-24**: Vessels operating within the Development Area will comply with requirements within Marine Order 96—Marine pollution—sewage. **CM-25**: Vessels operating within the Development Area will comply with requirements within Marine Order 15—Construction—Fire protection, fire detection and fire extinction. **CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								(OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the location and nature of the receiving environment • requires the selection of the least hazardous material where technically and operationally feasible.
Planned discharges – subsea operations	Planned subsea operational discharges may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • injury or mortality benthic habitats and associated communities.	–	–	–	**EPO-26**: Planned discharges from subsea operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge. **EPO-27**: Undertake hydrotest dispersion modelling (or equivalent) at sites representative of the deep water and shallow water environments within the Development Area. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development.	**CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme (OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the location and nature of the receiving environment • requires the selection of the least hazardous
			A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	–	–	–		
			A localised and temporary reduction in water quality may result in: • change to the functions, interests and activities of other marine users.	–	–	–		
			Planned subsea operational discharges within a KEF may result in: • change to values and sensitivities of KEFs	–	–	–		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								material where technically and operationally feasible.
			Planned subsea operational discharges may result in: • change to cultural heritage values: Traditional Owners.	6	6	Very Low (10)	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.
Planned discharges – drilling operations	Planned drilling discharges may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	5	4	Low (8)	**EPO-28**: Planned discharges from drilling operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge. **EPO-29:** Planned discharges from drilling operations within the Development Area will only cause localised changes to sediment quality (i.e. within the vicinity of the drill centres). **EPO-30**: Undertake drill cuttings dispersion modelling (or equivalent) at sites representative of the deep water and shallow water environments within the	**CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme (OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the
	Planned drilling discharges may result in: • localised and temporary reduction in sediment quality.	6	Planned drilling discharges within a KEF may result in: • change to values and sensitivities of KEFs.	5	4	Low (8)		
	Planned discharges—drilling may result in: • alteration of benthic habitats	5						

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
	and associated communities.						Development Area. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development. **EPO-31:** Planned discharges from drilling operations within the Development Area will only cause localised changes to benthic habitats and communities (i.e. within the vicinity of the drill centres). **EPO-32:** Planned discharges from drilling operations within the Development Area will not cause toxicity effects to benthic habitats or marine fauna.	location and nature of the receiving environment • requires the selection of the least hazardous material where technically and operationally feasible. **CM-27:** Where selected for use, NADFs are managed in accordance with CAPL's Wells Fluid Field Guidelines Offshore (Ref. 391), including: • no whole NADF will be discharged to the environment • maintain a <10% w/w synthetic base fluid on dry cuttings averaged over the combined well sections drilled with NADF • NADF will not be used to drill top holes • ensure that any displaced fluids potentially contaminated with NADF have <1% v/v residual synthetic based oil prior to discharge. **CM-28**: Mercury and cadmium concentrations in stock barite will be limited to: • mercury: maximum 1 mg/kg dry weight • cadmium: maximum 3 mg/kg dry weight.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								CM-29: Implement CAPL's management process for unused bulk product (barite, cement, and bentonite). **CM-30**: Any produced water circulated to the MODU during well flowback or well intervention activities will have <30 ppm oil-in-water concentration prior to discharge.
			Planned drilling discharges may result in: • change to cultural heritage values: Traditional Owners.	5	4	Low (8)	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.
Physical presence – other marine users	N/A	–	Unplanned interactions with commercial fisheries may result in: • change to the functions, interests and activities of other marine users.	6	4	Very Low (9)	**EPO-33:** No interference with other lawful marine users from planned activities associated with the Development to a greater extent than is necessary for the reasonable	**CM-31**: Vessels operating within the Development Area will comply with any Notice to Mariners requirements under the *Navigation Act 2012* (Cth).

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Unplanned interactions with petroleum activities may result in: • change to the functions, interests, and activities of other marine users.	6	3	Low (8)	exercise of the rights and performance of duties.	**CM-32**: Vessels operating within the Development Area will comply with requirements within Marine Order 27—Safety of navigation and radio equipment. **CM-33**: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-34**: Apply for petroleum safety zones for relevant Development infrastructure in accordance with section 616 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth). **CM-35**: CAPL will comply with any Notice to Mariners requirements under the *Navigation Act 2012* (Cth) regarding notifications of installed subsea infrastructure. **CM-03**: Remove all property above the mudline unless an alternative decommissioning approach has been accepted by NOPSEMA. **CM-04**: If property is accepted to be decommissioned in situ, a
			Unplanned interactions with petroleum activities and commercial shipping may result in: • change to the functions, interests and activities of other marine users.	6	3	Low (8)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								sea dumping permit will be acquired in accordance with the *Environmental Protection (Sea Dumping) Act 1981* (Cth).
Physical presence – marine fauna	N/A	–	Unplanned interactions with birds may result in: • injury or mortality of marine fauna.	6	3	Low (8)	**EPO-34**: No death or injury of an EPBC Act listed threatened, migratory, or cetacean species from Development activities within the Development Area.	**CM-18**: Vessels under transit[16] within the Development Area will implement caution and no approach zones as described in sections 8.05 and 8.06 of the EPBC Regulations 2000 (Cth). **CM-19**: Helicopters under transit within the Development Area will operate in alignment with section 8.07 of the EPBC Regulations 2000 (Cth). **CM-36**: Inlet screens will be used when winning water from the sea during flowline flooding and pre-commissioning activities.
			Unplanned interactions with fishes, including sharks and rays may result in: • injury or mortality of marine fauna.	6	3	Low (8)		
			Unplanned interactions with marine reptiles may result in: • injury or mortality of marine fauna.	6	3	Low (8)		
			Unplanned interactions with marine mammals may result in: • injury or mortality of marine fauna.	6	3	Low (8)		
			Injury or mortality of marine fauna may result in: • change to cultural heritage values: Traditional Owners.	6	3	Low (8)		

[16] For safety reasons this control measure is not applied to vessels holding station or with limited manoeuvrability (e.g. during lifts, bunkering, etc.) or during emergence situations.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
Introduction of invasive marine pests	N/A	–	Introduction of an IMP to a benthic habitats and associated communities or KEF may result in: • displacement of, or competition with, endemic species.	3	6	Low (8)	**EPO-35**: No introduction and establishment of an invasive marine pest attributable to the Development.	**CM-37:** Vessels operating within the Development Area will comply with ballast water management as required under the *Biosecurity Act 2015* (Cth) and best practice guidance within the Australian Ballast Water Management Requirements (Ref. 60). **CM-38:** Vessels operating within the Development Area will comply with biofouling management as required under the *Biosecurity Act 2015* (Cth) and best practice guidance within the Australian Biofouling Management Requirements (Ref. 61). **CM-39**: Vessels operating within the Development Area will comply with requirements within Marine Order 98—Marine pollution—anti-fouling systems.
			Introduction of an IMP to a KEF may result in: • change to values and sensitivities.	3	6	Low (8)		
			Introduction of an IMP may result in: • change to cultural heritage values: Traditional Owners.	3	6	Low (8)		
Unplanned release – solid objects	N/A	–	Unplanned release of solid objects in the marine environment may result in: • localised and temporary reduction in water quality	6	5	Very Low (10)	**EPO-36**: No unplanned release of solid objects to the environment attributable to the Development.	**CM-23**: Vessels operating within the Development Area will comply with requirements within Marine Order 95—Marine pollution—garbage. **CM-40**: Develop and implement a Lift Plan (or equivalent) for Development activities. **CM-41**: Dropped equipment will be retrieved wherever
			Unplanned release of solid objects may interact with marine fauna to result in: • injury or mortality of marine fauna	6	5	Very Low (10)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Unplanned release of solid objects may result in: • alteration of benthic habitats and associated communities.	5	5	Very Low (9)		practicable within operational and safety constraints.
			Unplanned release of solid objects in a KEF may result in: • change to values and sensitivities	6	5	Very Low (10)		
			Unplanned release of solid objects may result in: • change to cultural heritage values: Traditional Owners.	5	5	Very Low (9)		
Unplanned release - minor LOC	N/A	–	Minor loss of containment may result in: • localised and temporary reduction in water quality.	5	5	Very Low (9)	**EPO-37**: No unplanned release of hydrocarbons or chemicals to the environment attributable to the Development.	**CM-40**: Develop and implement a Lift Plan (or equivalent) for Development activities. **CM-42**: Develop and implement a Bunkering and Bulk Transfer Procedure (or equivalent) for Development activities. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil.
			Minor loss of containment may result in: • injury or mortality of marine fauna.	5	5	Very Low (9)		
Unplanned release – vessel	N/A	–	Unplanned release of MDO due to a vessel collision event may result in: • change in water quality.	5	5	Very Low (9)	**EPO-38**: No unplanned release of hydrocarbons to the environment attributable to the Development.	**CM-32**: Vessels operating within the Development Area will comply with requirements within Marine Order 27—Safety

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
collision (MDO)			Unplanned release of MDO due to a vessel collision event may result in: • alteration of coastal habitats and associated communities.	5	5	Very Low (9)		of navigation and radio equipment. **CM-33**: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-31**: Vessels operating within the Development Area will comply any Notice to Mariners requirements under the *Navigation Act 2012* (Cth). **CM-43**: Vessel crew will hold a current Standards of Training, Certification and Watchkeeping for Seafarers (or equivalent) certificate as appropriate to duties. **CM-44**: Develop (and implement in the event of an unplanned hydrocarbon release) an Oil Pollution Emergency Plan and
			Unplanned release of MDO due to a vessel collision event may result in: • injury or mortality of marine fauna.	5	5	Very Low (9)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to the functions, interests and activities of other marine users.	5	5	Very Low (9)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of Australian Marine Parks.	5	5	Very Low (9)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of KEFs.	–	–	–		
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of the Ningaloo Coast.	5	5	Very Low (9)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Unplanned release of MDO due to a vessel collision event may result in: • change to cultural heritage values: Traditional Owners.	5	5	Very Low (9)		Operational Scientific Monitoring Plan that satisfies the requirements under regulation 22 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth).
Unplanned release – hydrocarbon system (condensate)	N/A	–	Unplanned release of condensate from the hydrocarbon system may result in: • change in water quality.	5	5	Very Low (9)	**EPO-38**: No unplanned release of hydrocarbons to the environment attributable to the Development.	**CM-32**: Vessels operating within the Development Area will comply with requirements within Marine Order 27—Safety of navigation and radio equipment. **CM-33**: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-31**: Vessels operating within the Development Area will comply any Notice to
			Unplanned release of condensate from the hydrocarbon system may result in: • alteration of coastal habitats and associated communities.	5	5	Very Low (9)		
			Unplanned release of condensate from the hydrocarbon system may result in: • injury or mortality of marine fauna.	5	5	Very Low (9)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of KEFs.	5	5	Very Low (9)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to the functions, interests and activities of other marine users.	5	5	Very Low (9)		Mariners requirements under the *Navigation Act 2012* (Cth). **CM-43**: Vessel crew will hold a current Standards of Training, Certification and Watchkeeping for Seafarers (or equivalent) certificate as appropriate to duties. **CM-44**: Develop (and implement in the event of an unplanned hydrocarbon release) an Oil Pollution Emergency Plan and Operational Scientific Monitoring Plan that satisfies the requirements under regulation 22 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth). **CM-45**: Develop and implement a Wells Operations Management Plan that satisfies the requirements under Part 5 of the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 (Cth). **CM-46**: Develop and implement a facility Safety Case that satisfies the requirements under Part 2 of the Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009 (Cth).
			Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of Australian Marine Parks.	5	5	Very Low (9)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to cultural heritage values.	5	5	Very Low (9)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to cultural heritage values: Traditional Owners.	4	5	Low (8)		

cumulative impact assessment

In addition to assessing the impacts and risks of the individual aspects, CAPL also assessed the cumulative impacts. The cumulative impact assessment (CIA) considered the potential additive effects on environmental values and sensitivities from activities within the Development and from other activities within the region, and the long-term cumulative effects from activities occurring over many years. The CIA considered potential changes to consequence levels, EPOs, and control measures as a result of cumulative effects.

For all values and sensitivities assessed, no changes to consequence, EPOs or control measures were indicated and the impacts were deemed acceptable.

implementation strategy

CAPL will carry out the Development in accordance with this OPP and all subsequent EPs. The implementation strategy will help achieve the EPOs.

CAPL's operations are managed in accordance with Chevron Corporation's Operational Excellence Management System (OEMS). The OEMS underpins the implementation strategy, aligns with ISO 14001:2015 and meets the requirements of the OPGGS(E)R.

Environmental monitoring and reporting will be undertaken to provide continuous review of procedures and activities, and to demonstrate regulatory compliance. Reporting will be carried out in compliance with the OPGGS(E)R.

The implementation strategy will be presented in more detail in subsequent EPs.

1 introduction

1.1 overview

Chevron Australia Pty Ltd (CAPL) is the operator of the Gorgon Gas Development, one of Australia's largest natural gas projects located off the north-west coast of Western Australia (WA). The first stage of the Gorgon Gas Development was the Gorgon Foundation Project (GFP), which included constructing the Gorgon Gas Treatment Plant (GTP) for both liquefied natural gas (LNG) and domestic gas processing on Barrow Island, and developing the Gorgon and Jansz–Io offshore fields (the first of the Greater Gorgon Area fields).

CAPL is proposing to undertake the Gorgon Gas Development: Backfill Fields Development (the Development), which represents the next phase of the Gorgon Gas Development. A backfill field is a supply of natural gas that is required to maintain the throughput to an operating facility. The intent of the Development is to maintain gas supply to the existing GTP on Barrow Island to sustain current production rates of LNG and domestic gas.

The proposed Development comprises the construction, installation, and operation of drill centres (DCs), flowlines, and subsea tiebacks to access seven backfill gas fields in the Greater Gorgon Area. The development of Greater Gorgon Area fields was outlined in the original two-train Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) (Ref. 1; Ref. 2), which stated that the other fields of the Greater Gorgon Area would be developed once production from the Gorgon and Jansz–Io fields began their natural decline. The *Barrow Island Act 2003* (WA) also refers to the Greater Gorgon Area, which includes the backfill fields.

All seven backfill fields are located in Commonwealth (Cth) waters off the north-west coast of WA; and comprise Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR). The Geryon and Eurytion (G&E) fields will be co-developed and fed into a single flowline. The Chrysaor and Dionysus (C&D) fields are anticipated to be co-developed in a similar manner. Consequently, while the OPP covers the seven backfill fields, activities, impacts, and risks associated with each set of co-developed fields are considered jointly.

1.2 document purpose

This Offshore Project Proposal (OPP) has been prepared by CAPL as operator of WA-5-R, WA-14-R, WA-15-R, WA-20-R, WA-21-R, WA-22-R, WA-53-R, WA-75-R, and WA-76-R in accordance with the requirements of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) (OPGGS Act) and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth) (OPGGS(E)R).

The OPP covers all phases of the Development project life from surveys, drilling, and installation, to operations and decommissioning.

The OPGGS(E)R require proponents of offshore projects to submit an OPP to the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA). NOPSEMA must accept an OPP before the proponent can submit more detailed environment plans (EPs) for project activities. The OPP process involves the proponent's evaluation and NOPSEMA's assessment of the potential environmental impacts and risks of petroleum activities conducted over the life of the Development. The process includes a public comment period and requires a

proponent to ensure environmental impacts and risks will be managed to acceptable levels.

1.3 location

The Development fields are located in Commonwealth waters offshore north-west WA. The fields lie to the north-west of Barrow Island, in the vicinity of the GFP fields. Water depths in the area range from ~100–1,400 m. Drilling will occur within petroleum titles WA-5-R, WA-14-R, WA-15-R, WA-22-R and WA-53-R. The location is shown in Figure 1-1.

The closest Development infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost Development infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow. Section 4 has detailed information about the location and layout of subsea infrastructure.

No petroleum activities in State waters or onshore are proposed under this OPP.

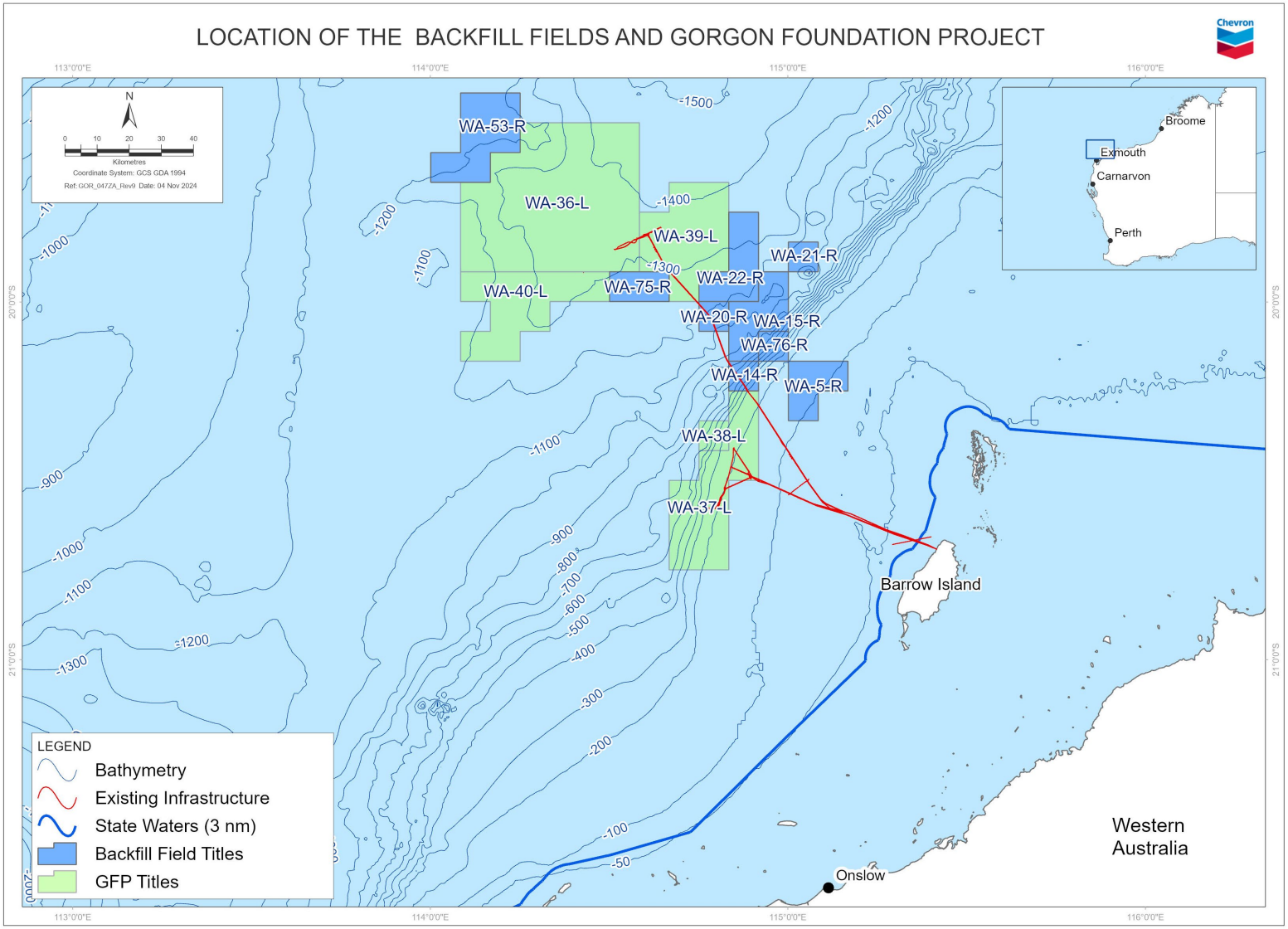


Figure 1-1: Location of the Backfill Fields and Gorgon Foundation Project

1.4 scope

1.4.1 in scope

This OPP addresses these petroleum activities associated with the Development:

- surveys—geophysical surveys and seabed geotechnical surveys, including pre-installation and as-built surveys, occurring throughout the Development
- drilling—covers well construction, including mobile offshore drilling unit (MODU) positioning, spread mooring, drilling of production wells, blowout preventer (BOP) installation, cementing and completions in each field
- installation and commissioning—includes seabed preparation, pipelay (flowline and pipeline), subsea equipment installation, verification and testing of infrastructure, pre-commissioning including hydrotesting, commissioning, and the introduction of hydrocarbons to the system
- operations—the gathering and transport of hydrocarbons and other fluids from the subsea wells to the existing GFP pipelines, inspection, maintenance and repair (IMR) including well intervention
- decommissioning—long-term planning for decommissioning of infrastructure no longer in use, including removing subsea infrastructure, and plug and abandonment (P&A) of wells
- support activities—includes MODU topside activities and vessel, helicopter and remotely operated vehicle (ROV) operations.

Section 4 describes these activities in more detail.

1.4.2 out of scope

The primary approvals for the GFP were granted under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) and *Environmental Protection Act 1986* (WA). These approvals were for constructing, installing, and operating facilities associated with producing and transporting gas (including offshore production wells and feed gas pipeline infrastructure) from the Gorgon and Jansz–Io gas fields to the Gorgon GTP. The Greater Gorgon Area is defined under the *Barrow Island Act 2003* (WA).

The GFP is defined as the combination of the following developments, currently in operation or yet to be implemented, in accordance with subsequent approval documents:

- GFP developments in operation:
  - the foundation ‘Gorgon Gas Development’, the development proposed in the EIS/ERMP (Ref. 1; Ref. 2) and subsequently approved under EPBC Reference: 2003/1294 and Ministerial Statement No. 748 (MS 748)
  - the ‘Revised and Expanded Gorgon Gas Development’, the development proposed in the Public Environmental Review (PER) (Ref. 3) and subsequently approved under EPBC Reference: 2008/4178 and MS 800 [as amended from time to time[17]]

[17] Since the Revised and Expanded Gorgon Gas Development was approved, further changes to the Gorgon Gas Development have been made and/or approved and are now also part of the Gorgon Gas Development. These include MS 865, MS 965, MS 1136, and MS 1198.

  - the 'Jansz–Io Development Project and Jansz Feed Gas Pipeline', the development assessed via Preliminary Documentation/Assessment on Referral Information (Ref. 4; Ref. 5) and subsequently approved under EPBC Reference: 2005/2184 and MS 769
  - the 'Gorgon Gas Development Additional Construction Laydown and Operations Support Area' (Additional Support Area), use of additional uncleared land for the Gorgon Gas Development as approved under MS 965 and regulated through variations to EPBC References: 2003/1294 and 2008/4178.

GFP developments approved but have not been implemented at this point in time:

- the 'Fourth Train Expansion Proposal' (Fourth Train Proposal), development proposed in the Public Environmental Review/Environmental Impact Statement (PER/EIS) (Ref. 6), and subsequently approved under MS 1002 and regulated through a variation to EPBC Reference: 2011/5942.

Petroleum activities covered under the above GFP approvals, and which are excluded from the scope of the OPP, include:

- drilling, commissioning, well maintenance, operations and support activities associated with the GFP (including Gorgon Stage 2 [GS2] infill development), which are covered under EPs accepted by NOPSEMA and/or the WA Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) (Ref. 7; Ref. 8; Ref. 9; Ref. 11; Ref. 12; Ref. 13)
- installing (Ref. 14) and operating (which will be covered under a revision to Ref. 9) infrastructure associated with the Jansz–Io Compression (J-IC) Project, including the field control station (FCS), which are covered under EPs accepted by and/or to be assessed by NOPSEMA
- vessels (including emergency response vessels) transiting to or from the development area (DA) (Section 4.1.3 defines the DA). These vessels are deemed to be operating under the *Navigation Act 2012* (Cth) and are not performing a petroleum activity
- helicopters transiting to or from the DA; these aircraft are subject to the *Air Navigation Act 1920* (Cth), *Civil Aviation Act 1988* (Cth), and associated regulations, and not performing the petroleum activity.

Note: Exploration and appraisal activities are not within scope of an OPP; these petroleum activities are subject to separate EP assessment process under the OPGGS(E)R.

1.5 proponent details

CAPL is the proponent for this OPP and the Development; Table 1-1 lists CAPL's contact details.

Table 1-1: Proponent's contact details

Proponent	Chevron Australia Pty Ltd
Business address	1 The Esplanade, Perth WA 6000
Telephone number	+61 8 9216 4000
Email address	feedback@chevron.com
Website	https://australia.chevron.com

1.6 structure of OPP

This OPP aligns with NOPSEMA's current OPP content requirements (Ref. 16) and OPP assessment policy (Ref. 17); Table 1-2 summarises its structure.

Table 1-2: OPP structure

Section		Content
1	Introduction	Provides an overview of the Development, location and proponent details.
2	Requirements	Describes the legislation, other regulatory requirements, relevant standards and guidelines that apply.
3	Stakeholder consultation	Summarises CAPL's stakeholder consultation methods, which includes the process of identifying stakeholders, consultation history and future consultation requirements.
4	Description of the project	Describes all activities including surveys, drilling, installation, commissioning, operations, and decommissioning.
5	Alternatives analysis	Analyses feasible alternative operations and procedures, and decision-making processes.
6	Description of the environment	Describes the existing environment, highlighting physical, ecological, and socio-economic values and sensitivities.
7	Environmental impact and risk assessment methodology	Describes how environmental impacts and risks were identified and evaluated.
8	Environmental risk assessment and management strategy	Details the results and justification of environmental impacts and risk assessments.
9	Cumulative impact assessment	Assesses the cumulative impacts for the Development.
10	Implementation strategy	Details how environmental performance outcomes stated in this OPP will be implemented.
11	Acronyms and abbreviations	
12	References	

2 requirements

The Development is located entirely in Commonwealth waters and therefore triggers these key Commonwealth acts: OPGGS Act and EPBC Act.

2.1 commonwealth legislation

2.1.1 offshore petroleum and greenhouse gas storage act 2006

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration and production activities occurring in Commonwealth waters.

The OPGGS Act addresses all issues related to offshore petroleum exploration and development operations, including licensing, health, safety, environment, and royalties. Regulations created under the Act include:

- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2024
- Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011
- Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (OPGGS(E)R).

The purpose of the OPGGS(E)R is to ensure that petroleum activities are undertaken in a way that:

- is consistent with the principles of ecologically sustainable development (ESD) as defined in section 3A of the EPBC Act
- reduces environmental impacts and risks of the activity to as low as reasonably practicable (ALARP)
- ensures that environmental impacts and risks of the activity are of an acceptable level.

Section 6 of the OPGGS(E)R specifies that before commencing an offshore project, a proponent must submit an OPP to NOPSEMA.

Table 2-1 specifies the OPGGS(E)R requirements in relation to the content of this OPP.

Table 2-1: Concordance table for the OPP requirements of the OPGGS(E)R

OPGGS(E)R Section	Description	OPP section
7(2)(a)	The proposal must: i. include the proponent's name and contact details;	Section 1.5
7(2)(b)	include a summary of the project, including the following: i. a description of each activity that is part of the project; ii. the location or locations of each activity; iii. a proposed timetable for carrying out the project; iv. a description of the facilities that are proposed to be used to undertake each activity; v. a description of the actions proposed to be taken, following completion of the project, in relation to those facilities;	Section 4
7(2)(c)	a description of the existing environment that may be affected by the project;	Section 6

OPGGS(E)R Section	Description	OPP section
7(2)(d)	details of the relevant values and sensitivities (if any) of that environment;	Section 6
7(2)(e)	the environmental performance outcomes for each activity that is part of the project;	Section 8
7(2)(f)	a description of any feasible alternative to the project, or an activity that is part of the project, including: i. a comparison of the environmental impacts and risks arising from the project or activity and the alternative; ii. an explanation, in adequate detail, of why the alternative was not preferred.	Section 5
7(3)	Without limiting paragraph (5)(d), relevant values and sensitivities may include any of the following: (a) the world heritage values of a declared World Heritage property; (b) the national heritage values of a National Heritage place; (c) the ecological character of a declared Ramsar wetland; (d) the presence of a listed threatened species or listed threatened ecological community; (e) the presence of a listed migratory species; (f) any values and sensitivities that exist in, or in relation to, part or all of: i. a Commonwealth marine area; or ii. Commonwealth land.	Section 6
7(4)	The proposal must: (a) describe the requirements, including legislative requirements, that apply to the project and are relevant to the environmental management of the project; and (b) describe how those requirements will be met.	Section 2
7(5)	The proposal must include: (a) details of the environmental impacts and risks of the activities that are part of the project; and (b) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk.	Section 8

2.1.1.1 environment plans

The OPGGS(E)R require a titleholder to have an accepted EP in place for any petroleum activity or greenhouse gas (GHG) activity. The EP must be appropriate for the nature and scale of the activity, and must describe the activity, the existing environment, the impact and risk assessment and proposed control measures.

An EP must include an implementation strategy, with an accompanying Oil Pollution Emergency Plan (OPEP) and Operational and Scientific Monitoring Plan (OSMP).

EPs for petroleum activities associated with the Development will be submitted after the OPP has been accepted by NOPSEMA.

Petroleum activities will not start until NOSPEMA has accepted the relevant EP.

2.1.2 environment protection and biodiversity conservation act 1999

The EPBC Act and the supporting Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations) provide for the protection

and management of nationally and internationally important flora, fauna, ecological communities, and heritage places. The aims of the EPBC Act are to:

- protect matters of national environmental significance (MNES)
- provide for Commonwealth environmental assessment and approval processes
- provide for an integrated system for biodiversity conservation and management of protected areas.

If there is the potential for an MNES to be impacted by offshore petroleum activities, an assessment of impacts must be presented in the OPP. The MNES identified as relevant to the Development are:

- listed threatened species and ecological communities
- listed migratory species (protected under international agreements)
- Commonwealth marine environment
- World Heritage properties
- National Heritage places.

NOPSEMA oversees the assessment process as the delegated authority for petroleum activities under the EPBC Act.

2.1.2.1 listed species recovery plans, conservation advices, threat abatement plans, and wildlife conservation plans

Under Part 13 of the EPBC Act, listed threatened species are managed through recovery plans, conservation advices, and threat abatement plans; and listed migratory, marine, cetacean or conservation dependent species are managed through wildlife conservation plans. These plans provide information on relevant impacts and threats and set requirements for management and protection.

The requirements of these documents were used to guide development of the appropriate management of the proposed activities for this OPP.

Table 2-2 summarises the recovery plans, conservation advices, threat abatement plans, and wildlife conservation plans relevant to the Development. These documents were considered when assessing impacts and risks, assessing acceptability, and developing environmental performance outcomes (EPOs). The objectives and actions from these documents, relevant to the Development, are listed in Table 2-2 and cross referenced to the applicable sections within the OPP where details of how the requirements are met are located.

Table 2-2: Relevant EPBC Act recovery plans, conservation advices, threat abatement plans, and wildlife conservation plans

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
Vertebrates					
EPBC Act listed threatened vertebrate marine fauna	Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Ref. 18)	*Objective 1*: Contribute to the long-term prevention of marine debris.	Marine debris	No explicit relevant management actions. Note: Management actions in the plan are largely the responsibility of Commonwealth, State, and local governments and associated government agencies to implement).	8.12.3
Marine mammals					
Blue whale (includes pygmy blue whale and Antarctic blue whale)	Conservation Management Plan for the Blue Whale 2015-2025 (Ref. 20)	*Recovery objective*: The long-term recovery objective for blue whales is to minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. *Interim recovery objective 4*: Anthropogenic threats are demonstrably minimised.	Noise interference	*Action A.2.2*: Assessing the effect of anthropogenic noise on blue whale behaviour. *Action A.2.3*: Anthropogenic noise in biologically important areas (BIAs) will be managed such that any blue whale continues to utilise the area without injury, and is not displaced from a foraging area.	8.5.6
			Vessel disturbance	*Action A.4.2*: Ensure all vessel strike incidents are reported in the National Ship Strike Database. *Action A.4.3*: 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.	8.10.3

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
			Habitat modification (including marine debris, acute and chronic chemical discharge)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.12.3, 8.13.3, 8.14.4, 8.15.4
			Climate variability and change	*Action A.3.1*: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	8.3.14
Fin whale	Conservation advice *Balaenoptera physalus* Fin Whale (Ref. 21)	No explicit relevant objectives.	Anthropogenic noise and acoustic disturbance	No explicit relevant management actions.	8.5.6
			Habitat degradation including coastal development, port expansion and aquaculture	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3
			Pollution (persistent toxic pollutants)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database.	8.10.3
			Climate and oceanographic variability and change	Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica	8.3.14
Sei whale	Conservation advice *Balaenoptera borealis* Sei Whale (Ref. 22)	No explicit relevant objectives.	Anthropogenic noise and acoustic disturbance	No explicit relevant management actions.	8.5.6

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
			Habitat degradation including pollution (increasing port expansion and coastal development)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3
			Pollution (persistent toxic pollutants)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database.	8.10.3
			Climate and oceanographic variability and change	Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica	8.3.14
Southern right whale	National Recovery Plan for the Southern Right Whale (*Eubalaena australis*) (Ref. 23)	*Long-term recovery vision*: The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. *Interim recovery objective 2*: Anthropogenic threats are managed consistent with ecologically sustainable development principles to facilitate recovery of southern right whales.	Habitat degradation—Infrastructure/offshore development (physical modification)	No explicit relevant management actions.	N/A
			Anthropogenic underwater noise	*Action A5.2*: Actions within and adjacent to southern right whale BIAs and habitat critical to the survival (HCTS) should demonstrate that it does not prevent any southern right whale from utilising the area or cause auditory impairment. *Action A5.3:* Actions within and adjacent to southern right whale BIAs and HCTS should demonstrate that the risk of behavioural disturbance is minimised.	8.5.6

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
				Action A5.4: Ensure environmental assessments associated with underwater noise generating activities include consideration of national policy (e.g. EPBC Act Policy Statement 2.1) and guidelines related to managing anthropogenic underwater noise and implement appropriate mitigation measures to reduce risks to southern right whales to the lowest possible level.	
			Collision—Vessel strike	*Action A6.5*: Ensure all vessel strike incidents are reported in the National Ship Strike Database managed through the Australian Marine Mammal Centre, Australian Antarctic Division.	8.10.3
			Entanglement—Marine debris	No explicit relevant management actions.	8.12.3
			Pollution—Chronic and acute chemical discharge	No explicit relevant management actions.	8.14.4, 8.15.4
			Anthropogenic climate change and climate variability	*Action A3.1*: Continue to meet Australia's international commitments to address causes of climate change, including greenhouse gas emissions.	8.3.14
Cetaceans (dolphins)					
Australian humpback dolphin	Conservation Advice for *Sousa sahulensis*	*Primary conservation objective*: To manage anthropogenic threats to the Australian humpback dolphin	Habitat loss and degradation—Climate variability and change	No explicit relevant management actions.	8.3.14

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
	(Australian humpback dolphin) (Ref. 663)	so that the conservation status can improve, and the species can be removed from the EPBC Act threatened species list.	Habitat loss and degradation—Marine pollution	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Vessel interactions—Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database. Ensure the risk of vessel strike on Australian humpback dolphins is considered when assessing actions that increase vessel traffic on areas Australian humpback dolphins occur and, if required, appropriate mitigation measures are implemented.	8.10.3
			Anthropogenic underwater noise—Industrial noise, vessel noise	No explicit relevant management actions.	8.5.6
Australian snubfin dolphin	Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin) (Ref. 664)	*Primary conservation objective*: To manage anthropogenic threats to the Australian snubfin dolphin so that the conservation status can improve, and the species can be removed from the EPBC Act threatened species list.	Habitat loss and degradation—Climate variability and change	No explicit relevant management actions.	8.3.14
			Habitat loss and degradation—Marine pollution	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Anthropogenic underwater noise—Industrial noise, vessel noise	No explicit relevant management actions.	8.5.6
			Vessel interactions—Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database. Ensure the risk of vessel strike on Australian snubfin dolphins is considered when assessing actions that increase vessel traffic	8.10.3

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
				on areas Australian snubfin dolphins occur and, if required, appropriate mitigation measures are implemented.	
Reptiles					
Flatback turtle, green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle Relevant individual genetic stocks: • flatback turtle Pilbara (F-Pil) • hawksbill turtle WA (H-WA) • green turtle North West Shelf (G-NWS) • loggerhead turtle WA (LH-WA)	Recovery Plan for Marine Turtles in Australia (Ref. 24)	*Recovery objective*: The long-term recovery objective for marine turtles 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. *Interim recovery objective 3*: Anthropogenic threats are demonstrably minimized.	Marine debris	*Action A3.5*: Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on the vertebrate marine life.	8.12.3
			Chemical and terrestrial discharge	*Action A4.2*: Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs. Note: This is also a specific action identified for the G-NWS, LH-WA, and F-Pil individual stocks.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Light pollution	*Action A8.1*: Artificial light within or adjacent to HCTS of marine turtles will be managed such that marine turtles are not displaced from these habitats (as per section 3.3 Table 6 of Ref. 24). Note: This is also a specific action identified for the G-NWS individual stock. *Action A8.3*: Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.	8.4.4

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
				In addition to the above actions, the following specific actions have been identified for individual turtle stocks: • F-Pil: Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue • H-WA: Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and dispersing hatchlings can continue.	
			Noise interference	*Action A1.5*: Manage anthropogenic activities to ensure marine turtles are not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24). *Action A1.6*: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	8.5.6
			Habitat modification (including infrastructure development)	*Action A1.5*: Manage anthropogenic activities to ensure marine turtles are not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24). Note: This is also a specific action identified for the F-Pil individual stock.	8.6.3, 8.7.4, 8.8.3

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
				Action A1.6: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	
			Vessel disturbance	No explicit relevant management actions.	8.10.3
			Climate change and variability	*Action A2.1*: Continue to meet Australia's international commitments to address the causes of climate change.	8.3.14
Leatherback turtle	Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Ref. 25)	No explicit relevant objectives.	Ingestion of marine debris	No explicit relevant management actions.	8.12.3
			Boat strike	No explicit relevant management actions.	8.10.3
Leaf-scaled Sea Snake	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 26)	No explicit relevant objectives.	Degradation of reef habitat	Ensure there is no disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	8.14.4, 8.15.4
Short-nosed Sea Snake	Approved Conservation Advice on *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 27)	No explicit relevant objectives.	Degradation of reef habitat	Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	8.6.3, 8.7.4, 8.8.3, 8.13.3,8.14.4, 8.15.4
Fishes					
All sawfish and river sharks	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 28)	The primary objective of this recovery plan is to assist the recovery of sawfish and river sharks with a view to: • improving the population status leading to the removal of the sawfish and river shark	Habitat degradation and modification	*Action 5c*: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Marine debris	No explicit relevant management actions.	8.12.3

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
		species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. The specific relevant objectives of the recovery plan 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 hark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on the Vertebrate Marine Life.			
Dwarf sawfish	Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 29)	No explicit relevant objectives.	Habitat degradation	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Largetooth sawfish	Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 30)	*Primary conservation objective*: The primary objectives are to (1) prevent further decline of any largetooth sawfish subpopulations (e.g. population units that are isolated from others via reproductive philopatry) and (2) ensure the recovery of the largetooth sawfish across its Australian range.	Climate change	No explicit relevant management actions.	8.3.14

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
Green sawfish	Approved Conservation Advice for Green Sawfish (Ref. 31)	No explicit relevant objectives.	No explicit relevant threats	N/A	N/A
Grey nurse shark	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 32)	The overarching objective of this recovery plan is to assist the recovery of the grey nurse shark in the wild with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future, or impact on the conservation status of the species in the future. The specific relevant objective of the recovery plan is: *Objective 8*: Continue to identify and protect HCTS of the Grey Nurse Shark and reduce the impact of threatening processes within these areas.	Pollution and disease	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Whale shark	Conservation Advice *Rhincodon typus* (whale shark) (Ref. 33)	No explicit relevant objectives.	Habitat disruption	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Marine debris	No explicit relevant management actions.	8.12.3
			Boat strike	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale	8.10.3

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
				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.	
			Climate change	No explicit relevant management actions.	8.3.14
White shark	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 34)	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 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 relevant specific objective of the recovery plan is: *Objective 7*: Continue to identify and protect HCTS of the white shark and minimise the impact of threatening processes within these areas.	Habitat modification	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
Barrow cave gudgeon[18]	Conservation Advice for *Milyeringa justitia* (Barrow cave gudgeon) (Ref. 764)	The primary conservation objectives are to: • ensure that the species is secure • reduce likelihood and severity of threats.	Climate change	No explicit relevant management actions.	8.3.14
Blind cave eel[19]	Conservation Advice for *Ophisternon candidum* (Blind Cave Eel) (Ref. 35)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A
Cape Range cave gudgeon, blind gudgeon[19]	Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 36)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A
Seabirds and shorebirds					
EPBC Act listed migratory or marine seabirds	Wildlife Conservation Plan for Seabirds (Ref. 38)	*Objective 2*: Seabirds and their habitats are identified, protected and managed in Australia.	Resource extraction	No explicit relevant management actions.	8.4.4, 8.10.3
			Pollution—Marine debris	No explicit relevant management actions.	8.12.3
			Pollution—Light pollution	*Action 2d*: Ensure all areas of important habitat for seabirds are considered appropriately and consistently in the development assessment process.	8.4.4
			Pollution—Chronic and acute pollution	*Action 2h*: Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.12.3, 8.14.4, 8.15.4

[18] The Barrow cave gudgeon is a subterranean species restricted to the aquatic subterranean habitat of Barrow Island (Ref. 792).

[19] The blind cave eel and Cape Range cave gudgeon are subterranean species found in caves and underwater waters on the Cape Range peninsula (Ref. 35; Ref. 36).

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
			Climate variability and change	No explicit relevant management actions.	8.3.14
EPBC Act listed migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39)	*Objective 3*: Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	Anthropogenic disturbance—Artificial lighting	*Action 3f*: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	8.4.4
			Habitat modification—Chronic and acute pollution	Action 3f: (see above)	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate variability and change	No explicit relevant management actions.	8.3.14
EPBC Act listed threatened albatross and petrel species	National Recovery Plan for Albatrosses and Petrels (Ref. 40)	*Long-term vision*: The populations of albatross and petrel species breeding and/or foraging in Australia's jurisdiction have increased to such a size that each species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. *Recovery plan objective*: To improve the conservation status of albatrosses and petrels so that these species are on a trajectory towards no longer being threatened in Australia's jurisdiction.	Marine pollution—Contamination	Action 5c: Risk based response strategies for marine pollution incidents are developed. Action 5b (adapted): Undertake, as feasible, monitoring of breeding colonies for marine pollution impacts, including as a priority: • incidence of oiled birds at nest • effect of marine pollution.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Marine pollution—Marine debris.	No explicit relevant management actions.	8.12.3
			Marine infrastructure interactions—Offshore installations and ships	No explicit relevant management actions.	8.10.3
			Marine infrastructure interactions—artificial lighting	No explicit relevant management actions.	8.4.4

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
			Climate variability and change	No explicit relevant management actions.	
Abbott's booby	Conservation Advice for the Abbott's Booby (*Papasula abbotti*) (Ref. 41)	*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 EPBC Act. *Short-term objective 2*: Anthropogenic threats to Abbott's booby are demonstrably reduced.	Marine debris	No explicit relevant management actions.	8.12.3
			Climate change	No explicit relevant management actions.	8.3.14
Asian dowitcher	Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 42)	*Primary conservation objective 1*: Ensure no further loss of HCTS of Asian dowitcher throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (includes chronic and acute pollution)	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Australian fairy tern	Conservation Advice for *Sternula nereis nereis* (Fairy Tern) (Ref. 43)	No explicit relevant objectives	Oil spills Note: This threat is noted as particularly relevant in Victoria.	Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	8.14.4, 8.15.4
	National Recovery Plan for (*Sternula nereis nereis*) (Australian Fairy Tern) (Ref. 44)	*Long-term objective*: The Australian fairy tern population has increased in size to such an extent that the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.	Pollution	No explicit management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate variability and change	No explicit relevant management actions.	8.3.14
Australian painted snipe	Conservation Advice for *Rostratula australis* (Australian Painted Snipe) (Ref. 45)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
	National Recovery Plan for the Australian Painted Snipe (*Rostratula australis*) (Ref. 665)	*Long-term objective*: The Australian painted snipe population has increased in size to such an extent that the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.	Climate variability and change	No explicit relevant management actions.	8.3.14
Christmas Island white-tailed tropicbird, golden bosunbird	Conservation Advice *Phaethon lepturus fulvus* white-tailed tropicbird (Christmas Island) (Ref. 46)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A
Common greenshank, greenshank	Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 47)	*Primary conservation objective 1*: Minimise further loss of HCTS of common greenshank throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Curlew sandpiper	Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (Ref. 48)	*Primary conservation objective 1*: Minimise further loss of HCTS of curlew sandpiper throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Eastern curlew	Conservation Advice for *Numenius madagascariensis* (Far Eastern Curlew) (Ref. 49)	*Primary conservation objective 1*: Minimise further loss of HCTS of far eastern curlew throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Greater sand plover	Conservation Advice for *Charadrius leschenaultia*	*Primary conservation objective 1*: Minimise further loss of HCTS of	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.14.4, 8.15.4

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
	(Greater Sand Plover) (Ref. 50)	greater sand plover throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Climate change	No explicit relevant management actions.	8.3.14
Grey falcon	Conservation Advice (*Falco hypoleucos*) Grey Falcon (Ref. 694)	No explicit relevant objectives	Climate change	No explicit relevant management actions.	8.3.14
Little tern	Conservation Advice for *Sternula albifrons* (little tern) (Ref. 666)	*Primary conservation objective 1*: Retain breeding colonies across the species' range by managing threats to the extent possible, including by facilitating breeding site re-positioning if needed, and achieve a stable or increasing population trend in both subpopulations. *Primary conservation objective 2*: Increase breeding success in existing breeding colonies in all range states through appropriate management of threats.	Climate change	No explicit relevant management actions.	8.3.14
Night parrot[20]	Conservation Advice *Pezoporus occidentalis* (night parrot) (Ref. 51)	*Primary conservation objective*: Maintain the persistence of night parrots in areas where it has been detected since 2013 and increase abundance and area of occupancy of the species by protection and appropriate management of threats at known or potentially occupied sites.	Climate change	No explicit relevant management actions.	8.3.14
Northern Siberian bar-	Conservation Advice for *Limosa lapponica*	*Primary conservation objective 1*: Minimise further loss of HCTS of	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.14.4, 8.15.4

[20] Species distribution for the night parrot occurs through arid and semi-arid regions of Australia (Ref. 51).

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
tailed godwit, Russkoye bartailed godwit	*menzbieri* (Yakutian bar-tailed Godwit) (Ref. 52)	Yakutian bar-tailed godwit throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Climate change	No explicit relevant management actions.	8.3.14
Red goshawk	Conservation Advice for *Erythrotriorchis radiatus* (red goshawk) (Ref. 53)	*Primary conservation objective 1*: By 2032, the population size of the red goshawk has increased across the species' range. *Primary conservation objective 2*: By 2032, the area of occupancy of the red goshawk has increased.	Climate change	No explicit relevant management actions.	8.3.14
	National recovery plan for the red goshawk (*Erythrotriorchis radiatus*) (Ref. 667)	*Overall objective*: Maintain populations of red goshawk across their range and implement measures to promote recovery of the species. *Specific objective 2*: Protect and appropriately manage important habitat areas to ensure long-term survival of the red goshawk.	No explicit relevant threats	N/A	N/A
Red knot	Conservation Advice for *Calidris canutus* (Red Knot) (Ref. 54)	*Primary conservation objective 1*: Minimise further loss of HCTS of red knot throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Red-tailed tropicbird (Indian Ocean)	Conservation Advice for *Phaethon rubricauda westralis* (Indian Ocean red-tailed tropicbird) (Ref. 55)	*Primary conservation objective:* A stable or increasing population trend within Australian territory is maintained to the extent that the subspecies is no longer eligible to be listed under the EPBC Act.	Climate change	No explicit relevant management actions.	8.3.14

Species	Plan or advice	Relevant objectives	Relevant threats identified	Relevant management or conservation actions	OPP section
Sharp-tailed sandpiper	Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 56)	*Primary conservation objective 1*: Minimise further loss of HCTS of the sharp-tailed sandpiper throughout Australia (including habitat predicted to become HCTS of the species in the future because of climate change).	Pollution (chronic and acute pollution)	No explicit relevant management actions.	8.6.3, 8.7.4, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Climate change	No explicit relevant management actions.	8.3.14
Shy albatross	Conservation Advice *Thalassarche cauta* (Shy Albatross) (Ref. 57)	Shy albatross are subject to the National Recovery Plan for Albatrosses and Petrels (Ref. 40); refer to above objectives.	Marine pollution (marine debris)	No explicit relevant management actions.	8.12.3
			Climate change	No explicit relevant management actions.	8.3.14
Soft-plumaged petrel	Conservation Advice for *Pterodroma mollis* (Soft-plumaged Petrel) (Ref. 58)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A
Southern whiteface	Conservation Advice for southern whiteface (*Aphelocephala leucopsis*) (Ref. 668)	*Primary conservation objective 1*: Stable population trends in both subspecies.	Climate change	No explicit relevant management actions.	8.3.14
White-winged fairy wren (Barrow Island), Barrow Island Black-and-white Fairy-wren	Approved Conservation Advice for *Malurus leucopterus edouardi* (White-winged Fairy-wren (Barrow Island) (Ref. 59)	No explicit relevant objectives	No explicit relevant threats	N/A	N/A

2.1.2.2 australian marine parks

Under the EPBC Act, Australian Marine Parks (AMPs) are recognised for the purpose of conserving marine habitats and the species that live and rely on these habitats. Details of AMPs relevant to the Development are included in Section 6.

2.1.3 additional relevant commonwealth legislation

Table 2-3 summarises other Commonwealth legislation (additional to the OPGGS Act and EPBC Act) that is relevant to the environmental management of the Development.

Note: This is not a comprehensive list of legislation relevant to the Development, but a list of legislation relevant to impact and risk assessment and proposed control measures.

Table 2-3: Relevant Commonwealth legislation

Legislation	Scope	Application to activities under the OPGGS(E)R
Australian Maritime Safety Authority Act 1990	This Act aims to: • promote maritime safety • protect the marine environment from: – pollution from ships – other environmental damage caused by shipping • provide for a national search and rescue service. The authority responsible for applying the Act is the Australian Maritime Safety Authority (AMSA).	This Act applies to offshore petroleum activities that have the potential to affect maritime safety and/or result in environmental damage, including pollution associated with operating vessels and oil spills from vessels during petroleum activities.
Biosecurity Act 2015 Biosecurity Regulations 2016	This Act defines 'quarantine' and is administered by Department of Agriculture, Fisheries and Forestry (DAFF). The Act aims to monitor, control, and respond to pests and diseases within Australia and its waters. The Maritime Arrivals Reporting System facilitates the collection of documentation required under the Act.	This Act regulates the condition of vessels and drilling rigs entering Australian waters with regard to ballast water and hull fouling. Obligations under the Act are set out in Australian Ballast Water Management Requirements (Ref. 60) and Australian Biofouling Management Requirements (Ref. 61). This Act also manages biosecurity risks in relation to goods that are brought into Australian territory from outside Australian territory.
Climate Change Act 2022	This Act sets out Australia's GHG emissions reduction targets in a manner consistent with Australia's 2030 Nationally Determined Contribution (NDC) under the Paris Agreement[21]. Australia's GHG emissions reduction targets are as follows: • reduce net GHG emissions to 43% below 2005 levels by 2030 which is implemented as a point	The Australian Government must meet the emissions targets established by this Act.

[21] The Australian Government has recently (September 2025) submitted its second NDC; refer to Section 8.3.5.1.

Legislation	Scope	Application to activities under the OPGGS(E)R
	target as well as an emissions budget covering the period 2021-2030. • reduce Australia's net GHG emissions to zero by 2050.	
Environment Protection (Sea Dumping) Act 1981	This Act aims to minimise pollution threats by prohibiting ocean disposal of waste considered too harmful to be released in the marine environment and regulating permitted waste disposal to ensure environmental impacts are minimised. This Act also fulfils Australia's international obligations under the London Protocol to prevent marine pollution.	This Act regulates the disposal of hazardous waste from installations and operational vessels associated with the Development. Sea dumping activities will be undertaken in accordance with the Act and under permit as required.
Environment Protection and Biodiversity Conservation Regulations 2000: Part 8.1	These regulations provide guidance for operating aircraft and vessels in the vicinity of cetaceans.	Relevant aircraft and vessels are required to operate at prescribed distances and speeds when interacting with cetaceans as per requirements of Part 8.1 of the regulations.
Industrial Chemicals Environmental Management (Register) Act 2021 Industrial Chemicals Environmental Management (Register) Instrument 2022	This Act gives provides for the establishment of the Industrial Chemicals Environmental Management Standard (IChEMS) and its associated Register. The IChEMS establishes nationally consistent standards for managing the import, manufacture, export, use, and disposal of industrial chemicals. Industrial chemicals will be listed on the IChEMS Register in one of seven schedules according to their environmental risk. The regulation and enforcement of IChEMS relies on the Commonwealth, States and Territories adopting them into their environmental laws.	Risk management measures identified under IChEMS may have implications for the use or disposal of industrial chemicals during the Development[22].
National Greenhouse and Energy Reporting Act 2007 (NGER Act) National Greenhouse and Energy Reporting (Measurement) Determination 2008 National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule	This Act provides for a single national framework for reporting and disseminating company information about GHG emissions, energy production and energy consumption. The Commonwealth Government's Safeguard Mechanism places a legislated obligation on Australia's GHG emitters with facilities that emit over 100,000 t CO_2-e per year to keep net emissions below their emissions limit (or baseline). The Australian Government's Safeguard Mechanism (Crediting) Amendment Bill 2023 (Safeguard Mechanism reforms) has been passed	Facilities that trigger the 100,000 t per annum CO_2-e Safeguard Mechanism threshold will need to comply with requirements of the Act, including energy and GHG reporting, and meeting any net emissions targets or baselines. Any new gas fields, as defined under the Safeguard Rule, will be required to meet net-zero reservoir carbon emissions.

[22] Note: Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 385).

Legislation	Scope	Application to activities under the OPGGS(E)R
2015 (Safeguard Rule) Carbon Credits (Carbon Farming Initiative) Rule 2015 Australian National Registry of Emissions Units Regulations 2011	by Parliament and is in effect. The emissions reductions established under the Safeguard Mechanism are designed to deliver emissions reductions consistent with Australia's NDC under the Paris Agreement.	
Navigation Act 2012	This Act regulates international ship and seafarer safety and also applies to protection of the marine environment from shipping and the actions of seafarers within Australian waters. In addition, the Navigation Act also gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). The Act regulates: • vessel crew • vessel survey and certification • occupational health and safety • passengers • personnel qualifications and welfare • vessel construction standards • handling of cargoes • marine pollution prevention • monitoring and enforcement activities.	All ships associated with petroleum activities within Australian waters must comply with the requirements under the Navigation Act. Marine orders that relate to petroleum activities include: • Marine Order 15: Construction—Fire protection, fire detection and fire extinction • Marine Order 27: Safety of navigation and radio equipment • Marine Order 28: Operations standards and procedures • Marine Order 30: Prevention of collisions.
Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003 Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Regulations 2004	This Act imposes levies relating to the regulation of offshore petroleum activities and GHG storage activities.	This Act will apply to CAPL as a licence holder and operator.
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	This Act aims to control and reduce the manufacturing, import and export of synthetic GHGs and substances that deplete the ozone layer.	This Act will apply to CAPL if the company manufactures, imports, or exports these kinds of substances.
Protection of the Sea (Harmful Antifouling Systems) Act 2006	This Act aims to protect the marine environment from the effects of harmful antifouling systems. Under the Act, the negligent application of a harmful antifouling	Ships involved with offshore petroleum activities within Australian waters must comply with the requirements under this Act.

Legislation	Scope	Application to activities under the OPGGS(E)R
	compound to a ship by a person or persons is an offence. The Act also requires that all Australian ships that meet specific criteria must hold 'antifouling certificates'.	The following marine order is enacted under this Act: • Marine Order 98: Marine Pollution Prevention—Anti-fouling systems.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act aims to protect the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage, and air pollution. This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (or equivalent, according to class) that describes emergency response activities.	Ships involved with petroleum activities within Australian waters are required to comply with the requirements under this Act. Numerous marine orders are enacted under this Act that relate to offshore petroleum activities, including: • Marine Order 91: Marine Pollution Prevention—Oil • Marine Order 95: Marine Pollution Prevention—Garbage • Marine Order 96: Marine Pollution Prevention—Sewage • Marine Order 97: Marine Pollution Prevention—Air Pollution.
Underwater Cultural Heritage Act 2018 (UCH Act)	This Act protects the heritage values of shipwrecks, sunken aircraft, and relics (>75 years old) in Australian Commonwealth waters from the low water mark to the outer edge of the continental shelf (excluding the State's internal waterways). The Act allows for protection through the designation of protection zones. Activities and conduct prohibited within each zone will be specified.	This Act requires that protected cultural heritage sites are identified and any impacts and risks to these sites are assessed.

2.2 relevant policies and guidelines

Table 2-4 summarises Commonwealth and/or international policies and guidelines that are relevant to the Development.

Table 2-4: Relevant Commonwealth and international policies and guidelines

Policy/guideline	Purpose	Relevance to the Development
Acoustic impact evaluation and management (Ref. 63)	Advice to titleholders to assist with preparing EPs for marine seismic survey activities, and in particular the components of an EP that relate to detailing, evaluating, and managing impacts from acoustic emissions.	General advice regarding acoustic modelling and impact assessment as applied more broadly to petroleum activities.

Policy/guideline	Purpose	Relevance to the Development
American Petroleum Institute (API) Compendium of GHG Emissions Methodologies (Ref. 64)	Provides currently recognised methods and emission factors for calculating GHG emissions for the oil and natural gas industry.	Used to calculate GHG emissions for the Development.
Antifouling and In-water Cleaning Guidelines for Australia and New Zealand (Ref. 65) Australian anti-fouling and in-water cleaning guidelines [Exposure Draft] (Ref. 504)	Provides best-practice approaches to applying, maintaining, removing, and disposing of antifouling coatings and the cleaning of biofouling on vessels and movable structures in Australia and New Zealand. Note: The 2024 exposure draft guidelines are currently out for public comment. Once finalised, these guidelines will replace the previous 2015 guidelines.	Guidance for evaluation of contamination and biosecurity risk of in-water cleaning; and for in-water cleaning, including suitable coatings, coating service life, methods to ensure minimal release of biological material into the water, and appropriate disposal of collected cleaning debris.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (Ref. 66)	Aims to achieve the sustainable use of water resources by protecting and enhancing their quality while maintaining economic and social development.	Provides guideline values for assessing ambient water quality and monitoring.
Australian Ballast Water Management Requirements (Ref. 60)	Provides guidance on how vessel operators should manage ballast water when operating within Australian waters in order to comply with the *Biosecurity Act 2015*. These requirements also align with the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (the Ballast Water Management Convention).	All vessels are required to manage their ballast water in accordance with the Convention and *Biosecurity Act 2015*.
Australian Biofouling Management Requirements (Ref. 61)	Sets out vessel operator obligations for the management of biofouling when operating vessels under biosecurity control within Australian territorial seas.	Biofouling management for vessels, including pre-arrival reporting, and having biofouling management plans.
Australian Offshore Petroleum Development Policy	Encourages ongoing investment in, and development of, Australia's offshore petroleum (oil and gas) resources.	CAPL has an obligation to explore and develop petroleum reserves within its held titles.
Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector (United Nations Economic Commission for Europe 2019)	Provides guidance for developing and implementing effective practices for monitoring, reporting and verifying methane emissions from the oil and gas sector. It also provides guidance on remediation practices.	Used as guidance for energy efficiency and fugitive emissions management in the Gorgon GTP Greenhouse Gas Management Plan (GHGMP) (Ref. 67).
EPBC Act Policy Statement 2.1 Interaction between offshore seismic exploration and whales	Provides practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations and provides a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in	Provides a framework for minimising acoustic injury and disturbances from seismic survey sources to whales. Note: The OPP (see description in Section 4) does not include seismic surveys.

Policy/guideline	Purpose	Relevance to the Development
	biologically important habitat areas or during critical behaviours.	
EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing, and mitigating impacts on EPBC Act listed migratory shorebird species	The purpose of this policy statement is to assist proponents in avoiding, assessing, and mitigating significant impacts on migratory shorebirds listed under the EPBC Act. This policy statement is a key action under the Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39)	Provides guidance for identifying important habitat and significant impacts to migratory shorebirds or their habitat.
Assessing and Managing Impacts to Underwater Cultural Heritage in Australian Waters: Guidelines on the application of the *Underwater Cultural Heritage Act 2018* (Ref. 68)	Provides guidance on identifying, assessing, and protecting underwater cultural heritage. Includes guidance on how proponents can comply with the UCH Act.	Used as guidance in stakeholder consultation and the description of the existing environment.
Identifying and Evaluating Opportunities for Greenhouse Gas Mitigation & Operational Efficiency Improvement at Oil & Gas Facilities (Ref. 69)	Provides guidance on a pragmatic, integrated approach to identifying, evaluating, and advancing cost-effective, high-impact opportunities to manage GHG emissions and energy use at oil and natural gas facilities.	Used as guidance for energy efficiency and fugitive emissions management in the GHGMP (Ref. 67).
International Maritime Organization (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) (Ref. 70)	Guidelines for controlling and managing ships' biofouling to minimise the transfer of invasive aquatic species.	Specific requirements are that vessels have a biofouling management plan and biofouling record book.
ISO 50001 Energy Management Systems (Ref. 71)	ISO 50001 provides a framework of requirements for organisations to: • develop a policy for more efficient use of energy • fix targets and objectives to meet the policy • use data to better understand and make decisions about energy use • measure the results • review how well the policy works • continually improve energy management.	Used as the basis for the GHG management system for the GHGMP (Ref. 67).
Marine Bioregional Plans (Ref. 613; Ref. 102; Ref. 614; Ref. 615)	Designed to improve decisions made under the EPBC Act, particularly in relation to protecting marine biodiversity and the sustainable use of oceans and their	The plans provide information on the Australian Government's marine environment protection and biodiversity conservation responsibilities, objectives, and

Policy/guideline	Purpose	Relevance to the Development
	resources by marine-based industries.	priorities in the four marine regions.
Matters of National Environmental Significance – Significant Impact Guidelines 1.1 (Ref. 72)	Provides overarching guidance on determining whether an action is likely to have a significant impact on a matter protected under the EPBC Act.	Impacts and risks of the petroleum activity can be demonstrated to be at an acceptable level if they do not result in a 'significant impact' as described in these guidelines.
National biofouling management guidelines for the petroleum production and exploration industry (Ref. 73)	A voluntary biofouling management guidance document that has been developed to assist industry manage biofouling risk.	Guidance for evaluating the biofouling risk of types of structures and facilities; and on biofouling management and decommissioning. Used as guidance for CAPL's Quarantine Procedure Marine Vessels (Ref. 74).
National Light Pollution Guidelines for Wildlife (Ref. 37)	Aims to raise awareness of the potential impacts of artificial light on wildlife and provide a framework for assessing and managing these impacts around susceptible listed wildlife.	Guidance for impact assessment, and identifying management tools to minimise and mitigate impacts and risks from artificial lighting.
National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 19)	Provides guidance on understanding and reducing the risk of vessel collisions and the impacts they may have on marine megafauna.	Guidance to determine risks of vessel strike and identify mitigation measures.
NGER (Measurement) Determination 2008 (as amended)	Provide methods, criteria, and measurement standards for calculating GHG emissions and energy data under the NGER Act.	Used to calculate GHG emissions for the Development.
Offshore Petroleum Decommissioning Guideline (Ref. 75)	Clarifies the application, operation, and interaction between components of the Commonwealth regime for decommissioning offshore petroleum infrastructure in Commonwealth waters under the OPGGS Act, associated regulations and, where applicable, other Commonwealth laws.	Completely removing infrastructure and plugging and abandoning wells is the default decommissioning requirement. Options other than complete removal may be considered; however, the alternative decommissioning approach must deliver equal or better environmental, safety and well integrity outcomes compared to complete removal.
Offshore project proposal content requirements Guidance Note (Ref. 16)	Reflects NOPSEMA's interpretation of the content requirements of the OPGGS€R to support proponents in the preparation of OPPs.	This OPP has been developed to meet the requirements described.
Petroleum activities and Australian Marine Parks Guidance Note (Ref. 76)	Supports understanding of titleholder obligations regarding AMPs and consultation with the Director of National Parks (DNP).	Used to inform consultation with the DNP.
Planning for proactive decommissioning Information Paper (Ref. 77)	Encourages titleholders to commence planning for commissioning at the earliest stage of project development.	Provides information on the level of detail required in an OPP.

Policy/guideline	Purpose	Relevance to the Development
Reducing marine pest biosecurity risks through good practice biofouling management Information Paper (Ref. 78)	Clarifies biosecurity requirements relevant to offshore activities. Supports the industry's contribution to marine pest risk management consistent with Australia's MarinePestPlan 2018–2023 (Ref. 79).	Provides guidance that is consistent with the expectations of all jurisdictions responsible for regulating biofouling management within the Australian marine environment.
Section 572 Maintenance and removal of property Policy (Ref. 80)	Sets out NOPSEMA's compliance and enforcement of section 572 of the OPGGS Act, which requires titleholders to: • maintain all structures, equipment, and property in a title area in good condition and repair • remove all structures, equipment, and property when it is neither used nor to be used in connection with operations authorised by the title.	Guidance for decommissioning property at end of Development life.

2.3 western australian legislation

Table 2-5 summarises Western Australian legislation that is relevant to the environmental management of the Development. Although the Development occurs in Commonwealth waters, some State legislation is relevant to the primary approvals of the Gorgon Gas Development or to risk assessment of defined environment that may be affected (EMBA).

Table 2-5: Relevant State legislation

Legislation	Scope/Purpose	Application to the Development
Biodiversity Conservation Act 2016	This Act provides a legislative framework for listing native species and ecological communities identified as under threat of extinction or collapse. The Act is administrated by the Department of Biodiversity, Conservation and Attractions (DBCA).	Species protected under the Act are present within the EMBA.
Aboriginal Heritage Act 1972	This Act recognises and protects Aboriginal cultural sites and objects of significance. Approval is required for activities that adversely impact Aboriginal cultural sites.	Sites protected under the Act overlap with the EMBA.
Barrow Island Act 2003	This Act ratifies an agreement between the State and Gorgon joint venturers, and makes provisions to enable land on Barrow Island to be used for gas processing project purposes, and for the conveyance and underground disposal of CO_2 on Barrow Island.	The Greater Gorgon Area is defined under the Act.

Legislation	Scope/Purpose	Application to the Development
Conservation and Land Management Act 1984 (CALM Act)	This Act regulates the use, protection and management of certain public lands and waters and the flora and fauns within them.	State protected areas proclaimed under the CALM Act overlap with the EMBA. The Act allows hunting of marine fauna by Traditional Owners.
Environmental Protection Act 1986 (EP Act)	This Act aims to reduce pollution and environmental damage in WA.	The Act is relevant to the primary approvals for the Gorgon Gas Development and the environmental management programme for the three-train Gorgon Gas Development.
Fish Resources Management Act 1994	This Act regulates fishing ad aquaculture in WA.	State-managed fisheries which are regulated under the Act overlap with the DA. The Act allows for customary fishing by Traditional Owners.

2.4 international agreements and conventions

The principal international agreement governing petroleum operations in Commonwealth waters is the United Nations Convention on the Law of the Sea, 1982. Australia is also a signatory to several international conventions of potential relevance to the Development, as listed in Table 2-6.

Table 2-6: Relevant international agreements and conventions

Agreement/convention	Purpose	Potential relevance to the Development
Agreement on the Conservation of Albatrosses and Petrels (ACAP)	Multilateral agreement that coordinates international activities to conserve albatross and petrel species and mitigate threats to these populations.	Advice on the conservation responsibilities regarding albatross and petrel species.
China Australian Migratory Birds Agreement (CAMBA)	Bilateral agreement between China and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Advice on the conservation responsibilities regarding bird species that may use the DA as a migratory flyway between China and Australia. The EPBC Act gives effect to CAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Convention Concerning the Protection of the World Cultural and Natural Heritage 1972	Designed to acknowledge and protect areas of cultural and natural heritage across the world.	Guidance around recognising protected areas and areas of cultural and natural heritage and mitigating any potential affects that the Development may have on them.
Convention of the Conservation of Antarctic Marine Living Resources 1979	Developed based on an increasing need to protect the Antarctic ecosystem and its marine species. Responsible for setting conservation measures that determine the use of marine resources in the Antarctic	Provides advice on conservation responsibilities regarding Antarctic species that may migrate to the DA

Agreement/convention	Purpose	Potential relevance to the Development
Convention on Biological Diversity 1993	Provides legal representation for the conservation of biodiversity, the sustainable use of its resources and the equal sharing of any advantages that result from the use of genetic resources.	Advice regarding conservation responsibilities that are relevant to the impact and risk assessment of the Development.
Convention on the International Maritime Organisation 1948	Designed to promote efficient and sustainable shipping through international cooperation that focuses on safe, secure, environmentally sound practices.	Advice on how to travel overseas efficiently and sustainably in relation to navigation, maritime safety and marine pollution.
Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGS)	Designed to create consistent guidelines for vessels operating in the sea and the responsibilities of their staff, including the risk of collision, a safe speed of travel and traffic separation schemes in areas of high traffic.	Provides instruction on the rules of operating vessels at sea in order to ensure safe travel. The *Navigation Act 2012* and subsidiary Marine Orders give effect to the regulations.
Extractive Industries Transparency Initiative 2003	Designed to set a standard for quality governance and accountable management of oil, gas, and mineral resources.	Provides instruction on established principles for resource-extracting activities.
Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services 2012	Provides policymakers with access to scientific assessments on information surrounding Earth's biodiversity, ecosystems, and their benefits to humanity.	Advice regarding the biodiversity and ecosystem communities relevant to the DA.
International Convention for the Prevention of Pollution from Ships, London, 1973/1978 (commonly known as MARPOL 73/78)	Provides advice on preventing and minimising accidental pollution and pollution that results from routine operations.	Guidance on preventing all potential and planned marine pollution associated with the Development. The *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsidiary Marine Orders give effect to MARPOL 73/78.
International Convention for the Safety of Life at Sea 1974 (SOLAS)	Promotes the safety of life at sea by establishing common principles and rules.	The *Navigation Act 2012* (Cth) and subsidiary Marine Orders give domestic effect to the SOLAS.
International Convention on Civil Liability for Oil Pollution Damage,1969 and 1992 (CLC 69; CLC 92)	In the case of oil pollution damage resulting from maritime casualties involving oil-carrying ships, ensures adequate compensation is made for those affected.	Provides insight into the ship's liability in the case of a maritime casualty.
International Convention on Harmful Anti Fouling Systems 2001 (AFS Convention)	Designed to protect the marine environment by prohibiting or restricting the use of harmful antifouling systems on ships.	Guidance for evaluating a vessel's condition and the process of applying, maintaining, removing, and disposing of antifouling coatings as required. The *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and subsidiary Marine Orders give effect to the Convention.

Agreement/convention	Purpose	Potential relevance to the Development
International Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	An environmental treaty that uses international coordination in the advocacy of conservation and sustainable use of migratory species, their habitats and migration routes.	Guidance on the conservation responsibilities regarding migratory species. The EPBC Act gives effect to the Bonn Convention through listing species as migratory under Part 3 of the Act.
International Convention on the Control and Management of Ship's Ballast Water and Sediment (Ballast Water Management Convention)	Adopted with aims to prevent the international spread of non-native marine species by creating standards and procedures for the regulation and control of ships' ballast water and sediments.	Guidance for managing ballast water to reduce the risk of transferring of invasive marine species. The *Biosecurity Act 2015* gives effect to the Convention.
International Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989 (Basel Convention)	Regulates the transboundary movements of hazardous waste to ensure that they are managed and disposed of in an environmentally safe manner. There is expectation that parties will also minimise the waste created and transported.	Provides instruction on appropriate handling, export and disposal of hazardous waste. The *Hazardous Waste (Regulation of Exports and Imports) Act 1989* gives effect to the convention.
International Union for Conservation of Nature (IUCN) 1948 (non-binding)	Created in hopes of finding logical solutions to the world's most critical environment and development challenges. Provides knowledge and tools that allow communities, economies, and nature to work together.	Advice regarding conservation responsibilities and protected area categories relevant to the DA and EMBA.
Japan Australia Migratory Birds Agreement (JAMBA)	Bilateral agreement between Japan and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Guidance on the conservation responsibilities regarding bird species that may use the DA as a migratory flyway between Japan and Australia. The EPBC Act gives effect to JAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Kyoto Protocol 1997	Designed to have industrialised countries commit to implementing policies and measures that reduce and limit their GHG emissions.	Advice on the impacts and risks associated with GHGs and is used in evaluating GHG emissions.
Law of the Sea Forum: The 1994 Agreement on Implementation of the Seabed Provisions of the Convention on the Law of the Sea 1994	The International Seabed Authority was established under the 1982 United Nations Convention on the Law of the Sea and the 1994 Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea (1994 Agreement). It organises and controls all mineral- and resource-related activities in the deep seabed.	Provides instruction on mandates established for activities related to the deep seabed.
London Protocol and Convention on the	Adopted to protect the marine environment from human	Guidance on preventing marine pollution and disposing of waste

Agreement/convention	Purpose	Potential relevance to the Development
Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1996	activities and promote the effective control of all marine pollution.	from installations and operational vessels associated with the Development. The *Environment Protection (Sea Dumping) Act 1981* gives effect to the London Convention.
The Minamata Convention on Mercury	The convention calls on signatories to protect human and environmental health from anthropogenic releases of mercury. The Convention came into force on 16 August 2017 and was ratified in Australia on 7 December 2021.	Australia is a signatory to the Convention. The Convention covers control and reduction of mercury in a range of processes and industries and is relevant to drilling and end of field life aspects that may result in mercury compounds being produced.
Montreal Protocol on Substances that Deplete the Ozone Layer 1987	Designed to protect the ozone layer by phasing out the production and consumption of ozone depleting substances (ODS).	Guidance on the impacts and risks associated with ODSs and evaluating GHG emissions. The *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* gives effect to the protocol.
Paris Agreement 2016 under the United Nations Framework Convention on Climate Change	Objective is to limit the global temperature rise to 2°C while pursuing efforts to limit it to 1.5°C in comparison to pre-industrial levels. Provide financial assistance to developing countries that will help them mitigate and adapt to the impacts of climate change.	Advice for evaluating risks and impacts associated with the activity in regard to climate change. The Australian Government is committed to developing legislation to implement the commitments made in the Paris Agreement.
The Republic of Korea Migratory Birds Agreement (ROKAMBA)	Bilateral agreement between the Republic of Korea and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Advice on the conservation responsibilities regarding bird species that may use the DA as a migratory flyway between the Republic of Korea and Australia. The EPBC Act gives effect to ROKAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Rotterdam Convention a multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals	Adopted to promote informed decisions and shared responsibility with regard to trade in hazardous chemicals. Enables cooperation and information exchange between nations to protect human health and the environment.	Provides instruction on the responsible handling and transport of specific hazardous chemicals.
Stockholm Convention on Persistent Organic Pollutants 2001	Created to protect the environment and human health from the adverse effects of persistent organic pollutants. Requires parties to adopt control measures that aim to reduce and potentially eliminate their use.	Provides instruction on the responsible management of specific hazardous chemicals and methods to decrease or eliminate handling.

Agreement/convention	Purpose	Potential relevance to the Development
United Nations 2030 Agenda for Sustainable Development (2030 Agenda)	Created 17 sustainable development goals that protect the planet and improve quality of life globally.	Informs acceptability evaluation for potential impacts that extend outside Australia's jurisdiction.
United Nations Framework Convention on Climate Change 1992	Objective is to stabilise global GHG concentrations at a level that allows ecosystems to adapt naturally to a changing climate.	Advice on the impacts and risks associated with GHGs and evaluating GHG emissions.

3 stakeholder consultation

CAPL is committed to building and maintaining relationships and conducting meaningful consultation with key stakeholders, including governments, Traditional Owners, and the communities where we operate. Stakeholder consultation is an integral aspect of the environmental impact assessment and CAPL's process in the development of this OPP.

As the proponent of the Development, CAPL will undertake a phased approach to stakeholder consultation throughout the lifecycle of environmental approvals:

- phase 1—early consultation with key stakeholders (including relevant Traditional Owners) undertaken during the preparation of the OPP
- phase 2—public consultation under NOPSEMA's public comment process
- phase 3—relevant persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance.

3.1 phase 1—early consultation with key stakeholders undertaken during the preparation of the OPP

3.1.1 overview

This section provides a description of the methods used, and outcomes of CAPL's early consultation with key stakeholders during the preparation of this OPP.

While the OPGGS(E)R do not require proponents to undertake consultation before submitting an OPP, CAPL considers it best practice to conduct early consultation with key stakeholders to allow them the opportunity to provide feedback on the Development.

The main objectives of this phase of CAPL's consultation are to:

- provide stakeholders with information about the Development
- provide stakeholders with a point of contact for the Development
- allow stakeholders the opportunity to comment on the Development and raise any concerns they may have about potential impacts and risks to their functions, interests, or activities
- inform stakeholders of the project timeframes and the mechanisms by which they can receive further updates or provide additional comment
- identify the social and cultural features of communities within the ecosystem
- inform the control measures to eliminate, reduce, or mitigate impacts and risks to those socio-cultural values and sensitivities in response to stakeholder concerns.

Early consultation with stakeholders commenced in February 2023 with a regulator engagement workshop. Broader consultation with stakeholders commenced in June 2023 and built on the ongoing consultation and engagement that CAPL has in place for the region.

3.1.2 key stakeholder identification

The consultation identification process was undertaken in accordance with CAPL's *Stakeholder Engagement and Issues Management Process: ABU Standardised OE Process* (Ref. 81) to ensure potentially interested and affected

stakeholders were identified and afforded the opportunity to provide feedback, identify concerns or seek further information on the Development. The key stakeholder list was developed through the:

- review of CAPL's current stakeholder list from prior and ongoing consultation in the region
- review of legislation applicable to petroleum and marine activities to ensure administrative agencies are consulted
- review of fishery catch data from Department of Primary Industries and Regional Development (DPIRD) and Australian Fisheries Management Authority (AFMA) for commercial fisheries that may potentially be impacted from the Development
- use of prior feedback from existing stakeholders
- identification of representative groups (including relevant Traditional Owners and Native Title holders) and bodies who were considered to have a function, interest, or activity within the geographical boundary of the Hydrocarbon Ecological and Social EMBAs (defined as outlined in Section 6.1) or which may otherwise be impacted by the identified environmental aspects, risks and impacts (as shown in Section 8)
- use of support from Traditional Owners and/or representative bodies including Registered Native Title Body Corporates (RNTBCs) to identify and facilitate introductions to other stakeholders who may be interested or relevant for the purposes of consultation
- use of Western Australian Fishing Industry Council's (WAFIC's) consultation service for oil and gas consultation for state commercial fishers in the DA of the Development.

The list of key stakeholders identified from these sources is shown in Table 3-1. CAPL will continue to revise and update this key stakeholder list throughout the life of the Development.

Table 3-1: Key stakeholders for preliminary consultation during the preparation of the OPP

Key stakeholders	
Commonwealth Government	
Australian Communications and Media Authority	Department of Climate Change, Energy, the Environment and Water (DCCEEW) (formerly Department of Agriculture, Water and the Environment [DAWE])
Australian Fisheries Management Authority (AFMA)	Department of Defence
Australian Institute of Marine Science (AIMS)	Department of Foreign Affairs and Trade (DFAT)
Australian Maritime Safety Authority (AMSA)	Department of Industry, Science and Resources (DISR)
Australian Marine Oil Spill Response Centre	Director of National Parks (DNP)
Australian Hydrographic Office (AHO)	National Offshore Petroleum Titles Administrator (NOPTA)
Clean Energy Regulator	Parks Australia

Key stakeholders	
Department of Agriculture, Fisheries and Forestry (DAFF) (formerly DAWE)	
State Government	
Department of Biodiversity, Conservation and Attractions (DBCA)	Exmouth Gulf Task Force
Department of Jobs, Tourism, Science and Innovation	Gascoyne Development Commission
Department of Energy, Mines, Industry Regulation and Safety (DEMIRS)	Minister for Environment
Department of Parks and Wildlife	Ningaloo Coast World Heritage Advisory Committee
Department of Primary Industries and Regional Development (DPIRD)	Pilbara Development Commission
Department of Transport (DoT) • Maritime Environmental Emergency Response (MEER) – Marine Pollution (formerly OSRC Unit) • Navigational Safety	Pilbara Ports Authority
Department of Water and Environmental Regulation (DWER)	Shark Bay World Heritage Committee
Environment Protection Authority (EPA)	Western Australia Museum
Commonwealth and State Commercial Fisheries	
Abalone Council Australia	Pearl Producers Association
Aquaculture Council of Western Australia	Recfishwest
Australian Council of Prawn Fisheries	Shark Bay Prawn Trawler Operators Association
Commonwealth Fisheries Association	Western Australian Fishing Industry Council (WAFIC)
Maxima Pearling Company	Western Rock Lobster Council
Northern Prawn Fishery	
Industry	
BP	PGS Australia Pty Ltd
Carnarvon Energy	Santos
Eni Australia	SapuraOMV Upstream
Exxon Mobil	TGS NOPEC Geophysical Company Pty Ltd
Jadestone Energy	Vermilion Oil & Gas
Kufpec	Vocus Communications
Pathfinder Energy	Woodside
Traditional Owners, Local Community and Environmental Nongovernmental Organisations	
Mardathoonera Cultural Heritage Pty Ltd	Murujuga Aboriginal Corporation
Australian Conservation Foundation	Nganhurra Thanardi Garrbu Aboriginal Corporation
Australian Marine Conservation Society	Ngarluma Aboriginal Corporation
Baiyungu Aboriginal Corporation	Ngarluma Yindjibarndi Foundation Ltd

Key stakeholders	
Buurabalayji Thalanyji Aboriginal Corporation	Oil Spill Response Limited
Cape Conservation Group	Onslow Chamber of Commerce and Industry
Care for Hedland Environmental Association	Protect Ningaloo
Carnarvon Chamber of Commerce	Robe River Kurama Aboriginal Corporation
Centre for Whale Research Western Australia	Shire of Ashburton (Pilbara)
City of Karratha (Pilbara)	Shire of Carnarvon (Gascoyne)
Conservation Council of Western Australia	Shire of Exmouth (Gascoyne)
Coral Bay Progress Association	Shire of Shark Bay
Coral Futures Corporation	Town of Port Hedland (Pilbara)
Exmouth Chamber of Commerce and Industry	WA Coastal and Marine Community Network
Greenpeace	WA Marine Science Institute
Kariyarra Aboriginal Corporation	Whale and Dolphin Conservation Society
Karratha & Districts Chamber of Commerce and Industry	Wilderness Island
Mackerel Islands & Onslow Beach Resort	Wirrawandi Aboriginal Corporation
Mangana Aboriginal Corporation	Yinggarda Aboriginal Corporation

3.1.3 phase 1 consultation activities

The following was undertaken as part of the Phase 1 early consultation activities:

- contact details for each of the identified stakeholders were confirmed via email and prior engagements
- information was provided in writing (via email) including details of the Development, planned activities, location and water depth, schedule and duration, the approval process, the EMBA and a summary of the impacts and risks and key proposed control measures
- a dedicated page on CAPL's website, australia.chevron.com, was published, including details of the Development, planned activities, location and water depth, schedule and duration, the approval process, the EMBA, multiple points of contact to provide feedback or request additional information, and a summary of the impacts and risks and key proposed control measures
- multiple avenues for feedback were provided, including via the website, a tollfree number, and direct reply to a CAPL email address
  - the avenues to submit feedback were outlined within the email correspondence to identified stakeholders and on the dedicated page on CAPL's website
- additional customised consultation interactions were facilitated on a case by case basis, including:
  - a briefing and engagement session designed and held for state and federal regulators
  - engagement via face-to-face meetings, phone calls and emails with Traditional Owner groups as part of ongoing consultation for broader CAPL projects.

A summary of early consultation interactions undertaken with key stakeholders in the preparation of the OPP is provided in Table 3-2. Where previous consultation has raised matters that CAPL considers may be relevant to the OPP, these have been included in the table.

Table 3-2: Summary of key stakeholder interactions from early consultation

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Climate Change, Energy, the Environment and Water (DCCEEW) (Cth) Department of Foreign Affairs and Trade (DFAT) (Cth) Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) (WA) Department of Jobs, Technology, Science and Innovation (WA) Parks Australia (Cth)	Feb 2023 Regulator engagement workshop	CAPL introduced the Gorgon Gas Development: Backfill Fields OPP and provided information on key components of the Development. The following stakeholders were invited to the workshop but were not in attendance: AFMA, AIMS, AMSA, DNP, DAFF (Cth), Department of Defence (Cth), DoT (WA), DWER (WA), Department of Jobs, Tourism, Science and Innovation (WA), DBCA (WA), Department of Parks and Wildlife (WA), DPIRD: Fisheries (WA), EPA (WA), Pilbara Ports Authority.	No change required to OPP.
Abalone Council Australia	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Abalone Council Australia to consult on the Development.	No change required to OPP.
Mardathoonera cultural Heritage Pty Ltd (MCH)	August 2023 – November 2023	CAPL engaged with MCH as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a factsheet of the Gorgon Gas Development: Backfill Fields OPP and invited MCH to consult on the Development. MCH raised the significance and importance of Barrow Island, and that they held concerns regarding impacts to stories of cultural significance. MCH raised concerns regarding compliance with the Paris Agreement and energy transition. MCH and CAPL agreed to work together to design how they consult on current and future activities. Consultation with this stakeholder is ongoing.	No change required to OPP (The Paris Agreement and energy transition are discussed in Section 8.3). Further consultation is ongoing.
Aquaculture Council of WA	June 2023	CAPL engaged Aquaculture Council of WA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Aquaculture Council of WA to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		Aquaculture Council of WA acknowledged receipt of email and advised that they had not received any feedback from potentially affected parties.	
Australian Communications and Media Authority (ACMA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACMA to consult on the Development. No feedback has been provided by ACMA regarding the proposed Development during early consultation.	No change required to OPP.
Australian Conservation Foundation (ACF)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACF to consult on the Development. No feedback has been provided by ACF regarding the proposed Development during early consultation.	No change required to OPP.
Australian Council of Prawn Fisheries (ACPF) Ltd.	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACPF to consult on the Development. No feedback has been provided by ACPF regarding the proposed Development during early consultation.	No change required to OPP.
Australian Fisheries Management Authority (AFMA)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AFMA to consult on the Development. AFMA stated they had no specific concerns, but recommended CAPL engage with relevant fisheries operators. CAPL confirmed that relevant fisheries operators were being engaged.	CAPL engaged with the Abalone Council Australia, Australian Council of Prawn Fisheries, Maxima Pearling Company, Northern Prawn Fishery, Pearl Producers Association, Shark Bay Prawn Trawler Operators Association and Western Rock Lobster Council during early consultation (refer to entries in this table).
Australian Hydrographic Office (AHO)	June 2023	CAPL engaged AHO as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AHO to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by AHO regarding the proposed Development during early consultation.	
Australian Institute of Marine Science (AIMS)	June 2023	CAPL engaged AIMS as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AIMS to consult on the Development. No feedback has been provided by AIMS regarding the proposed Development during early consultation.	No change required to OPP.
Australian Marine Conservation Society (AMCS)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMCS to consult on the Development. No feedback has been provided by AMCS regarding the proposed Development during early consultation.	No change required to OPP.
Australian Marine Oil Spill Response Centre (AMOSC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMOSC to consult on the Development. No feedback has been provided by AMOSC regarding the proposed Development during early consultation.	No change required to OPP.
Australian Maritime Safety Authority (AMSA)	June 2023	CAPL engaged AMSA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMSA to consult on the Development. No feedback has been provided by AMSA regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters: • Requirement to mitigate risk of collision within charted shipping fairways • Requirement to provide notification to JRRC and AHO prior to activity commencement • Requirement to ensure lighting requirements comply with relevant regulations.	All notification and lighting requirements are commonplace and industry standard and have been applied. Sections 8.4.5 and 8.9.4 list the relevant control measures, including CM-16, CM-31, CM-32, CM-33, and CM-35. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.

Stakeholder	Early consultation period	Summary	Section of OPP
Baiyungu Aboriginal Corporation (BAC)	June 2023 – August 2023	CAPL engaged BAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BAC to consult on the Development. BAC advised CAPL to engage with DBCA and NTGAC. BAC advised CAPL that they support CAPL's approach of continuing to engage with NTGAC and BAC, and the formalising of an engagement plan with NTGAC. The development of this plan is ongoing. There were no matters raised by BAC regarding the proposed Development during early consultation. Previous engagements with this stakeholder for other activities within the region identified the following values and sensitivities: • Protecting land and Sea Country is a significant focus of the BAC. • The Baiyungu coastal area, Sea Country, and adjacent islands are highly valuable to the Baiyungu people. Engagement with this stakeholder is ongoing.	CAPL engaged with DBCA and NTGAC during early consultation (refer to entries in this table). The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
BP	June 2023	CAPL engaged BP as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BP to consult on the Development. No feedback has been provided by BP regarding the proposed Development during early consultation.	No change required to OPP.
Buurabalayji Thalanyji Aboriginal Corporation (BTAC)	June 2023 – September 2023	CAPL engaged BTAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BTAC to consult on the Development. There were no matters raised by BTAC regarding the proposed Development during early consultation. During previous and ongoing engagements, CAPL and BTAC collaborated to draft an engagement plan to facilitate meaningful engagement. BTAC and CAPL discussed ongoing consultation, relationship building and support opportunities. The development of this plan is ongoing. CAPL and BTAC will continue to engage as part of ongoing consultation. Previous engagements with this stakeholder for other activities within the region identified that the Thalanyji people have a deep connection to Sea Country north	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.

Stakeholder	Early consultation period	Summary	Section of OPP
		of Onslow, extending out into the islands off the coast of the Pilbara including the Montebello Islands, Barrow Island, and Mackerel Islands.	
Cape Conservation Group (CCG)	June 2023	CAPL engaged CCG as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCG to consult on the Development. No feedback has been provided by CCG regarding the proposed Development during early consultation.	No change required to OPP.
Care For Hedland Environmental Association (CFH)	June 2023 – July 2023	CAPL engaged CFH as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CFH to consult on the Development. CFH indicated that they did not have any specific concerns regarding the activities but advised that the flatback turtles that nest in Port Hedland have been genetically linked to Barrow Island and the North West Shelf (NWS) flatback turtle population. CAPL provided CFH with information on the activity and controls to be implemented to reduce impacts and risks. CAPL also provided information on the Chevron Community Spirit Fund and turtle monitoring programs. CAPL advised if CFH has any further questions about CAPL activities they should make contact.	Threatened and/or migratory marine turtles with the potential to be present within the EMBA are discussed in Section 6.3.3.2 and are considered in risk assessment (Section 8)
Carnarvon Chamber of Commerce Inc. (CCCI)	June 2023	CAPL engaged CCCI as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCCI to consult on the Development. No feedback has been provided by CCCI regarding the proposed Development during early consultation.	No change required to OPP.
Carnarvon Energy	June 2023	CAPL engaged Carnarvon Energy as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Carnarvon Energy to consult on the Development. No feedback has been provided by Carnarvon Energy regarding the proposed Development during early consultation.	No change required to OPP.
Centre for Whale Research Western Australia (CWR)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CWR to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by CWR regarding the proposed Development during early consultation.	
City of Karratha (Pilbara)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the City of Karratha to consult on the Development. No feedback has been provided by the City of Karratha regarding the proposed Development during early consultation.	No change required to OPP.
Clean Energy Regulator (CER) (Cth)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CER to consult on the Development. No feedback has been provided by CER regarding the proposed Development during early consultation.	No change required to OPP.
Commonwealth Fisheries Association (CFA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CFA to consult on the Development. No feedback has been provided by CFA regarding the proposed Development during early consultation.	No change required to OPP.
Conservation Council of WA (CCWA)	July 2023 – September 2023	CAPL engaged CCWA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCWA to consult on the Development. CCWA responded requesting further engagement. CAPL met with CCWA virtually. At the meeting CAPL and CCWA agreed that it was important to focus on opportunities for positive engagement and collaboration around data and research gaps. CCWA advised that they will respond with any further questions. CAPL continues to engage with CCWA regarding the Development.	No change required to OPP.
Coral Bay Progress Association (CBPA)	September 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CBPA to consult on the Development. No feedback has been provided by CBPA regarding the proposed Development during early consultation.	No change required to OPP.
Coral Futures Corporation	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Coral Futures Corporation to consult on the Development.	No change required to OPP. Topics raised during previous engagement

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by Coral Futures Corporation regarding the proposed Development during early consultation. Previous engagements with this stakeholder for other activities within the region identified their desire to be notified in the event of an emergency as well as receive ongoing engagement.	which are relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Agriculture, Fisheries and Forestry - Fishing impacts (DAFF) (Cth)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DAFF to consult on the Development. No feedback has been provided by DAFF regarding the proposed Development during early consultation.	No change required to OPP.
Department of Biodiversity, Conservation and Attractions (DBCA) (WA)	June 2023 – July 2023	CAPL engaged DBCA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DBCA to consult on the Development. DBCA provided a written response that identified: • ecologically important areas within the vicinity of proposed operations, including the Barrow Island Marine Park and the Barrow Island Nature Reserve • the requirement to establish appropriate baseline survey data on the current state of areas supporting important ecological values and any current contamination if present within the area of potential impact of hydrocarbon releases • requirements for emergency management including, recommendations for information acquisition to support a before - after, control impact (BACI) framework, notification requirement and clean up expectations in the event of an oil spill • the following guidance documents for CAPL to refer to: – National Light Pollution Guidelines for Wildlife – Offshore Petroleum Industry Guidance Note of September 2018 titled Marine Oil Pollution: Response and Consultation Arrangements – DoT web content regarding marine pollution requirements for consultation. CAPL responded to DBCA indicating that the values of ecologically important areas had been considered in the development of the OPP. CAPL also confirmed	Ecologically important areas which overlap with the EMBA, and available baseline data are discussed in the Description of the environment (Section 6). The National Light Pollution Guidelines (Ref. 37) are considered in Section 8.4 and CM21. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.

Stakeholder	Early consultation period	Summary	Section of OPP
		that spill response and monitoring requirements would be assessed and addressed in subsequent activity specific EPs.	
Department of Climate Change, Energy, the Environment and Water (DCCEEW) (Cth)	June 2023	CAPL engaged DCCEEW as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DCCEEW to consult on the Development. No feedback has been provided by DCCEEW regarding the proposed Development during early consultation. During previous engagements for other activities within the region this stakeholder provided feedback on underwater cultural heritage (UCH) including: • engaging a suitably qualified and experienced maritime or underwater archaeologist for advice on how to mitigate risks associated with protected UCH • recommending undertaking a desktop UCH Assessment to identify known and potential UCH • identifying mitigation measures to adequately reduce the risk of and avoid impacts • advising that the UCH Act provides that the discovery of specified UCH must be notified • considering potential impacts to First Nations UCH and recommending engagement with First Nations Peoples.	The OPP was revised to include Section 6.6.4 which details UCH within the EMBA. CAPL has been and continues to engage with Traditional Owners to identify UCH. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Climate Change, Energy, the Environment and Water - Director of National Parks (DNP) (Cth)	June 2023	CAPL engaged DNP as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DNP to consult on the Development. No feedback has been provided by DNP regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters: • Regulation of petroleum activities within marine management and park areas • Presence of the Montebello Marine Park Multiple Use Zone (IUCN VI) which is managed under the North-west Marine Parks Network Management Plan 2018.	The requirements of the North-west Marine Parks Network Management Plan (Ref. 82) are considered in risk assessment (Section 8).

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Defence (DoD) (Cth)	June 2023 – September 2023	CAPL engaged DoD as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoD to consult on the project. No feedback has been provided by DoD regarding the proposed Development during early consultation.	No change required to OPP.
Department of Foreign Affairs and Trade (DFAT) (Cth)	June 2023	CAPL engaged DFAT as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DFAT to consult on the project. No feedback has been provided by DFAT regarding the proposed Development during early consultation.	No change required to OPP.
Department of Industry, Science and Resources (DISR) (Cth)	June 2023	CAPL engaged DISR as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DISR to consult on the project. No feedback has been provided by DISR regarding the proposed Development during early consultation.	No change required to OPP.
Department of Jobs, Tourism, Science and Innovation (JTSI) (WA)	June 2023	CAPL engaged JTSI as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited JTSI to consult on the project. No feedback has been provided by JTSI regarding the proposed Development during early consultation.	No change required to OPP.
Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) (WA)	June 2023	CAPL engaged DEMIRS as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DEMIRS to consult on the project. No feedback has been provided by DEMIRS regarding the proposed Development during early consultation.	No change required to OPP.
Department of Primary Industries and Regional Development (DPIRD) (WA): Fisheries	June 2023 – July 2023	CAPL engaged DPIRD as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DPIRD to consult on the project.	No change required to OPP. CAPL engaged with WAFIC during early

Stakeholder	Early consultation period	Summary	Section of OPP
		During OPP consultation DPIRD identified the potential impacts on the commercial fishing sector. DPIRD recommended CAPL liaise with WAFIC. CAPL confirmed that WAFIC had been engaged and all matters raised were addressed.	consultation (refer to entry in this table).
Department of Transport (DoT) (WA) - Maritime Environmental Emergency Response (MEER) - Marine Pollution (formerly OSRC Unit)	June 2023	CAPL engaged DoT MEER as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoT marine pollution to consult on the project. No feedback has been provided by DoT MEER regarding the proposed Development during early consultation. During previous engagements on other activities within the region DoT MEER requested that CAPL implement the requirements of the Transport Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (July 2020).	No change required to OPP. Topics raised during previous engagement which are relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Transport (DoT) (WA) - Navigational Safety	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoT Navigational Safety to consult on the project. DoT Navigational Safety recommended CAPL engage with the Pilbara Ports Authority. CAPL confirmed that the Pilbara Ports Authority were being engaged. There were no other matters raised by DoT Navigational Safety regarding the proposed Development during early consultation.	No change required to OPP. CAPL engaged with the Pilbara Ports Authority during early consultation (refer to entry in this table).
Department of Water & Environmental Regulation (DWER) (WA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DWER to consult on the project. No feedback has been provided by DWER regarding the proposed Development during early consultation.	No change required to OPP.
Eni Australia	July 2023 – August 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Eni Australia to consult on the Development. Eni Australia responded stating they had no concerns with the Development at this stage.	No change required to OPP.
Exmouth Chamber of Commerce and Industry (ECCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ECCI to consult on the Development. No feedback has been provided by ECCI regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Exmouth Gulf Task Force - DWER	June 2023 – September 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Exmouth Gulf Task Force to consult on the Development. No feedback has been provided by Exmouth Gulf Task Force regarding the proposed Development during early consultation.	No change required to OPP.
Exxon Mobil	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Exxon Mobil to consult on the Development. No feedback has been provided by Exxon Mobil regarding the proposed Development during early consultation.	No change required to OPP.
Gascoyne Development Commission (GDC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited GDC to consult on the Development. GDC thanked CAPL for the update of the upcoming OPP. There were no matters raised by GDC regarding the proposed Development during early consultation.	No change required to OPP.
Greenpeace	July 2023 – October 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Greenpeace to consult on the Development. No feedback has been provided by Greenpeace regarding the proposed Development during early consultation.	No change required to OPP.
Jadestone Energy	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Jadestone Energy to consult on the Development. No feedback has been provided by Jadestone Energy regarding the proposed Development during early consultation.	No change required to OPP.
Kariyarra Aboriginal Corporation (KAC)	June 2023 – August 2023	CAPL engaged KAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited KAC to consult on the Development. KAC confirmed receipt of the written notice and advised CAPL of the importance of protection of marine fauna in the instance of an emergency event. CAPL met with KAC to further discuss the OPP and other CAPL activities within the region. KAC raised that they were interested in flatback turtles and the impact of rubbish in the sea, particularly bait and ice bags.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features. Topics relevant to the EP phase will be addressed as part of Phase 3 of

Stakeholder	Early consultation period	Summary	Section of OPP
			stakeholder consultation.
Karratha & Districts Chamber of Commerce and Industry (KDCCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited KDCCI to consult on the Development. No feedback has been provided by KDCCI regarding the proposed Development during early consultation.	No change required to OPP.
Kufpec	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Kufpec to consult on the Development. No feedback has been provided by Kufpec regarding the proposed Development during early consultation.	No change required to OPP.
Mackerel Islands & Onslow Beach Resort	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Mackerel Islands & Onslow Beach Resort to consult on the Development. No feedback has been provided by Mackerel Islands & Onslow Beach Resort regarding the proposed Development during early consultation.	No change required to OPP.
Malgana Aboriginal Corporation	June 2023 – September 2023	CAPL engaged Malgana Aboriginal Corporation as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Malgana Aboriginal Corporation to consult on the Development. There were no matters raised by Malgana Aboriginal Corporation regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following: • concerns about the significance and environmental protection of Shark Bay seagrass • request to initiate a structured communication agreement. CAPL and Malgana Aboriginal Corporation collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and Malgana Aboriginal Corporation will continue to engage as part of ongoing consultation.	Seagrass known to be present within the EMBA is considered in risk assessment (Section 8). The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
Maxima Pearling Company	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Maxima Pearling Company to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by Maxima Pearling Company regarding the proposed Development during early consultation.	
Minister for Environment (WA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the Minister for Environment to consult on the Development. No feedback has been provided by the Minister for Environment regarding the proposed Development during early consultation.	No change required to OPP.
Murujuga Aboriginal Corporation	June 2023 – August 2023	CAPL engaged Murujuga Aboriginal Corporation as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Murujuga Aboriginal Corporation to consult on the Development. There were no matters raised by Murujuga Aboriginal Corporation regarding the proposed Development during early consultation. During previous engagement with this stakeholder for other activities within the region, Murujuga Aboriginal Corporation noted the cultural significance of Sea Country and the need to ensure it is protected.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
National Offshore Petroleum Titles Administrator (NOPTA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NOPTA to consult on the Development. No feedback has been provided by NOPTA regarding the proposed Development during early consultation.	No change required to OPP.
Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC)	June 2023 – September 2023	CAPL engaged NTGAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NTGAC to consult on the Development. There were no matters raised by NTGAC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region has not identified specific areas of significance, however NTGAC noted the cultural significance of Sea Country and the need to ensure it is protected. During previous and ongoing engagements, CAPL and NTGAC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and NTGAC will continue to engage as part of ongoing consultation.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.

Stakeholder	Early consultation period	Summary	Section of OPP
Ngarluma Aboriginal Corporation RNTBC	June 2023 – September 2023	CAPL engaged Ngarluma Aboriginal Corporation RNTBC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Ngarluma Aboriginal Corporation RNTBC to consult on the Development. During consultation, Ngarluma Aboriginal Corporation RNTBC noted that offshore islands are culturally significant. During previous engagements, CAPL and Ngarluma Aboriginal Corporation RNTBC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and Ngarluma Aboriginal Corporation RNTBC will continue to engage as part of ongoing consultation.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
Ngarluma Yindjibarndi Foundation Ltd (NYFL)	June 2023 – September 2023	CAPL engaged NYFL as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NYFL to consult on the Development. There were no matters raised by NYFL regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities: • The people from the land speak for and care about the marine animals, even if they are far out to sea. • Marine fauna, specifically whales, dugongs, and turtles are species of importance. • Many traditional narratives have origins and connection to the seascape and impacts to the seascape can have cultural repercussions. • Important intangible values are present, such as Barrimirndi (the serpent), which is an important part of dreaming for Ngarluma and Yindyibarndi people. • The cultural landscape is interconnected, whereby Traditional Owners from the western Pilbara are held to account by other Nyambali (cultural bosses) when proponents impact land and sea. • There are cultural responsibilities that transcend Native Title and other boundaries. During previous and ongoing engagements, CAPL and NYFL collaborated to draft an engagement plan to facilitate meaningful engagement. The development of	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features.

Stakeholder	Early consultation period	Summary	Section of OPP
		this plan is ongoing. CAPL and NYFL will continue to engage as part of ongoing consultation.	
Ningaloo Coast World Heritage Advisory Committee (NCWHAC)	June 2023	CAPL engaged NCWHAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NCWHAC to consult on the Development. No feedback has been provided by NCWHAC regarding the proposed Development during early consultation.	No change required to OPP.
Northern Prawn Fishery (NPF)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NPF to consult on the Development. No feedback has been provided by NPF regarding the proposed Development during early consultation.	No change required to OPP.
Oil Spill Response Limited (OSRL)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited OSRL to consult on the project. No feedback has been provided by OSRL regarding the proposed Development during early consultation.	No change required to OPP.
Onslow Chamber of Commerce and Industry (OCCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited OCCI to consult on the Development. OCCI indicated to CAPL that they would share the factsheet provided to their committee and wider community. There were no matters raised by OCCI regarding the proposed Development during early consultation.	No change required to OPP.
Pathfinder Energy	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pathfinder Energy to consult on the Development. No feedback has been provided by Pathfinder Energy regarding the proposed Development during early consultation.	No change required to OPP.
Pearl Producers Association (PPA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited PPA to consult on the Development. No feedback has been provided by PPA regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
PGS Australia Pty Ltd	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited PGS Australia Pty Ltd to consult on the Development. No feedback has been provided by PGS Australia Pty Ltd regarding the proposed Development during early consultation.	No change required to OPP.
Pilbara Development Commission	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pilbara Development Commission to consult on the project. No feedback has been provided by Pilbara Development Commission regarding the proposed Development during early consultation.	No change required to OPP.
Pilbara Ports Authority	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pilbara Ports Authority to consult on the Development. No feedback has been provided by Pilbara Ports Authority regarding the proposed Development during early consultation.	No change required to OPP.
Protect Ningaloo	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Protect Ningaloo to consult on the Development. No feedback has been provided by Protect Ningaloo regarding the proposed Development during early consultation.	No change required to OPP.
Recfishwest (WA)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Recfishwest to consult on the Development. Recfishwest stated they had no concerns regarding the OPP and would appreciate it if CAPL kept Recfishwest up to date on the OPP moving forward. Previous engagement with this stakeholder for other activities within the region identified the following matters: • disturbance of recreation and charter fishing • presence of valued fish species in the region (including emperor, tropical snapper, mackerel, billfish).	No change required to OPP. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Robe River Kuruma Aboriginal Corporation (RRKAC)	June 2023 – September 2023	CAPL engaged RRKAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited RRKAC to consult on the Development.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional

Stakeholder	Early consultation period	Summary	Section of OPP
		RRKAC requested they be included in future correspondence. There were no other matters raised by RRKAC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities: • the area within their Kuruma Marthudunera native title claim, Jajiwurra (Robe River) and the waters extending seaward from the river mouth. • ecological integrity of Jajiwurra. Consultation with this stakeholder is ongoing.	Owner consultation regarding cultural values and features.
Santos	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Santos to consult on the Development. No feedback has been provided by Santos regarding the proposed Development during early consultation.	No change required to OPP.
SapuraOMV Upstream	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited SapuraOMV Upstream to consult on the Development. No feedback has been provided by SapuraOMV Upstream regarding the proposed Development during early consultation.	No change required to OPP.
Shark Bay Prawn Trawler Operators Association (SBPTOA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited SBPTOA to consult on the Development. No feedback has been provided by SBPTOA regarding the proposed Development during early consultation.	No change required to OPP.
Shark Bay World Heritage Committee	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the Shark Bay World Heritage Committee to consult on the Development. No feedback has been provided by the Shark Bay World Heritage Committee regarding the proposed Development during early consultation.	No change required to OPP.
Shire of Ashburton (Pilbara)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Ashburton (Pilbara) to consult on the Development. The Shire provided CAPL with a written response on the following:	The results of the ACHIS consultation are noted in Section 6.6. Topics relevant to the EP phase will be

Stakeholder	Early consultation period	Summary	Section of OPP
		• the expectation that CAPL will identify, manage, and mitigate all possible impacts and risks in line with the relevant regulatory frameworks and world leading standards (regarding ocean waters and islands). • consultation of the Aboriginal Cultural Heritage Inquiry System (ACHIS) to ensure sites of Aboriginal Cultural Heritage significance are not impacted without consent. • emergency management matters including CAPL undertaking their own emergency management planning as well as briefing and communicating with appropriate emergency management agencies at either/or National, State, District and Local levels. • engagement with the community. The Shire also requested that CAPL provide the Shire with further updates on this proposal as it progresses. CAPL responded to the Shire confirming: • risks and impacts from the proposed activities would be managed and mitigated in line with relevant regulatory frameworks and standards. • ACHIS had been consulted in the development of the OPP. • emergency management matters would be addressed during the EP phase of the activities. • relevant stakeholders within the community had been consulted during the development of the OPP.	addressed as part of Phase 3 of stakeholder consultation.
Shire of Carnarvon (Gascoyne)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Carnarvon (Gascoyne) to consult on the Development. No feedback has been provided by the Shire of Carnarvon (Gascoyne) regarding the proposed Development during early consultation.	No change required to OPP.
Shire of Exmouth (Gascoyne)	June 2023	CAPL engaged Shire of Exmouth (Gascoyne) as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Exmouth (Gascoyne) to consult on the Development. There were no matters raised by Shire of Exmouth (Gascoyne) regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Shire of Shark Bay	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Shark Bay to consult on the Development. No feedback has been provided by Shire of Shark Bay regarding the proposed Development during early consultation.	No change required to OPP.
TGS NOPEC Geophysical Company Pty Ltd	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited TGS NOPEC Geophysical Company Pty Ltd to consult on the Development. No feedback has been provided by TGS NOPEC Geophysical Company Pty Ltd regarding the proposed Development during early consultation.	No change required to OPP.
Town of Port Hedland (Pilbara)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Town of Port Hedland (Pilbara) to consult on the Development. Town of Port Hedland (Pilbara) acknowledged receipt of the information. There were no matters raised by Town of Port Hedland (Pilbara) regarding the proposed Development during early consultation.	No change required to OPP.
Vermilion Oil & Gas	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Vermilion Oil & Gas to consult on the Development. Vermilion responded questioning how they were considered a relevant stakeholder and if CAPL activities would have any impact on the Wandoo operations. CAPL advised that there were no planned associated risks or impacts to the Wandoo operations.	No change required to OPP.
Vocus Communications	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Vocus Communications to consult on the Development. No feedback has been provided by Vocus Communications regarding the proposed Development during early consultation.	No change required to OPP.
WA Coastal and Marine Community Network	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the WA Coastal and Marine Community Network to consult on the Development. No feedback has been provided by the WA Coastal and Marine Community Network regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
WA Marine Science Institute	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the WA Marine Science Institute to consult on the Development. No feedback has been provided by the WA Marine Science Institute regarding the proposed Development during early consultation.	No change required to OPP.
Western Australian Fishing Industry Council (WAFIC)	June 2023 – September 2023	CAPL engaged with WAFIC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited WAFIC to consult on the Development. There were no matters raised by WAFIC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters for consideration: • engagement with local fishers • concerns regarding decommissioning and seismic activities • presence of bluefin tuna spawning area within the region as a potential receptor. During previous and ongoing engagements, CAPL and WAFIC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing.	The potential presence of Bluefin Tuna breeding in the EMBA is addressed in Section 6.3.3 and assessed with fish in Section 8. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Western Australian Museum (WAM)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited WAM to consult on the Development. WAM provided a written response that: • directed CAPL to engage with DCCEEW, who would engage the WAM as its Delegate, if deemed necessary. • recommended referring to and addressing the requirements of the Underwater Cultural Heritage (UCH) Guidance for Offshore Developments and Guidelines for Working in the Near and Offshore Environment to Protect Underwater Cultural Heritage. • advised that a suitably qualified and experienced maritime archaeologist should be engaged to undertake a UCH Desktop Assessment to identify Aboriginal and non-Aboriginal UCH within the project area. • recommended CAPL consult with Traditional Owners, where appropriate.	The OPP was revised to include Section 6.6.4 which details UCH within the EMBA. CAPL engaged with DCCEEW during early consultation (refer to entry in this table). CAPL has been and continues to engage with Traditional Owners.

Stakeholder	Early consultation period	Summary	Section of OPP
		CAPL confirmed that DCCEEW were being engaged. CAPL acknowledged WAM's guidance in relation underwater cultural heritage (UCH) and confirmed that CAPL have and continue to consult with relevant Traditional Owners and that CAPL will comply with the applicable UCH guidance where appropriate.	
Western Rock Lobster Council (WRLC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited WRLC to consult on the Development. No feedback has been provided by WRLC regarding the proposed Development during early consultation.	No change required to OPP.
Whale and Dolphin Conservation Society	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited the Whale and Dolphin Conservation Society to consult on the Development. No feedback has been provided by Whale and Dolphin Conservation Society regarding the proposed Development during early consultation.	No change required to OPP.
Wilderness Island	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited Wilderness Island to consult on the Development. No feedback has been provided by Wilderness Island regarding the proposed Development during early consultation.	No change required to OPP.
Wirrawandi Aboriginal Corporation RNTBC (WAC)	June 2023 - August 2023	CAPL engaged WAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited WAC to consult on the Development. During consultation with WAC, explanatory questions regarding the following matters were raised: • turtle species on Barrow Island. • environmental impacts of emergency response processes. • drilling processes and risks. • gas leaks from transporting gas. • CO_2 injection. • mercury content of gas extracted. • flaring at gas plants.	The OPP was revised to include Table 6-19, which includes specific responses from Traditional Owner consultation regarding cultural values and features. Turtle species with the potential to be present within the EMBA are addressed in the Description of the environment (Section 6) and are considered in risk

Stakeholder	Early consultation period	Summary	Section of OPP
		CAPL provided a response to these queries during the meeting and encouraged WAC to make contact should they have any further questions. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities: • The coastal area, Sea Country and adjacent islands are highly valuable to the Yaburara and Mardudhunera people. • connection to Barrow Island.	assessment (Section 8). Drilling processes are addressed in the Description of the project (Section 4) and considered in risk assessment (Section 8). Potential gas leaks are addressed in the risk assessment (Section 8.15). CO_2 injection is addressed in the GHG emissions risk assessment (Section 8.3). Flaring during the Development is addressed in the Description of the project (Section 4) and risk assessment (Section 8). Flaring at gas plants is not within the scope of the OPP. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Woodside	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Woodside to consult on the Development. No feedback has been provided by Woodside regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Yinggarda Aboriginal Corporation (YAC)	June 2023 - August 2023	CAPL engaged YAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited YAC to consult on the Development. There were no matters raised by YAC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified a need for informed engagement, interest in developing an engagement framework with CAPL, and interest in receiving further information regarding partnership opportunities. The development of this engagement framework is ongoing. CAPL and YAC will continue to engage as part of ongoing consultation.	No change required to OPP.

3.2 phase 2—public consultation under NOPSEMA's public comment process

A public comment period is part of NOPSEMA's OPP assessment process, which includes the publication of the OPP on NOPSEMA's website. This formal consultation period allows stakeholders, including those not initially identified by CAPL during Phase 1 consultation (Section 3.1), an opportunity to provide comment on the Development. The public comment period of an OPP is undertaken for a period at least four weeks, at NOPSEMA's discretion.

The Backfill Fields Development OPP was published by NOPSEMA for a 12-week public comment period, between 9 August to 1 November 2024. The OPP was made publicly available on NOSPEMA's website:

- https://consultation.nopsema.gov.au/environment-division/gorgon-gas-development-backfill-fields/
- https://www.nopsema.gov.au/offshore-industry/environmental-management/assessment-process/public-comment

In alignment with NOPSEMA's information paper on public comment on OPPs (Ref. 503), CAPL promoted the public comment period via their website and in national, state, and regional newspapers.

The proposed Development was first listed on CAPL's Consultation Hub website during June 2023 as part of the Phase 1 early consultation activities (Section 3.1). The Development's activity information page was then updated at the commencement of the NOPSEMA public comment period to provide a link and direct interested stakeholders to the NOPSEMA consultation webpage to be able to review the OPP and provide a written submission.

Advertisements were placed in the following national, state and regional newspapers to promote the NOPSEMA public comment process:

- The West, and The Australian (12 August 2024)
- Pilbara News, Midwest Times, and North West Telegraph (14 August 2024)
- National Indigenous Times (27 August 2024)
- Business News (2 September 2024).

Prominent advertisements were also placed in local Onslow and Karratha Chamber of Commerce newsletters, local Facebook discussion boards, and on a CAPL LinkedIn post, all including a direct link to the NOPSEMA consultation webpage.

In addition, CAPL also directly notified the stakeholders that were identified during Phase 1 consultation via email and provided a link to the NOPSEMA consultation website for the formal public comment period submissions.

Eight submissions (seven via the NOPSEMA website, and one via the CAPL website) were received during the 12-week public comment period. A summary of the comments received, including an assessment of the merits of any objection or claim raised, and where changes to the OPP were made, is provided in appendix g.

3.3 phase 3—relevant persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance

Following acceptance of the OPP, all the petroleum activities within the scope of the OPP must have a NOPSEMA accepted EP in place before CAPL can commence the proposed activities.

Relevant persons consultation, as required under regulation 25 of the OPGGS(E)R, will be completed during the preparation of the EPs to inform decision-making and planning for the petroleum activities. This consultation will be described in the EPs for the petroleum activities associated with this Development.

Ongoing consultation, as required under regulation 22(15) of the OPGGS(E)R, will be undertaken after acceptance of the EPs and will be outlined within the EPs for the petroleum activities associated with this Development.

4 description of the project

4.1 overview

The Development will develop and operate seven gas fields and associated flowlines and tie-ins, which will feed into the Gorgon GTP on Barrow Island.

This section summarises the Development as required under regulation 7(2)(b) of the OPGGS(E)R. The description of the Development activities is presented in the following subsections:

- the hydrocarbon system—includes all the infrastructure used for the gathering and transporting hydrocarbons to the existing GFP pipelines, and other supporting infrastructure (Section 4.2)
- surveys—geophysical surveys and seabed geotechnical surveys, including pre-installation and as-built surveys, occurring throughout the Development (Section 4.3.1)
- drilling—covers well construction and includes MODU positioning, spread mooring, drilling of production wells, BOP installation, cementing and completions in each field (Section 4.3.2)
- installation and commissioning—includes seabed preparation, pipelay (flowline and pipeline), subsea equipment installation, verification and testing of infrastructure, pre-commissioning, including hydrotesting and commissioning, and the introduction of hydrocarbons to the system (Section 4.3.3)
- operations—the gathering and transport of hydrocarbons and other fluids from the subsea wells to the existing GFP pipelines, including IMR and well intervention (Section 4.3.4)
- decommissioning—long-term planning for decommissioning of infrastructure no longer in use, including removing subsea infrastructure, and P&A of wells (Section 4.3.5)
- support activities—includes MODU topside activities and vessel, helicopter, and remotely operated vehicle (ROV) operations (Section 4.3.6).

The activities, locations and infrastructure described in this section are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

4.1.1 gorgon foundation project context

The GFP included the construction of the Gorgon GTP for both LNG and domestic gas processing on Barrow Island, which is located off the Pilbara coast (WA), 85 km north-north-east of Onslow. The Gorgon Gas Development was approved under the EPBC Act for constructing and operating facilities associated with producing and transporting gas (including offshore production wells and feed gas pipeline infrastructure) from the Gorgon and Jansz–Io gas fields to the GTP. The Greater Gorgon Area is defined under the *Barrow Island Act 2003* (WA).

Construction of GFP infrastructure began in December 2009, drilling activities in 2011 and LNG production commenced in 2016. Subsea gathering systems and pipelines deliver feed gas from the Gorgon and Jansz–Io gas fields to the west coast of Barrow Island. The underground feed gas pipeline system then traverses Barrow Island to the GTP on the east coast. The GTP includes natural gas

production lines (also known as trains) that produce LNG as well as condensate and domestic gas. Carbon dioxide (CO_2), which occurs naturally in the feed gas, is separated during the production process, and a proportion is injected into deep rock formations below Barrow Island. The LNG and condensate are loaded onto ships from a jetty and transported to international markets. Gas for domestic use is delivered by pipeline from Barrow Island to the domestic gas collection and distribution network on the WA mainland.

CAPL has undertaken further developments to maintain supply to the GTP with the GS2 Project, which involves the installation of additional wells in the Gorgon and Jansz-Io fields and accompanying offshore production pipelines and subsea structures.

4.1.2 location

The Development includes seven gas fields, all located in Commonwealth waters off the north-west coast of WA, and north-west of Barrow Island. The seven fields[23] are Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR).

The area includes a steep scarp which represents the transition from the shallow waters of the continental shelf at ~150 m depth to water settings of ~1,400 m in the deeper water ~100 km out from the scarp. The closest infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow.

Existing GFP infrastructure comprises feed gas pipelines from the Jansz–Io gas field and the Gorgon gas field. These pipeline routes converge before the pipelines connect to the GTP on Barrow Island. The new flowlines will be tied-in to the Jansz or Gorgon Feed Gas Pipelines.

Figure 4-1 shows the location of the fields[24].

[23] Reference to fields includes any reservoirs within the fields.

[24] The Semele field is a prospect at this time. The field is contained within retention leases WA-14-R and WA-15-R, which also cover the Chrysaor and Dionysus fields.

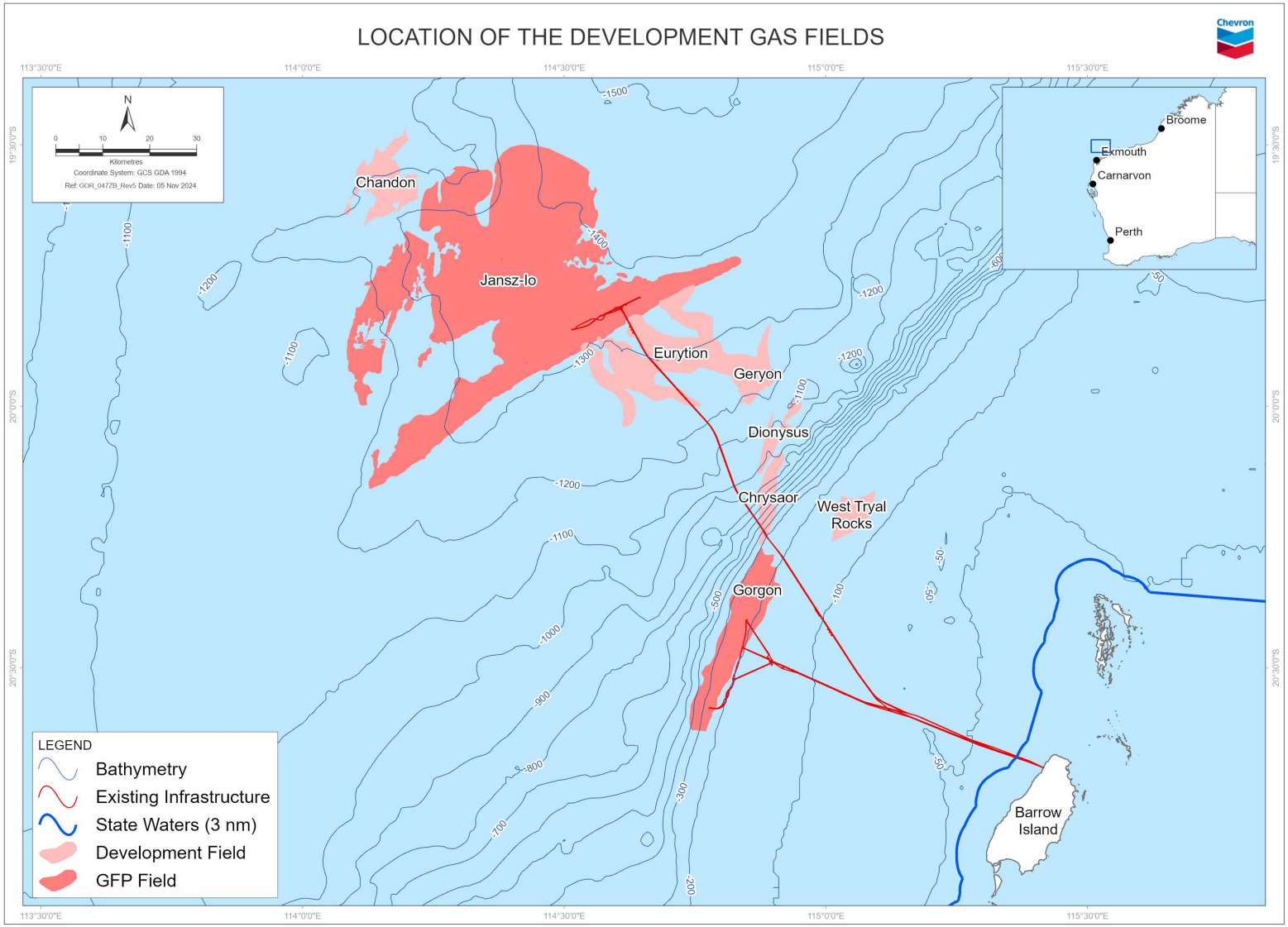


Figure 4-1: Location of Development gas fields

4.1.3 development area

The DA is a defined area within which all petroleum activities associated with the Development occur, and which allows impact assessment of those activities. For this OPP, the DA includes the extent of all planned activities described in this OPP, with a 5 km radius around the expected position of subsea infrastructure (Figure 4-2).

As the final routes for the flowlines, monoethylene glycol (MEG) pipelines and umbilicals have not yet been confirmed; and multiple flowline, pipeline and umbilical routes or potential locations are under consideration, a 5 km buffer has been included around the outermost route or location, to give a conservative area to use for impact assessment. These indicative routes have been chosen to connect the fields to the Feed Gas Pipeline tie-in point (i.e. Gorgon or Jansz), while taking into account geographical features such as the scarp. In addition, to allow more flexibility, the DA boundary has been enlarged in some sections, such as around the existing Jansz Feed Gas Pipeline. Final flowline, pipeline and umbilical routes and location of structures will be confirmed later, following seabed surveys and coring, and detailed engineering design, and will be specified in the EP phase.

The Development includes well construction from 10 drill centres (DCs). Table 4-1 lists the approximate water depth and indicative coordinates of each proposed DC. Indicative well locations have been chosen to minimise the number of wells and DCs required for optimal access to the reservoir. More accurate locations and water depths of the infrastructure will be included in the relevant EPs once final locations are selected.

Table 4-1: Water depth and indicative coordinates of DCs at each field

Fields	DC	Approx. water depth (m)	Indicative coordinates of DCs[25]	
			Latitude	Longitude
Chandon	Chandon DC-1	1,200	−19.566894752	114.128503654
	Chandon DC-2	1,200	−19.550449305	114.112716243
C&D	C&D DC-1	1,150	−20.059302764	114.895980290
	C&D DC-2	1,000	−20.129470731	114.864375418
	C&D DC-3	800	−20.195676362	114.878809246
G&E	G&E DC-1	1,200	−19.937438510	114.882671257
Semele	Semele DC-1	1,200	−19.960763696	114.989444688
	Semele DC-2	1,200	−19.992837921	114.950818998
WTR	WTR DC-1	150	−20.241792298	115.030611257
	WTR DC-2	150	−20.214084371	115.044652696

While the final routes may move from the indicative locations presented in Table 4-1 and Figure 4-3, all final infrastructure will be located within the DA described in Section 4.1.3 (Figure 4-2).

The DA covers the operation and movement of vessels and helicopters that will be undertaking activities described in this OPP. The general transit of vessels, the MODU and helicopters to and from the DA is not considered a petroleum activity and therefore is excluded from the scope of this OPP. These activities will be

[25] Geocentric Datum of Australia 94

undertaken in accordance with other relevant maritime and aviation legislation, including the *Navigation Act 2012* (Cth) and *Civil Aviation Act 1988* (Cth).

The operation of onshore facilities required to support the Development is outside the scope of the OPP.

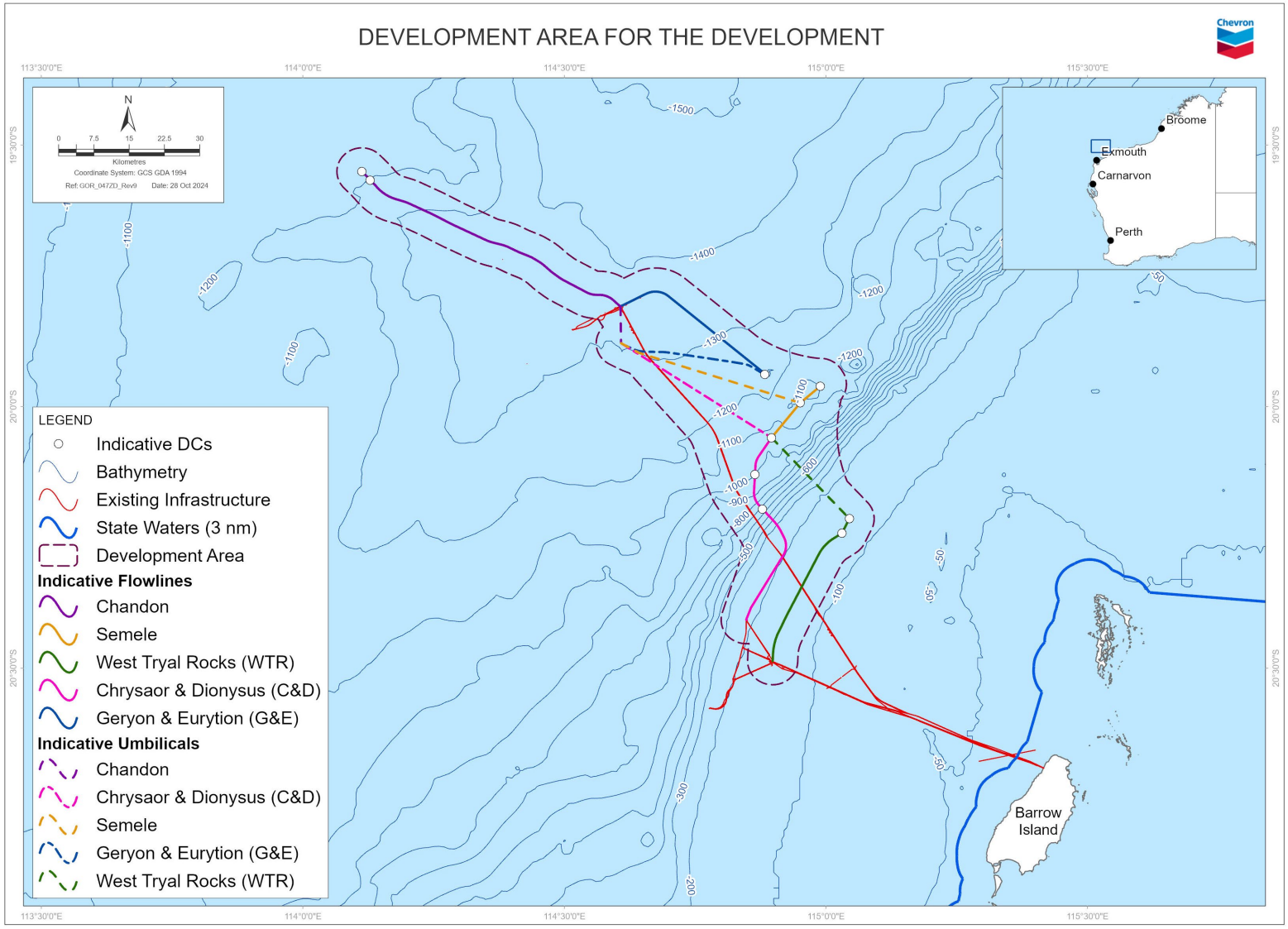


Figure 4-2: Development area for the Development

4.1.3.1 disturbance area

As the Development is in the early planning phase, the exact footprint of the infrastructure to be installed is still to be finalised. The exact details of each stage will be included in the respective EPs. To allow for environmental impact assessment in the OPP, a conservative disturbance area has been adopted. This seabed disturbance is classified as either long-term disturbance or short-term disturbance.

Long-term disturbance is a result of infrastructure that may remain on the seabed from installation through to decommissioning. The long-term infrastructure disturbance area comprises the direct footprint of the infrastructure as well as a buffer area either side of the flowlines, pipelines and umbilicals, and an area around the DCs and tie-ins (Section 8.1.1.7). For ease of reference and conservatism, the direct footprint of the infrastructure as well as the buffer area will be referred to as the long-term disturbance area throughout this document. CAPL has allowed for a further 50% as contingency for the long-term infrastructure disturbance area to allow for any changes to infrastructure footprints or placement within the DA boundary. All infrastructure described in Section 4.2 will be located within the long-term disturbance area.

Short-term disturbance is caused when infrastructure or equipment has contact with the seabed during a particular phase but is removed at or before the end of that phase. Anchoring of vessels or the MODU is an example. A further 50% contingency has been provided for the short-term disturbance area to allow for any changes to short-term infrastructure footprints or placement within the DA boundary.

Further detail on long-term and short-term disturbance is described in Section 8.1.1.7.

4.1.4 timing

The Development will be staged, that is, the fields will be developed over multiple campaigns with the G&E co-development earmarked as the first stage of the Development. Subject to relevant approvals and other constraints, the earliest that G&E is likely to be ready for activities to commence in the DA is late-2026, with subsequent ready for start-up (RFSU) from late-2028. The end of life for the Development is notionally ~2070 (i.e. aligned with the overall Gorgon Gas Development), with each field identified in the Development having its own end of field life. The indicative range for the duration of operations is 10–30 years for each field, which captures the potential for future technology and variance in field performance. Decommissioning and any post-decommissioning monitoring will occur as applicable following each field's end of life. The indicative timeframes and schedule of key Development activities are presented in Table 4-2.

Table 4-2: Indicative timeframes and schedule of key Development activities

Development activity	Approximate timing for commencement of activity	Approximate duration
G&E Drilling	Late-2026	Up to 24 months
G&E Installation and commissioning	Mid-2027	12 months

Development activity	Approximate timing for commencement of activity	Approximate duration
G&E Operations[26]	Late-2028	20–25 years
Subsequent field development	Timing of the subsequent field developments will be based on the production outcomes of the GFP and G&E fields; i.e. new field(s) will be developed to feed into the Gorgon and Jansz trunklines as needed to maintain gas supply to the Gorgon GTP. The order that the fields will be developed has not yet been finalised. The activity durations for the individual fields will be similar to the durations presented for G&E except for installation and commissioning activities at C&D which may take longer (~15 months) due the presence of the scarp. Additionally, WTR may have an operational life up to 30 years.	

While the Development will typically be staged so that not all fields will be developed in a single campaign, some phases may occur concurrently within and across fields. There is potential for multiple Development activities to occur at the same time within a single field, for example drilling, installation and support activities could occur concurrently. There is also potential for concurrent activities to occur intermittently across fields for example drilling may be occurring at one field, while installation operations are occurring at a different field, or drilling and installation may occur in one field while commissioning occurs in another. As the Development is in the early planning phase the exact sequence of the activities is still to be finalised, and the details of each sequence and the related cumulative impacts and risks will be included and assessed in the respective EPs. Where relevant, Sections 8 and 9 of this OPP consider potential concurrent and cumulative impacts and risks to maintain operational flexibility in schedules.

IMR activities on operational infrastructure may occur at any time, including during installation, commissioning, start-up, and operations.

Activities covered by this OPP can occur 24 hours a day, 7 days a week and at any time of the year.

4.1.5 options to be selected after OPP phase

Because OPPs are written prior to detailed engineering design, some activity and design options will not be finalised until later in the project design phase, which will likely occur after the OPP phase.

The Development has a long project life, and the OPP framework under the OPGGS(E)R does not have a change mechanism. Any changes would require a new or revised OPP to be submitted. As a result, the alternatives analysis process undertaken for design and activity options (Section 5.3) has identified some instances where multiple options need to be outlined in the OPP. This enables CAPL to consider methodologies and technologies that are not currently feasible or available, but which may be an option during the Development life. It also allows the flexibility to select the option with the best environmental outcome at the time.

[26] Operation duration is from the RFSU for each development. A time range is provided to capture the potential for future technology and variance in field performance.

Table 4-3 summarises the key options that will be selected prior to the EP phase, which are included in Section 4.3. The different options may have different impacts and risks; therefore Table 4-3 identifies which option presents the scenario with the greater environmental impact for specific key aspects. These options will be used for the impact assessment in Section 8 to ensure the option that presents the greatest potential environmental impact is assessed.

Table 4-3: Design and activity options included in the OPP

Activity / Design option	Option overview	Key aspects for impact assessment	Implications / discussion
MODU type	Moored MODU	Seabed disturbance	Moored and DP MODUs have similar total scores in the comparative environmental assessment, but the scores vary on some specific criteria. Moored MODUs impact the seabed due to anchoring and have greater potential to interact with marine fauna compared to a MODU on DP. Jack-up MODUs impact the seabed, but to a lesser extent than Moored MODUs. DP MODUs cause more underwater sound and atmospheric emissions compared to moored MODUs.
	Dynamically Positioned (DP) MODU	Underwater sound Atmospheric emissions	
	Jack-up MODU	Seabed disturbance	
Flowline retrieval	Cut and lift	Seabed disturbance Planned emissions and discharges Physical presence	The cut and lift option is much slower than reverse lay. Therefore, impacts and risks associated with vessel activities are greater for cut and lift due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of flowline retrieval used for impact assessment in Section 8 was based on the cut and lift option. Cut and lift also requires disturbance of the seabed around each cut site to allow access for the cutting tools. Reverse lay for this size of pipe and water depth is not currently feasible at time of writing. However, it may become a more feasible option in future, which is why both options are selected.
	Reverse S-lay / J-lay	Introduction of invasive marine pests (IMPs)	
Umbilical retrieval	Recover and cut on deck / reverse reel	Planned emissions and discharges Physical presence	Recover and cut on deck / reverse reel is slower than reverse carousel. Therefore, impacts and risks associated with vessel activities are greater for recover and cut / reverse reel due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of umbilical retrieval used for impact assessment in Section 8 was based on the recover and cut on deck / reverse reel option. In consideration of potential future challenges associated with suitable vessel availability, both options have been included in this OPP.
	Reverse carousel	N/A. There is no material difference in key aspects.	

4.2 description of hydrocarbon system

4.2.1 overview

The proposed Development hydrocarbon system supplements the existing GFP to tie-in the additional fields and includes this subsea infrastructure:

- production wells
- production trees, manifolds, pipeline termination structures (e.g. pipeline end terminations [PLETs], pipeline end manifolds [PLEMs]) and other tie-in structures (e.g. slug catchers, overpressure protection system)
- flowlines to tie new production wells to the Gorgon or Jansz Feed Gas Pipelines
- associated MEG pipelines, spools, jumpers, manifolds, structures and in-line tees
- umbilicals, flying leads and controls distribution units (CDUs).

The key infrastructure components proposed for the Development are described in Sections 4.2.2 to 4.2.6. Any dimensions provided are based on early engineering estimates and may change; however, the intent of the long-term disturbance area (Section 8.1.1.7) is to allow for the footprint of all infrastructure described in Section 4.2.

In this OPP the term ‘flowline’ refers to new infield flowlines to be installed as part of the Development; ‘production pipeline’ refers to existing infrastructure. This helps differentiate existing infrastructure from that associated with the Development. Further terminology definitions are given in the following subsections and in the acronym/definitions table (Table 11-1).

The backfill fields within the scope of the Development will likely be tied-in to the GFP as follows:

- the Chandon field, which is the furthest from Barrow Island (~190 km), will be tied-in to the Jansz pipeline
- the C&D fields are anticipated to be co-developed and will feed into a single flowline; C&D will tie-in to the Gorgon pipeline
  - the C&D flowline will traverse the scarp on its route to the Gorgon pipeline
- the G&E fields will be co-developed and will feed into a single flowline; G&E will be tied-in to the Jansz pipeline
- the Semele field will be tied-in to the proposed C&D flowline
- the WTR field will be tied-in to the Gorgon pipeline.

Umbilicals will be required to provide power and controls to the new infrastructure. Umbilicals will be laid in the same corridor as the flowlines or follow a separate route to the flowlines. All umbilical routes will be within the DA. Umbilicals likely to be installed are described in Section 4.2.5.

The final routes for the flowlines, MEG pipelines or umbilicals have not yet been identified, and multiple route options are being considered. The figures in this OPP present a single indicative route for each proposed flowline, MEG pipeline or umbilical.

These indicative routes are considered the outermost routes or represent the worst-case environmental impact (i.e. longest route) for the Development. These indicative ‘worst-case’ routes were used for the impact assessment. All final flowline, MEG pipeline and umbilical routes will occur within the DA described in Section 4.1.3.

Figure 4-3 shows the indicative flowline and umbilical routes for the Development and the existing infrastructure.

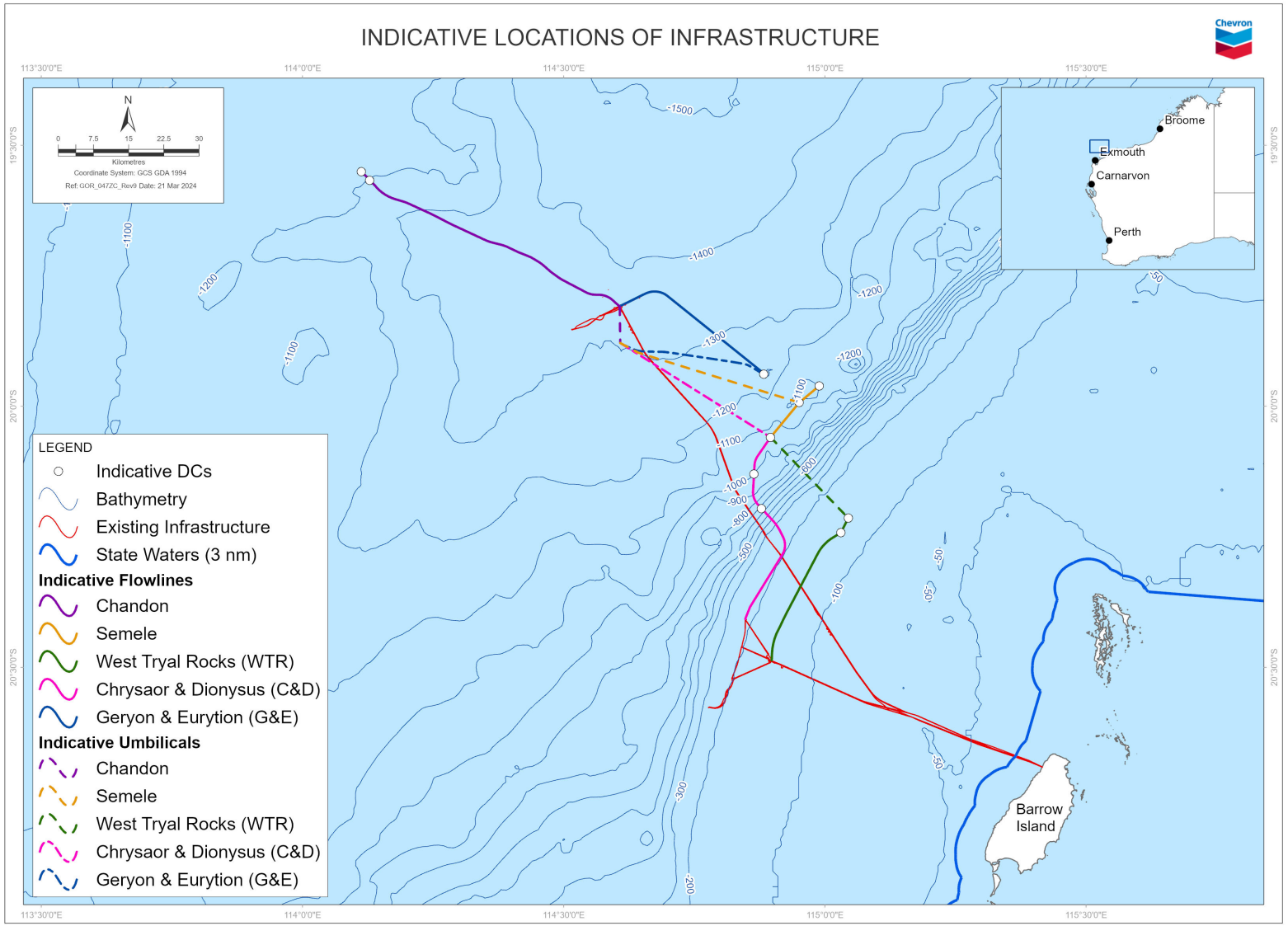


Figure 4-3: Indicative locations of infrastructure

Although the layout of subsea infrastructure at each DC will be different and specific infrastructure locations are yet to be finalised, a diagram showing an indicative DC layout has been prepared (Figure 4-4). This diagram illustrates the infrastructure described in this section; it is for illustrative purposes only as the DCs may vary slightly.

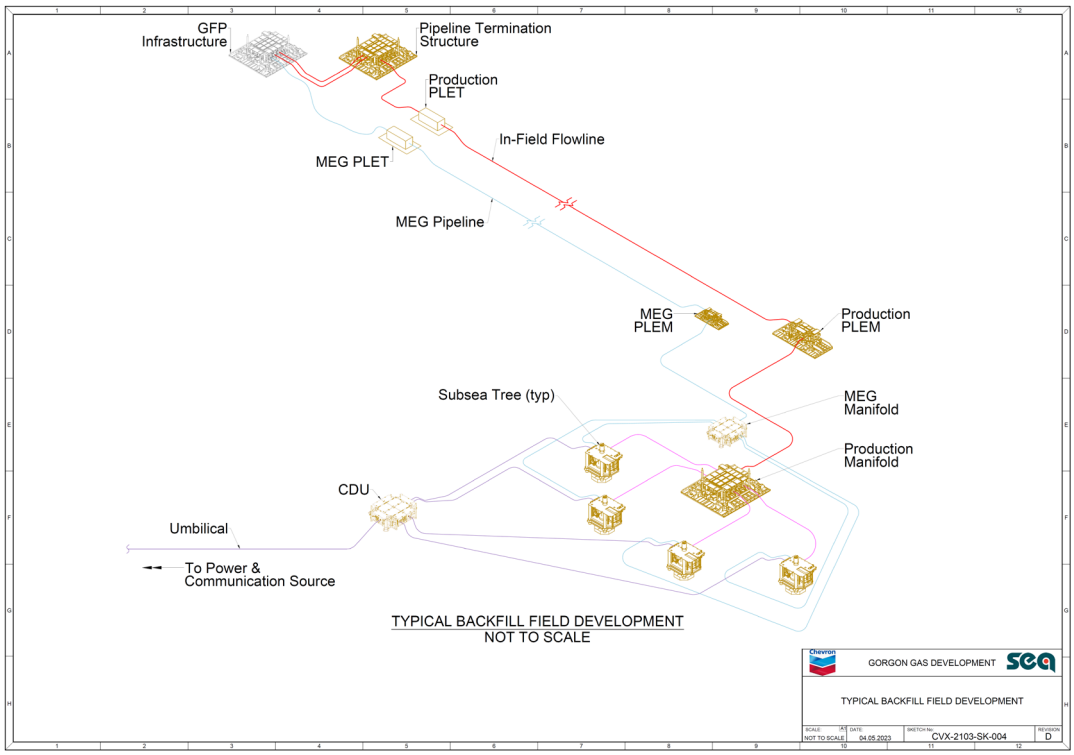


Figure 4-4: Indicative drill centre layout

4.2.1.1 field characteristics

Table 4-4 details the hydrocarbon compositions for the seven fields.

Table 4-4: Primary inert and hydrocarbon composition (mol%) for each field

Component	Field						
	Chandon	Chrysaor	Dionysus	Eurytion	Geryon	Semele[27]	WTR
Carbon dioxide	0.3	9.9	8.3	0.6	1.2	6	12.8
Nitrogen	3.4	4.4	3.4	2.3	2.1	4	14.4
C1 Hydrocarbons	85.2	78.9	81.9	89.6	88.8	84	65.3
C2 Hydrocarbons	5.1	4.0	3.9	4.5	4.5	4	3.9
C3 Hydrocarbons	2.6	1.3	1.2	1.6	1.6	1.2	1.4
≥C4 Hydrocarbons	3.3	1.4	1.3	1.5	1.7	0.8	2.2

[27] The Semele field is a prospect at this time and as a result, no measured composition data is available. The field is located within retention lease permits WA-14-R and WA-15-R, which also cover the Chrysaor and Dionysus fields. Estimated Semele composition is interpretations based on a combination of analogues fields, and therefore may change. Nearby fields within the Gorgon Gas Development area were chosen as compositional analogues with consideration to both stratigraphy and location, for each of the various Semele reservoir intervals. The worst case of these analogues was selected to represent CO2 and methane compositions, with the remaining hydrocarbon components represented as a mix of the analogue fields.

4.2.2 production wells

A number of production wells[28] will be drilled for each field, with a maximum 40 wells (total) for the Development. These wells will be distributed between the 10 DCs (Table 4-1).

Each production well is fitted with a wellhead and a production tree, which is the primary infrastructure for distributing hydrocarbons from the wells. Production trees include an arrangement of valves, controls, and instrumentation to monitor, direct and control hydrocarbon flow and facilitate injection of MEG and other chemicals.

Table 4-5 provides the key characteristics of the wells.

Table 4-5: Key characteristics of the wells

Characteristic	Field				
	Chandon	C&D	G&E	Semele	WTR
Maximum number of wells	8	8	8	8	8
Approximate water depth	1,200 m	800–1,150 m	1,200 m	1,200 m	150 m
Approximate total footprint	336 m^2	336 m^2	336 m^2	336 m^2	336 m^2

4.2.3 subsea structures

Subsea structures, such as foundation (support) structures, manifolds and other structures (e.g. slug catcher, overpressure protection system) will be installed at DCs.

The production wells are connected to subsea production manifolds at each DC. These manifolds enable production fluids from each well to be commingled before entering the infield production flowlines. The infield production flowlines run from the production manifolds to the GFP tie-in points for each field. At each tie-in point, a variety of manifolds may be required to facilitate the flow of hydrocarbons at different stages of the Development.

Valve isolation is provided on the subsea production manifolds using valves that may be operated by an ROV if required.

Manifolds may also be required for MEG transfer at the DCs and tie-in locations.

Seabed support for subsea structures is achieved using foundation structures such as mudmats, which are used to prevent structures from sinking into soft sediment on the seabed. The largest predicted footprint for a single manifold ~900 m^2. The design of the manifolds is currently preliminary, with the final design footprint to be provided in subsequent EPs.

Other structures (e.g. slug catcher, overpressure protection system) may also be installed. The overpressure protection system may be required to further safeguard the transfer of the Development hydrocarbons via the subsea compression station associated with J-IC. The predicted footprint is estimated to

[28] Where ‘production well’ includes new production wells and the potential to convert a suspended exploration/appraisal well to a production well. Note: Exploration and appraisal petroleum activities are not within scope of an OPP (Section 1.4.2).

be ~2,100 m^2 for each unit. These structures are likely to be required at one of the Jansz tie-in locations only, with an expected one of each required.

4.2.4 flowlines, MEG pipelines, jumpers, and spools, PLETs and PLEMs

Each production tree is connected to a subsea production manifold via jumpers. Jumpers, and spools, are also used to connect manifolds to flowlines/pipelines and flowlines/pipelines to GFP tie-in points. Jumpers and spools will have a nominal diameter of ~24″.

Subsea DC infrastructure connects to respective GFP tie-in points by infield flowlines and MEG pipelines.

The flowlines, which transport production fluids, will have a nominal diameter of 24″ and are typically constructed from corrosion-resistant alloys and carbon steel.

Table 4-6 lists the estimated lengths of the longest flowline routes and the approximate range of water depths that each flowline will pass through.

MEG pipelines provide MEG and other production chemicals to the field. These chemicals are then returned via the flowlines and GFP production pipelines to the GTP on Barrow Island, where MEG is regenerated for re-use. MEG pipelines will likely be 8″ in diameter and of a similar length to the flowlines for each field (Table 4-6).

Pipeline termination structures (e.g. PLETs or PLEMs) may be installed (typically on foundations) at each end of the flowlines and MEG pipelines. There may be four installed for each field. The predicted footprint is expected to be ~900 m^2 each.

The Semele and C&D flowlines and MEG pipelines will most likely incorporate in-line tees laid on an integral foundation (Section 4.3.3.1).

Table 4-6: Expected lengths of flowlines

Flowline	Estimated flowline length (km)	Approximate range of water depths (m)
Chandon	60	1,200–1,400
C&D	45	200–1,150
G&E	35	1,200–1,400
Semele	15	900–1,200
WTR	35	150
Total expected length	**~190**	**–**

Note: Well/subsea engineering use imperial measurements and thus some measurements in this and subsequent sections are provided in inches.

4.2.5 umbilicals and power supply

The intent is to supply power and controls from GFP infrastructure. At the time of submitting this document the options are to utilise the FCS or other alternative GFP infrastructure which are out of scope of this OPP (Section 1.4.2).

New electrohydraulic umbilicals will be installed to power each of the fields. The umbilicals will provide hydraulic power, electric power, chemicals, and fibre-optic communications. The umbilical system is a medium-voltage (~3kV[29]) system.

In some cases, umbilicals will run along the same routes as the flowlines. The following proposed umbilicals are likely to follow a separate route to the flowlines:

- from the power supply to G&E, C&D and Semele
- from the power supply to one of the Jansz–Io tie-in locations (to power Chandon)
- from C&D to WTR.

Figure 4-3 shows possible umbilical routes running from the FCS to the fields. These depicted routes represent the longest possible routes of umbilicals that run in a separate corridor to the flowlines (Table 4-7) lists their lengths. Umbilical routes that correspond with flowline routes are not shown. The final routes are yet to be identified but if a different route is selected, it will be shorter and still within the DA.

A CDU may be installed at each DC. The CDU is where the umbilical from the power supply splits to distribute supply hydraulics, chemicals, power and communications to each well at the DC and to connect additional DCs.

Flying leads, which are commonly used to connect subsea equipment to a CDU, will also be required. The Development may use electrical (EFL), steel tube (STFL) and/or hydraulic flying leads (HFL).

Table 4-7: Key characteristics of umbilicals that are separate to flowlines

Power supply element	Characteristic	Field				
		Chandon	C&D	G&E	Semele	WTR
Umbilical	Diameter	Likely ~5″, up to ~18″ diameter[30]				
	Length	8 km	36 km	30 km	38 km	23 km
	Approximate footprint	1,040 m^2	4,680 m^2	3,900 m^2	4,940 m^2	2,990 m^2

4.2.5.1 temporary contingency power supply

If the planned umbilical power supply is unavailable, temporary contingency options will be used to ensure power is available. If contingency power is required, one of the two options detailed below will be used at any one time at a field.

When the umbilical power supply is restored, the temporary power supply equipment will either be retrieved to surface and transported onshore for preservation and storage, or it may remain deployed on the seabed so it is available for use until planned power and controls are restored and stable. While deployed, the equipment will be maintained and inspected as part of the ongoing maintenance program described in Section 4.3.4.3.

[29] The umbilicals are not expected to generate an electromagnetic field (EMF) at a significant spatial scale. Previous modelling of the EMF from a high voltage (132 kV) cable found that the EMF (B field) decreased to background levels within 20 m of the cable (Ref. 83). This is a much higher voltage cable and would therefore generate a higher intensity EMF, compared to the medium voltage (3 kV) umbilicals. As they are low voltage systems, they are not considered a source of risk to electromagnetically sensitive marine fauna.

[30] Diameter of ~18″ is at the small sections where buoyancy cans are located.

4.2.5.1.1 subsea battery system

A subsea lithium-ion battery contingency option may be required to provide power until a longer term power supply is available. This subsea battery system (SBS) connects to the CDU at the DC, and consists of:

- battery storage skids, containing lithium-ion battery storage modules
- a power skid
- open communication hub, used to enable control of the SBS from the GTP

EFLs connecting the SBS to the CDU.

The SBS will be located beside the relevant DC on foundations such as mudmats. The footprint on the seabed is estimated to be ~500 m^2 and will be within the long-term disturbance area (Section 8.1.1.7). The battery system is a low-voltage (~600 V[31]) system.

Vessel support would be required to charge the battery every ~2–4 weeks and would take ~1 week.

4.2.5.1.2 downline power system

A second contingency option is providing power via a downline system from a vessel. The downline system consists of:

- a downline umbilical
- a downline termination unit (DTU) and junction box (installed on a mudmat)
- an infield umbilical (~700 m in length) laid on the seabed connecting this equipment to a CDU
- grout bags, which may be used to stabilise the umbilical.

To ensure safe lifting near live infrastructure, the DTU needs to be located ~700 m from the CDU. As the downline connects into long-term infrastructure (the CDU), part of the footprint associated with this infrastructure is located in the long-term disturbance corridor associated with the CDU. Additionally, the downline may remain deployed on the seabed, so it is available for use until planned power and controls are restored and stable. Consequently, while this is a contingency option, to allow for conservatism, an additional (~13,600 m^2) at each field has been included in the long-term disturbance area used for impact assessment (Section 8.1.1.7).

The vessel would use DP and would need to stay on location while providing power to the field. If this contingency option is required, there is likely to be only one downline vessel in a field at any given time (for further details refer to Section 4.3.4.3). The downline system is a low-voltage (~600 V[31]) system.

All installed power supply infrastructure will be located within the long-term disturbance area (Section 8.1.1.7).

[31] The SBS or downline contingencies are not expected to generate an EMF at a significant spatial scale. Previous modelling of the EMF from a high voltage (132 kV) cable found that the EMF (B field) decreased to background levels within 20 m of the cable (Ref. 83). This is a much higher voltage cable and would therefore generate a higher intensity EMF, compared to the low voltage (~600 V) temporary power supply systems. As they are low voltage systems, they are not considered a source of risk to electromagnetically sensitive marine fauna.

4.2.6 GFP tie-in points

The existing GFP infrastructure includes midline pipeline termination structures (MPTS), manifolds and DCs at both the Gorgon and Jansz–Io fields. The two feed gas pipelines run from this infrastructure to the GTP on Barrow Island (Figure 4-1).

The flowlines and MEG pipelines from G&E and Chandon are planned to be tied-in to Jansz–Io infrastructure. From the tie-in points, hydrocarbons from these fields are planned to be transported to the GTP on Barrow Island via the Jansz Feed Gas Pipeline. This pipeline runs for ~134 km between the Jansz–Io MPTS to the shore crossing at North Whites Beach on Barrow Island.

The flowlines and MEG pipelines from C&D and WTR (and from Semele via C&D infrastructure) will be tied-in to Gorgon infrastructure. Hydrocarbons from these fields will be transported from the tie-in points to the GTP on Barrow Island via the Gorgon Feed Gas Pipeline. This pipeline runs for ~65 km between the Gorgon MPTS to the shore crossing at North Whites Beach on Barrow Island.

The specific locations of the tie-in points have not yet been finalised. Any tie-in points shown in figures in this OPP are indicative only and do not indicate final locations or numbers. Conservative estimates of the required infrastructure at tie-in points are provided in Sections 4.2.3, 4.2.4 and 4.2.5.

The total footprint of infrastructure installed at the tie-in points will be within the long-term disturbance area (Section 8.1.1.7); which is used for the purpose of impact assessment.

4.3 description of activities

The following subsections outline activities associated with each phase of the Development; these grouped phases are used for the impact assessment:

- survey
- drilling
- installation and commissioning
- operations
- decommissioning
- support activities (all phases).

Survey activities (Section 4.3.1) are likely to be carried out at the beginning of the Development but will also be required at various other times.

Support activities (Section 4.3.6) may occur throughout all phases of the Development and cover common activities on vessels and facilities that are not process related. These activities include sewage and greywater discharge, refuelling and bulk transfer.

For each field, the typical progression of phases is drilling, installation and commissioning, then operations. Due to the large scale of the Development, activities from multiple phases may be happening concurrently at different fields. There is also potential for multiple Development activities to occur at the same time within a single field (e.g. drilling and pipelay).

The sequence of field development will be finalised closer to the start of the Development and will be included in future EPs.

Activities described in this section are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

4.3.1 surveys

Surveys, each of which may take ~3–4 weeks, may be undertaken at various times during the life of the Development.

Pre-pipelay surveys will inform the final route selection.

4.3.1.1 geophysical survey

Geophysical surveys of the activity locations may be required at various times including during engineering design, before drilling, before pipelay or structures installation, after pipelay or structures installation, operations IMR, and before and after decommissioning. The pre-lay survey will confirm the bathymetric profile along the flowline and umbilical route and identify any seabed features or obstructions that may impact activities.

Inspection programs will use various survey techniques including:

- side-scan sonar (SSS)
- sub-bottom profiler (SBP)
- multibeam echo sounder (MBES)
- magnetometer
- general video inspection.

Surveys are undertaken from a vessel and are supported by ROVs or autonomous underwater vehicles (AUVs). As technology develops, future options for inspections will be evaluated.

4.3.1.2 geotechnical survey

Geotechnical surveys of the activity locations may be required at various times, during the life of the Development. Drilling cores may be taken for in situ testing and sample collection.

Surveys are undertaken from a vessel and are supported by ROVs/AUVs. The indicative footprint associated with geotechnical equipment is ~2 m^2 per deployment. Multiple deployments may be required at each location, giving a conservative footprint of ~20 m^2 per survey location. If drilling cores are taken, the footprint for the borehole sampling unit is expected to be ~14 m^2 at each location.

4.3.2 drilling

Drilling will be carried out using a MODU.

Multiple wells will be drilled in each field, with each well taking ~3 months to drill, depending on well depth (Table 4-8).

Drilling activities are expected to take up to 24 months per field (assuming the maximum number of wells are drilled).

The MODU will position at each DC and drill multiple wells. Drilling may be undertaken across multiple campaigns, so the MODU may return to a particular DC for further drilling activities.

Table 4-8: Estimated duration for the drilling phase

Characteristic	Field				
	Chandon	C&D	G&E	Semele	WTR
Maximum number of wells	8	8	8	8	8
Number of DCs	2	3	1	2	2
Estimated total duration	24 months	24 months	24 months	24 months	24 months

The well design details are subject to change. As per the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011, detailed well designs will be submitted to NOPSEMA via a Well Operations Management Plan (WOMP). Drilling will not begin until after the WOMP has been accepted by NOPSEMA.

4.3.2.1 MODU positioning

The type of MODU has not yet been finalised and depending on the water depth, may be a semisubmersible, drill ship or jack-up (also referred to as a self-elevating MODU). The MODU will moor or be positioned at each DC to drill wells in that area.

The MODU will either be moored using anchors connected to mooring chains or kept on location with DP using thrusters; or, in the case of a jack-up, be positioned on the seabed with legs. A jack-up MODU is only feasible at WTR due to the shallower water.

The MODU used may be supported by anchor-handling tugs as it moves between drilling locations (Section 4.3.6).

If a mooring system is used, up to 16 drag embedment anchors will be required; these will be placed on the seabed then set and pre-tensioned by support vessels before the MODU arrives. At each location, the area of benthic habitat disturbed by anchoring is estimated to be up to 28,480 m^2.

If the MODU is moored, the anchors may be outside the long-term disturbance area (Section 8.1.1.7).

If a jack-up MODU is used, three legs with spud cans will sit on the seabed. The legs are first soft-pinned, preloaded, then the rig is elevated to working height. At each location, the area of benthic habitat disturbed by the legs is estimated to be ~950 m^2.

Transponders may be used to accurately position the MODU over the proposed well locations. Transponders are attached to clump weights, lowered onto the seabed and then retrieved after positioning is finished.

4.3.2.2 drilling top- and bottom-holes

Drilling will begin with the top-hole section and proceed in this sequence:

- Commence drilling of initial riserless hole section, run a conductor casing and cement it back to the seabed. Use sea water with high-viscosity gel sweeps and discharge cuttings at the seabed.
- Drill a further, deeper riserless section, run a casing string and cement it to the mudline. Use sea water with high-viscosity gel sweeps and discharge cuttings at the seabed.

- Following installation of the BOP and riser, drill next section to the required depth and cement a casing string into position. Use water-based fluids (WBF) or nonaqueous drilling fluids (NADF) and discharge cuttings at the sea surface.
- Drill the final section/s and cement a production casing string into place. At total depth, set the production liner into position. Use NADF and discharge cuttings at the sea surface.

The required depth of each step depends on the formation and reservoir details specific to the field and drilling location.

4.3.2.3 drilling fluids and cuttings handling

Drilling fluids lubricate and cool the drill bit, help stabilise the strata, and carry rock cuttings to the surface. Drilling fluids also maintain hydrostatic pressure greater than formation pressure, preventing the influx of hydrocarbons from the formation into the wellbore–forming the primary well control barrier.

The initial stages of drilling will use sea water with high-viscosity gel sweeps, with cuttings circulated to the seabed. High-viscosity sweeps comprise ~90% sea water, with the remaining 10% made up of drilling fluid additives that are either completely inert in the marine environment, naturally occurring benign materials, or readily biodegradable organic polymers with a very fast rate of biodegradation in the marine environment.

Drilling additives typically used include sodium chloride, potassium chloride, bentonite (clay), cellulose polymers, guar gum, barite, and calcium carbonate.

Throughout the drilling program various fluids will be run through the closed circulation system including:

- NADF—such as a hydrocarbon, ether, ester, or acetal, organophilic clays, barite, lime, aqueous chlorine, rheology modifiers, fluid loss control agents and emulsifiers
- WBF—such as water or saltwater, bentonite clay, barite and gellants (e.g. guar gum or xanthan gum)
- sea water
- suspension/completion brine.

Specific drilling fluid details will depend on conditions encountered on site. Consequently, the fluids used in the drilling program may vary based on project risks and/or new technology available at the time but will be managed to maintain or reduce the risk profile assessed in the OPP and will be captured in the activity-specific Eps.

Once the top-hole section is complete, installing the riser and BOP provides a conduit back to the MODU, forming a closed circulating system allowing solids control equipment to remove cuttings from drilling fluids before being recycled and circulated back to the MODU for further use. Solids control equipment may include:

- vibrating screens (shale shakers)
- centrifuge
- cuttings dryer.

Cuttings are expected to range from very fine to very coarse (<1 cm diameter) after separation from the drilling fluid, and will likely comprise predominantly claystone, marl, and calcilutite from the upper sections of the wellbore, and sandstone and siltstone from the lower sections.

Tanks used to store NADF will be emptied and cleaned after drilling is completed. NADF tank washing residue (<1% residual hydrocarbon) may be discharged to the marine environment.

Volumes of drilling fluids and cuttings that are released to the environment will depend on the field and well site. Details of estimated volumes are provided in Table 8-68 in the Planned discharges—Drilling impact assessment (Section 8.8).

4.3.2.4 cementing operations

During drilling, cement is used to seal the space between the casing and the formation, and for permanently positioning the casing into place. Cement may also be used to set a plug in an existing well in order to sidetrack or to plug a well so it can be abandoned

Cementing top-hole sections (without a riser in place), may result in small amounts of surplus fluids and cement slurry being discharged directly to the seabed at the mudline.

For the remainder of the drill hole, small volumes of cement and spacer may be returned to the MODU and discharged to sea. Once a job is completed, the cement unit is cleaned, and the residual cement discharged overboard.

Details of all estimated cement discharge volumes are provided in Table 8-68 in the planned discharges—drilling operations impact and risk assessment (Section 8.8).

4.3.2.5 pressure-control equipment installation

The BOP is installed after the top-hole sections of the well have been completed.

Because BOPs are critically important to the integrity and safety of the MODU and the well, they are inspected, tested, and refurbished at regular intervals. The timing is determined by a combination of manufacturer recommendations, risk assessment, local practice, well type and legal requirements.

BOPs release small volumes of water-based hydraulic control fluid to the marine environment during function and pressure tests; ~4.5 m^3 for a full function or pressure test, and potentially a small amount of MEG with hydrotesting dye.

Regular ongoing function and pressure tests will occur during the drilling phase.

4.3.2.6 well suspension

Well suspension (including de-suspension) may be required after drilling and during operations (Section 4.3.4.5).

During well suspension activities, small volumes of reservoir gas may need to be handled back to the rig. These volumes would be too small for flaring and would be cold vented to the atmosphere.

Following suspension, a wellhead cap may be installed to provide mechanical protection to the wellhead and protect it from marine growth. To inhibit marine growth or corrosion, ~210 L of a dilute biocide and corrosion inhibitor is injected into or placed within the wellhead cap.

4.3.2.7 completions installation

Well completion steps include casing, cementing, perforating, installing screens, gravel packing and installing a production tree.

Completions generally follow this sequence:

- install lower completion, which may be a liner or screen assembly (no discharge to the environment)
- run wellbore clean-up (casing scrapers, circulate well to clean fluid)
- run the production tubing, including the wellhead (at surface).

The tubing will include safety and production devices; specifically, a downhole subsurface safety valve placed ~500 m below the seabed.

Bottom-hole completions options are to:

- install standalone sand screens
- install sand screens with gravel pack
- install slotted liners
- case-and-perforate style completions.

Completion brines will be released during this activity. The worst-case volume is ~500 m^3 at the end of each well campaign.

4.3.2.8 production tree installation

Finally, a subsea production tree will be installed just above the seabed, supported on the main conductor from a MODU or support vessel. Installation would involve:

- remove wellhead cap (if in place). Biocide and corrosion inhibitor may be released. The cap is then cleaned using mechanical means or seawater jetting, or a few litres of acid if there are calcareous deposits.
- install isolation plug
- remove BOP
- install production tree on the conductor. May release a few litres of hydraulic control fluid and dilute biocide and corrosion inhibitor.
- rig up slickline pressure-control equipment and recover isolation plug
- rig down slickline pressure-control equipment.

After installation, testing is carried out to confirm the pressure integrity of the production tree and to confirm that it is secured in place. Valve functionality testing will discharge small volumes of control fluid to sea.

4.3.2.9 well clean-up and testing

Wellbore and casing clean-up is required at various stages of the drilling activity to ensure the contents of the well are free of contaminants before the next stage of drilling. Cleaning agents and other chemicals may be used to remove residual fluids (including drilling and completion fluids such as NADF) from the wellbore.

During the clean-up process, fluids are circulated back to the MODU, and may be analysed before they are discharged overboard. Any displaced fluid that has the

potential to contain contaminants or oil is analysed for residual hydrocarbons before discharge into the environment (<1% oil in water).

At the end of the completions phase, some wells may be subject to flowback. During this activity, completions fluids (consisting of completion brine and any produced water or condensate present in the wellbore) will be circulated back to the MODU for flaring and subsequent discharge overboard. The volumes of produced water in this discharge are expected to be minimal due to the low formation water content associated with the reservoir gas. Prior to discharge to the marine environment, fluids will be analysed to confirm residual oil-in-water concentration is <30 ppm. Fluids not meeting this standard may be retained for onshore disposal. The total volume of completion fluids discharged is anticipated to be consistent with the estimates provided in Section 4.3.2.7.

Flaring may be required as a contingency during flowback. Based on CAPL's operational experience on the NWS a typical volume of reservoir gas flared during well flowback has been estimated at 60 MMscf per well, with this flaring occurring over ~1 day. Flaring may not be constant during well flowback (i.e. it may intermittently occur over ~1 day). Unforeseen circumstances such as weather events or a trip of safety systems, may cause the flowback and flaring to be done again. For each drilling campaign (i.e. per field or co-developed field), flowback and flaring will only occur from one well at a time.

As flowback may not occur at all wells, and as flaring is a contingency during flowback, for the purpose of the impact and risk evaluation within this OPP an allowance of 60 MMscf over ~1 day of flaring per well has been carried. Based on operational experience, CAPL consider that this allowance is sufficient to cover any initial and repeated flaring if it is required.

4.3.2.10 well evaluation

The wells may be evaluated using 'logging while drilling' techniques and mud logging. Wireline logging and formation testing/sampling may be done based on the results of the primary evaluation tools.

Wireline evaluation may be undertaken to determine rock and fluid properties of the targets. A suite of standard wireline logs may be run, including gamma ray, neutron-density, resistivity, sonic, acquisition of pressures and fluid samples, vertical seismic profiling (VSP), and side-wall coring.

While some well evaluation tools contain radioactive sources no radioactive material will be released to the environment. Generally, radiation fields are not detectable outside the tool if it is not energised; therefore, radiation does not present an environmental risk.

VSP uses a small airgun array as an acoustic source to generate a high-resolution seismic image of the geology in the well's immediate vicinity and it may take up to 24 hours to complete, depending on the wellbore's depth and the number of stations profiled.

4.3.3 installation and commissioning

The installation and commissioning phase includes installing flowlines and other infrastructure, stabilisation works, and testing. Commissioning activities ensure that all components of the system are installed, tested, and function as per the project design documentation and specifications. Once commissioning is complete, start-up activities will introduce hydrocarbons to the system. Installation, commissioning, and start-up activities may include some or all of the following:

- pre-lay works and associated surveys
- excavation and trenching
- pipelay
- installation of structures, spools, jumpers, and umbilicals
- post-lay works and associated surveys
- hydrotest and pre-commissioning
- commissioning
- start-up.

The duration of installation and commissioning activities will vary for each field due to the differences in flowline and pipeline lengths, location, and infrastructure. The durations of the main activities have been estimated for the impact assessment, but do not include potential delays such as weather events and vessel mechanical downtime.

All seabed disturbance from installation and commissioning is located within the long and short-term disturbance area (Section 8.1.1.7).

4.3.3.1 pre-lay works

Pre-lay works will vary depending on the flowline option or infrastructure installation being undertaken. Pre-lay activities are done to ensure infrastructure is installed on a solid, supported foundation. If seabed surveys show a clear pipelay route, minimal seabed preparation will be required before laying the flowlines, MEG pipelines and umbilicals.

Suction piling or gravity foundations may be used. Mattresses and foundations are commonly used in pre-lay works.

The total number of stabilisation elements will not be known until the pre-lay survey is performed. All stabilisation elements will be installed within the long-term disturbance area (Section 8.1.1.7).

Table 4-9 details the materials commonly used in pre-lay works.

Table 4-9: Key characteristics of pre-lay materials

Stabilisation materials	Description
Mattresses / grout bags	Usually made of concrete. Mattresses may be installed in groups and may be stacked on top of each other.
Foundations	Can be made of steel or concrete. Includes mudmats. Placed underneath structures such as manifolds.
Pipe support	A-frame structures on a mudmat foundation that supports and aligns loads in adjacent infrastructure.
Global buckling mitigation structures	Can be made of steel or concrete. Used to support the pipeline / flowline above the seabed.

In addition, an initiation anchor (deadman anchor) or suction pile will be deployed to fix the end of the flowline in place at the beginning of pipelay. A suction pile is installed by lowering a bucket to the seabed and pumping the entrapped water out of it to form suction. One initiation anchor or suction pile and its wire are required for each flowline. The anchor or pile is installed up to 3,000 m behind the flowline or MEG pipeline and the initiation wire is laid out on the seabed to the end of the

flowline or MEG pipeline. These anchors and wires are recovered from the seabed at the end of the pipelay process.

If third-party infrastructure is present within 3,000 m of the start of the flowline, the initiation anchor will be positioned to avoid the infrastructure.

4.3.3.1.1 pipeline crossings

The Development will require at least two pipeline crossings:

- the C&D flowline will cross the Jansz Feed Gas Pipeline and umbilicals
- the WTR flowline will cross the Jansz Feed Gas Pipeline and umbilicals.

Three of the proposed umbilicals may also cross the Jansz Feed Gas Pipeline.

If new flowlines, MEG pipelines or umbilicals need to cross existing pipelines, pipeline supports would usually be laid on either side of the pipeline. Crossings may influence flowline or MEG pipeline routes as they may need to cross at close to 90 degrees as practicable.

Mattresses, ramping, plinths, or rock berms may be used at crossings. The footprint of these supports will be larger where new flowlines or MEG pipeline cross existing pipelines than where new umbilicals cross pipelines. If a flowline or MEG pipeline crosses an existing pipeline, the supports may extend for 500 m along the flowline or MEG pipeline but will be within the 30 m long-term disturbance area (Section 8.1.1.7).

If any third-party pipeline crossings are required, the details will be negotiated with the third-party.

4.3.3.2 excavation and trenching

The C&D flowline and MEG pipeline route will cross the scarp to tie-in to the Gorgon Feed Gas Pipeline.

Excavation may be required at the top of the scarp to create a suitable seabed profile for the flowline and MEG pipeline, thus preventing the flowline/pipeline from exceeding their strength and fatigue limits. Excavation of the scarp was required during the GFP for the Jansz pipeline; the methodology used in this Development would be similar.

Based on the excavation undertaken for the existing Jansz pipeline, the trench required is estimated to be ~12 m wide, 50 m long and 8 m deep. More accurate estimates will not be available until the final route is selected, engineered and pre-lay surveys are performed. The final trench dimensions will be included in subsequent EP/s.

An umbilical may also run over the scarp—the trenching required will be smaller in scale than for the flowline.

Excavation and trenching using either high-pressure jetting/mass flow excavation or mechanical excavation are not planned along other parts of the flowlines but may be required. Excavation alongside infrastructure may be required to gain access for inspection or minor repairs at any time during the Development.

Drilling or blasting will not be used as an excavation method.

Spoil generated will be left in situ and will be within the long-term disturbance area.

Rock stabilisation or rock dumping may be required as a contingency. A barge would transport rock, then a vessel with specific capability would transfer the rock to the seabed (see Section 4.3.3.5).

4.3.3.3 installation of flowlines, MEG pipelines, and PLETs/PLEMs

Flowlines and MEG pipelines will primarily be installed using an S-lay or J-lay technique. Some smaller diameter flowlines and MEG pipelines may be installed using the reeling technique, where feasible.

S-lay installation methods involve welding the pipe joints on the vessel and then lowering pipe off the vessel over a support structure that extends behind the vessel.

J-lay installation methods involve lowering the pipe off the vessel in an almost vertical position. The pipe joints are welded inside the lay tower on the vessel before being lowered through the water column to the seabed.

Where the reeling technique is used, the flowline or MEG pipeline is welded together at an onshore spool base, reeled onto an installation carousel, transported to the DA via installation vessel and installed.

Pipeline/flowline termination structures (e.g. PLETs or PLEMs) may be installed at each end of the flowlines or MEG pipelines to a spool. The structure is welded to the ends of the flowline or MEG pipeline on board the installation vessel and then is lowered to the seabed. Pipeline termination structures may be installed on foundations (e.g. steel mudmats or concrete mattresses) (Section 4.3.3.1) or directly onto the seabed.

The largest flowline used for the Development will be a 24″ diameter production flowline. As detailed in Section 8.1.1.7, assessment of seabed disturbance uses the long-term disturbance area which is 30 m wide to encompass infrastructure and materials around the lines, as well as the trench.

The speed of pipelay varies depending on water depth, pipeline/flowline type and installation technique. The estimated duration of flowline installation is 3–6 months per field (or co-developed field), including excavation and trenching (where required).

4.3.3.4 installation of subsea structures

The subsea structures associated with the Development include manifolds, tie-in structures, slug catchers, overpressure protection structures, jumpers, spools, in-line tees, umbilicals and CDUs.

Some of these—manifolds, tie-in structures, in-line tees and CDUs—may be installed on foundations (e.g. steel mudmats or concrete mattresses) (Section 4.3.3.1) or directly onto the seabed.

Before installing any structure, jumper or spool, a seabed survey will be conducted to ensure there are no obstacles that may hinder installation activities. If debris or an obstruction is encountered, it will be cleared, if possible. If a significant obstruction is encountered, the alignment will be rerouted (but will remain within the DA).

Equipment may also need to be stored on the seabed as a contingency, in response to events such as cyclone demobilisation.

The estimated duration of subsea structure installation is ~4 months per field.

4.3.3.4.1 jumpers and spools

Before connection of jumpers and spools, any marine growth and calcareous build-up present on existing subsea structures that will be tied-in to will be removed via mechanical cleaning, acid wash or similar. Only small volumes of chemicals will be used for acid washing, and these chemicals will be applied directly to infrastructure. The volume will depend on the type of infrastructure and would be ~100 L to 1,000 L per application.

Jumpers and spools will be lowered by crane to the manifolds, pipeline termination structures, tie-in structures, slug catchers, overpressure protection structures, in-line tees and production trees. During tie-in of jumpers and spools, a small amount of preservation fluid will be released. Preservation fluid generally comprises treated water, MEG, and conditioning chemicals. The volume per tie-in is expected to be ~15 m^3 but is likely to be much lower.

Isolation valves and high-pressure caps are installed on the GFP infrastructure at the Development infrastructure tie-in locations. The isolation valves will be tested prior to performing the tie-in. When the high-pressure caps are removed to facilitate a tie-in, there is potential for a small volume of trapped hydrocarbon (e.g. ~1.5–175 m^3 of gas and <1 m^3 of condensate[32]) to be released to the environment.

Tie-in of jumpers and spools will be supported by ROVs or AUVs.

4.3.3.4.2 in-line tee

The in-line tees are likely to be welded into the flowline or MEG pipeline on board the pipelay vessel (PLV) and laid along with the flowline or MEG pipeline.

4.3.3.4.3 umbilicals

The umbilicals will be installed by a lay system or carousel, assisted by cranes. Umbilicals will be reeled off the vessel and connected to the CDU. During connection to the CDU there is potential for a small volume of hydraulic control fluid to be released. A larger volume may be released if the initial connection is unsuccessful.

The other end of the umbilicals will be connected to the FCS or the alternative power supply.

Following the connection, umbilicals will be leak tested using hydraulic control fluid. On completion of the leak test, it is estimated that a small volume of this control fluid will be released into the environment. The largest single release of hydraulic control fluid during connection to the CDU and leak testing is estimated to be ~2.5 m^3.

4.3.3.4.4 flying leads

Flying leads will be installed via reels (for STFLs) and deployment frames (for EFLs and HFLs) from the installation vessel. Flying leads will be connected to the various structures by ROV.

Flying leads may need to be stabilised after installation (Section 4.3.3.5).

[32] Note: These are indicative in situ subsea release volumes (subsea ambient pressures are ~15 barg for Gorgon tie-ins, and ~135 barg for Jansz tie-ins).

4.3.3.4.5 other subsea structures

Manifolds, tie-in structures, slug catchers, overpressure protection structures and CDUs will be lifted off the installation vessel by an onboard crane and then deployed to depth. Structure positioning may be controlled using pre-installed baseline seabed arrays.

4.3.3.5 post-lay works

Post-lay works (e.g. span rectification, stabilisation of flowlines and umbilicals) may be required, depending on the results of any post-lay surveys. A range of stabilisation methods may be used such as concrete mattresses and grout bags. Stabilisation may occur during installation, operations, or decommissioning.

Concrete mattresses and grout bags (Table 4-9) typically have a footprint of up to ~27 m^2.

Rock dumping is not planned but may be required, so it is included in this OPP as a contingency. Rock dump material may be sourced from outside Australia. A barge would transport rock, then a vessel with specific capability would transfer it to the seabed.

The total number and location of these stabilisation materials will not be known until the post-lay survey is performed. All post-lay materials will be installed within the long-term disturbance area (Section 8.1.1.7).

4.3.3.6 hydrotest and pre-commissioning

Following installation, the flowlines and MEG pipelines may undergo flood, clean, gauge and testing (FCGT), leak testing and pre-commissioning (conditioning) as required. The estimated duration of hydrotest and pre-commissioning is 2 months per field or co-developed field. Planned discharges will generally be released at controlled discharge rates.

The pig launchers and receivers used will be temporary. They will be deployed, attached to a suitable connection point, and then removed when the process is complete.

4.3.3.6.1 FCGT

During FCGT activities, treated water or a MEG/treated water blend will be used to flood the flowline/pipeline. Gauge pigs pre-installed in the laydown/initiation head on one end of the flowline or MEG pipeline are sent through, driven by the flooding media. The flooding media may be discharged to the environment after pigging.

Flowlines and pipelines are typically subjected to a hydrostatic pressure test (a hydrotest) to test integrity. The flowline/pipeline is filled with treated water or MEG/treated water blend and held at pressure for the duration of the test. Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions. This hydrotest media will be discharged to the environment after completion of the test.

Some flowlines or pipelines may be subject to a ‘dry commissioning and hydrotest replace’ approach instead of FCG and hydrotest. Dry commissioning relies on data gathered during fabrication and installation to provide assurance of integrity. These flowlines/pipelines would be preserved with nitrogen at low pressure to avoid air ingress. The nitrogen would be purged during commissioning activities (Section 4.3.3.7).

4.3.3.6.2 leak testing

To conduct leak/barrier testing, the system is pressurised using a blend of MEG and/or treated water. After testing, depressurisation may discharge small volumes of test fluid to the environment.

During valve actuation, a small amount of hydraulic control fluid will be released to the marine environment from the valves and chokes on the production trees, manifolds, and other infrastructure.

4.3.3.6.3 pre-commissioning

After testing and prior to when commissioning starts, the flowline or MEG pipeline will be dewatered and conditioned with a MEG/treated water blend preservation media, compressed air and/or nitrogen.

If MEG/treated water blend preservation media is used, several releases of the preservation media will occur while deploying the subsea pig launcher receiver (SSPLR)—from the SSPLR at the tie-in points, during pigging and when removing the SSPLR. The flowline will be left filled with a MEG/treated water blend ready for commissioning.

If compressed air or nitrogen is used for dewatering, the flowline will be conditioned, dried, and then packed with nitrogen to inert and preserve it, until commissioning and operations begin. Nitrogen and/or air will be vented in the DA as part of this process, primarily at the sea surface through a downline running between the flowline and a vessel.

Treated water and MEG/treated water blend may also be released during dewatering and conditioning at the SSPLR at the seabed. MEG pipelines may be dewatered with MEG/treated water blend.

4.3.3.6.4 hydrotesting and pre-commissioning volumes

Table 4-10 lists the estimated volumes of the largest single discharges as a result of hydrotesting and pre-commissioning activities. The volumes in this table are based on the longest flowline in the Development (Chandon at ~60 km), and therefore are the largest discharge volumes expected for each material. These values are included to allow for impact assessment using the volume likely to have the most significant impact.

Table 4-10: Estimated discharge and emission volumes from hydrotesting and pre-commissioning for a single field

Discharge type	Volume (per event)	Discharge location
Treated water	35,000 m^3	DC or GFP tie-in point At seabed
MEG	1,750 m^3	DC or GFP tie-in point At seabed
Hydraulic control fluid	2.5 m^3	DC or GFP tie-in point At seabed
Emission type	**Volume (per event)**	**Emission location**
Nitrogen gas / Compressed air	5,250,000 m^3	DC or GFP tie-in point At sea surface

4.3.3.7 commissioning (verification and pre-start-up testing)

Verification and pre-start-up testing activities may include testing subsea valves, testing the emergency shutdown of infrastructure, and leak testing jumpers. These tests are likely to result in small discharges of hydraulic control fluids and MEG / treated water blend from valves.

These activities will be supported by a vessel (see Section 4.3.6.2 for vessel operations) and ROVs equipped with video cameras.

During commissioning of the production flowlines, dry hydrocarbon gas (methane sourced from the GTP) will be used to pressurise the flowline in readiness for the start-up phase. There may be a requirement to purge some or all of the pre-commissioning nitrogen gas at the end of the flowline at the seabed. This would result in a controlled subsea release of a maximum of ~400 m^3 (equivalent to ~25,000 Sm^3) nitrogen gas, followed by a maximum of ~400 m^3 (equivalent to ~25,000 Sm^3) methane for the deep-water[33] (i.e. C&D, G&E, Semele, and Chandon) gas fields (based on the longest flowline from these fields); and a controlled subsea release of a maximum of ~200 m^3 (equivalent to ~6,000 Sm^3) nitrogen gas, followed by a maximum of ~200 m^3 (equivalent to ~6,000 Sm^3) methane for the shallow-water[33] (i.e. WTR) gas field (based on the longest flowline at WTR). Note: While the equivalent gas volumes at surface pressure have been provided, this is not indicative that all of these volumes would release to atmosphere; refer to Section 8.7.1.1.2 for a discussion on the predicted fate and behaviour of the subsea release of nitrogen and methane gases.

The displacement and flushing of nitrogen from the flowline and pressurisation of the flowline with methane is required to prepare the flowline for further commissioning work. Pressurisation will be required to de-isolate the flowline from the existing production system at operating pressure in readiness for the start-up phase of the system.

4.3.3.8 start-up (introduction of hydrocarbons)

Start-up activities commence with the controlled introduction of reservoir hydrocarbons into the infield production flowlines and production pipeline. The subsea infrastructure (including the MEG pipelines and the umbilicals) are then further function tested.

During the introduction of reservoir hydrocarbons, residual drilling fluids (within the wells) and other residual fluids (which may include MEG/water preservation media and nitrogen), within the flowlines will be displaced via production fluids from the production trees back to the GTP.

The estimated duration of commissioning (Section 4.3.3.7) and start-up is ~3 months per field.

4.3.4 operations

The principal activity during operations will be the flow and transportation of hydrocarbons and other produced fluids from the wells to the GFP tie-in points, and then to the GTP for processing.

[33] Note: These volumes represent the maximum expected subsea release volumes. The estimated in situ subsea release volumes are ~400 m^3 at ~15 bara shallow water seabed ambient pressure and ~200 m^3 at ~124 bara deepwater seabed ambient pressure. The conversion from these subsea ambient pressures to the equivalent volumes at 0 bara equates to ~25,000 Sm^3 for deep-water and ~6,000 Sm^3 for shallow-water.

Section 572(2) of the OPGGS Act requires a titleholder to maintain in good condition and repair all structures, equipment, and other property that is within the title area and is used in connection with the operations authorised by the title. Subsea infrastructure IMR activities are undertaken to ensure that the integrity of the hydrocarbon system is maintained.

IMR activities may occur at any time during operations, as well as during the commissioning and start-up phase.

Activities associated with operations include:

- operation of the hydrocarbon system
- inspection
- maintenance and repair
- major repairs
- well intervention.

At the operations phase, the Development activities will generally be consolidated with, and carried out as part of, the ongoing GFP operations.

The duration of operations will be 10–30 years, depending on the field. Section 4.1.4 has further details on timing and duration of operations.

4.3.4.1 operation of the hydrocarbon system

During the operations phase, the hydrocarbon system will be a permanent fixture on the seabed of the DA. This system includes flowlines, manifolds, and other structures, and is described in detail in Section 4.2.

This subsea infrastructure is predominantly a closed system; however, there are discharge points (valves) located at the subsea electrohydraulic control systems and at production trees and manifolds (as described in Section 4.2). Operation of this system will result in discharges of hydraulic control fluid to the marine environment from the valves, with each valve actuation estimated to result in a loss of, on average, a few litres to the marine environment.

If field shut-in is required, system verification and pre-start-up testing will be required before start-up (see Section 4.3.3.7).

4.3.4.2 inspection

Inspections provide assurance that infrastructure integrity is being maintained, and equipment is being operated according to design. Inspections also proactively identify maintenance or repair activities that may be required. Inspections are generally conducted using a vessel and AUV or ROV.

Inspections will be undertaken with a frequency determined based on risk. Inspections are typically conducted more often during early operations, with the frequency likely to decrease during steady-state operations, depending on previous inspection results. Events such as cyclones or seismic activity that could affect the subsea infrastructure may also trigger inspections.

Inspection will be undertaken by a vessel and ROV or AUV and techniques may include but are not limited to:

- visual inspections
- marine acoustic surveys

- non-destructive testing
- cathodic protection measurements
- fatigue monitoring/inspection
- pigging

Pigging may be used to internally inspect the flowline to ensure the integrity of infrastructure is maintained. Pigging occurs from the DCs to the GFP tie-in points.

Temporary pig launchers and receivers may use a combination of treated water, gel, MEG, and/or nitrogen slugs to complete pigging activities. The maximum volume of pigging fluids that may be discharged is ~4.5 m^3.

Hydrocarbon may also be contained within the isolated temporary pig launcher or receiver. If the pressure within the isolated temporary pig launcher or receiver is close to operating pressures at the start of discharge, it is anticipated that a small volume of trapped hydrocarbon (e.g. ~3 m^3 of gas and <0.5 m^3 of condensate[34]) may also be released from the end cap.

Some inspections may require the use of specialised monitoring equipment, SSS and MBES which are typically done from a vessel using towed acoustic instruments, ROVs, or AUVs (see Section 4.3.1)

Section 4.3.6 includes details of vessels, AUVs and ROVs.

4.3.4.3 maintenance and repairs

Maintenance and repair activities, including equipment change-out, will be conducted during the operational life of the Development to:

- prevent deterioration and failure of infrastructure
- maintain reliability and performance of infrastructure
- ensure infrastructure is adequately maintained to enable the potential for future removal.

The exact frequency of maintenance and repair activities depends on the results of inspections. If minor maintenance or repair is required, vessels may remain on site for an estimated ~6 months. If major maintenance or repair is required, vessels may be on site for an estimated ~12 months.

Maintenance and minor repairs (and any associated testing) may include, but are not limited to:

- module/component/infrastructure change-out
- rectification and stabilisation activities
- cathodic protection system maintenance
- hydrate remediation
- sediment removal/ excavation to gain access to, or enable minor repairs of, infrastructure
- removing marine growth and calcareous deposits

[34] Note: These are indicative in situ subsea release volumes (subsea ambient pressures are ~15 barg for shallow-water backfill fields and GFP tie-ins [WTR, Gorgon], and ~124–135 barg for deep-water backfill fields and GFP tie-ins [C&D, G&E, Semele, Chandon, and Jansz]).

- maintenance and repair activities typically require support vessels (see Section 4.3.6.2).

Acid wash and chemicals may be used for removing marine biological growth and calcareous deposits (typically using <4.5 m^3 of water-soluble sulfamic acid or similar). This will generally precede pigging or equipment change-out activities. This type of cleaning may be done using water jetting from an ROV.

4.3.4.4 major repairs

In the unlikely event that major repairs are required during the life of the Development, CAPL will use Emergency Pipeline Repair System (EPRS) equipment. The EPRS delivers a set of repair procedures and common repair equipment for repairing or replacing a range of infrastructure (including flowlines) and includes methods for repairing support infrastructure such as umbilicals and non-production pipelines.

The target repair duration is between ~6 to 12 months—from mobilisation of equipment and vessels, undertaking in situ repair, to recommissioning. Several vessels are likely needed to conduct and support the repair works or provide temporary power and controls to maintain system operability and reliability.

Repairing a flowline is the most complex major repair activity. To support this, the EPRS includes equipment that enables a section of the production flowline to be cut out and replaced. This equipment is deployed off the back deck of a support vessel and supported with ROVs. The EPRS equipment includes:

- hydraulic-actuated pipeline lifting and repair equipment deployment frames
- pipe preparation tools, including but not limited to, coating removal, weld seam removal, end preparation, and water blasting equipment
- pipeline-specific repair clamps and flange adapters.

Major repair activities on a flowline can be divided into temporary decommissioning, repair, and recommissioning phases, with the use of contingency power if required.

4.3.4.4.1 pipeline temporary decommissioning

If a major defect or full-bore rupture occurs, the field would be shut-in, and the flowline allowed to naturally depressurise to subsea ambient pressure with sea water. The flowline would then be flooded with treated water (water inhibited with chemical additives including biocide and oxygen scavenger) that will propel a pig towards the defect.

This may result in discharges of treated water, sea water, residual gas condensate and MEG at the location of the defect. Discharges of treated water from this activity would be smaller than the two full flowline inventories assessed for pipeline recommissioning (~35,000 m^3 based on the longest flowline). Treated water may have some hydrocarbon content.

4.3.4.4.2 pipeline repair

Pipeline repair includes these stages:

- undertaking a pre-deployment survey—the survey type depends on location and the event causing the defect but may include techniques described in Section 4.3.1. The flowline may require unburial or rock removal before repair, resulting in seabed disturbance.

- removing the damaged section.
- deploying the EPRS.
- installing the replacement section—after the flowline is installed, the entire flowline is then typically leak tested; this may involve the techniques described in Section 4.3.3.6.
- stabilising the pipeline (if required)—stabilisation needs will depend on the specific location and stabilisation types may include those described in Section 4.3.3.5.

4.3.4.4.3 pipeline recommissioning

Following the successful leak test, the flowline must be recommissioned via a dewatering and conditioning pig train. The re-commissioning activity is similar to pre-commissioning and commissioning (Section 4.3.3.6).

The flowline contents will be discharged subsea at the appropriate GFP tie-in points.

4.3.4.5 well intervention

Well intervention generally occurs within the wellbore and may include the following activities, as well as any other drilling activities described in Section 4.3.2:

- well logging activities (slickline, wireline, coil tubing)
- well testing and flowback (Section 4.3.2.9)
- well workovers
- replace/repair of well equipment (including casing, tubing, completions)
- drill a side-track wellbore
- suspend the well (Section 4.3.2.6).

CAPL estimates that intervention on a single well may be required once a year; however, intervention activities may be more or less frequent depending on well performance.

During intervention activities, local control of the production trees may be required, which would release small volumes of hydraulic control fluids to the environment. Intervention activities also include removing marine fouling by mechanical or acid soaking, resulting in the release of marine-fouling debris and small amounts of acid to the environment. When retrieving intervention tooling, small volumes of wellbore fluids may be displaced back into the well using nitrogen gas. The nitrogen will then be vented to the environment.

If discharges are required during intervention, they will be the same types as during drilling, but the volumes will be lower than those estimated for drilling.

Flaring may be required as part of well intervention. In the event of unforeseen circumstances (e.g. weather events or a trip of safety systems), flaring may need to be done again. For the purpose of the impact and risk evaluation within this OPP an allowance of 60 MMscf over ~1 day of flaring per well intervention has been carried. This rate and duration is consistent with estimates for flaring during well flowback (Section 4.3.2.9).

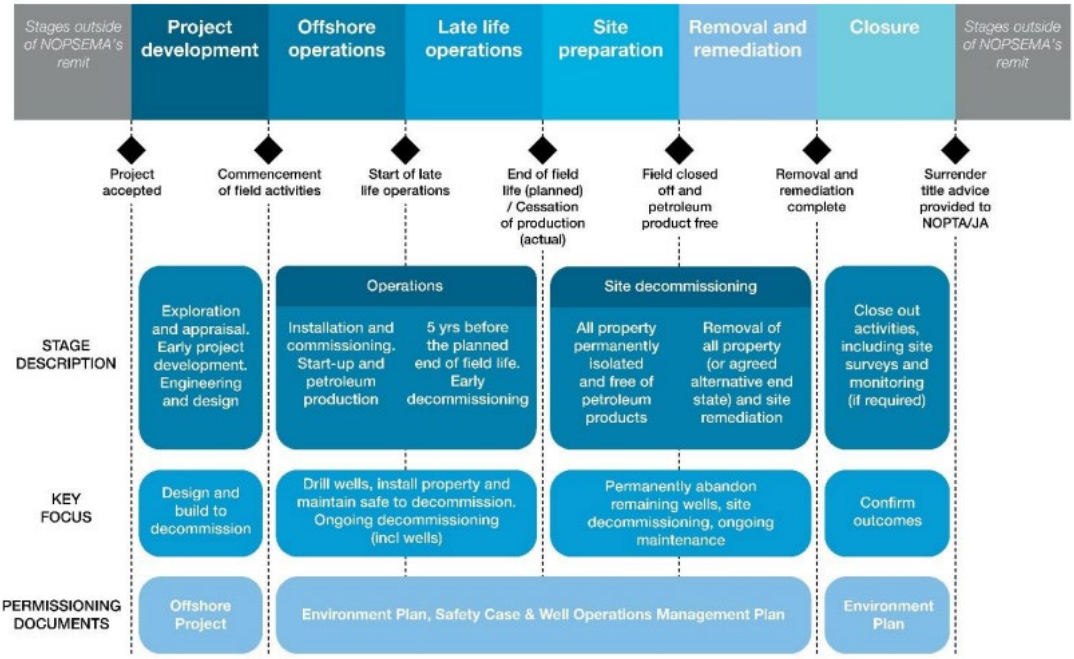
Venting may be required during well suspension activities (Section 4.3.2.6). Small volumes of reservoir gas may need to be handled back to the rig but would be too small for flaring and therefore would be cold vented to the atmosphere.

4.3.5 decommissioning

Decommissioning refers to the "process of removing or otherwise satisfactorily dealing with offshore petroleum property (including wells) in a safe and environmentally responsible manner when it is neither used nor intended to be used" (Ref. 77).

Figure 4-5 illustrates key decommissioning focus areas that are applicable during the different phases of the Development and are aligned with good practice proactive decommissioning planning. The key focus during this early phase of the engineering design for the Development (and this OPP) is that the design considers decommissioning. As described further in Section 4.3.5.1, all subsea infrastructure (above the mudline) associated with the Development will be designed to be removable when no longer in use in connection with operations.

The following sections describe CAPLs approach to proactive decommissioning planning for the Development and provides a high-level overview of the types of petroleum activities that will likely be required as part of the decommissioning of structures, equipment, and property. It is not possible to fully scope the future decommissioning methodology that will be used as the many variables are not yet known. CAPL will continue to review and identify improvements in technology that may occur between now and the time decommissioning occurs. Finalised details of decommissioning activities will be specified in the EP phase.



(Source: Ref. 77)

Figure 4-5: Decommissioning planning over the life of an offshore project

4.3.5.1 regulatory obligation and decommissioning planning

CAPL recognises its obligations under the OPGGS Act related to the decommissioning of offshore infrastructure. In accordance with the OPGGS Act the following decommissioning requirements apply to the Development:

- Full removal (referred to as the ‘base case’) or otherwise satisfactorily dealing with structure, equipment, and property.
- Alternative arrangements from the requirement to remove structure, equipment, and property are subject to agreement and approval via acceptance of an EP by NOPSEMA. Options other than full removal must comply with the OPGGS Act and its regulations, including the principles of ESD.
  - If alternate arrangements are agreed and any property is to remain in situ, the requirements of other relevant legislation (e.g. the *Environment Protection (Sea Dumping) Act 1981* (Cth) will also apply.
- Design for all fields will be undertaken to meet the requirement for full removal of structures, equipment and property.
- All structures, equipment and property in the title area will be maintained in a state to ensure full removal can be achieved, unless a deviation from full removal has previously been accepted by NOPSEMA via acceptance of an EP.
- Decommissioning will occur as either a standalone campaign or as part of a wider decommissioning campaign. Progressive decommissioning including progressive well plug and abandonment and progressive removal of structures, equipment and property or seeking acceptance for alternative arrangements will be undertaken in accordance with timeframes outlined in regulatory policy and guidelines. Any deviation to timeframes beyond those within regulatory guidance will be agreed with the regulator via the EP assessment process.
- Where required, environmental survey, site rehabilitation and monitoring will be undertaken.
- Decommissioning must be completed before the end of title.

To be able to surrender a petroleum title associated with the Development, CAPL must satisfy the criteria in section 270 of the OPGGS Act, including but not limited to 270(3)(c) to (f):

- removed or caused to be removed all property brought into the surrender area or made arrangements that are satisfactory to NOPSEMA in relation to that property
- plugged or closed off all wells in the surrender area
- provided for the conservation and protection of natural resources in the surrender area
- made good any damage to the seabed or subsoil in the surrender area caused by the operations authorised by the permit, lease or licence.

These requirements are detailed within CAPL’s Asset Retirement philosophy that aligns with key regulatory requirements and expectations for decommissioning offshore infrastructure.

4.3.5.2 decommissioning overview

Activities associated with decommissioning will be conducted to ensure the requirements of section 572 of the OPGGS Act are undertaken to the satisfaction of NOPSEMA. These activities are likely to include, but are not limited to:

- studies and survey activities
- suspending wells—if applicable
- well P&A
- flushing and cleaning flowlines
- removing flowlines
- removing other subsea structures and infrastructure
- post well abandonment and decommissioning monitoring (where required).

The list above does not indicate a particular sequence (e.g. flushing and cleaning may begin before well P&A can be carried out).

The following subsections describe the decommissioning activities at a high level based on current technologies and methodologies. Over the Development's operational life, CAPL will continually investigate and evaluate technology advances and opportunities for different approaches. Where new methodologies or technology are proposed to be used for decommissioning that have not been specifically considered in this OPP, they will be evaluated and approved under the EP process before deployment.

4.3.5.3 studies, surveys, and monitoring

Details of surveys to be undertaken during the operational life of the asset will be provided in the respective EPs for each phase of the Development, when design has been finalised.

Studies and surveys that may be needed include:

- environmental surveys and studies to inform understanding of environmental conditions within the title areas including benthic, physicochemical and/or biological surveys, if required
- review of IMR surveys during operations to confirm infrastructure integrity
- surveys of infrastructure to confirm burial status, condition of infrastructure including structural integrity for removal
- as-left survey following decommissioning activities
- monitoring surveys, as determined on a case by case basis, in consideration of the impacts and risks, and as agreed within a decommissioning EP accepted by the NOPSEMA.

An overview of some these surveys is provided in Sections 4.3.1, 4.3.3 and 4.3.4.2.

4.3.5.4 flush and clean

When the Development fields are ready for decommissioning, the flowline contents will be flushed to remove hydrocarbons, and flowlines will be decontaminated if necessary.

Options for decontaminating the flowlines will be considered in more detail closer to end of field life and be informed by results of contaminant surveys.

Materials used for flushing and decontamination may include surfactants, hydrochloric acid, and MEG. Mercury and hydrocarbons may be present in the flushing materials after decontamination and will be managed accordingly.

Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

4.3.5.5 flowline and MEG pipeline decommissioning

Each flowline and MEG pipeline may be filled with sea water following flushing and cleaning; this would subsequently be released to the marine environment during decommissioning. The sea water may contain residual hydrocarbon, mercury, NORMs, surfactants, hydrochloric acid, or MEG. The volume of sea water that is likely to be released is determined by the flowline and MEG pipeline inventory (a maximum of 17,500 m^3 based on the longest flowline).

Implementing the base case removal requirement would involve some preparatory works such as jetting, mass flow excavation (MFE) or mechanical grab to remove sediment that has built up over the project's life and allow access for cutting tools.

The flowlines and MEG pipelines may be removed in various ways. Current methodologies include:

- cut and lift
- reverse S-lay
- reverse J-lay.

4.3.5.6 umbilical decommissioning

To facilitate removal, some preparatory works may be required, as described in Section 4.3.5.5.

The umbilicals may be removed in various ways. Current methodologies include:

- reverse reel
- recovery to carousel
- recover and cut on vessel deck.

4.3.5.7 other subsea structures decommissioning

Manifolds and other structures (e.g. PLETs, production trees) will be flushed and cleaned as far as practicable during flowline flushing. Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

Activities to facilitate removal of the remaining subsea structures and infrastructure may involve:

- disconnecting spools, jumpers, manifolds, and any other medium-to-large structures and preparing them for recovery
- removing overburden or sediment to get access for cutting, water jetting, MFE or mechanical excavation.

4.3.5.8 well plug and abandonment

Well plug and abandonment (P&A) procedures involve isolating the reservoir and verifying this isolation, all with the intent of preventing the release of wellbore fluids into the marine environment. Any residual gas (returned during production tubing or well casing perforation/cutting) may be flared, or where the flow of gas is not sufficient to sustain the flare, it will be cold vented. During abandonment, along with a range of associated activities, cement and mechanical plugs or

another suitable barrier may be set within the wellbore to form a permanent reservoir barrier, and the severing and removal of the conductor, surface casing and wellhead at mudline or below.

Once production has ceased, wells will be shut in and monitored as part of IMR activities until well P&A is undertaken.

At this stage, it is assumed that well suspension and well P&A activities will be performed with either a MODU similar to that used for drilling, using drag embedment anchors for mooring or DP (Section 4.3.2.1). Well suspension is discussed in Section 4.3.2.6.

4.3.6 support activities

Support activities associated with the Development will encompass MODUs, vessels, helicopters and ROVs. These support operations cover common activities occurring across all the activity phases (e.g. surveys, drilling, operations) which are not process related—such as sewage discharge, navigational lighting, and refuelling.

The support requirements will vary depending on phase (Table 4-11).

Table 4-11: Support activities for each development phase

Support activity		Development phase				
		Survey	Drilling	Installation	Operations	Decommissioning
MODU			✓		✓ If required	✓
Vessels	Survey vessels	✓	✓	✓	✓	✓
	Operational support vessels		✓	✓	✓	✓
	PLV and cable lay vessels			✓		✓
	Construction vessels			✓	✓	✓
	Supply vessels		✓	✓	✓	✓
Helicopter			✓	✓	✓	✓
ROV/AUV		✓	✓	✓	✓	✓

4.3.6.1 MODU operations

The MODU used will be semisubmersibles, drilling ships, intervention vessels or potentially a jack-up for shallow water well activities.

Semisubmersibles are a type of floating vessel that is supported primarily on large pontoon-like structures submerged below the sea surface; whereas drillships and intervention vessels are typically a vessel modified to include a drilling rig and special station-keeping equipment. A jack-up rig is a type of mobile platform fitted with its legs extended in the ‘up’ position, then once on location the legs are extended down onto the seafloor, and the hull then ‘jacked-up’ a pre-determined height above the sea surface.

The other types of MODU will be positioned either by mooring using drag embedment anchors or kept on location with DP using thrusters.

Non-drilling activities occurring on the MODU will include:

- bunkering and bulk transfer of fuel, chemicals, and supplies
- transferring waste to supply vessels
- discharging:
  - sewage, greywater, and food waste
  - cooling water and reverse osmosis brine
  - deck drainage and bilge.
- helicopter operations.

A MODU will be in the DA throughout the drilling and decommissioning phases and will be used as needed during operations.

An estimate of ~250 personnel on board (POB) is expected on the MODU. The estimated POB for the MODU is significantly smaller than for the largest vessel likely to be used (Section 4.3.6.2), so vessel POB estimates have been used for impact assessment.

4.3.6.2 vessel operations

Vessels of different sizes and capabilities are required for various functions throughout all phases of the Development. The indicative types of vessels that will be used include:

- survey vessels
- operational support vessels such as transportation vessels, tugs, and barges (referred to as offshore support vessels (OSV) in the underwater sound impact assessment [Section 8.5])
- pipelay vessels (PLVs) and cable lay vessels
- construction vessels (referred to as offshore construction vessels (OCV) in the underwater sound impact assessment [Section 8.5])
- supply vessels (referred to as OSV in the underwater sound impact assessment [Section 8.5]).

Activities associated with these vessels may include:

- bunkering and bulk transfer of fuel, chemicals, and supplies to the MODU/vessels
- collecting and potentially treating waste from the MODU/vessels
- discharging:
  - sewage, greywater, and food waste
  - cooling water and brine
  - deck drainage and bilge water
  - atmospheric emissions
- vessel positioning and anchoring
- installation and decommissioning activities
- supporting anchoring operations

- assisting in emergency response situations
- monitoring the 500 m safe navigation area (SNA)
- IMR activities.

Vessels will typically use DP; however, in certain circumstances, anchoring may be required.

Vessels will use light marine fuel such as marine diesel oil (MDO) or marine gas oil (MGO), instead of heavy fuel oil. Fuels described in this OPP are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new fuel selected for the Development will be assessed and presented in subsequent applicable EPs.

Vessels transiting to and from the DA are managed under the *Navigation Act 2012* (Cth) and are not within the scope of this OPP.

All vessels are collectively termed ‘support vessels’. Larger vessels (e.g. PLVs, construction vessels) will be serviced by helicopters. Crew changes for smaller vessels (e.g. supply vessels, tugs) will typically be conducted at a port outside the DA. All vessels will initially mobilise and demobilise at the port. The largest vessel is likely to be a PLV with an indicative POB of ~700.

Vessels may be sourced domestically or internationally, depending on operational requirements and availability.

As with all activities, CAPL will continue to seek and assess emerging technologies. Unmanned surface vessels and Marine Autonomous Surface Ships will be evaluated for future use in the Development.

4.3.6.3 helicopter operations

Where required, helicopters may be used for crew transfers and minor supplies to and from facilities and vessels in the DA. Helicopters may be required to evacuate personnel in the event of an emergency.

Helicopters will typically operate from Barrow Island. Refuelling helicopters offshore is not planned.

Passenger and crew transfers for larger installation vessels (e.g. PLVs, construction vessels) will be supported by helicopter logistics. Helicopter flight frequency is estimated to be ~15-16 flights per week for the largest vessel, and ~5 flights per week for the MODU.

4.3.6.4 ROV operations

ROV and AUV operations may be conducted during all phases of the Development. ROVs and AUVs support activities such as site survey, installation, commissioning, start-up, IMR, subsea valve operations, recovery of dropped objects and decommissioning. They may also be required during an unplanned event, such as a loss of well control (LOWC).

As technology develops, future options for ROV and AUV activities will be evaluated; these options include resident ROVs, which do not require a support vessel.

ROVs generally do not contact the seabed, but in rare circumstances may be required to wet park within the long-term disturbance area. The ROV footprint is ~3 m × 3 m.

5 alternatives analysis

This section describes the method used to identify and evaluate development alternatives to support regulation 7(2)(f) of the OPGGS(E)R, which requires the OPP to include:

> "a description of any feasible alternative to the project, or an activity that is part of the project, including:
>
> i. a comparison of the environmental impacts and risks arising from the project or activity and the alternative; and
>
> ii. an explanation, in adequate detail, of why the alternative was not preferred."

Consideration of alternatives for the Development was conducted in accordance with NOPSEMA's guidance on OPP content requirements (Ref. 16).

This section addresses this requirement by analysing the feasible alternatives for the:

- development concept (Section 5.2)
- design and activity elements of the selected concept (Section 5.3).

5.1 decision-making process

Various decision-making process options exist. Typically, these processes follow similar principles and involve evaluating available alternatives against a range of different criteria to enable selection of a preferred option. An overarching principle is that of multi-criteria decision analysis.

This method is commonly used within the industry for evaluating options for decommissioning (typically termed 'comparative assessment'), with net environmental benefit analysis used for spill response.

CAPL's assessment processes were adapted to develop the process described in the subsections below.

5.1.1 assessment criteria

Factors that influenced CAPL's selection of feasible alternatives were based on these focus areas, which align with critical operational excellence (OE) risks:

- environment
- technical feasibility
- safety
- commercial
- social.

Each focus area is further divided into categories and assessment criteria, as listed in Table 5-1.

Table 5-1: Feasible alternatives assessment criteria

Focus area	Criteria
Environment	
Physical presence	• Seabed disturbance • Interaction with marine fauna (vessel movements)
Emissions	• Underwater sound emissions • Atmospheric emissions and GHG emissions • Light emissions
Discharges	• Planned liquid and solid discharges • Accidental releases
Introduction of invasive marine pests	• IMPs
Onshore physical presence[35]	• Ground disturbance • Non-indigenous species (NIS) • Fire • Interaction with terrestrial fauna
Lifecycle environmental impacts[36]	• Life-of-field impact spanning both infrastructure construction, in-place footprint, production operations and any abandonment legacy
Technical feasibility	
Operability and feasibility risk	• Technically feasible and ability to operate and maintain
Technical readiness	• Acceptable technology readiness level
Constructability, re-usability and decommissioning feasibility	• Feasibility to construct • Re-usability • Feasibility to decommission
Safety	
Safety and risk	• OHS and risk exposure • Process safety
Commercial	
Schedule risk	• Ability to meet the Development timeline
Cost risk	• Economic viability
Future flexibility risk	• Ability to accommodate future development including tie-ins for other fields
Social	
Socio-economic impacts	• Impact to other marine users
Reputation	• Social licence to operate
Cultural	• Impact to cultural heritage values

[35] Relevant for development concepts with onshore components only.

[36] Relevant for development concept evaluation only.

The assessment is carried out in two steps:

- undertake a comparative assessment of the alternatives against environmental criteria to identify the options with the least environmental impact
- further assess alternatives against the other criteria (technical feasibility, safety, commercial and social focus areas) to justify the final selected option.

Each option is assessed against the criteria and assigned a ranking score between 1 and 4 (Table 5-2). If there was no material difference between two or more options, each was given a score of 2.

Table 5-2: Scoring criteria for alternatives analysis

Score	Guidance
1	Few issues. Best in group
2	Good. Some minor issues. No material difference
3	Some more significant issues. More significant difference
4	Significant issues. Worst in group

5.2 concept alternatives

CAPL considered six different development concepts during the alternatives analysis process. These concepts represent the primary development options for gas fields. Table 5-3 summarises each concept.

Floating LNG was not considered as a development concept option, as it is not commercially viable, does not have demonstrated feasibility, and does not have a robust operating record in the industry to date.

Table 5-3: Development concept alternatives overview

Concept	Overview
Option 1—FPSO	• Uses an offshore floating production storage and offloading (FPSO) unit similar to the NWS Okha facility. • Production fluids are gathered from wells via flowlines and risers to the FPSO. • Fluids are separated and treated; condensate is exported directly via the FPSO. • Gas is exported via existing GFP infrastructure to the Gorgon GTP, with capacity for carbon capture and storage (CCS). • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.
Option 2—Offshore fixed facility	• Uses an offshore fixed structure, such as a tension-leg platform (TLP) or semisubmersible floating production system, similar to the Scarborough development. • Production fluids are gathered from wells via flowlines and risers to the TLP/semisubmersible. • Fluids are treated and exported via existing GFP infrastructure to the Gorgon GTP, with capacity for CCS. • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.
Option 3—Subsea tieback to new GTP	• Uses subsea infrastructure tied back to a new GTP, similar to the original GFP) on Barrow Island or the mainland. • Production fluids are gathered from wells via flowlines, which are tied-in to a new trunkline.

Concept	Overview
	• Fluids are exported via the new trunkline to a new onshore GTP facility with no capacity for CCS.
Option 4—Subsea tieback to existing Gorgon GTP	• Selected concept (described in detail in Section 4). • Uses subsea infrastructure tied back to the existing Gorgon GTP. • Production fluids are gathered from wells via flowlines, which are tied-in to existing GFP subsea infrastructure. • Fluids are exported via GFP existing pipelines to existing Gorgon GTP, with capacity for CCS. • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.
Option 5—Subsea tieback to existing third-party mainland GTP	• Uses subsea infrastructure tied back to an existing third-party GTP on the mainland, similar to the GFP development concept. • Production fluids are gathered from wells via flowlines, which are tied-in to a new trunkline. • Fluids are exported via the new trunkline to an existing GTP facility on the mainland, with no capacity for CCS.
Option 6–No development / lesser development	• No development or lesser development (i.e. of less fields).

Option 6 – No development / lesser development was not evaluated further for the reasons presented below.

CAPL is one of the largest energy suppliers to Western Australia and a major supplier in the Asia Pacific region. The CAPL-operated Gorgon GTP has the capacity to produce approximately 300 terajoules (TJ) of domestic gas per day, about 25% of the current Western Australian domestic market gas supply (Section 8.3.7.1), and ~15.6 million tonnes of LNG per year, primarily supplied to the Asia Pacific region under binding long-term agreements (Section 8.3.7.2). A small volume of condensate is also produced under supplied to the Asia Pacific region (Section 8.3.7.3).

Both the original two-train Gorgon Gas Development EIS/ERMP (Ref. 1; Ref. 2) and the three-train Revised Gorgon Gas Development PER (Ref. 3) outlined that gas fields from the Greater Gorgon Area would be developed once production from the Gorgon and Jansz-Io fields began their natural decline (Sections 1.1 and 8.3.6).

CAPL considered the impact of not developing these seven backfill fields (i.e. Chandon, C&D, G&E, Semele, and WTR) for the Gorgon Gas Development. Existing gas production from the Gorgon and Jansz-Io fields will naturally decline, and if these backfill fields are not developed the production of both domestic gas and LNG from the Gorgon GTP on Barrow Island will reduce earlier than planned. Given the significant role the Gorgon Gas Development plays in providing energy security for Western Australia and the Asia Pacific region, an earlier than expected reduction in production from the development will have a corresponding negative impact on the Western Australian and Asia Pacific gas markets.

The Australian Government's Future Gas Strategy (Ref. 509) "establishes the role gas will play in the transition to net zero by 2050, securing affordable gas for Australia as we move to a more renewable grid, and confirming our commitment to being a reliable trading partner" (Ref. 510). This continued role of gas in the energy market is mirrored in the most recent domestic gas supply and

consumption scenario analysis for Western Australia which states that “gas will continue to be used by Western Australian households, businesses, and industry, and support the reliability and security of the electricity sector” (Ref. 566). Further, the analysis for Western Australia indicates risks of supply gaps from 2030 onwards under all scenarios (Ref. 566; Section 8.3.8).

In the Asia Pacific region, growing global energy needs mean demand for Australian LNG will remain for existing customers, but demand will also come from other countries that look to use more LNG in their energy mix. The projected trends in global energy use also continue to indicate that natural gas will maintain a role through to 2050 under all modelled scenarios (Ref. 529; Section 8.3.9). Under the Stated Policies Scenario (STEPS) demand for natural gas is projected to peak ~2030 and then have only a slight decline through to 2050; while LNG demand is still projected to increase by >2.5% per year from 2023 to 2035 (Ref. 529). The International Energy Agency (IEA)’s scenario analyses did identify the potential for an LNG oversupply to the global market; however, under STEPS this potential oversupply does not extend post-2040 (Section 8.3.9.2.1). As described above, there are long-term sales agreements for LNG from the Gorgon Gas Development in place with Asia Pacific buyers, and the demand for LNG in this region is projected to continue to 2050 under all IEA scenarios. Further, the Development will also be developed in stages (Section 4.1.4), and as such if there are economic factors (e.g. if an oversupply does eventuate and cause downward pressure on prices), or other factors, affecting the market, these would be considered at the time of investment and development.

As energy systems transition to a more diverse and lower carbon energy mix, it is critical that energy security is maintained, and the Gorgon Gas Development, including the Backfill Fields Development, supports this objective. In addition to this, CAPL also has an obligation to develop any commercially viable hydrocarbon reserves to satisfy offshore permit retention lease requirements under the OPGGS Act.

Regarding the development of lesser fields, CAPL considered the intent of the Policy Statement Staged Developments – Split referrals: Section 74A of the EPBC Act (Ref. 84). To align with this Policy, CAPL prepared this OPP for the development of the seven backfill fields being considered at the time of writing to allow an appropriate and robust assessment of cumulative impacts. This approach ensures the long-term backfill plan for the Gorgon Gas Development is transparent and the potential cumulative impacts of the Development are not under-represented.

For these reasons, Option 6 was not considered further.

5.2.1 analysis of concept alternatives

The common activities associated with all concepts were identified and have been grouped in Table 5-4.

Each activity was systematically mapped against the focus areas and the key criteria (as identified in Section 5.1.1), and the relevant concepts were identified. Table 5-5 details the qualitative ranking score for the environmental criteria for each concept. The lowest score indicates the best result from an environmental perspective. The totals ranged from 43 (Option 5) to 18 (Option 4), with a large difference between the lowest score of 18 and the next lowest score of 27 (Option 2).

The assessment shows that the most favourable outcome environmentally is Option 4—Subsea tieback to existing Gorgon GTP.

Table 5-4: Environmental criteria related to activities associated with each development concept

Activity	Related concept	Offshore physical presence		IMP risk	Emissions			Discharges		Onshore physical presence				Lifecycle environmental impacts
		Seabed disturbance	Interaction with marine fauna	IMP	Underwater sound	Atmospheric & GHG	Light	Planned discharges	Accidental releases	Ground disturbance	NIS	Interaction with terrestrial fauna	Fire	Life-of-field impact
Surveys														
Geophysical survey	1,2,3,4,5		✓	✓	✓	✓		✓	✓					
Geotechnical survey	1,2,3,4,5	✓	✓	✓	✓	✓		✓	✓					
Onshore surveys	3,5					✓				✓		✓		
Drilling														
Mobilisation and demobilisation of rig	1,2,3,4,5	✓	✓	✓		✓			✓					✓
Drilling of wells	1,2,3,4,5	✓			✓	✓	✓	✓	✓					✓
Well clean-up	1,2,3,4,5					✓	✓	✓	✓					✓
Installation, hook-up and commissioning														
Installing & commissioning of flowlines	3,5	✓	✓	✓	✓			✓	✓					✓
Installing piles and anchors	1,2	✓			✓									✓
Installing & commissioning production facilities	2,3	✓	✓	✓	✓	✓		✓	✓					✓
Installing mooring system	1,2	✓	✓	✓	✓			✓	✓					✓
Onshore construction and installation														
Clearing and site preparation	3,5					✓			✓	✓	✓	✓	✓	✓
Constructing new GTP and associated infrastructure	3					✓			✓	✓	✓	✓		✓
Shore crossing	3,5								✓	✓	✓	✓		✓
Installing onshore pipeline component	3,5								✓	✓	✓	✓		✓
Operations														
Produced water treatment and disposal	1,2,3,4,5	✓				✓		✓	✓					✓
Hydrocarbon extraction and processing	1,2,3,4,5					✓			✓				✓	✓
Decommissioning														
Plug and abandon wells	1,2,3,4,5	✓	✓	✓	✓			✓	✓					✓
Removing infrastructure	1,2,3,4,5	✓	✓	✓	✓			✓	✓					✓
Decommissioning and closure	3, 5					✓		✓	✓	✓		✓		✓
Rehabilitation	3, 5					✓						✓		✓
Support Operations														
Facility operations – offshore	1,2,3,4,5	✓	✓	✓	✓	✓	✓	✓	✓					
Facility operations – onshore	1,2,3,4,5	✓				✓	✓	✓	✓				✓	
Vessel operations	1,2,3,4,5	✓	✓	✓	✓	✓	✓	✓	✓					
Aircraft operations	1,2,3,4,5					✓								
ROV operations	1,2,3,4,5								✓					
Onshore equipment operations	3,5					✓			✓	✓	✓	✓	✓	

Table 5-5: Assessment of environmental criteria for development concept alternatives

Focus area	Criteria	Development concepts—qualitative ranking and justification									
		Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Physical presence	Seabed disturbance	Localised development footprint. Similar infield flowline distance as Options 2 and 4. Mooring spread footprint from anchoring the FPSO.	2	Localised development footprint. Similar infield flowline distance as Options 1 and 4. Requires disturbance footprint for the fixed platform or mooring system.	2	Most seabed disturbance of all options, due to longest flowline/pipeline required. New flowline to Barrow Island/mainland, shore crossing and onshore pipeline component. Also requires large footprint of ground disturbance for a new GTP and associated infrastructure/utilities.	4	No FPSO mooring or fixed platform disturbance footprint. Similar infield flowline distance as Options 1 and 2.	2	Most seabed disturbance of all options, due to new pipeline required (longest of all options). New pipeline to the mainland, shore crossing and onshore pipeline component.	4
	Interaction with marine fauna	Permanent surface facilities	2	Permanent surface facilities	2	No surface facilities. Fauna interaction would peak during construction and decommissioning. Nearshore environment is sensitive during construction, shore crossing, dredging (if required). Longer duration and greatest spatial extent of vessel activities.	4	No surface facilities. Fauna interaction would peak during construction and decommissioning.	1	No surface facilities. Fauna interaction would peak during construction and decommissioning. Nearshore environment is sensitive during construction, shore crossing, dredging (if required). Longer duration and greatest spatial extent of vessel activities.	4
Emissions	Underwater sound	Permanent surface facilities including rotating equipment and onboard machinery noise. Subsea chokes.	3	Permanent surface facilities with onboard noise. Potential for dry trees or subsea chokes.	3	No surface facilities. Noise generated by subsea chokes and subsea processing. Noise generation from vessels during construction in shallow water.	2	No surface facilities. Noise generated by subsea chokes and subsea processing.	2	No surface facilities. Noise generated by subsea chokes and subsea processing. Noise generation from vessels during construction in shallow water.	2
	Atmospheric and GHG	Power generation and process emissions from operation of the offshore facility. The CO_2 injection system on Barrow Island can be used. Similar to the proposed Barossa Development—CO_2 would have to be comingled to existing pipeline, not separated on FPSO.	3	Power generation and process emissions from operating the offshore facility. CO_2 injection system on Barrow Island can be used.	3	No facilities or emissions associated with subsea development. Minor fugitive emissions. Emissions generated by more significant construction footprint and much longer flowlines. Duplication of utilities. CO_2 injection not available.	4	No facilities or emissions associated with subsea development. Minor fugitive emissions. Processing is done at the existing GTP, and CO_2 injection system can be used.	2	No facilities or emissions associated with subsea development. Minor fugitive emissions. Processing is done at the existing third-party GTP on the mainland, which does not have a CO_2 injection system.	4
	Light	Permanent surface facilities. >60 km from Barrow Island. Assume would require flaring, and distance of change in ambient light is greater.	3	Permanent surface facilities. >60 km from Barrow Island.	2	Additional activities on Barrow Island or new mainland coastal GTP may have impact on turtle nesting beaches. Artificial light would peak during drilling, construction and decommissioning. New onshore facility lighting.	4	Minor temporary impact. Artificial light would peak during drilling, construction and decommissioning.	1	Minor temporary impact. Additional activities at new mainland coastal GTP may have impact on turtle nesting beaches, depending on proximity to coast and location. Artificial light would peak during drilling, construction and decommissioning. New onshore facility lighting.	3
Discharges	Planned discharges	Full range of emissions/discharges from FPSO. Normally-manned facility.	4	Moderate emissions of open non-hazardous drains, sewage, hydrotest and maintenance from permanent surface facilities. Assume minimally-manned or not normally manned (NNM).	3	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity. Additional discharge sources from new GTP.	3	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity.	1	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity. Greater spatial extent and duration of vessel activities for new pipeline. Greatest hydrotest discharge volumes due to greatest distance (to mainland). Additional discharge sources from new GTP.	4

Focus area	Criteria	Development concepts—qualitative ranking and justification									
		Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
	Accidental releases	Large liquid hydrocarbon volumes maintained/stored on FPSO. Risk of spills during offloading. Hydrocarbon spill risk from wells and flowlines.	4	Small liquid hydrocarbon volumes maintained/stored on facility. Oil spill risk from wells and flowlines.	3	Low risk of subsea wells and flowline loss of containment (LOC) / constrained inventory. Additional onshore GTP facilities incrementally increase the risk of accidental releases.	3	Low risk of subsea wells and flowline LOC / constrained inventory.	2	Low risk of subsea wells and flowline LOC / constrained inventory. Additional onshore GTP facilities incrementally increase the risk of accidental releases.	2
Introduction of IMP	IMP	Permanent floating structure required, dry dock in international location means increased IMP risk. Construction and IMR fleet risk. IMP associated with export vessel movements. Deep water. Domestic supply vessel transit to facility also a vector.	3	Permanent fixed structure manufactured in foreign country. Construction and IMR fleet risk. Deep water. Domestic supply vessel transit to facility also a vector.	2	Construction and IMR fleet risk only.	1	Construction and IMR fleet risk only.	1	Construction and IMR fleet risk only.	1
Onshore physical presence	Ground disturbance	No onshore component.	1	No onshore component.	1	Requires ground disturbance onshore for a new shore crossing and onshore pipeline to connect to the existing GTP.	3	No onshore component.	1	Requires ground disturbance onshore for a new shore crossing and onshore pipeline and clearing and site preparation for the new GTP site, and all associated infrastructure.	4
	NIS	No onshore component.	1	No onshore component.	1	Risk of introducing NIS from ground-disturbing activities and physical presence on site.	3	No onshore component.	1	Risk of introducing NIS from ground-disturbing activities and physical presence on site.	4
	Fire	No onshore component.	1	No onshore component.	1	Risk of fire from onshore equipment and hot works (e.g. pipeline welding).	2	No onshore component.	1	Risk of fire from onshore equipment and hot works (e.g. welding). Fire/explosion risk from hydrocarbon processing at new GTP. May require flare system.	4
	Interaction with terrestrial fauna	No onshore component.	1	No onshore component.	1	Risk of injury/mortality to terrestrial fauna due to vehicle strike and entrapment in excavations.	3	No onshore component.	1	Risk of injury/mortality to terrestrial fauna due to vehicle strike and entrapment in excavations.	4
Lifecycle impacts	Life-of-field impact	Many sources of environmental risk and impact.	3	Many sources of environmental risk and impact.	3	Moderate sources of environmental risk and impact. Significant additional onshore and moderate seabed physical footprint. Highest GHG emissions.	4	Moderate sources of environmental risk and impact. Moderate seabed physical footprint.	2	Moderate sources of environmental risk and impact. Moderate seabed physical footprint.	3
Environment total		**31**		**27**		**40**		**18**		**43**	

The next part of the assessment considered each concept against the remaining focus areas and corresponding criteria. Table 5-6 details the comparative assessment of the concept alternatives against these other criteria.

Table 5-6: Assessment of other focus area criteria for development concept alternatives

Focus area		Criteria	Development concepts – qualitative ranking and justification									
			Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Third-Technical feasibility	Operability and feasibility	Technically feasible	Feasible. NWS has difficult metocean conditions.	2	Feasible. Water depth limits fixed facility options to a tension-leg platform or semisubmersible. NWS has difficult metocean conditions.	3	Feasible with some flow assurance challenges (long trunkline).	2	Feasible.	1	Feasible with some flow assurance challenges (long trunkline).	2
	Technical readiness	Technology readiness levels	Readily deployed technology.	1	Readily deployed technology.	1	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2
	Constructability, re-usability, decommissioning feasibility	Feasibility to construct	Less complex than fixed platform.	2	Requires an international fabrication yard, many more contractors and complex work.	3	Constructability of a new GTP is challenging. Shore crossing and nearshore construction challenging.	4	Least complex option to install.	1	Shore crossing and nearshore construction challenging.	3
		Re-usability	FPSO can be re-used. Flexible flowlines could be re-used.	1	Platform/facility could potentially be re-used (e.g. Angel platform for CCS), but more difficult than an FPSO (e.g. Bayu-Undan).	2	No further difference between options (i.e. re-usability within the development is still feasible)	2	No further difference between options (i.e. re-usability within the development is still feasible)	2	No further difference between options (i.e. re-usability within the development is still feasible)	2
		Feasibility of decommissioning	Ability to remove all facilities (assume infield flowlines to one FPSO location). More difficult if anchors are piled.	2	Ability to remove all facilities. Feasibility challenges with decommissioning TLPs (see OHS row).	3	Significant length of flowlines may make full removal more challenging, or some equipment may be required to be left in situ. Shore crossing difficult to remove. Onshore facilities with foundations and undergrounds—full removal and remediation is challenging. Vegetation rehabilitation and ongoing monitoring is long-term.	4	Similar length of flowlines (Options 1, 2 and 4) may make full removal more challenging, or some equipment may be required to be left in situ.	2	Significant length of flowlines may make full removal more challenging, or some equipment may be required to be left in situ. Shore crossing difficult to remove.	3
Safety	Safety and risk	Occupational health and safety (OHS) and risk exposure	Personnel required offshore to operate facility (normally-manned). Highest number of exposure hours and maintenance.	3	Minimally manned facility to NNM facility. Offshore maintenance hours likely still required. Less offshore equipment and OHS risks than FPSO alternative.	2	Subsea facility offshore. Significant additional onshore manhours for construction and operations at the new GTP.	4	Subsea facility only – no topsides facilities to be manned. OHS risk from vessel activities.	1	Subsea facility only – no topsides facilities to be manned. OHS risk from vessel activities. Additional manhours to install trunkline and shore crossing.	1
		Process safety	Many new sources of risk. Likely to require disconnectable FPSO. Minimal separation distances available on FPSO (congestion). Higher inventory than fixed facility. Controls typically lower down hierarchy of control/inherently safe design requiring blast walls and blast overpressure management when compared to onshore facility.	4	Some offshore personnel – typically not-normally manned is likely. Many new sources of risk. Cyclone risk must be managed.	3	Subsea facility offshore. Additional onshore facilities introduce additional process safety risks. Separation distances possible onshore to manage blast overpressure and segregate people from the risk.	3	Subsea infrastructure only – no topsides facilities to be manned.	1	Subsea infrastructure only – no topsides facilities to be manned.	1

Focus area		Criteria	Development concepts – qualitative ranking and justification									
			Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Commercial	Schedule risk	Ability to meet the development timeline	Facility and topsides construction likely to significantly increase schedule.	3	Facility and topsides construction likely to significantly increase schedule.	3	Construction of a new GTP and associated facilities significantly increases schedule. Components in State waters require State approvals. Onshore environmental approvals have a significant lead time.	4	No significant issues identified.	1	Some interface and ullage issues identified integrating with an existing third-party GTP. Trunkline/shore crossings in State waters require State approvals.	2
	Cost risk	Economic viability	Large amount of capital expenditure (CAPEX) required. i.e. new FPSO (vessel and topside facilities). Reduced availability due to disconnectable nature.	3	Large amount of CAPEX required. i.e. new surface facility (TLP / semisubmersible)	3	Construction of a new GTP facility. Duplication of infrastructure components from GFP.	4	Backfill to existing facility using major GFP components. Best commercial outcome.	1	Backfill to existing facility using major GFP components. Significant additional pipeline CAPEX.	2
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2	No material difference.	2	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	Some restrictions on marine activities. Ongoing exclusion zone around facility.	3	Some restrictions on marine activities. Ongoing exclusion zone around facility.	3	Minimal restrictions on marine activities in Commonwealth waters. Disruption to coastal water users, potentially other port users depending on shore crossing location. Tourism.	4	Minimal restrictions on marine activities.	2	Minimal restrictions on marine activities in Commonwealth waters. Disruption to coastal water users, potentially other port users depending on shore crossing location. Tourism.	3
	Reputation	Social licence to operate	Additional floating visible structure.	3	Additional floating visible structure.	3	Requires new onshore development. Additional clearing, disruption to neighbours. GHG emissions may introduce further issues as there is no CCS.	4	Consistent with existing project. Minimal additional infrastructure. Availability of CCS may introduce further issues around GHG.	2	Consistent with existing project. Construction activities nearshore are more visible. GHG emissions may introduce further issues as there is no CCS.	3
	Cultural	Impact to cultural heritage values	Smaller seabed disturbance footprint. Greater potential impact to marine fauna, primarily due to underwater sound, GHG and light emissions, planned discharges and accidental releases from permanent surface facilities. No onshore or nearshore disturbance.	3	Smaller seabed disturbance footprint. Greater potential impact to marine fauna, primarily due to underwater sound, GHG and light emissions, planned discharges and accidental releases from permanent surface facilities. No onshore or nearshore disturbance.	2	Larger seabed disturbance footprint and therefore impact to benthic habitats. Some potential to impact onshore terrestrial environment and cultural heritage values due to onshore ground disturbance footprint. Disturbance to nearshore environment.	4	Smaller seabed disturbance footprint. Less potential to impact marine fauna from underwater sound and light emissions, planned discharges and accidental releases, due to no permanent surface facilities. No onshore or nearshore disturbance.	1	Larger seabed disturbance footprint and therefore impact to benthic habitats. Disturbance to nearshore environment. Larger potential to impact onshore terrestrial environment and cultural heritage values due to largest onshore ground disturbance footprint.	4
Other focus areas total			**32**		**33**		**43**		**19**		**30**	

As with the environmental criteria scoring, the lowest score indicates the best outcome. As the totals in Table 5-6 show, the most favourable outcome with respect to the technical feasibility, safety, commercial and social focus areas is Option 4—Subsea tieback to existing Gorgon GTP.

Figure 5-1 shows the total qualitative ranking score for each concept against the criteria from all focus areas (environment, technical feasibility, safety, commercial and social). Option 4 is clearly the most favourable option when all criteria are considered.

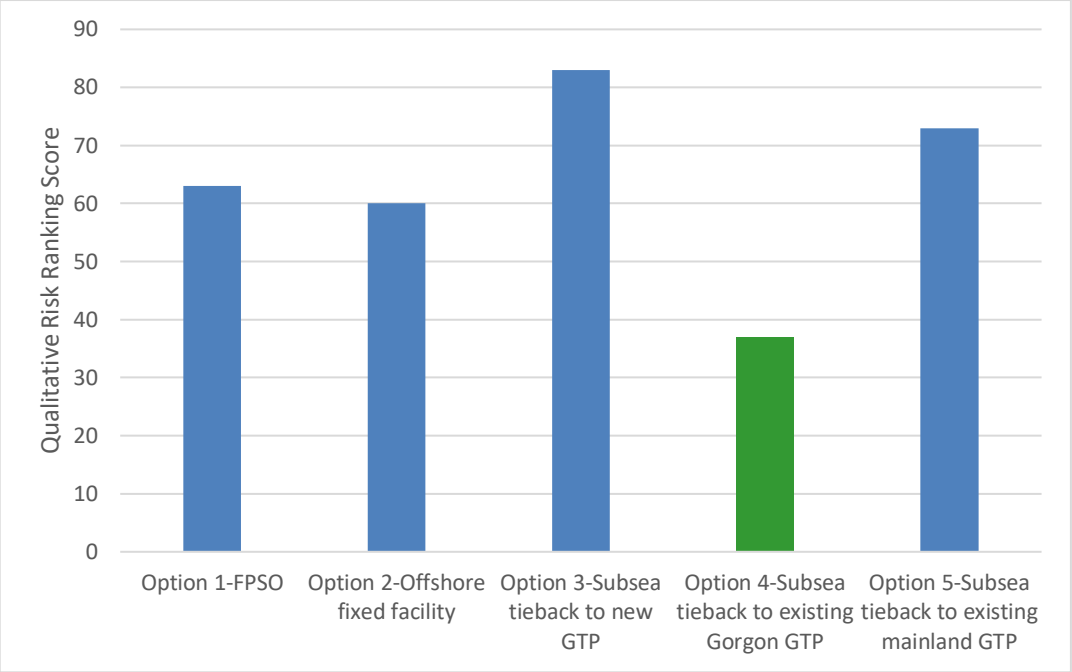


Figure 5-1: Qualitative ranking scores for Development concept alternatives against all focus areas

The most favourable concept identified though the ranking process was Option 4 for subsea tieback to the existing Gorgon GTP. Option 4 scores a ranking of 37. This option maximises the use of existing infrastructure, does not require additional surface process facilities, and requires no onshore crossing or additional lengthy pipeline installation, which notably reduces its lifecycle impacts.

Using existing subsea infrastructure already tied back to the current Gorgon GTP avoids seabed disturbance that would otherwise be associated with installing new pipelines, anchoring from an FPSO, or footings for a fixed platform. The lack of additional surface process structures and reduced vessel presence limits the potential interaction with marine fauna and the risk of introducing IMPs. The absence of a surface structure reduces the sources of artificial light.

The absence of an FPSO or platform removes additional noise sources such as rotating equipment and onboard machinery, which reduces the risk of behavioural change in, and injury to, fauna as a result of changes in ambient noise.

The design will not require local power generation or offshore processing, reducing the volume of emissions generated to minor fugitive emissions only. Because processing would take place at the existing GTP, the emissions generated would be managed through the existing CO_2 injection system.

With no offshore storage and processing, there is a far lower risk of accidental releases from subsea wells and flowline loss when compared with the volumes of

liquid hydrocarbon stored and offloaded with an FPSO or stored on a permanent facility.

As most processing and technology requirements are ready for deployment, the project is technically feasible. The design is the least complex to install and the most economically viable. Safety and commercial risks are reduced greatly because no extra topside facilities, onshore facilities or onshore crossings are required. The limited new infrastructure components and the availability of existing CCS lessen the social impact of the design, which is further supported by the minimal restrictions expected to influence marine activities such as fishing, tourism, and other petroleum-based activities.

Table 5-7 summarises the key reasons for adopting or rejecting development concept alternatives.

Table 5-7: Summary of assessment of alternative development concepts

Concept	Summary of comparative assessment	
Option1—FPSO	• Although FPSOs are redeployable, the Development field size and field life are not deemed sufficient to support the costs associated with installing and recovering a mooring system and subsea flowline and riser architecture for an FPSO. • The elevated risk of accidental releases of large hydrocarbon volumes associated with an FPSO increases the negative operational environmental impact. • Removing the facility for cyclone events further reduces its economic viability over the anticipated short field life. • Tie-in to the existing GFP pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected reservoir emissions. • Despite no new pipeline or new shore crossing and the use of CCS, the subsea construction activity and footprint result in greater overall environmental impact.	X
Option 2—Offshore fixed facility	• The field size and field life are not sufficient to support the cost of a fixed facility, topside construction and/or pipeline to the existing facility. • The inability to relocate the facility does not allow other isolated oil fields to be developed. • The lower section of a fixed platform (and subsea storage tank or pipelines if used) has the potential to remain in place if it is shown to have a lower environmental impact than removing it. • Tie-in to the existing GFP pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected emissions. • Using a TLP or semisubmersible means this option is technically feasible; however, it requires more complex construction and a greater number of contractors.	X
Option 3—Subsea tieback to new GTP	• The field size and field life are not sufficient to support the cost of subsea development, a new trunkline, and a new onshore processing facility. • A large development footprint is associated with the pipeline and onshore facilities. • No CCS is available.	X

Concept	Summary of comparative assessment	
	• The requirement for a shore crossing and onshore component significantly increases the environmental impact.	
Option 4—Subsea tieback to existing Gorgon GTP	• Using existing subsea infrastructure with tie back to the existing Gorgon GTP means this option is technically feasible; it does not require the deployment of any emerging or new technology. • Using tie-ins to the existing Gorgon pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected emissions. • Lower schedule and commercial risk as CAPL are the operator of the existing Gorgon GTP, rather than a third-party. • The existing CO_2 injection system at the GTP can be used to capture the expected reservoir emissions.	✓
Option 5—Subsea tieback to existing mainland GTP	• Additional seabed disturbance is associated with installing a trunkline to the main line. • Using the existing GTP facility on the mainland reduces the development footprint. • Works would be undertaken in sensitive nearshore environments for the shore crossing and onshore pipeline components. • No CCS is available. • Although technically feasible, this option has potential flow assurance challenges associated with long trunklines and may require emerging technology in the form of subsea compression/separation. • There is a high schedule and commercial risk due to the need for agreements/contracts between CAPL and the third-party owner of the GTP.	X
No development / lesser development	• The Development is being undertaken to maintain the production capacity of the Gorgon LNG and domestic gas facilities on Barrow Island to enable continued supply of the Western Australian domestic market and world's LNG supply. • The titleholder must undertake certain petroleum exploration and production related activities towards commercialising the resource having regard to government policy, regulation, and international commitments in relation to reducing greenhouse gas emissions to net zero. • Submitting an OPP for fewer fields does not align with the Policy Statement Staged Developments – Split referrals: Section 74A of the EPBC Act (Ref. 84) - and understates the potential impact of the Development.	X

The concept determined to be the most favourable option, based on all criteria, and which has been selected for the Development, is Option 4—Subsea tieback to the existing Gorgon GTP.

5.3 design and activity alternatives

Once the overall development concept (subsea tieback to the existing Gorgon GTP) was selected, the design features and activities with feasible alternatives were subject to a comparative assessment.

5.3.1 design and activities not assessed

The following design features and activities were not considered for the alternatives assessment.

5.3.1.1 well location and number

The indicative location of Development infrastructure, wells, and associated tie-in infrastructure, is linked to and limited by the location of each fields reservoir (i.e. the field wells are located to minimise the number needed and maximise the optimisation of the reservoir). As such, only minimal well relocation is expected, and will be based on pre-installation verification of geophysical and topography data and further alternative analysis outside of this framework not considered optimal.

5.3.1.2 temporary contingency power supply

There are two temporary contingency power supply options for the Development (subsea battery system and vessel downline). However, these are short-term solutions only, and are not intended to provide power for the whole field life. Therefore, the temporary contingency power supply options are not assessed below.

5.3.1.3 activity specific ALARP demonstrations

While demonstration of acceptability is presented in the alternatives analysis (Ref. 16) as required of an OPP, the more detailed, activity-specific demonstrations that all reasonably practicable measures have been considered to reduce impacts and risks to ALARP will be presented in the subsequent EP for each activity that is part of the project. These more detailed activity options or alternatives present a lesser nature and scale in terms of generating environmental impacts and risks.

Examples of these lower order activity alternatives typically evaluated in the EP phase as part of the ALARP process include:

- evaluations on conducting an activity (often assessed as an ‘elimination ‘control); e.g.
  - eliminating where possible vessel-based activities, drilling, or production activities
  - eliminating pile-driving
  - not anchoring vessels
  - evaluating hydrotesting chemical additives
- drill fluid type (e.g. water-based or synthetic-based muds)
- eliminating the use of MDO in vessels.

5.3.2 design and activities assessed

This section describes the key design and activity alternatives, and the associated comparative assessment.

The key design and activity elements of the Development include:

- MODU type
- hydrotest discharge
- flowline retrieval
- umbilical retrieval.

The following subsections outline the alternatives for each key element above and describe the comparative assessment that was carried out (as per Section 5.1). While decommissioning options have been presented, these options represent current methodologies. It is possible that new methodologies will be available and considered when the fields are ready to be decommissioned. Permission for these methodologies will be sought at the time through relevant EPs.

5.3.3 MODU type

CAPL will use a MODU for drilling, decommissioning and operations (if required) during the Development. The MODUs used may be semisubmersibles, drilling ships or intervention vessels. The method used for MODU positioning was considered in the alternatives analysis. Semisubmersibles, drilling ships and intervention vessels may be positioned using either a mooring system (i.e. anchors and mooring chains), or on DP (i.e. using thrusters to hold position).

Jack-up MODUs have legs which are extended down to sit on the seafloor. This MODU type is only suitable in shallower water depths, limited by the length of the legs.

Table 5-8 outlines the three alternatives that were considered.

Table 5-8: MODU alternatives overview

Concept	Overview
Option 1—Moored MODU	• MODU is moored to the seabed using anchors. • Up to 16 anchors are required, tethered to the MODU with mooring lines. • Total estimated footprint of anchors is ~28,480 m^2 per location.
Option 2—DP MODU	• MODU uses DP. • Thrusters are used to keep the MODU in position. • Sound emissions from thrusters is a continuous non-impulsive source, and additional to other onboard machinery.
Option 3—Jack-up MODU	• MODU has three legs with spud cans on the ends, which sit on the seabed. • Unsuitable in deeper water. • Total estimated footprint of anchors is ~950 m^2 per location.

Table 5-9 details the comparative assessment of these MODU alternatives against the environmental criteria (Section 5.1.1). Table 5-10 assesses them against the criteria for the other focus areas.

Table 5-9: Assessment of environmental criteria for MODU alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification					
		Option 1—Moored MODU		Option 2—DP MODU		Option 3—Jack-up MODU	
Physical presence	Seabed disturbance	Anchor spread/mooring footprint—assume 28,480 m^2 per well. Large spread in deep water.	4	No direct seabed disturbance.	1	Spud can footprint (typically three per jack-up rig)—assume 950 m^2 per well.	3
	Interaction with marine fauna	Physical presence. Potential for fauna entanglement in mooring lines.	3	Physical presence.	2	Physical presence.	2
Emissions	Underwater sound	Onboard machinery noise.	2	Continuous non-impulsive thruster sound emissions from use of DP. Acoustic modelling was undertaken (Section 8.5) for worst case. Onboard machinery noise.	4	Onboard machinery noise, however, the hull is not in contact with the sea surface, limiting underwater noise.	1
	Atmospheric and GHG	Onboard power generation.	2	Increased fuel consumption for DP thrusters.	4	Onboard power generation.	2
	Light	No material difference.	2	No material difference.	2	No material difference.	2
Discharges	Planned discharges	No material difference.	2	No material difference.	2	No material difference.	2
	Accidental releases	No material difference.	2	No material difference.	2	No material difference.	2
Introduction of IMP	IMP	Slightly greater risk due to mooring chains and anchor spread in close contact with the seabed.	3	No contact with seabed. No additional risk to bring a MODU into the DA.	2	Slightly greater risk due to the spud cans contact with the seabed.	3
Environment total:		**20**		**19**		**17**	

Table 5-10: Assessment of other focus area criteria for MODU alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification					
			Option 1—Moored MODU		Option 2—DP MODU		Option 3—Jack-up MODU	
Technical feasibility	Operability and feasibility	Technically feasible	No material difference.	2	No material difference.	2	Option is limited to shallower water depths; but the MODU would be contracted per campaign regardless.	2
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference.	2	No material difference.	2
	Constructability, re-usability, and decommissioning feasibility	Feasibility to construct	No material difference.	2	No material difference.	2	No material difference.	2
		Re-usability	No material difference.	2	No material difference.	2	No material difference.	2
		Feasibility of decommissioning	No material difference.	2	No material difference.	2	No material difference.	2
Safety	Safety and risk	OHS and risk exposure	Anchor handling increases occupational exposure from anchor-handling and winching activities.	3	No anchor handling required.	1	No anchor handling required.	1
		Process safety	No material difference.	2	No material difference. Incremental risk of loss of DP station keeping; not considered a material difference.	2	No material difference.	2
Commercial	Schedule risk	Ability to meet the development timeline	No material difference.	2	No material difference.	2	No material difference.	2
	Cost risk	Economic viability	No material difference.	2	No material difference. Requires fewer support vessels to move and position MODU within field.	2	No material difference. Option is limited to shallower water depths, but rig will be contracted per campaign regardless.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification					
			Option 1—Moored MODU		Option 2—DP MODU		Option 3—Jack-up MODU	
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Larger seabed disturbance footprint and therefore impact to benthic habitats. However, less potential impact to marine fauna, primarily from sound emissions.	3	No direct seabed disturbance; therefore, no impact to benthic habitats. Greater potential impact to marine fauna, primarily due to underwater sound and GHG emissions	3	Smaller seabed disturbance footprint. Less potential impact to marine fauna from underwater sound and physical interaction.	1
Other focus areas total:			**28**		**26**		**24**	
Total score (including environmental scores):			**48**		**45**		**41**	

The comparative environmental assessment shows a small difference in environmental ranking between the Option 1 and 2, as the only two options available for all fields and water depths; with Option 2–DP MODU ranked as slightly more favourable. This result was due to seabed disturbance, interaction with marine fauna and IMP risk, which together outweighed the potential noise and atmospheric/GHG impacts of Option 2. Option 3 – Jack-up MODU was ranked slightly better than both, with less impact from noise and a smaller disturbance footprint.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed similar results, with Option 2 and 3 ranked slightly better than Option 1. This difference was due to the OHS risks from anchor handling for Option 1. However, Option 3 has limited applicability as it can only be used in shallower water, meaning it is not useable for most of the drilling required for the Development.

The total qualitative ranking score for each option shows Option 3 is ranked better than the other two options by a small margin. All options have been selected for assessment in the OPP, noting Jack-up MODU is only suitable in shallower water (see Section 5.3.7).

All options for MODU positioning were determined to be suitable for the Development and will be included in the OPP.

5.3.4 hydrotest discharge

CAPL considered two alternatives for the discharge of hydrotest fluids, as outlined in Table 5-11.

Table 5-11: Hydrotest discharge alternatives overview

Concept	Overview
Option 1—Discharge to sea	• Hydrotest water is discharged at the seaward end of the test section at a controlled release rate. • Discharge occurs in deep ocean water. • Discharge occurs at the end of hydrotesting.
Option 2—Onshore disposal (deep well injection at Barrow Island)	• Hydrotest water is discharged via the GFP pipelines to Barrow Island. • Discharge occurs with process wastewater via deep well injection. • Discharge occurs at the end of hydrotesting.

Table 5-12 details the comparative assessment of these hydrotest discharge alternatives against the environmental criteria (Section 5.1.1); Table 5-13 assesses them against the criteria for the other focus areas.

Table 5-12: Assessment of environmental criteria for hydrotest discharge alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Discharge to sea		Option 2—Onshore disposal	
Physical presence	Seabed disturbance	No seabed disturbance.	2	No seabed disturbance.	2
	Interaction with marine fauna	Discharge to sea temporarily affecting water quality. Treated water contains chemical additives including biocide. The worst-case single discharge is for Chandon – ~35,000 m^3 (based on double the inventory of the longest flowline), which is smaller than the dispersion study volume for Jansz pipeline (60,000 m^3) (Ref. 85). Based on the dispersion study, subsea discharges are expected to be localised and rapidly diluted. Marine fauna are highly mobile and are not expected to be affected by minor increases in toxicity.	4	No discharge to sea.	1
Emissions	Underwater sound	No material difference.	2	No material difference.	2
	Atmospheric and GHG	No additional atmospheric emissions identified. Shutdown start-up of LNG plant avoided.	1	Flaring associated with process shutdown and start-up while dewatering pipeline. Additional power is required to inject water.	4
	Light	No material difference.	2	No material difference.	2
Discharges	Planned discharges	Discharge to sea temporarily affecting water quality. The worst-case single discharge is for Chandon – 35 000 m^3. This is smaller than the dispersion study volume for Jansz pipeline (60,000 m^3) (Ref. 85). Based on the GFP modelling subsea discharges are expected to be localised and rapidly diluted	4	Discharge to a deep aquifer onshore at Barrow Island.	2
	Accidental releases	Planned discharge as above. Limited potential for accidental release	2	Potential accidental release to land while in transit to disposal well.	3
Introduction of IMP	IMP	No material difference.	2	No material difference.	2

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Discharge to sea		Option 2—Onshore disposal	
Onshore Physical Presence	Ground Disturbance	No ground disturbance	1	New infrastructure required on BWI to facilitate disposal. Potential new clearing on Class A nature reserve	4
Environment total:		**20**		**22**	

Table 5-13: Assessment of other focus area criteria for hydrotest discharge alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Discharge to sea		Option 2—Onshore disposal	
Technical feasibility	Operability and feasibility risk	Technically feasible	Feasible	1	Requires shutdown of gas production systems for the GFP. Potential issues with fluid incompatibility and solids formation in deep injection wells.	4
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference	2
	Constructability, re-usability and decommissioning feasibility	Feasibility to construct	Install suitable pig launcher/receiver at relevant locations.	2	To discharge onshore, there needs to be a suitable pig receiver onshore at the GTP, and ability to divert the hydrotest fluids to enter the wastewater treatment plant and/or deep well injection. This would require additional onshore installation of supporting infrastructure.	4
		Re-usability	N/A		N/A	
		Feasibility of decommissioning	No material difference.	2	No material difference.	2
Safety	Safety and risk	OHS and risk exposure	No additional risks.	1	Flaring associated with process shutdown and start-up while dewatering pipeline and removal / treatment of fluid introduces additional occupational safety risks.	4
		Process safety	No additional risks.	1	Flaring associated with process shutdown and start-up while dewatering pipeline introduces additional process safety risks.	4

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Discharge to sea		Option 2—Onshore disposal	
Commercial	Schedule risk	Ability to meet the development timeline	No impact to schedule	2	Overall impact to schedule from loss of production from the GFP (and therefore the Development) during shutdown and re-start of the GTP.	4
	Cost risk	Economic viability	Most commercially viable.	1	Loss of production from the GFP (and therefore the Development) during shutdown and re-start of the GTP.	4
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Greater potential impact to marine fauna from hydrotest discharge to sea. Discharges will be localised and rapidly diluted. Marine fauna are highly mobile and are not expected to be affected by minor increases in toxicity. Neither option impacts benthic habitats.	3	Less potential impact to marine fauna, due to no discharge to sea. However, this option does involve additional flaring, and deep well injection of hydrotest water under Barrow Island to deep aquifers. Neither option impacts benthic habitats.	2
Other focus areas total:			**21**		**36**	
Total score (including environmental scores):			**41**		**58**	

The comparative environmental assessment shows little difference in environmental criteria between the two options. This result was mainly due to Option 1 scoring poorly on planned discharges to sea, while Option 2 scored poorly on atmospheric/GHG emissions through flaring.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed varying results, with Option 1 scoring more favourably than Option 2 overall. This difference was mainly due to technical feasibility, occupational safety and economic viability. CAPL identified a range of inherent risks to the operation of the GTP, including:

- requirement for production to mobilise hydrotest fluids to the inlet area, hydrate mitigation, and liquids management
- potential flow assurance issues
- insufficient slug catcher capacity for surge volumes
- requirement for water to be extracted from the MEG system, which risks hydrotest chemicals affecting the production chemistry
- requirement to take the GTP offline and cease production to transport hydrotest fluids to shore.

In addition, Option 2 would require substantial engineering design and installation work to allow receival, treatment and disposal of the hydrotest fluids at Barrow Island, making the feasibility of this option low. The hydrotest discharge Option 1—Discharge to sea was determined to be the only feasible option and has been selected for the Development.

5.3.5 flowline retrieval

CAPL considered two alternatives for flowline retrieval, as outlined in Table 5-14.

Table 5-14: Flowline retrieval alternatives overview

Concept	Overview
Option 1—Cut and lift	• Flowline is cut into manageable segments on the seabed. • Segments lifted onto vessel using cranes. • Segments offloaded to a pipe supply vessel or barge and transported to disposal facility. • Removal rate depends on length of cut sections but is estimated to be ~500–600 m/day.
Option 2—Reverse S-lay / J-lay	• Flowline recovery tooling is deployed to recover flowline into the removal vessel stinger/J-lay tower. • Flowline is secured on vessel tensioners and cut into manageable segments on the vessel deck. • Segments offloaded to a pipe supply vessel or barge and transported to disposal facility. • Removal rate estimated to be ~2–2.4 km/day.

Table 5-15 details the comparative assessment of these flowline retrieval alternatives against the environmental criteria (Section 5.1.1); Table 5-16 assesses them against the criteria for the other focus areas.

Table 5-15: Assessment of environmental criteria for flowline retrieval alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Cut and lift		Option 2—Reverse S-lay/J-lay	
Physical presence	Seabed disturbance	Physical disturbance of seabed and surrounds. Sections to be cut may need to be disturbed to access with machinery (e.g. by jetting / excavation). A small amount of debris may be released when cut, comprising concrete and coating materials, which may include epoxy and polypropylene.	3	Seabed disturbance for line removal but additional disturbance to gain access is only required at initial recovery and not at every cut location.	2
	Interaction with marine fauna	Extended duration of vessels in field.	3	Shorter duration.	2
Emissions	Underwater sound	Noise generation by underwater machinery—hydraulic shears or diamond wire saw. Noise source from vessel activities.	3	Minimal disturbance—noise source from vessel activities.	2
	Atmospheric and GHG	More emissions due to longer duration of vessel spread in field.	3	Less offshore time in field and therefore less overall GHG emissions	2
	Light	No material difference.	2	No material difference. Although the duration is longer, due to distance from shore (~60–190 km depending on which field), there is no difference in impact.	2
Discharges	Planned discharges	Residual fluid discharge to sea from pipe system. Pipeline contents flushed before recovery. Potential residual fluid discharge to vessel deck from pipe system. A small amount of debris may be released, comprising concrete and coating materials, which may include epoxy and polypropylene, mercury scale and NORM scale in very small quantities.	3	Residual fluid discharge to sea from pipe system. Pipeline contents flushed before recovery. Potential residual fluid discharge to vessel deck from pipe system. Debris may be released onto the deck from cutting segments and has to be contained.	2
	Accidental releases	Some potential for residual hydrocarbon and contaminant release to marine environment and seabed during cutting.	2	Some potential for residual hydrocarbon and contaminant release on vessel deck during cutting.	2

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Cut and lift		Option 2—Reverse S-lay/J-lay	
Introduction of IMP	IMP	No material difference.	2	Removal of marine growth is required before passing through tensioners, meaning more marine growth debris is dislodged onto the seabed.	3
Environment total:		**21**		**17**	

Table 5-16: Assessment of other focus area criteria for flowline retrieval alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		Option 2—Reverse S-lay / J-lay	
Technical feasibility	Operability and feasibility risk	Technically feasible	Established technology. Commonly used in Australian waters.	2	Not currently technically tested at scale at this water depth. As the flowlines are not concrete-coated, the Development may be a good candidate for this method. However, achieving the desired tension to recover the flowline becomes more challenging with greater water depth and presence of marine growth. Resistance to crushing and bending loads during recovery can be compromised due to reduced integrity of the flowline over its life.	4
	Technical readiness	Technology readiness levels	Established technology. Commonly used in Australian waters.	2	Not currently technically tested at scale at this water depth. Common method outside Australia in shallower water.	4
	Constructability, re-usability and decommissioning feasibility	Feasibility to construct	N/A		N/A	
		Re-usability	Pipeline is cut subsea—re-use is not possible. Recycling steel components would be targeted.	2	Pipeline is cut on board—re-use is not possible. Recycling steel components would be targeted. No material difference from a re-usability perspective.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		Option 2—Reverse S-lay / J-lay	
			No material difference from a re-usability perspective.			
		Feasibility of decommissioning	N/A		N/A	
Safety	Safety and risk	OHS and risk exposure	More offshore work hours to complete, more lifts, and more handling of pipe sections.	3	Fewer offshore work hours; however, still significant handling of pipe joints. The pipe is under greater tension in deeper waters. There is potential for the tensioner to lose grip, causing the pipe section to be abandoned and removal started again.	3
		Process safety	N/A		N/A	
Commercial	Schedule risk	Ability to meet the development timeline	More offshore work hours to complete, more lifts, and more handling of pipe sections	3	No material difference.	2
	Cost risk	Economic viability	No material difference. Longer duration.	2	No material difference. Requires a higher specification vessel but is shorter duration. Acceptance of liability/risk of pipelay construction companies to use their equipment to recover flowline using a reverse S-lay technique—may lead to increased cost.	2
	Future flexibility risk	Ability to accommodate future developments	N/A		N/A	
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		Option 2—Reverse S-lay / J-lay	
	Cultural	Impact to cultural heritage values	More physical disturbance of seabed required therefore greater potential impact to benthic habitats. Also, greater potential impact to marine fauna, primarily from emissions and planned discharges.	4	Less physical disturbance of seabed required therefore less potential impact to benthic habitats. Also, less potential impact to marine fauna from emissions and discharges and physical interaction.	1
Other focus areas total:			**22**		**22**	
Total score (including environmental scores):			**43**		**40**	

The comparative environmental assessment shows a difference in environmental criteria between the two options, with Option 2 ranked as more favourable. Option 1 ranked poorly against several environmental criteria, including seabed disturbance and planned discharges, whereas Option 2 only ranked worse on IMP.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed differences, with Option 1—Cut and lift scoring more favourably than Option 2. This difference was partly due to the technical feasibility and readiness for Option 2—Reverse S-lay/J-lay, which has not been demonstrated to be feasible in this water depth to date.

The total qualitative ranking score for each option shows Option 2 is ranked slightly better than Option 1. Although the environmental score also showed Option 2 was the preferable option, there are technical challenges associated with this unproven technique in deeper waters. If successful demonstration of reverse S-lay/J-lay is shown in deeper Australian waters in the future, it may prove to be a reliable option.

To ensure the option with the best environmental profile is used and to mitigate risks with unproven methodology, both options were selected for the OPP (see Section 5.3.7).

The flowline retrieval option determined to be the most favourable, based on all criteria, is Option 2—Reverse S-lay/J-lay. However, this option has risks associated with the feasibility of the technique. To allow for potential future technological advancement, both options will be included in the OPP.

5.3.6 umbilical retrieval

As discussed in the project description (Section 4), there are several potential options for umbilical retrieval. In the alternatives analysis, the overall impacts of using a reverse reel method or a recover and cut on vessel deck method were considered broadly similar. As a result, these options have been combined for consideration in the subsequent assessment. The two alternatives that CAPL considered for umbilical retrieval are outlined in Table 5-17.

Table 5-17: Umbilical retrieval alternatives overview

Concept	Overview
Option 1—Recover and cut on deck / reverse reel	• Umbilicals are recovered onto a reel or secured through tensioners, then cut on the vessel deck into manageable sections and bundled. • The cut sections are then offloaded to a supply vessel or barge for transportation to a disposal facility. • Recovery rate would be ~2.4–3 km/day.
Option 2—Reverse carousel	• Umbilicals are recovered onto a carousel on a vessel and delivered to quayside in the carousel vessel. • The umbilicals would then be unspooled onshore and cut into manageable sections for subsequent disposal. • Recovery rate would be ~6–7 km/day.

Table 5-18 details the comparative assessment of the umbilical retrieval alternatives against the environmental criteria (Section 5.1.1); Table 5-19 assesses them against the criteria for the other focus areas.

Table 5-18: Assessment of environmental criteria for umbilical retrieval alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Recover and cut on deck/Reverse reel		Option 2—Reverse carousel	
Physical presence	Seabed disturbance	Minimal seabed disturbance.	2	Minimal seabed disturbance.	2
	Interaction with marine fauna	Extended duration of vessels in field	3	Shorter duration.	2
Emissions	Underwater sound	Noise generation from vessel activity. Longer duration of vessel spread in the field.	3	Less offshore time in the field, therefore shorter duration of noise emissions.	2
	Atmospheric and GHG	More emissions due to longer duration of vessel spread in field.	3	Less offshore time in field and therefore less overall GHG emissions. A larger vessel may be required for the carousel option, which would use more fuel.	2
	Light	No material difference. Although the duration of this option is longer because of distance from shore (~60-190 km), there is no difference in impact.	2	No material difference.	2
Discharges	Planned discharges	No material difference.	2	No material difference.	2
	Accidental releases	Some potential for residual chemical release on vessel deck during cutting.	2	Minimal potential for residual chemical release on vessel deck due to significantly less cutting on the vessel.	1
Introduction of IMP	IMP	No material difference.	2	No material difference.	2
Environment total:		**19**		**15**	

Table 5-19: Assessment of other focus area criteria for umbilical retrieval alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Recover and cut on deck/Reverse reel		Option 2—Reverse carousel	
Technical feasibility	Operability and feasibility	Technically feasible	Feasible.	1	Feasible.	1
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference.	2
		Feasibility to construct	N/A		N/A	

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Recover and cut on deck/Reverse reel		Option 2—Reverse carousel	
	Constructability, re-usability and decommissioning feasibility	Re-usability	Umbilical is cut; limited re-usability.	4	Recovered as whole as it can be. Could potentially be repurposed, depending on capacity of the carousel and length of umbilical recovered.	3
		Feasibility of decommissioning	N/A		N/A	
Safety	Safety and risk	OHS and risk exposure	Greater risk to personnel of contaminants if cutting on deck. More cutting activities offshore.	3	Less cutting activities offshore; more cutting onshore.	2
		Process safety	N/A		N/A	
Commercial	Schedule risk	Ability to meet the development timeline	Slower recovery time but more flexibility in implementation.	2	Quicker recovery time, but vessel and reel availability may present challenges.	3
	Cost risk	Economic viability	Lower cost vessel spread, slightly lower recovery time, but likely more cost effective.	1	Higher cost vessel spread, but quicker recovery time.	2
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Greater potential impact to marine fauna, primarily from underwater sound and GHG emissions and physical interaction. No material difference for impact to benthic habitats.	3	Less potential impact to marine fauna, primarily from underwater sound and GHG emissions and physical interaction. No material difference for impact to benthic habitats.	1
Other focus areas total:			**22**		**20**	
Total score (including environmental scores):			**41**		**35**	

The comparative environmental assessment shows a small difference in environmental criteria between the two options, with Option 2 ranked as more favourable. Option 2 involves an umbilical retrieval rate that is almost double that of Option 1. Therefore, impacts and risks associated with vessel activities are greater for Option 1 due to the longer duration of vessels in the field.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed differences in individual criteria ranking but produced the same total score for both options.

The total qualitative ranking score for each option shows Option 2 is ranked better than Option 1, due to the lower environmental score. Option 2 relies on the availability of a suitable vessel and reel spread, both of which may present challenges. As a result, both options were selected for the OPP (see Section 5.3.7).

The umbilical retrieval option determined to be the most favourable, based on all criteria, is Option 2—Reverse carousel. However, this option has risks associated with the feasibility of the technique. To allow for potential future technological advancement, both options will be included in the OPP.

5.3.7 options to be selected after OPP phase

OPPs are written early in project development, therefore some activity and design options will not be finalised until later in the project design phase, which will likely occur after the OPP phase.

The Development has a long project life (end of life is ~2070) and the OPP framework under the OPGGS(E)R does not have a change mechanism. Consequently, the alternatives analysis process for the design and activity options (Section 5.3) identified some instances where multiple options need to be included in the OPP.

For the decommissioning options, CAPL considered methodologies and technologies that may not be feasible at the time of writing this OPP but may become available towards the end of field life. This allows flexibility to select the methodology with the best environmental outcome at the time.

Table 5-20 summarises the key options that will be selected after the OPP is submitted. All these options are included in the description (Section 4) and are within the scope of this OPP.

These options may have different impacts and risks; therefore Table 5-20 identifies which option presents the worst-case for specific key aspects. These options will be used for the impact assessment in Section 8 to ensure the option that presents the greatest potential environmental impact is assessed.

For example, the moored MODU option presents the worst-case for seabed disturbance; however, the DP MODU option presents the worst-case for underwater sound emissions. In this example, Section 8.1 Seabed Disturbance will assess the moored MODU option, and Section 8.5 Underwater Sound will assess the DP MODU option.

Table 5-20: Design and activity options included in the OPP

Activity / Design option	Option overview	Key aspects for impact assessment	Implications / discussion
MODU type	Moored MODU	Seabed disturbance	Moored and DP MODUs have similar total scores in the comparative environmental assessment, but the scores vary on some specific criteria. Moored MODUs impact the seabed due to anchoring and have greater potential to interact with marine fauna compared to a MODU on DP. Jack-up MODUs impact the seabed, but to a lesser extent than Moored MODUs. DP MODUs cause more underwater sound and atmospheric emissions compared to moored MODUs.
	DP MODU	Underwater sound Atmospheric emissions	
	Jack-up MODU	Seabed disturbance	
Flowline retrieval	Cut and lift	Seabed disturbance Planned emissions and discharges Physical presence	The cut and lift option is much slower than reverse lay. Therefore, impacts and risks associated with vessel activities are greater for cut and lift due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of flowline retrieval used for impact assessment in Section 8 was based on the cut and lift option. Cut and lift also requires disturbance of the seabed around each cut site to allow access for the cutting tools. However, reverse lay for this size of pipe and water depth is not currently feasible at time of writing. It may become a more feasible option in future, which is why both options are selected.
	Reverse S-lay / J-lay	Introduction of IMPs	
Umbilical retrieval	Recover and cut on deck / reverse reel	Planned emissions and discharges Physical presence	Recover and cut on deck / reverse reel is slower than reverse carousel. Therefore, impacts and risks associated with vessel activities are greater for recover and cut / reverse reel due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of umbilical retrieval used for impact assessment in Section 8 was based on the recover and cut on deck / reverse reel option. Both options are included in this OPP because the availability of the vessel capability and reel spread may present challenges.
	Reverse carousel	N/A. There is no material difference in key aspects.	

6 description of the environment

6.1 environment that may be affected

The EMBA by the petroleum activity within scope of this OPP has been defined as an area where a change to environmental receptors may potentially occur as a result planned activities or unplanned events.

For this OPP, CAPL has defined sub-areas of the EMBA that are used to support the subsequent impact and risk assessments (Table 6-1, Figure 6-1, Figure 6-2). The term 'EMBAs' within this section refers to the definitions in Table 6-1.

Table 6-1: Description of EMBAs and associated areas for the Development

EMBA sub-area	Description and purpose
Development Area (DA)	As described in Section 4.1.3, the DA is the area in which the petroleum activities will be undertaken.
Unplanned Hydrocarbon Release Ecological EMBA (Hydrocarbon Ecological EMBA)	The Hydrocarbon Ecological EMBA is relevant to the risk assessments for ecological receptors from unplanned hydrocarbon release events (Sections 8.14 and 8.15), and is determined by the predicted spatial extent of hydrocarbon exposure at the relevant thresholds (Table 6-2, Figure 6-1).
Unplanned Hydrocarbon Release Social EMBA (Hydrocarbon Social EMBA)	The Hydrocarbon Social EMBA is relevant to the risk assessments for social, economic, and cultural receptors from unplanned hydrocarbon release events (Sections 8.14 and 8.15), and is determined by the predicted spatial extent of hydrocarbon exposure at the relevant thresholds (Table 6-2, Figure 6-2). The Hydrocarbon Social EMBA incorporates lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil but are below concentrations at which ecological impacts are expected to occur.

The above approach to defining the spatial extent of the EMBA is considered to be consistent with NOPSEMA's 2019 oil spill modelling environment bulletin (Ref. 86).

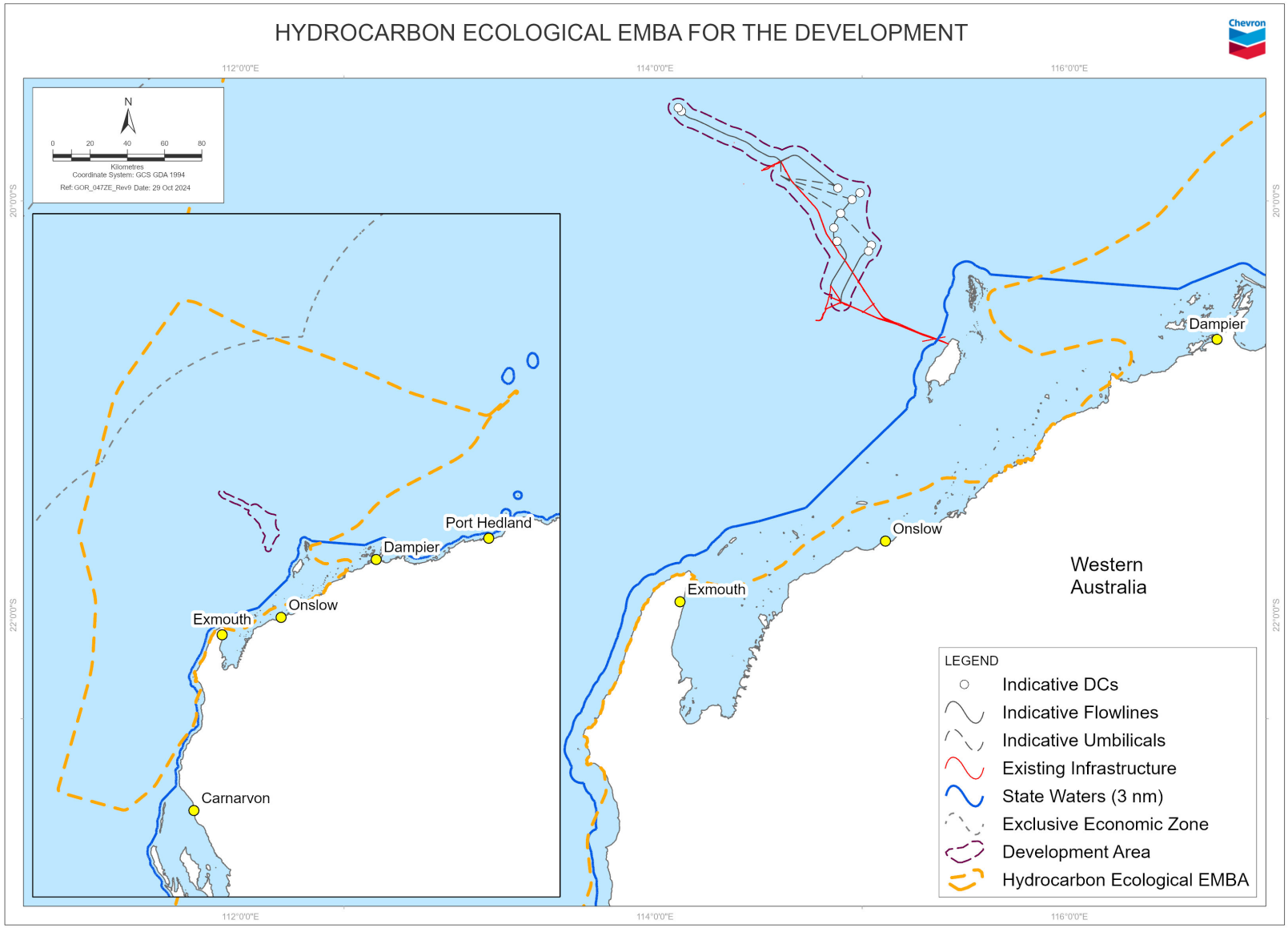


Figure 6-1: Hydrocarbon Ecological EMBA for the Development

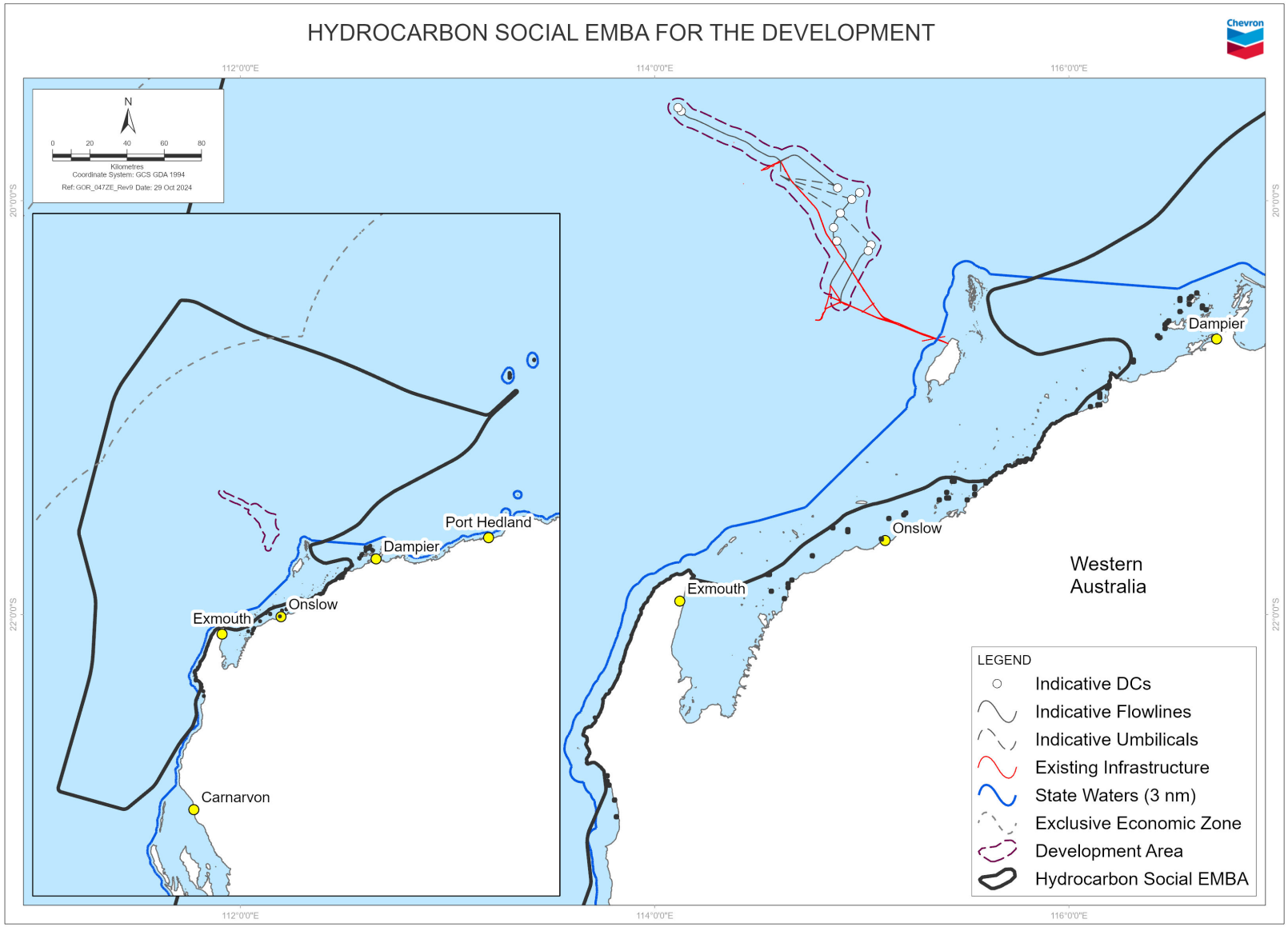


Figure 6-2: Hydrocarbon Social EMBA for the Development

The Hydrocarbon EMBAs above are determined by the predicted spatial extent of hydrocarbons from stochastic spill modelling (appendix c). Table 6-2 describes the modelled hydrocarbon exposure thresholds.

Table 6-2: Hydrocarbon environmental exposure thresholds

Threshold type	Threshold level	Justification
Hydrocarbon Social EMBA	Surface ≥1 g/m^2 (low)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the surface impact threshold for socio-economic effects at ≥1 g/m^2, which is equivalent to ~1,000 L/km^2 or a layer thickness of ~1 µm. At this concentration, oil on the water surface is expected to be visible. The Bonn Agreement Oil Appearance Code (Ref. 87) describes a 0.3–5.0 µm thick oil layer as having a rainbow-coloured appearance. Due to this visibility, there is the potential to impact nature-based activities (such as tourism) via a reduction in aesthetics.
Hydrocarbon Ecological EMBA	Surface ≥10 g/m^2 (moderate)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the surface impact threshold for ecological effects at ≥10 g/m^2, equivalent to ~10,000 L/km^2 or a layer thickness of ~10 µm. The Bonn Agreement Oil Appearance Code (Ref. 87) describes a 5–50 µm thick oil layer as having a metallic appearance. This threshold is considered by NOPSEMA to approximate the lower limit of harmful effects to birds and marine mammals (Ref. 86), and is consistent with observations within literature ranging from physical oiling to toxicity effects for marine fauna (e.g. French et al. [Ref. 88], French-McCay [Ref. 89] Engelhardt [Ref. 90], Clark [Ref. 91], Geraci and St. Aubin [Ref. 92] and Jenssen [Ref. 93]).
Hydrocarbon Ecological EMBA Hydrocarbon Social EMBA	In-water (dissolved) ≥50 ppb (moderate)	Laboratory studies have shown that dissolved oil exerts most of the toxic effects of oil on aquatic biota (e.g. Carls et al. [Ref. 94], Nordtug et al. [Ref. 95], Redman [Ref. 96]). Dissolved oil, which is soluble, can be taken up by organisms directly from the water column by absorption (through external surfaces and gills) and/or ingestion. In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the in-water (dissolved) impact threshold for sublethal ecological effects at ≥50 ppb, which is considered by NOPSEMA to approximate potential toxic effects, particularly sublethal effects to sensitive species (Ref. 87). This threshold is based on an instantaneous concentration, and therefore only requires the dissolved oil to be at this concentration for one hour (based on minimum model time-step) to trigger this threshold.
Hydrocarbon Ecological EMBA Hydrocarbon Social EMBA	In-water (entrained) ≥100 ppb (high)	Entrained oil is insoluble droplets suspended in the water column—exposure pathways are direct contact with external tissue or direct oil consumption. In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the in-water (entrained) impact threshold for sublethal ecological effects at ≥100 ppb, which is considered by NOPSEMA as appropriate for informing risk evaluation (Ref. 87). This threshold is based on an instantaneous concentration, and therefore only requires the entrained oil to be at this concentration for one hour (based on minimum model time-step) to trigger this threshold. French-McCay (Ref. 97) identified that if total hydrocarbons in entrained oil droplets was to be evaluated as a risk, 100 ppb would be an extremely conservative sublethal threshold.
Hydrocarbon Social EMBA	Shoreline	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the shoreline impact threshold for

Threshold type	Threshold level	Justification
	≥10 g/m^2 (low)	socio-economic effects at ≥10 g/m^2, equivalent to ~10 mL/m^2 or ~2 teaspoons/m^2. At this concentration, oil on the shoreline is expected to be visible. Due to this visibility, there is the potential to impact nature-based activities (such as tourism or recreational use) via a reduction in aesthetics.
Hydrocarbon Ecological EMBA	Shoreline ≥100 g/m^2 (moderate)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 86), CAPL has set the shoreline impact threshold for ecological effects at ≥100 g/m^2, equivalent to ~100 mL/m^2 or ~20 teaspoons/m^2. French et al. (Ref. 88) and French-McCay (Ref. 89) define shoreline oil accumulation at ≥100 g/m^2 as potentially harmful to wildlife (including invertebrates, birds, furbearing aquatic mammals and marine reptiles), based on studies for sublethal and lethal impacts. Impacts on vegetated habitats (such as saltmarsh and mangroves) have been observed at higher concentrations of shoreline oil. Observations by Lin and Mendelssohn (Ref. 98) demonstrated that loadings of >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 (e.g. Grant et al. [Ref. 99], Suprayogi and Murray [Ref. 100]).

The following sections describe the environment in relation to the DA and EMBAs for the Development.

6.2 matters of national environmental significance

MNES are protected under the EPBC Act (Cth). The presence of MNES within the EMBA has been determined from the Australian Government's online Protected Matters Search Tool (PMST) (Ref. 122). Table 6-3 summarises the presence of relevant marine and/or coastal MNES within the EMBA; the full PMST reports[37] are included in appendix b.

It should be noted that the EPBC Act PMST is a general database that conservatively identifies areas in which protected species have the potential to occur.

Table 6-3: Presence of MNES within the EMBA

MNES	DA	Hydrocarbon Ecological and Social EMBA
World Heritage properties^	×	✓
National Heritage places^	×	✓
Wetlands of international importance (Ramsar wetlands)^	×	×
Nationally listed threatened species and communities^	✓ species × communities	✓ species × communities
Nationally listed migratory species^	✓	✓

[37] The PMST is a general database that includes all MNES, including species or features (such as terrestrial-based species or features) that are not expected to credibly occur within the EMBA.

MNES	DA	Hydrocarbon Ecological and Social EMBA
Commonwealth marine area^	✓	✓
Great Barrier Reef Marine Park	×	×
Nuclear actions (including uranium mining)	–	–
Water resources (in relation to coal seam gas or large coal mining development)	–	–

^ These MNES are also identified as relevant values and sensitivities under the OPGGS(E)R.
Where ✓ = present, × = not present, and – = not relevant to the Development.

6.3 ecosystems and their constituent parts including people and communities

6.3.1 benthic habitats and associated communities

Benthic communities are biological communities that inhabit the seabed and are important for primary or secondary production. Benthic habitats are areas of seabed that do or can support these communities. Benthic communities play important roles in maintaining the integrity of marine ecosystems and the supply of ecological services. There is strong evidence that benthic communities are important for maintaining biological diversity by providing structurally complex and diverse habitat, refuge for vulnerable life stages, and a varied and increased food supply (Ref. 101).

The EMBA occurs within the North-west Marine Region (NWMR), which is typically characterised by shallow-water tropical marine ecosystems and high species richness (Ref. 102, Ref. 103). The high species richness is thought to be associated with the diversity of habitats available, such as limestone pavement, coral reefs, and pinnacles (Ref. 102). The broader benthic habitats and communities that may be present within the EMBA are summarised below, with additional data specific to the DA summarised in Section 6.3.1.1.

The geomorphology of Australia's continental margin is varied. Preliminary mapping of seabed geomorphology identified eight broad geomorphic feature types—mostly bare sediments, bedforms, irregular seabed, mounds, depression/scours, rock veneer, rock reef and scarp (Ref. 104; appendix a).The primary geomorphic features include the continental shelf, the upper, middle, and lower continental slope, the Kangaroo Syncline (deepwater area separating Barrow Island from the Exmouth Plateau), and the Exmouth Plateau (see Section 6.3.1.1; Ref. 104; appendix a).

Surveys in the NWMR have recorded a diverse species inventory, comprising infauna (organisms inhabiting the seabed sediments) dominated by marine worm, polychaete worms and crustaceans (Ref. 539). For example, a benthic study for Woodside in the NWS identified worms and polychaetes, concluding that these are representative of tropical deepwater soft sediment habitats reported in the region (Ref. 114). In offshore, deeper regions, epifauna (benthic organisms on the seabed) are typically sparse and patchy in distribution, often associated with areas of hard substrate. The presence of epifauna is closely linked to substrate type, with hard substrates generally supporting more diverse benthic communities (Ref. 115). Offshore seabed surveys across the region have observed a general reduction in epibenthic coverage with increasing depth (Ref. 103; Ref. 106).

The composition, distribution, and movement of marine sediments is an important component of a marine ecosystem. These sediments can influence the primary biological production in the water column as well as the evolution and distribution of benthic habitats. The north-west region of WA comprises bio-clastic, calcareous, and organogenic sediments deposited from relatively slow and uniform sedimentation rates (Ref. 105). Sediments in the NWMR generally become finer with increasing water depth, ranging from sand and gravels on the continental shelf to mud on the continental slope and abyssal plain (Ref. 106).

Based on the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) marine benthic substrate database (Ref. 107), the predominant seabed sediment type within the DA is 'calcareous gravel, sand and silt'. Within the Hydrocarbon EMBAs, four seabed sediment types were identified —'calcareous gravel, sand and silt', 'calcareous ooze', 'Biosiliceous marl and calcareous clay', and 'mud and calcareous clay'.

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) is a biogeographic regionalisation of oceanic waters within Australia's exclusive economic zone (EEZ) (Ref. 108). The DA occurs within the Northwest Province and Northwest Shelf Province bioregions. The Hydrocarbon EMBAs also intersect with the Northwest Transition, Central Western Transition, Central Western Shelf Transition, Central Western Shelf Province bioregions. Table 6-4 summarises the geomorphology characteristics, biological communities, and features or areas of ecological importance for each of these bioregions.

Listed Threatened Ecological Communities (TECs) are an MNES under the EPBC Act, and a relevant value and sensitivity under the OPGGS(E)R. There are no known TECs within the EMBA.

Table 6-4: Features of provincial bioregions

IMCRA provincial bioregion[38]	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Northwest Province	✓	**0**	✓
Geomorphic and biological characteristics of the Northwest Province include: • bioregion occurs entirely on the continental slope and comprises muddy sediments • distinguished by a number of topographic features, such as the Exmouth Plateau, terraces and canyons (including the Swan and Cape Range canyons), as well as deep holes and valleys on the inner slope (including the Montebello Trough) • the benthic shelf and slope communities of this bioregion comprise both tropical and temperate species with a north-south gradient • the continental slope between North West Cape and the Montebello Trough has been identified as one of the most diverse slope habitats of Australia • the Exmouth Plateau is also likely to be an important area for biodiversity as it provides an extended area offshore for communities adapted to depths of ~1,000 m • based on information available on sediments in the bioregion: – benthic communities are likely to include filter feeders and epifauna – soft-bottom environments are likely to support patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea pens – biological communities within canyons in the bioregion are poorly understood.			

[38] Source: Ref. 103.

IMCRA provincial bioregion[38]	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Features and areas of ecological importance within the Northwest Province are: • Exmouth Plateau • canyons on the slope, including the Cape Range Canyon • demersal fish communities associated with the slope. Of these features and areas within the Northwest Province, the demersal fish communities and Exmouth Plateau associated with the slope occurs within the DA and Hydrocarbon EMBAs. The canyons on the slope also occur within the Hydrocarbon EMBAs. Section 6.3.6.1 has further descriptions of these features.			
Northwest Shelf Province	✓	**0**	✓
Geomorphic and biological characteristics of the Northwest Shelf Province include: • bioregion occurs almost entirely on the continental shelf, except for a small area north of Cape Leveque that extends onto the continental slope • the continental shelf gradually slopes from the coast to the shelf break, but displays a number of sea floor features such as banks/shoals and holes/valleys, including: – Glomar Shoals, which occur in waters ~33–77 m deep and are distinguished by highly fractured molluscan debris, coralline rubble, and coarse carbonate sand (Ref. 109) – Leveque Rise (large plateau), one of only two shelf plateaux within the NWMR – tidal sandwaves or sandbanks (~5–10 m high), which occur on the innermost reaches of Exmouth Gulf, and are one of only three major occurrences of this type of feature in the NWMR – shelf, which also contains several terraces and steps that extend into adjacent bioregions and reflect ancient coastlines from when the sea level in the NWMR was lower; the most prominent of these occurs at a water depth of ~125 m. • sediment differentiation occurs on a north–south gradient: – south of Broome, sediment is relatively homogenous and dominated by sands with small proportion of gravel – north of Broome, sediment is highly variable with sand or gravel dominance in no discernible spatial pattern – mud increases within ~100 km of the coast and within ~100 km of the shelf break but is mostly absent from other areas. • sandy substrates on the shelf within this bioregion are thought to support low-density benthic communities of bryozoans, molluscs, and echinoids • sponge communities are also sparsely distributed on the shelf but are found only in areas of hard substrate. Features and areas of ecological importance within the Northwest Shelf Province are: • Browse Island and surrounding waters • Lacepede Islands and surrounding waters • Quondong Point, north of Broome and surrounding waters • west coast of the Dampier Peninsula, including Beagle and Pender bays and surrounding waters • Pilbara coast (between Exmouth and Broome) and surrounding waters • Exmouth Gulf—Muiron Islands and surrounding waters • ancient coastline at 125 m depth contour • Glomar Shoals. Of these features and areas within the Northwest Shelf Province, the ancient coastline at 125 m depth contour occurs within the DA and Glomar Shoals, Exmouth Gulf—Muiron Islands and surrounding waters (partially), and the Pilbara coast (partially) occur within the Hydrocarbon EMBAs. Section 6.3.6.1 has further descriptions of the ancient coastline at 125 m depth contour and Glomar Shoals features.			

IMCRA provincial bioregion[38]	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Northwest Transition	–	**56.6**	✓
Geomorphic and biological characteristics of the Northwest Transition include: • about half of the bioregion occurs on the continental slope, with smaller areas in the north-west of the bioregion located on the Argo Abyssal Plain and continental rise • encompasses a range of water depths, from the shelf break (~200 m water depth) to ~5,980 m over the Argo Abyssal Plain • other topographic features within the bioregion include rises, ridges, canyons and apron/fans • sediments of the slope are dominated by sands, whereas the sediments of the abyssal plain/deep ocean floor are dominated by muds • the bioregion also has reefs such as Mermaid, Clerke, and Imperieuse reefs, which are collectively known as the Rowley Shoals • the benthos of the deep ocean areas is likely to support meiofauna (e.g. nematodes), larger infauna (e.g. polychaete worms, isopods), and sparsely distributed epibenthic communities (e.g. sea pens) • mobile benthic species (e.g. deepwater sea cucumbers, crabs, polychaetes) are likely to be associated with the sea floor, and the bioregion may support sparse populations of bentho-pelagic fish and cephalopods in low densities. Features and areas of ecological importance within the Northwest Transition are: • Rowley Shoals—Mermaid Reef Marine National Nature Reserve, Clerke and Imperieuse reefs and surrounding waters • fish communities associated with the slope. Of these features and areas within the Northwest Transition, the demersal fish communities associated with the slope occurs within the DA and Hydrocarbon EMBAs. Section 6.3.6.1 has further descriptions of this feature.			
Central Western Transition	–	**207.7**	✓
Geomorphic and biological characteristics of the Central Western Transition include: • the bioregion is characterised by large areas of continental slope, with sediments dominated by muds and sands that decrease in grain size with increasing depth • about 40% of the bioregion occurs in water depths greater than 4,000 m and the deepest areas of the bioregion occur within the Cuvier Abyssal Plain at ~5,330 m • the continental slope is incised by numerous topographic features such as terraces (e.g. Carnarvon Terrace), canyons (e.g. Cloates and Carnarvon canyons) and rises • a large part of the bioregion comprises the Cuvier Abyssal Plain • Wallaby Saddle is another important topographic feature within this bioregion and is the most extensive area of this type of topographic feature in the NWMR • the benthic slope communities of this bioregion comprise both tropical and temperate species along a north-south gradient • the biological communities of the Central Western Transition are thought to be distinctive owing to the proximity of deep ocean areas to the continental slope and shelf, resulting in close interaction between pelagic species of the Cuvier Abyssal Plain and those of the slope and shelf • the harder substrate of the slope in waters of 200–2,000 m deep is likely to support populations of epibenthos such as bryozoans, sponges and encrusting coralline algae; these support larger infauna and benthic animals such as crabs, cephalopods, echinoderms and other suspension-feeding epibenthic organisms • in the deeper waters of the abyss, the benthic communities are likely to be sparse and include meiofauna (e.g. nematodes). . Features and areas of ecological importance within the Central Western Transition are: • Wallaby Saddle			

IMCRA provincial bioregion[38]	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
• Cape Range Canyon and Cloates Canyon. Of these features and areas within the Central Western Transition, the Cape Range Canyon and Cloates Canyon occurs within the Hydrocarbon EMBAs. Section 6.3.6.1 has further descriptions of this feature.			
Central Western Shelf Transition	–	128.2	✓
Geomorphic and biological characteristics of the Central Western Shelf Transition include: • bioregion is located entirely on the continental shelf and is comprised mainly of sandy sediments • this bioregion includes both State and Commonwealth waters between water depths of 0 m to ~80 m – Commonwealth waters in this bioregion represent <1% of the total area of the NWMR • the benthic ecological communities of the bioregion, include both tropical and temperate species transitioning along a north-south gradient • Ningaloo Reef[39] is the most significant geomorphic feature of this bioregion: – it extends along the Cape Range Peninsula for over 260 km, and is the only example in the world of an extensive fringing coral reef on the west coast of a continent – it is marked by a well-developed spur and groove system of fingers of coral formations penetrating into the ocean with coral sand channels in between – a lagoon on the inshore side separates Ningaloo reef from the mainland – the biological communities of the Ningaloo Reef differ from the hard coral reefs located elsewhere in the NWMR • a large proportion of this bioregion is covered by the State and Commonwealth Ningaloo Marine Parks, which are one of the most significant hotspots of biodiversity within the NWMR • the Ningaloo Marine Parks incorporate a diversity of habitats including the seabed of the continental slope and shelf that supports demersal and benthic plants and animals including fish, molluscs, algae, sponges, soft corals and burrowing bivalves; as well as coral reefs and intertidal areas such as rocky shores and mangroves in State waters. Features and areas of ecological importance within the Central Western Shelf Transition are: • Ningaloo Marine Park – North West Cape. Of these features and areas within the Central Western Shelf Transition, the Hydrocarbon EMBAs intersect with the Commonwealth and State Ningaloo Marine Parks. Section 6.5 has further descriptions of this feature.			
Central Western Shelf Province	–	415.6	✓
Geomorphic and biological characteristics of the Northwest Transition include: • bioregion is located on the Dirk Hartog Shelf and is generally very flat • a small area of reef and tidal sandwaves or sandbanks occur at the entrance to Shark Bay and within its vicinity • other topographic features include a deep hole and associated area of banks and shoals offshore of Kalbarri – the banks and shoals in this bioregion are of note because they occur at latitudes significantly south of banks and shoals elsewhere in the NWMR • sand is the dominant component of the sediments, with small amounts of gravel and muds – the substrate within Shark Bay itself is predominantly sandy, with a small area of temperate reef at the opening of the bay			

[39] Ningaloo Reef also extends into the Northwest Province, Central Western Transition Province, and a small portion of the Northwest Shelf Province. The geomorphology and biological communities of Ningaloo Reef are discussed in this bioregion summary.

IMCRA provincial bioregion[38]	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
• the bioregion is a transitional zone between the predominantly tropical flora and fauna of the north and temperate flora and fauna further south • biological communities of the shelf are likely to include a sparse invertebrate assemblage of sea cucumbers, urchins, crabs and polychaetes on sandier substrates; harder substrate areas are likely to contain sessile invertebrates such as sponges, gorgonians and more diverse fish than sandy habitats • fish communities predominantly comprise temperate species with very little distinction between coastal and shelf communities • Shark Bay is a declared World Heritage Area; the bay includes a diversity of habitats including areas of seagrass, sandy plains and rocky shoreline, shallow fringing coral reefs, sponge gardens and communities of bivalves and other mollusc species. Features and areas of ecological importance within the Central Western Shelf Province are: • Shark Bay—Dirk Hartog Island and surrounding waters. Of these features and areas within the Central Western Shelf Province, the Hydrocarbon EMBAs intersect with the Commonwealth Shark Bay Marine Park. Section 6.5 has further descriptions of this feature.			

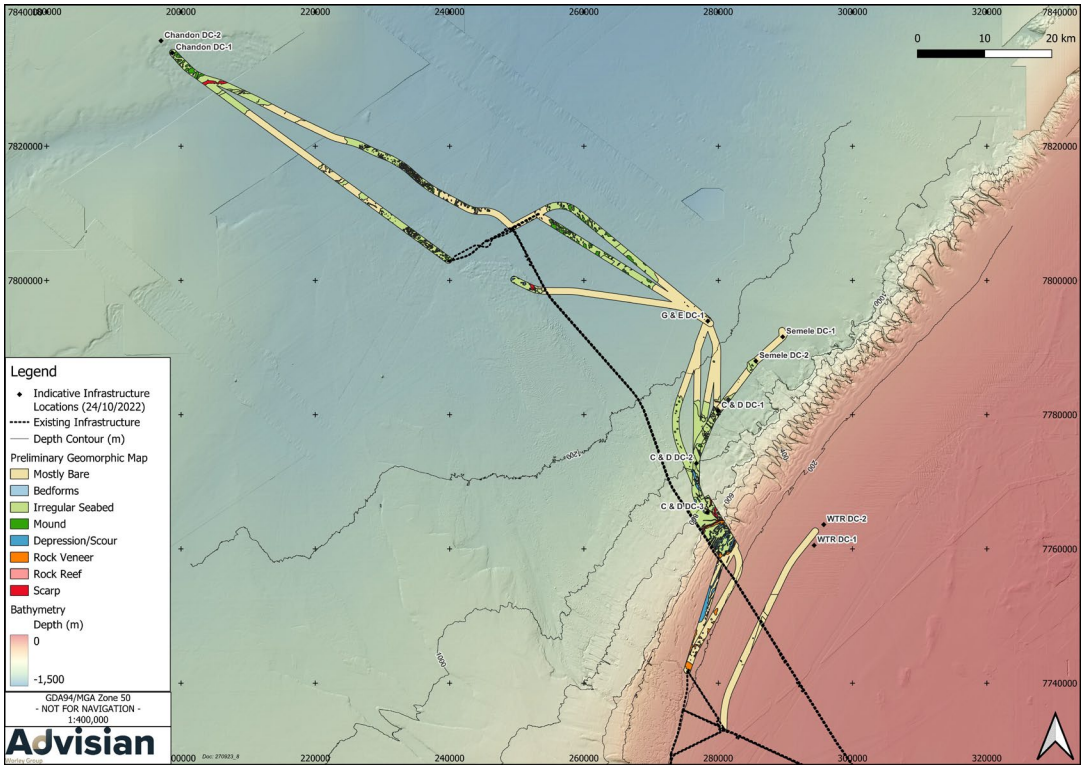
6.3.1.1 development area

A benthic survey was conducted at the Jansz–Io field and pipeline route in Commonwealth waters, which overlaps the western section of the DA, in waters depths ranging ~210 m to ~1,300 m (Ref. 741). The survey was undertaken at 18 sites along the Jansz-Io pipeline. Like other deep areas on the NWS, benthic fauna was depauperate, with low abundances, richness and diversity (Ref. 741).

An ROV video survey was undertaken at the Jansz–Io field and pipeline in Commonwealth waters, which overlaps the western section of the DA, in waters depths ranging from ~700–1,360 m, to assess the benthic habitats and fauna assemblages (Ref. 112). The video footage was collected between 2015 and 2018 across two separate areas, comprising a total of 37 sites (29 sites on existing infrastructure and eight sites away from Jansz–Io pipelines). In line with other studies at similar depth contours around Australia, species richness, diversity and abundance decreased with depth (Ref. 112). However, standardised comparisons showed overall diversity, abundance, and species richness were typically greater at sites on the surveyed infrastructure (Ref. 112).

In addition, CAPL conducted extensive surveys to characterise the marine environment within the DA (Ref. 104; appendix a).

Prior to these surveys, a preliminary benthic habitat map was developed based on an assessment of geomorphic features derived from sonar and seismic survey data. This mapping identified a total of eight broad geomorphic features (Figure 6-3). Based on the preliminary benthic habitat, the DA is dominated by bare and irregular bare seabed, which comprised over 75% of the mapped area. No canyon features were observed in the DA.



Source: Ref. 104; appendix a.

Figure 6-3: Preliminary benthic habitat map based on assessment of geomorphic features within the DA

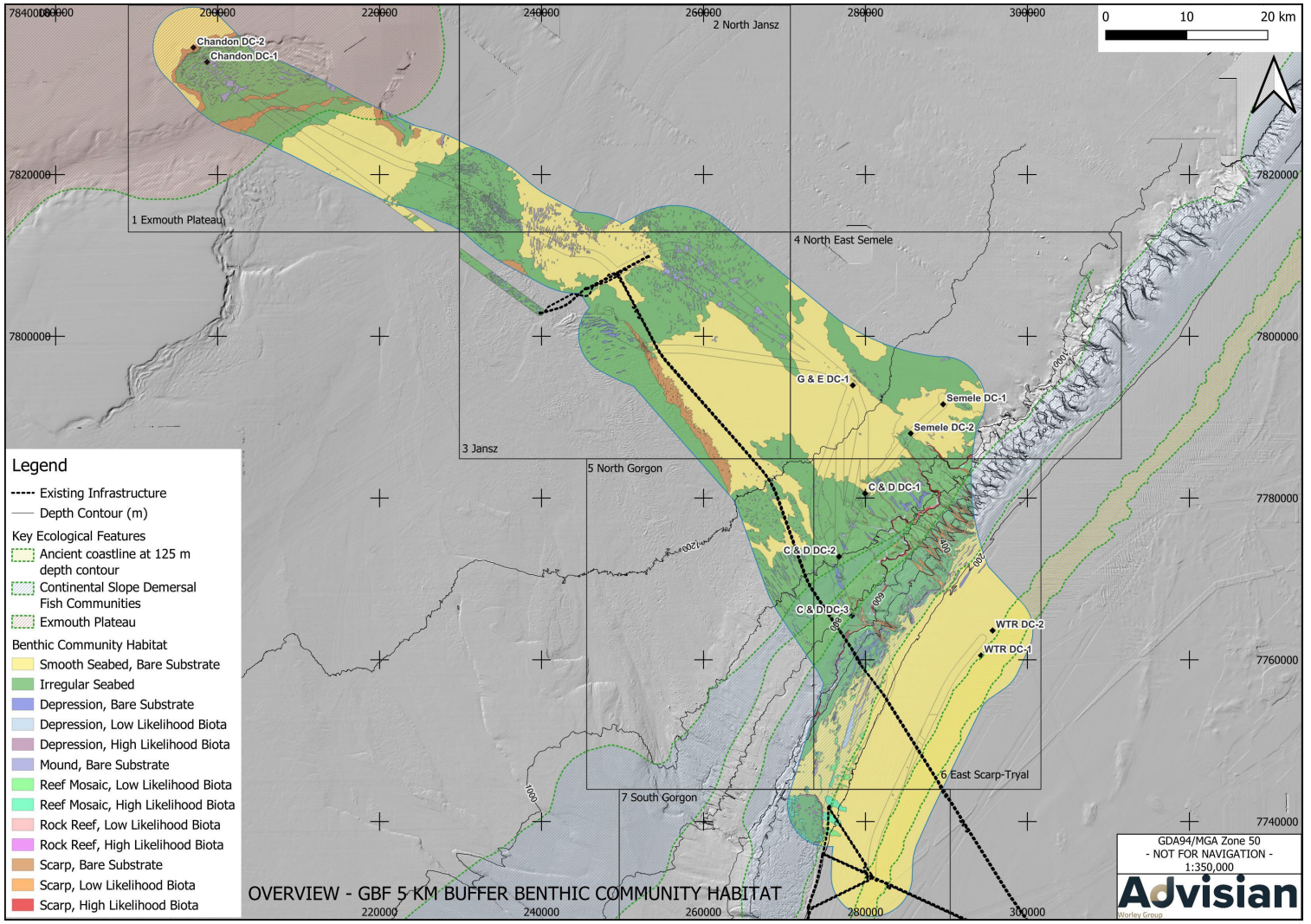
Field surveys were undertaken to collect data on benthic habitat, sediment, benthic infauna, marine water and fish assemblages within the DA. Site selection was based on predicted geomorphic features, KEF habitats, indicative infrastructure location and identified data gaps (Ref. 104; appendix a).

A total of 39 sites were surveyed around the proposed drill centres, tie-in locations, and associated subsea infrastructure (Ref. 104; appendix a). Of these, 14 sites (i.e. proposed drill centres and tie-in locations) were more discrete and surveyed to enable quantitative assessment of benthic cover (%). All 39 sites were classified using the collaborative and automated tools for analysis of marine imagery (CATAMI) classification scheme (Ref. 104; appendix a).

Broad-scale environmental data within the DA was subsequently developed using a supervised classification approach, integrating geophysical survey data and targeted ROV ground truthing footage (Ref. 104; appendix a). The resulting outputs were grouped by taxonomic levels for regional-scale assessment, as shown in Figure 6-4. A summary of the description of this benthic community habitats is provided in Table 6-5.

Overall, the distribution of benthic community and habitat (BCH) within the DA comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 108; Ref. 111). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed during the ROV visual ground-truthing (Ref. 104; appendix a).

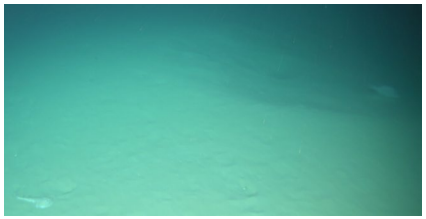
No endemic benthic infauna was identified in the survey (Ref. 104; appendix a).

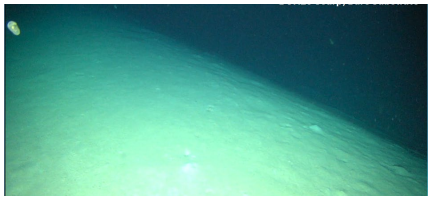


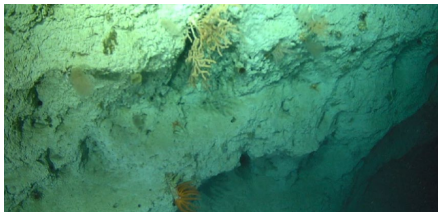
Source: Ref. 104; appendix a.

Figure 6-4 Overall distribution of benthic habitats within the Development DA, subdivided into seven broad areas (1 Exmouth Plateau, 2 North Jansz, 3 Jansz, 4 North East Semele, 5 North Gorgon, 6 East Scarp-Tryal, and 7 South Gorgon areas)

Table 6-5: Benthic community habitat description

Benthic community habitat	Description	Example image(s)
Smooth seabed, bare substrate	Featureless sedimentary terrain. Bathymetry is smooth with no identifiable features. It can comprise of fine or coarse sediment; the slope is typically <2° with no topographic features. No identifiable biological features on substrate but may include motile echinoderms and/or bioturbation.	
Irregular seabed	Mostly flat sediment terrain with minor features which may be derived from underlying geology. Bathymetry is smooth with identifiable, regular but small bedforms or mounds. Fine or coarse sediment. Slope is typically <2°, with minor topographic features.	
Depression, bare substrate	Local depression which may be geological or biological in origin (e.g. scour or pockmark). No identifiable biological features on substrate but may include motile echinoderms and/or bioturbation.	
Depression, low likelihood biota	Local depression which may be geological or biological in origin (e.g. scour or pockmark). Biota is typically absent. in areas of smooth or soft seabed, as indicated by low backscatter returns	No ROV transect footage of this type of habitat is available as it was outside of survey corridor. Habitat type mapped east of the scarp in shallower waters using geophysical data sources only.
Depression, high likelihood biota	Local depression which may be geological or biological in origin (e.g. scour or pockmark). Biota is typically present in areas of hard or raised substrate, as indicated by high backscatter returns and/or ROV visual verification.	

Benthic community habitat	Description	Example image(s)
Mound, bare substrate	Locally elevated sediment or rock veneer feature. Typically, an isolated, smooth edged feature with no structure which may be geological or biological in origin. Bathymetric features are measurable in profile. Slope can be varied, but smooth. No identifiable biological features on substrate but may include motile echinoderms and/or bioturbation.	
Reef mosaic, low likelihood biota	Irregular or patchwork arrangement of bedrock or other consolidated material outcrops over a large area. Rough bathymetric features measurable in profile. Varied and complex slope. Biota is typically absent in areas of smooth or soft seabed, as indicated by low backscatter returns and/or ROV visual verification.	
Reef mosaic, high likelihood biota	Irregular or patchwork arrangement of bedrock or other consolidated material outcrops over a large area. Rough bathymetric features measurable in profile. Varied and complex slope. Biota is typically present in areas of hard or raised substrate, as indicated by high backscatter returns and/or ROV visual verification.	
Rock reef, low likelihood biota	Bedrock or other consolidated material outcrop. Rough bathymetric features measurable in profile. Varied and complex slope. Biota is typically absent in areas of smooth or soft seabed, as indicated by low backscatter returns.	No ROV transect footage of this type of habitat is available as it was outside of survey corridor. Habitat type mapped east of the scarp in shallower waters using geophysical data sources only.
Rock reef, high likelihood biota	Bedrock or other consolidated material outcrop. Rough bathymetric features measurable in profile. Varied and complex slope. Biota is typically present in areas of hard or raised substrate, as indicated by high backscatter returns.	No ROV transect footage of this type of habitat is available as it was outside of survey corridor. Habitat type mapped east of the scarp in shallower waters using geophysical data sources only.
Scarp, bare substrate	Bedrock or other consolidated material outcrop, subject to landslide erosion. Rough bathymetric features measurable in profile. The slope is typically >15° and may have steep sides. No identifiable biological features on substrate.	

Benthic community habitat	Description	Example image(s)
Scarp, low likelihood biota	Bedrock or other consolidated material outcrop, subject to landslide erosion. Rough bathymetric features measurable in profile. The slope is typically >15° and may have steep sides. Biota is typically absent in areas of smooth or soft seabed, as indicated by low backscatter returns and/or ROV visual verification.	
Scarp, high likelihood biota	Bedrock or other consolidated material outcrop, subject to landslide erosion. Rough bathymetric features measurable in profile. The slope is typically >15° and may have steep sides. Biota is typically present in areas of hard or raised substrate, as indicated by high backscatter returns and/or ROV visual verification.	

Low likelihood biota: Sediment habitat coverage is likely to provide a less diverse and/or lower benthic assemblage than other habitat types

High likelihood biota: Raised geomorphic features with hard substrate potentially supports more extensive communities and provides refuge to epibenthic and encrusting biota

6.3.1.1.1 BCH at KEFs

The presence of benthic community habitats identified in the KEFs are listed in Table 6-6 and further described below.

Table 6-6: Summary of benthic community habitat at KEFs

Benthic community habitat	Exmouth Plateau KEF	Continental slope demersal fish communities KEF	Ancient coastline at 125 m depth contour
Smooth seabed, bare substrate	✓	✓	✓
Irregular seabed	✓	✓	—
Depression, bare substrate	—	✓	—
Depression, low likelihood biota	—	✓	—
Depression, high likelihood biota	—	✓	—
Mound, bare substrate	✓	✓	—
Reef mosaic, low likelihood biota	—	✓	—
Reef mosaic, high likelihood biota	—	✓	—
Rock reef, low likelihood biota	—	✓	—
Rock reef, high likelihood biota	—	✓	—
Scarp, bare substrate	✓	✓	—
Scarp, low likelihood biota	—	✓	—
Scarp, high likelihood biota	—	✓	—

Exmouth Plateau KEF

In the section of the Exmouth Plateau KEF that intersects with the DA (as shown in Figure 6-4), three large discrete scarps with bare substrate were identified int the habitat mapping (Figure 4-2 of the appendix a). Of these, two scarps ~5.5 km and 2.5 km from the KEF border, cross through the indicative Chandon flowline route from east to west, likely representing the edge of the Exmouth Plateau. The third scarp that runs from east to west is ~500 m wide and located ~1.4 km north of the Chandon DC-1. These scarps however, are devoid of epibenthic fauna as observed in the ground-truthing videos (Ref. 104; appendix a). It should be noted that limited field surveys were acquired along raised geomorphic features, including scarps, resulting in a moderate level of confidence in these areas.

The remaining and most dominant BCH were identified as relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota with significant habitat (Figure 6-4). Similar to the low slope areas, deep water areas of complex bathymetry appear to support sparse to no biota (Ref. 104; appendix a). It is probable that the spatial distribution of benthic biota across different benthic habitats depends on several factors such as water temperature, sediment characteristics, food availability, depth, and the nature of the underlying substrate.

Continental slope demersal fish communities KEF

Where the DA overlaps the continental slope demersal fish communities KEF, the most dominant BCH identified in the habitat mapping (Figure 6-4) were irregular and smooth seabed with bare substrates and discrete depressions of bioturbated sediments (Ref. 104, appendix a).

Larger scarps (in relation to the scarp adjacent to the furthest south C&D DC) are evident north, south and east of C&D DC. A mixture of BCH are predicted to extend along the indicative flowline from this DC to the indicative tie-in location. This includes the presence of a continuous south-west to north-east scarp with low and high likelihood of biota, discrete patches of depressions over bare substrate, and reef mosaic adjacent to the scarps with a low likelihood of biota.

Ground-truthing transects within the KEF showed sections of rock reef mosaic that cross through the C&D flowline are colonised by sponges and cnidarians (Ref. 104; appendix a).

Topographically complex scarps in a south-east to north-west orientation with both low and high likelihood of biota are predicted to be present traversing through the DA within the continental slope demersal fish communities KEF between ~400–800 m depths. Ground-truthing transects verified the presence of cnidarians, echinoderms, sponges and a mixture of these biotic groups along the scarps in varying percent cover (from low [<10%] to high cover [>80%]) (Ref. 104; appendix a).

Patches of reef mosaic with a low likelihood of biota, and rock reef and depressions with a high likelihood of biota are predicted to be present to the west of the C&D flowline, which are likely to support sponges and cnidarians, as verified by the ground-truthing transects. Based on the ground-truthing videos, a scarp orientated north to south with a high likelihood of biota is present ~650 m west of the Gorgon M1 tie-in location, and runs parallel to existing subsea infrastructure (Ref. 104; appendix a). Comprehensive ground-truthing conducted at and adjacent to indicative infrastructure locations confirmed the presence of these habitats within this KEF, supporting a high level of confidence in the mapping.

Ancient coastline at 125 m depth contour KEF

Mapping of the survey area that lies within the ancient coastline at 125 m depth contour KEF captured the indicative tie-in location at the Gorgon MPTS. Although the entire KEF is identified as having unique seafloor features comprising areas of hard substrate (Ref. 102), the BCH at Gorgon MPTS and the entire DA is predicted to comprised of smooth seabed with bioturbation and bare substrate (Figure 6-4, Table 6-6), and appears to be devoid of epibenthic biota (Ref. 104; appendix a). This may indicate a layer of soft substrate over consolidated hard substrate, which is unlikely to provide significant habitat to biota (Ref. 104; appendix a). Ground-truthing transects at the indicative tie-in location support these findings. However, due to the limited number of surveys and the variable resolution (ranging from low to high) of geophysical data in the area, the mapping should be interpreted with moderate confidence.

These results are comparable to previous studies of the Exmouth Plateau (Ref. 109), continental slope demersal fish communities (Ref. 102) and ancient coastline at 125 m depth contour (Ref. 113) that identified soft sediments (sand and mud/silt) as the dominant substrate type.

6.3.1.1.2 BCH at low slope areas

Low slope areas within the DA include flowlines and umbilical corridors situated outside KEFs in the lower slope and Kangaroo Syncline area. These areas are predicted to be characterised by low structural complexity/rugosity, with substrate composed of carbonate and clay muds (Ref. 104; appendix a).

Habitat mapping (Figure 6-4) indicated a mixture of low structural habitats present along the Chandon DC-1 to Jansz MPTS corridor. The BCH is predicted to be comprised by smooth seabed with bioturbation and irregular seabed with bare substrate, with intermittent mounds with bare substrate and scattered patches of depressions over bare substrate. No epifaunal communities were identified during the ground-truthing surveys across these low slope areas.

In the Jansz to G&E corridors, BCH are predicted to be consist of smooth seabed with bioturbation, irregular seabed with bare substrate, intermittent mounds, and scattered depressions. A continuous scarp with bare substrate was predicted to be parallel to existing subsea infrastructure, with small patches of low likelihood of biota. However, ground-truthing did not identify epifauna, likely due to thick sediment cover. Due to natural sediment transport processes and varying degree of smothering of consolidated substrates, BCH may be dynamic and as such, there is some uncertainty in the habitat classification around scarps in this area (Ref. 104; appendix a).

The BCH within the C&D to Gorgon corridor are predicted to be predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation. Along the corridor from Semele to C&D, scarps with both a low and high likelihood of biota, orientated north-west to south-east, were predicted ~500 m south of the proposed flowline. Ground-truthing transects along this indicative flowline have validated the presence of benthic biota, supporting a high level of confidence in the habitat mapping in this section (Ref. 104; appendix a).

6.3.1.1.3 BCH at DCs

The presence of benthic community habitats identified in or around the DCs are listed in Table 6-7 and further described below.

Table 6-7: Summary of benthic community habitat at DCs

Benthic Community Habitat	Chandon DC-1	Chandon DC-2	C&D DC-1	C&D DC-2 & DC-3	G&E DC-1	Semele DC-1	Semele DC-2	WTR DC-1 & DC-2
Smooth seabed, bare substrate	–	✓	✓	–	✓	✓	–	✓
Irregular seabed	✓	–	✓	✓	–	–	✓	–
Mound, bare substrate	✓	–	–	–	–	–	–	–
Scarp, bare substrate	–	✓	✓	–	–	–	–	–

Based on the results from the 14 surveyed sites around the proposed DCs and tie-in locations, a quantitative assessment of benthic cover was conducted. Bare substrate (soft unconsolidated sand/mud <2 mm) with no biota was the dominant benthic category (Table 6-7; Ref. 104; appendix a). Bioturbation with cnidarians was observed at site Gorgon M1 where they contributed to 1% of the overall cover. Bioturbation in bare sediment was also observed. Overall, the proposed drill centre and tie-in locations are considered to be relatively devoid of epifauna (Ref. 104; appendix a).

The seabed immediately surrounding Chandon DC-1 (i.e. extending ~5 km east and west, and ~6 km along the Chandon flowline) is comprised of bioturbated irregular seabed and large patches of depressions over bare substrate. The BCH at Chandon DC-2 were identified as smooth seabed and scarps, both dominated by bare substrate. Little to no biota is predicted to occur in these bare substrates.

The BCH around the indicative locations of the Semele DC-1 and Semele DC-2 associated flowlines is of low structural complexity and dominated by seabed with bioturbation. Similarly, the WTR DC-1 and G&E DC-1 are primarily comprised of smooth seabed (Figure 6-5 and Figure 6-6). Bioturbation and scattered patches of bedforms with bare substrate were also identified to the north and north-east of the indicative G&E DC-1 location (Figure 6-5). Ground truthing transects at each of these locations did not reveal any epifaunal communities.

At the proposed C&D DC-1, scarps orientated south-west to north-east with bare substrate (~60 m north and ~1 km south) were identified. Ground-truthing did no identified epifauna on these scarps. The BCH surrounding the proposed C&D DC-2, consists primarily of irregular seabed with bare substrate. Although higher or rougher topographic features were not identified in any of the captured still images, habitat mapping of the indicative C&D DC-3 location suggests that consolidated and steep scarps are likely to be present and may support benthic communities (Ref. 104; appendix a). The ground-truthing conducted at the indicative DCs confirmed the lack of complex seafloor structures, supporting a high level of confidence in the mapping.

Sediments samples for benthic infauna were collected across the DC. A total of five individual benthic infauna, belonging to three families across three phyla (Sipuncula, Annelida and Mollusca) were identified. The identified benthic infauna were located in both deep-sea sediments (1,100-1,200 m) and shallow seabed (100-200 m) as follows (Ref. 104; appendix a):

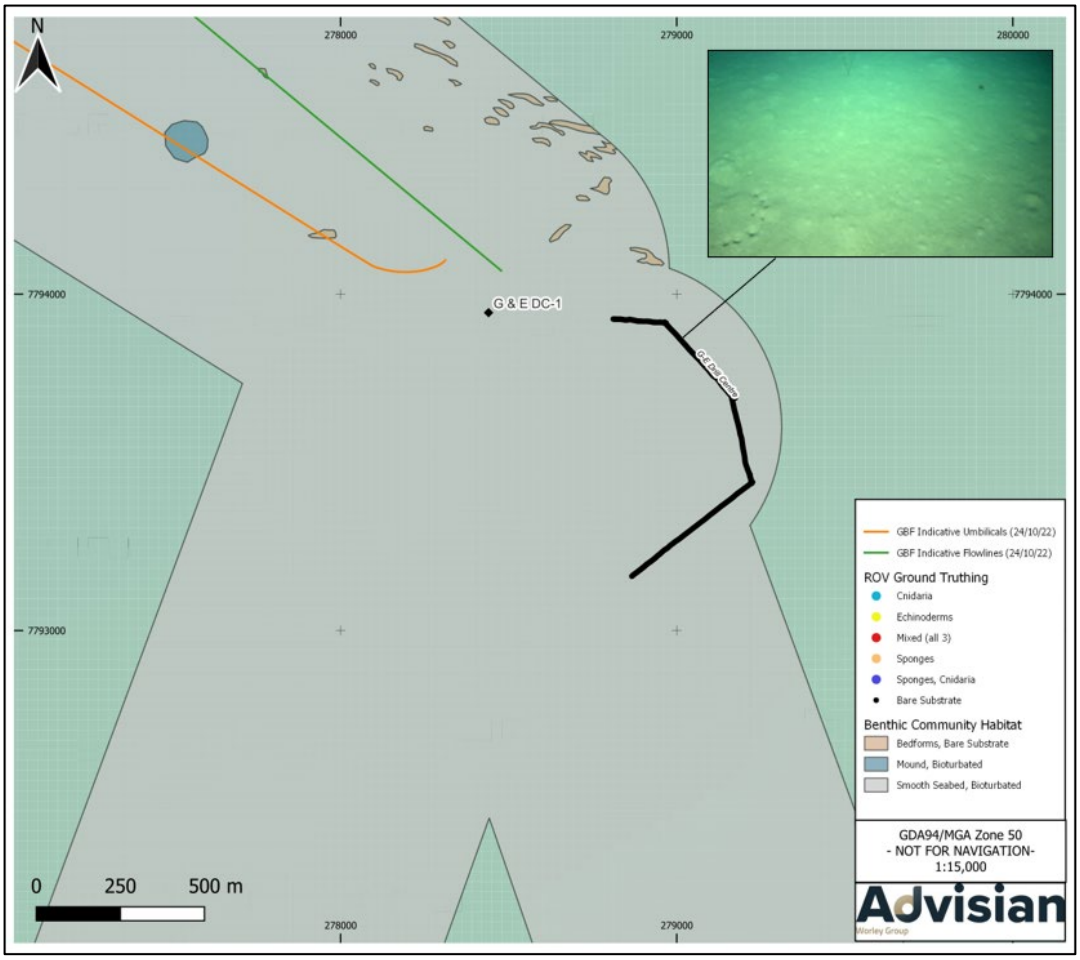
- Sipuncula (Sipuncula) around proposed drill centres Semele DC-1 and Semele DC-2
- Sipuncula (Sipuncula) and Polychaeta (Annelida) in the area around WTR DC-1
- Gastropod (Mollusca) in the indicative flowline transect around Chandon DC-1.

The benthic infauna collected, which included marine worms, a mollusc and a polychaete worm, is similar to those found in previous seabed surveys in the NWS region (Ref. 109; Ref. 114; Ref. 115), whereby polychaetes and crustaceans are the dominant epibenthic and infaunal invertebrates of soft sediment habitats. While the survey used ROV push corers which capture a smaller surface area compared to traditional box corers, the results are consistent with other surveys in the NWS region which have also recorded a sparse distribution of epifaunal and infaunal benthic biota, with abundances ranging from one to 47 individuals (Ref. 115; Ref. 114; Ref. 104; appendix a).

Furthermore, studies completed within the region indicate that benthic infauna composition in deep water habitats is generally lower in abundance than shallow water habitats of the region (Ref. 103; Ref. 106). Gage (Ref. 116) reported that the density of benthic fauna tends to be lower in deep water sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar. Regardless of the survey methodology associated with infauna, when considering the distribution of benthic habitat within the DA comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, which are typical of the Northern Carnarvon Basin (Ref. 109).

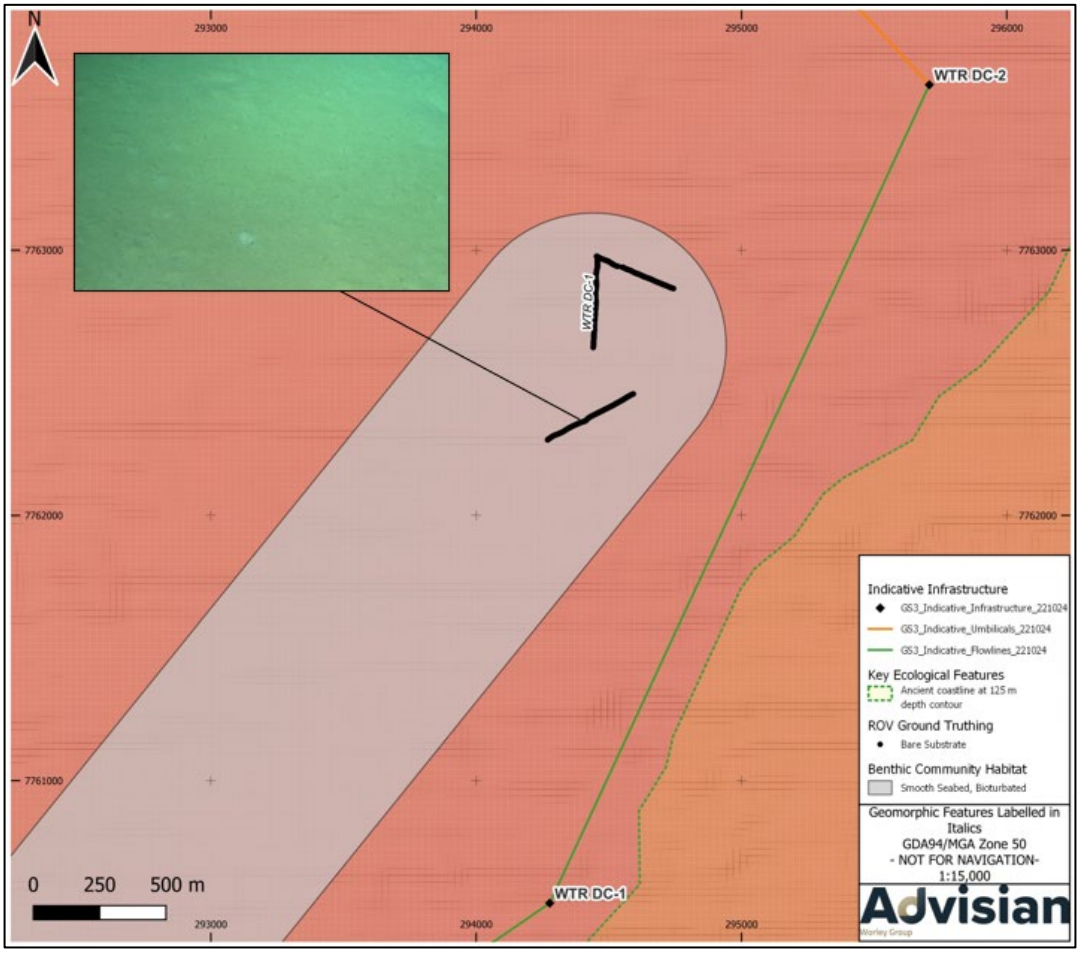
Based on others benthic habitat surveys identified in the region (Section 6.3.1, Ref. 109; Ref. 114; Ref. 115), no new benthic habitats or communities were observed, suggesting that the infauna communities within the wider DA are representative of infaunal communities within region.

The distribution of BCH around G & E DC-1, WTR DC-1 and Semele DCs are shown in Figure 6-5 to Figure 6-7.



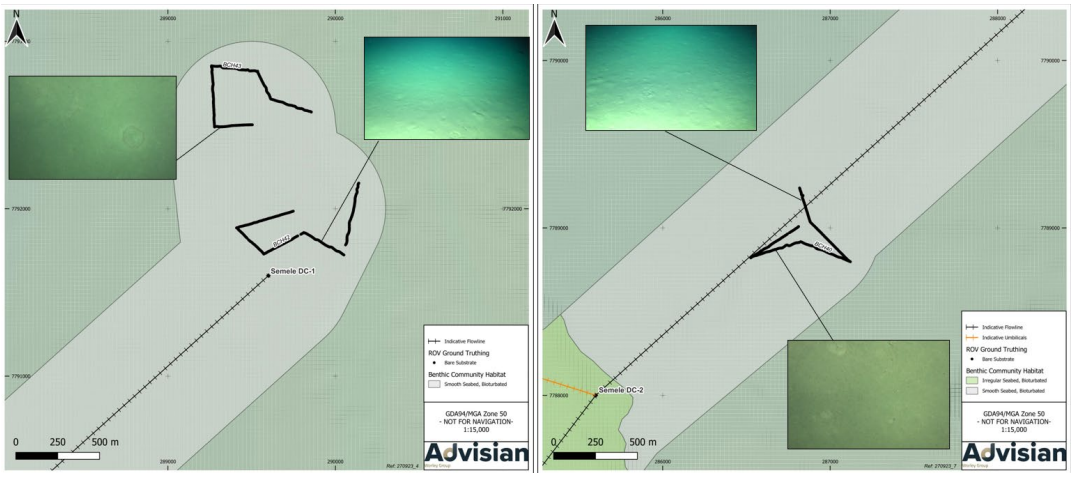
Source: Ref. 104; appendix a.

Figure 6-5: Distribution of benthic habitats within G&E DC-1 with representative images of the BCH



Source: Ref. 104; appendix a.

Figure 6-6: Distribution of benthic habitats within WTR DC-1 with a representative image of the BCH



Source: Ref. 104; appendix a.

Figure 6-7: Distribution of benthic habitats around Semele DCs with a representative image of the BCH

6.3.1.2 reefs, banks, and shoals

There are no shallow (<100 m water depth) complex bathymetric features within the DA. Rankin Bank and Glomar Shoal do occur within the broader Hydrocarbon

Ecological and Social EMBAs (Figure 6-8); key characteristics are described below.

6.3.1.2.1 rankin bank

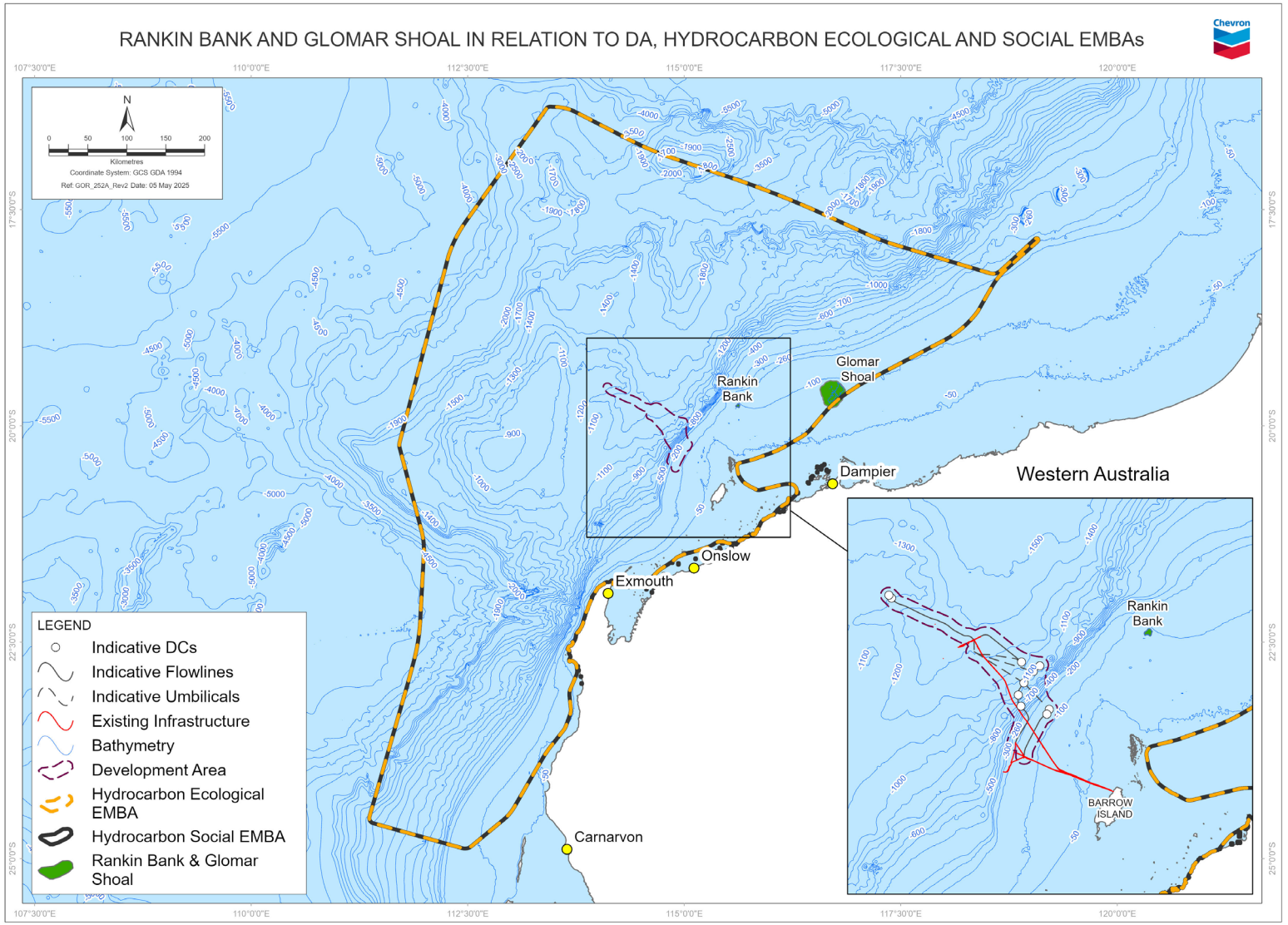
Rankin Bank is ~55 km east of the DA. Although Rankin Bank is not protected and is not a KEF, it is a large, complex bathymetrical feature on the outer western shelf of the west Pilbara region and represents habitats that are likely to play an important role in the productivity of the Pilbara region (Ref. 117). Rankin Bank has three submerged shoals delineated by the 50 m depth contour with water depths of ~18–30.5 m (Ref. 117). In 2013 and 2017, AIMS and Woodside co-invested in a project to better understand the habitats and complexity of the submerged shoal ecosystems. Rankin Bank represents a diverse marine environment, predominantly comprising consolidated reef and algae habitat (~55% cover), followed by hard corals (~25% cover), unconsolidated sand/silt habitat (~16% cover), and benthic communities comprising macroalgae, soft corals, sponges, and other invertebrates (~3% cover) (Ref. 117). The proportion of cover at Rankin Bank was highest for macroalgae and hard corals, particularly at depths <40 m, and cover decreased with increasing depth (Ref. 118). Encrusting corals (reaching cover of ~12.5%) at depths <40 m and solitary corals (~10% cover) primarily at 40–60 m depths were also present (Ref. 118). Other benthic taxa, including soft corals and sponges, were present in lower proportions at all depths (Ref. 118). The high cover of macroalgae and hard corals in shallower water depths are likely due to greater light penetration and lower sand cover (Ref. 118).

6.3.1.2.2 glomar shoal

Glomar Shoal is located ~165 km east of the DA. Glomar Shoal is a large (~215 km^2) and complex bathymetrical feature situated on the outer continental shelf off the Pilbara coast. Glomar Shoal is ~8.5 times wider than Rankin Bank at the 60 m contour. Glomar Shoal is a shallow sedimentary bank comprised of coarser biogenic material than the surrounding seabed. The shoal is ~26–70 m below the sea surface (Ref. 109). Together with Rankin Bank, these remote shallow water areas represent regionally unique habitats and are considered likely to play an important role in the productivity of the Pilbara region (Ref. 118; Ref. 669).

Abdul Wahab et al. (Ref. 118) found several hard coral and sponge species in water depths less than 40 m. A total of 170 different species of fish were also detected, with greatest species richness and abundance in shallow hard coral habitats (Ref. 118).

Glomar Shoals has also been identified as a KEF for its high productivity and aggregations of marine life (Ref. 109). This KEF encompasses a wider area than the shoal feature itself (see Section 6.3.6.1 for a description of the Glomar Shoals KEF).



Note: Rankin Bank delineated by 50 m bathymetry isobath; Glomar Shoal by the Glomar Shoals KEF.

Figure 6-8: Location of Rankin Bank and Glomar Shoals in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.2 coastal habitats and associated communities

Coastal communities are biological communities that inhabit the coastal zone. Coastal habitats are areas of shoreline that can support these communities. Similar to benthic communities (Section 6.3.1), coastal communities are likely to play roles in maintaining the integrity and diversity of coastal ecosystems, and in supplying ecological services.

The DA occurs offshore and does not have any overlap with the coast. However, the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA do overlap with coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Passage Islands, Cape Range National Park, Muiron Islands, and around the Point Cloates / Ningaloo Station area (Figure 6-9 to Figure 6-12). The Hydrocarbon Social EMBA includes additional shoreline points dispersed along the coast from North West Cape to islands in the Dampier Archipelago (including Enderby Island and Rosemary Island) (Figure 6-12).

The coastal habitats and communities that may be present within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are summarised below.

Based on Smartline (Ref. 119), a spatial database containing geomorphic classifications for Australia's coasts, the types of shoreline present within the Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA include:

- sandy and soft sediment shores (points along the coast from Tubridgi Point to Burrup Peninsula) (Hydrocarbon Social EMBA only; Figure 6-11 and Figure 6-12)
- rocky coasts and sandy beaches (Barrow and Montebello islands and Lefroy Bay to North West Cape)
- sandy tidal flats (Point Cloates / Ningaloo Station).
- shoreline types based on Smartline classifications (Figure 6-9 to Figure 6-12).

The Seamap Australia spatial database collates and classifies marine and coastal habitats on the Australian continental shelf (Ref. 120). Based on this dataset, areas of saltmarsh may be present on Barrow Island, the Pilbara Coast, Dampier Archipelago Islands and Exmouth Gulf. Areas of mangroves may be present along the Pilbara coast and Exmouth Gulf and on several islands including the Montebello Islands, Muiron Islands, Barrow Island, and some of the Dampier Archipelago islands. Mangroves grow within the intertidal zone, typically within sheltered areas. The mangrove communities within the Montebello Islands are considered globally unique because they occur in the lagoons of offshore islands (Ref. 121).

Listed TECs and wetlands of international importance (Ramsar wetlands) are MNES under the EPBC Act, and a relevant value and sensitivity under the OPGGS(E)R. There are no known TECs or Ramsar wetlands within the Hydrocarbon Social EMBA or the Hydrocarbon Ecological EMBA (Figure 6-13).

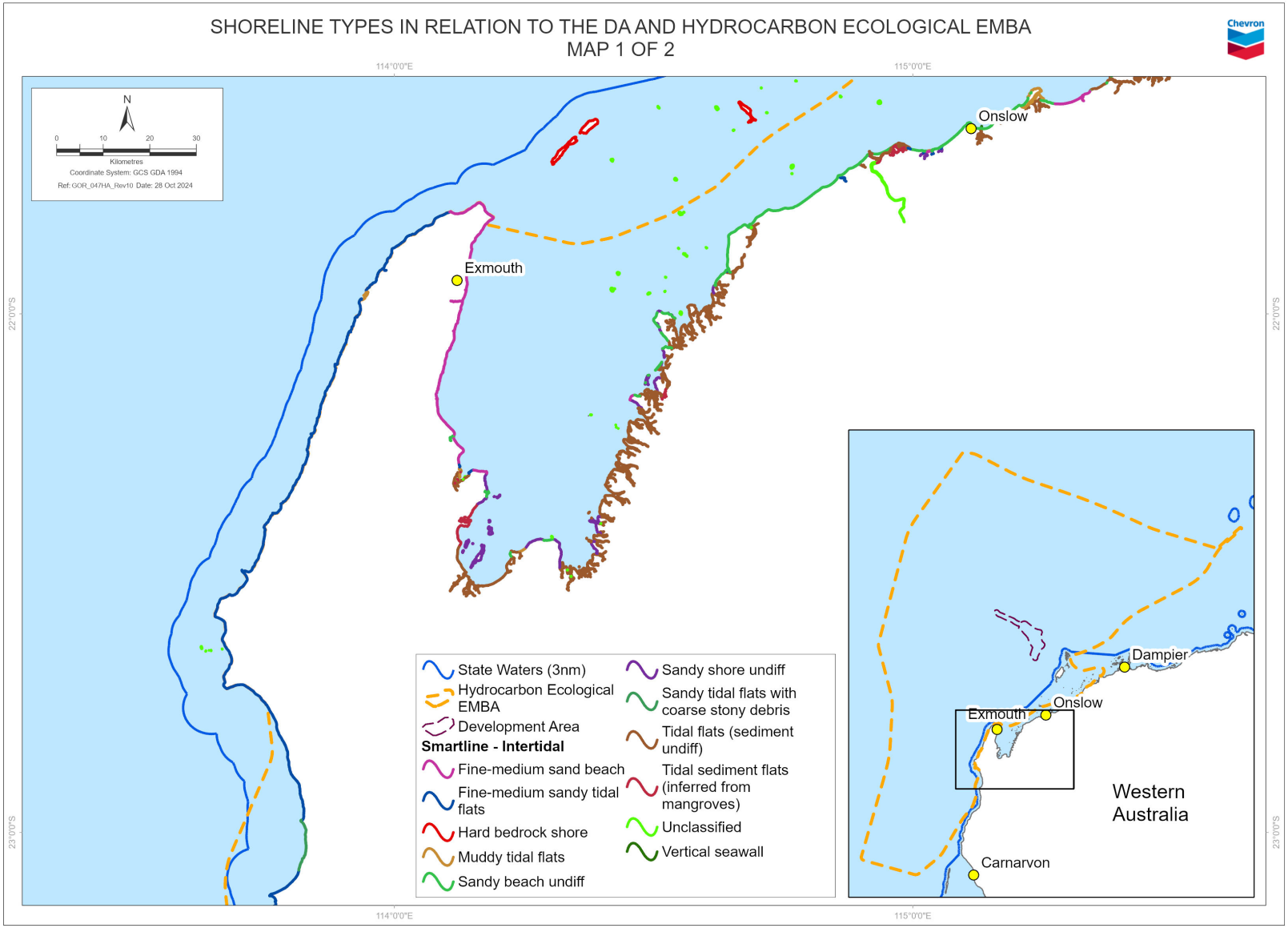


Figure 6-9: Shoreline types in relation to the DA and Hydrocarbon Ecological EMBA (Map 1 of 2)

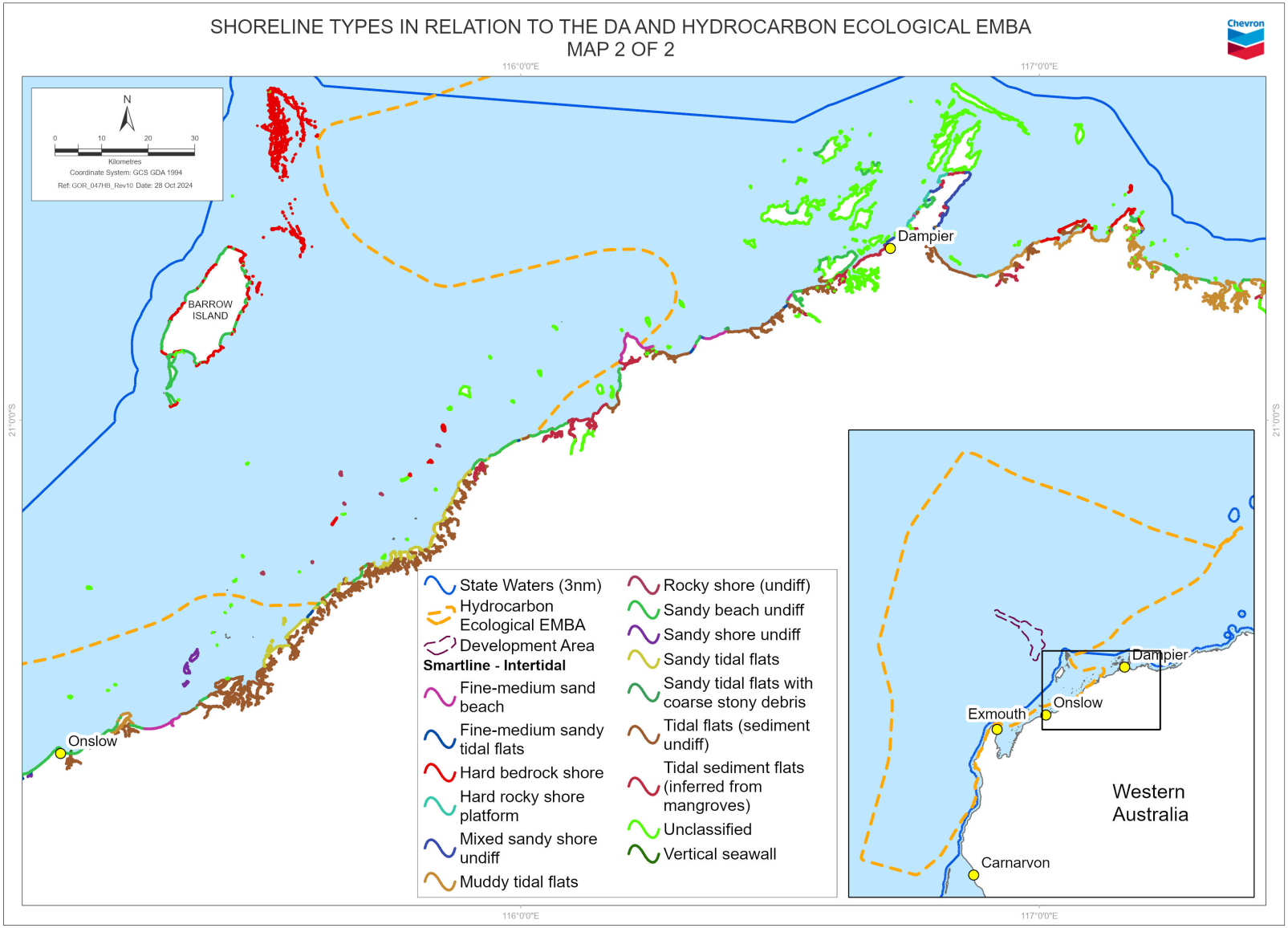


Figure 6-10: Shoreline types in relation to the DA and Hydrocarbon Ecological EMBA (Map 2 of 2)

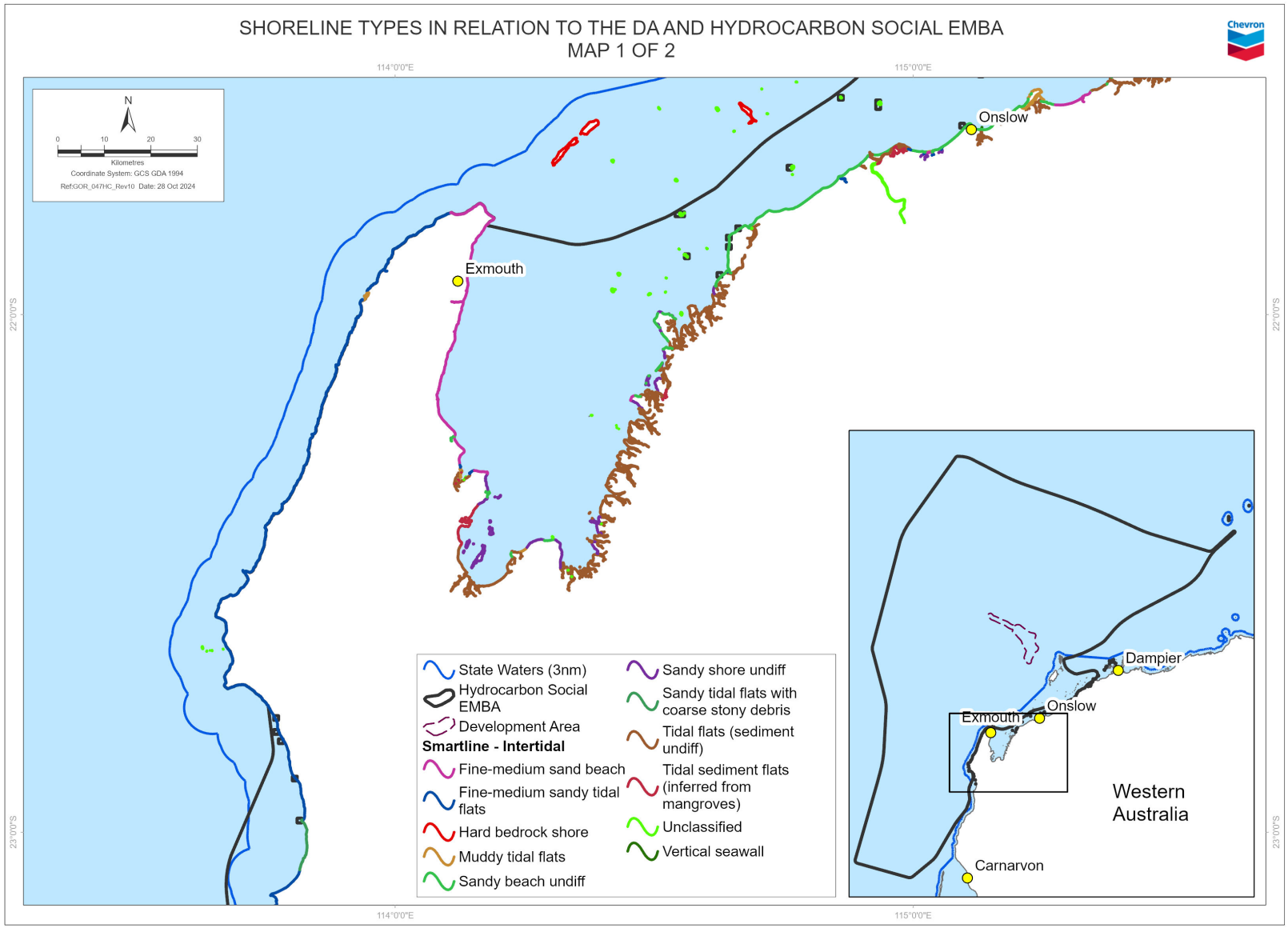


Figure 6-11: Shoreline types in relation to the DA and Hydrocarbon Social EMBA (Map 1 of 2)

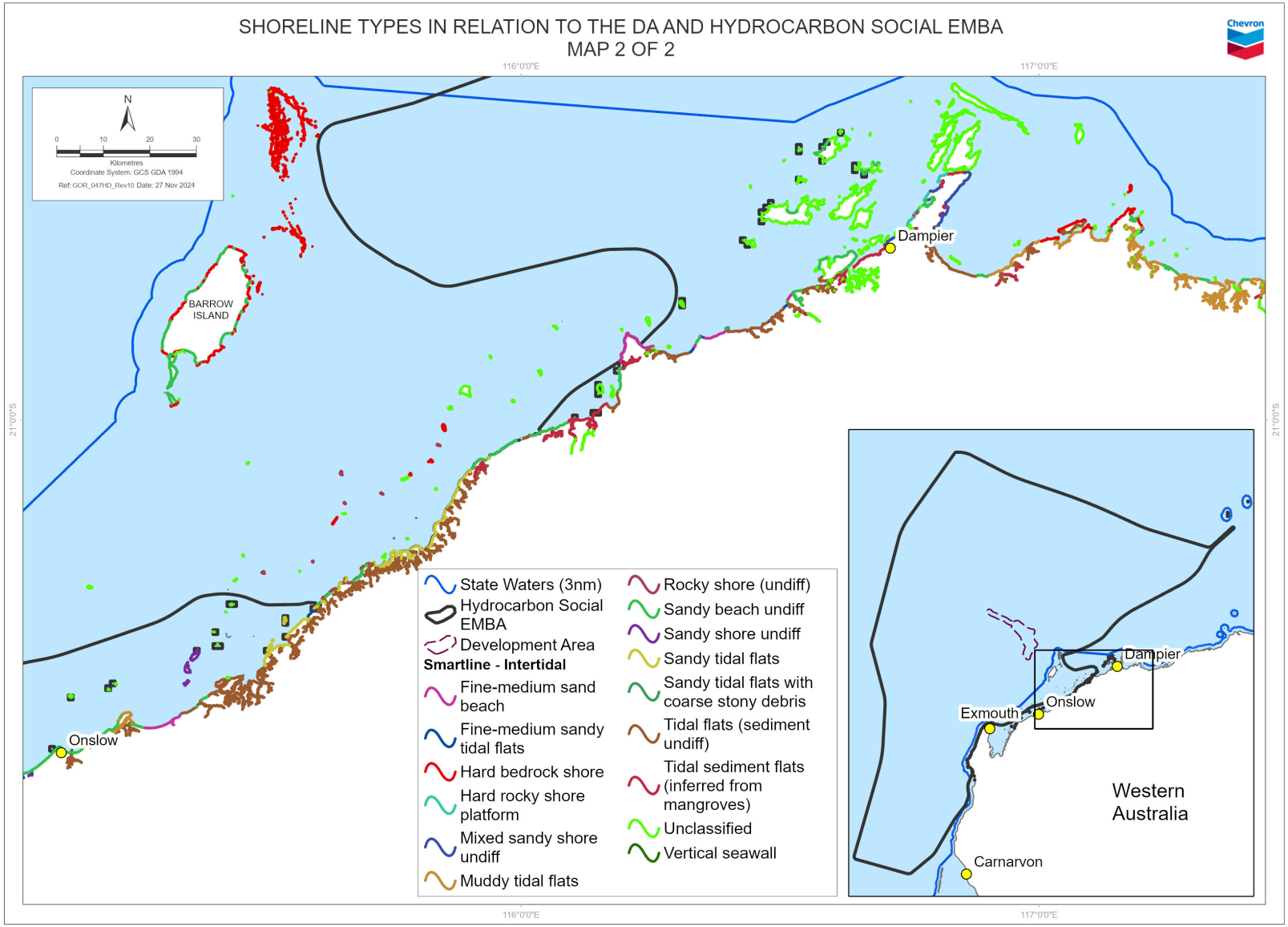


Figure 6-12: Shoreline types in relation to the DA and Hydrocarbon Social EMBA (Map 2 of 2)

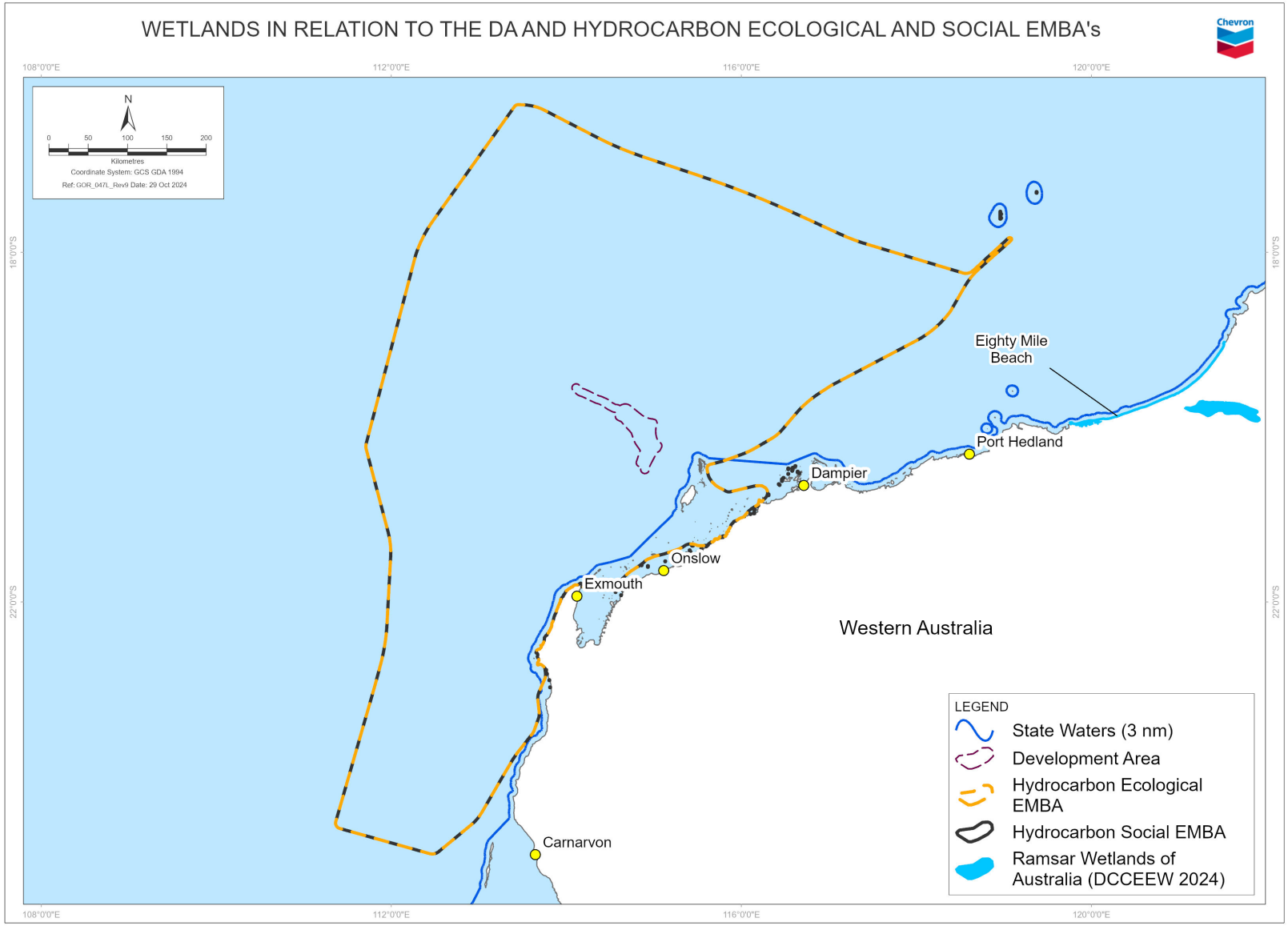


Figure 6-13: Ramsar wetlands in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3 marine fauna

Listed threatened or migratory species are MNES under the EPBC Act, and a relevant value and sensitivity under the OPGGS(E)R. The following subsections detail the presence of these species and any habitat critical to the survival (HCTS) of a species, and BIAs for protected marine species within the DA, and Hydrocarbon Ecological and Social EMBAs.

HCTS of a species or ecological community are areas necessary:

- for activities such as foraging, breeding, roosting, or dispersal
- for the long-term maintenance of the species or ecological community
- to maintain genetic diversity and long-term evolutionary development
- for the reintroduction of populations or recovery of the species or ecological community (Ref. 72).

BIAs are areas and times used by protected marine species for critical life functions, such as reproduction, feeding, migration or resting (Ref. 502). These behaviours are referred to as biologically important behaviours.

6.3.3.1 marine mammals

Based on searches of the EPBC Act protected matters database (Ref. 122; appendix b), the threatened and/or migratory mammal species shown in Table 6-8 may be present within the DA and/or Hydrocarbon Ecological and Social EMBAs. The full list of marine species identified from the protected matters database is provided in appendix b. HCTS of a species and BIAs associated with protected marine species are listed in Table 6-9 and Table 6-10 respectively.

The threatened and/or migratory cetaceans that may be present within the DA are predominantly low frequency cetaceans[40] (e.g. Antarctic minke, blue, Bryde's, fin, humpback, and sei whales) and high frequency cetaceans[41] (e.g. sperm whale, Australian humpback, Australian snubfin, and spotted bottlenose dolphins). Very high frequency cetaceans[42] (e.g. dwarf sperm and pygmy sperm whales) were also identified within the protected matters database (Ref. 122; appendix b) as species or species habitat that may occur within the DA, however these species are not listed as threatened and/or migratory under the EPBC Act (Table 6-8).

CAPL deployed three acoustic loggers for a full year period in 2019 located at various sites and depths adjacent to the existing Jansz field infrastructure. Several species of cetaceans were identified, including pygmy blue, Antarctic blue, Omura's, Bryde's, dwarf minke, Antarctic minke, fin, humpback, sei and sperm whales. Small odontocetes (e.g. dolphins) were also detected (Ref. 123). This monitoring detected three cetacean sub-species that were present in the vicinity of the DA that are not listed under the EPBC Act at a sub-species level, but they are at their species level (Antarctic blue whale (*Balaenoptera musculus intermedia)*, dwarf minke whale (*Balaenoptera acutorostrata* unnamed subsp.), and pygmy blue whale (*Balaenoptera musculus brevicauda)*. These sub-species have been included in Table 6-8.

[40] Low frequency cetaceans are the functional cetacean hearing group that are specialised for hearing low frequencies (e.g. baleen whales).

[41] High frequency cetaceans are the functional cetacean hearing group that are specialised for hearing high frequencies (e.g. toothed whales, beaked whales, dolphins).

[42] Very high frequency cetaceans are the functional cetacean hearing group that are specialised for hearing very high frequencies (e.g. *Kogia* spp.).

Further soundscape monitoring was undertaken from late-2021 to early-2023 using acoustic loggers deployed over a broader (~200 km x 200 km) area extending around the Jansz infrastructure (Ref. 659). There were no additional cetacean species that were not already identified from the 2019 monitoring described above identified during the 2021–2023 period.

Table 6-8: Presence of threatened and/or migratory marine mammals

Common name	Scientific name	Species presence detected during 2019[43]	EPBC Act presence		EPBC Act status			WA BC Act
			DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Cetacean	Conservation status
Cetaceans (whales)								
Antarctic minke whale, dark-shoulder minke whale	*Balaenoptera bonaerensis*	✓	LO	LO	–	✓	✓	MI
Antarctic blue whale[44]	*Balaenoptera musculus intermedia*	✓	–	–	E (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	E (as *Balaenoptera musculus)*
Blainville's beaked whale, dense-beaked whale	*Mesoplodon densirostris*	–	MO	MO	–	–	✓	–
Blue whale	*Balaenoptera musculus*	–	MKO	MKO	E	✓	✓	E
Bryde's whale	*Balaenoptera edeni*	✓	LO	LO	–	✓	✓	MI
Cuvier's beaked whale, goose-beaked whale	*Ziphius cavirostris*	–	MO	MO	–	–	✓	–
Dwarf sperm whale	*Kogia sima*	–	MO	MO	–	–	✓	–
Dwarf minke whale[44]	*Balaenoptera acutorostrata* unnamed subsp.	✓	–	–	–	–	✓ (as *Balaenoptera acutorostrata*)	–
Fin whale	*Balaenoptera physalus*	✓	LO	FLO	V	✓	✓	E
Gingko-toothed beaked whale	*Mesoplodon ginkgodens*	–	–	MO	–	–	✓	–

[43] Species presence identified in 2019 Jansz-Io Soundscape monitoring (Ref. 123).

[44] Sub-species not listed under the EPBC Act, but is listed at species level (Ref. 122; Ref. 525).

Common name	Scientific name	Species presence detected during 2019[43]	EPBC Act presence		EPBC Act status			WA BC Act
			DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Cetacean	Conservation status
Humpback whale	*Megaptera novaeangliae*	✓	BKO	BKO	–	✓	✓	CD & MI
Longman's beaked whale	*Indopacetus pacificus*	–	–	MO	–	–	✓	–
Minke whale	*Balaenoptera acutorostrata*	–	MO	MO	–	–	✓	–
Omura's whale	*Balaenoptera omurai*	✓	LO	LO	–	✓	✓	–
Pygmy blue whale[44]	*Balaenoptera musculus brevicauda*	✓	–	–	E (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	E (as *Balaenoptera musculus)*
Pygmy sperm whale	*Kogia breviceps*	–	MO	MO	–	–	✓	–
Sei whale	*Balaenoptera borealis*	✓	LO	FLO	V	✓	✓	E
Southern right whale	*Eubalaena australis*	–	–	LO	E	✓ (as *Balaena glacialis australis*)	✓	V
Sperm whale	*Physeter macrocephalus*	✓	MO	MO	–	✓	✓	V
Cetaceans (dolphins)								
Australian humpback dolphin	*Sousa sahulensis*	–	MO	KO	V	✓ (as *Sousa chinensis*)	✓	MI & P4
Australian snubfin dolphin	*Orcaella heinsohni*	–	MO	KO	V	✓	✓	MI & P4
Bottlenose dolphin	*Tursiops truncatus* s. str.	–	MO	MO	–	–	✓	–
Common dolphin, short-beaked common dolphin	*Delphinus delphis*	–	MO	MO	–	–	✓	–
False killer whale	*Pseudorca crassidens*	–	LO	LO	–	–	✓	–

Common name	Scientific name	Species presence detected during 2019[43]	EPBC Act presence		EPBC Act status			WA BC Act
			DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Cetacean	Conservation status
Fraser's dolphin, sarawak dolphin	*Lagenodelphis hosei*	–	MO	MO	–	–	✓	MI
Indian Ocean bottlenose dolphin, spotted bottlenose dolphin	*Tursiops aduncus*	–	MO	LO	–	–	✓	MI
Killer whale, orca	*Orcinus orca*	–	MO	MO	–	✓	✓	MI
Long-snouted spinner dolphin	*Stenella longirostris*	–	MO	MO	–	–	✓	MI & P4
Melon-headed whale	*Peponocephala electra*	–	MO	MO	–	–	✓	–
Pygmy killer whale	*Feresa attenuata*	–	MO	MO	–	–	✓	–
Risso's dolphin, grampus	*Grampus griseus*	–	MO	MO	–	–	✓	–
Rough-toothed dolphin	*Steno bredanensis*	–	MO	MO	–	–	✓	–
Short-finned pilot whale	*Globicephala macrorhynchus*	–	MO	MO	–	–	✓	–
Spotted bottlenose dolphin (Arafura/Timor Sea populations)	*Tursiops aduncus (Arafura/Timor Sea populations)*	–	MO	KO	–	✓	✓	MI
Spotted dolphin, pantropical spotted dolphin	*Stenella attenuata*	–	MO	MO	–	–	✓	–
Striped dolphin, euphrosyne dolphin	*Stenella coeruleoalba*	–	MO	MO	–	–	✓	–

Common name	Scientific name	Species presence detected during 2019[43]	EPBC Act presence		EPBC Act status			WA BC Act
			DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Cetacean	Conservation status
Sirenians								
Dugong	*Dugong dugon*	–	–	BKO	–	✓	✓	MI
Likely Presence *MO: Species or species habitat may occur within area.* *LO: Species or species habitat likely to occur within area.* *KO: Species or species habitat known to occur within area.* *BKO: Breeding known to occur within area.* *FLO: Foraging, feeding or related behaviour likely to occur within area* *MKO: Migration route known to occur within area*					***Conservation Status:*** *CD: Conservation Dependent* *E: Endangered* *MI: Migratory* *P4: Priority 4, Rare, Near Threatened and other species in need of monitoring* *V: Vulnerable*			

Table 6-9: HCTS of marine mammals

Common name	HCTS location	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Southern right whale	All reproductive BIAs	May to September	–	148	✓

Table 6-10: Presence of BIAs for marine mammals

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Humpback whale	Migration (north and south)	Northern migration, late July to September	✓	0	✓
	Resting	Winter	–	144	✓
Pygmy blue whale	Foraging	(Not defined in database)	–	171.7	✓
	Migration	Northern migration (enter Perth Canyon Jan–May; pass Exmouth Apr–Aug; continue north to Indonesia). Southern migration (follow WA coastline from Oct–late Dec)	✓	0	✓
Southern right whale	Migration	April to October	–	152.8	✓
	Reproduction	May to September	–	148	✓
Dugong	Breeding	Year round	–	141.5	✓
	Calving	Year round	–	141.5	✓
	Foraging (high-density seagrass beds)	Year round	–	141.5	✓
	Nursing	Year round	–	141.5	✓

6.3.3.1.1 humpback whale

The humpback whale (*Megaptera novaeangliae*) is listed as migratory under the EPBC Act. A migration BIA for the humpback whale overlaps the DA and Hydrocarbon Ecological and Social EMBAs, and a resting BIA overlaps the Hydrocarbon Ecological and Social EMBAs (Figure 6-14).

Humpback whales migrate north from their Antarctic feeding grounds to their calving grounds in Kimberley waters (Ref. 125). The exact timing of the migration period can vary from year to year; however in general the species are sighted in southern Australian waters in May, they then migrate northwards and southwards along the coast, with sightings rare after November (Ref. 192). Humpback whale song was detected during soundscape monitoring from mid-July to late-September (Ref. 123; Ref. 659) and non-song sounds in early-July and October (Ref. 123).

Northbound humpback whales tend to remain around the 200 m water depth contour, while southbound humpback whales tend to travel closer to Barrow Island and generally occur between 50 m and 200 m water depths (Ref. 125). The

migration (north and south) BIA corridor extends from the coast to ~100 km offshore in the Kimberley and Pilbara regions; reducing to ~50 km offshore south of North West Cape.

The humpback whale breeding and calving grounds in the southern Kimberley region extend from Broome to the northern end of Camden Sound, particularly between Lacepede Islands and Camden Sound (Ref. 125). Breeding and calving occur in the region between mid-August and early-September (Ref. 125), followed by the start of the southern migration. Exmouth Gulf and Shark Bay are both important resting areas for migrating humpback whales, particularly for cow-calf pairs on the southern migration (Ref. 125). The southerly migration, from around the Lacepede Islands (north of Broome) extends parallel to the coast on approximately the 20–30 m depth contour (Ref. 125, Ref. 127). Southbound migration is more diffuse and irregular, lacking an obvious peak. An increase in southerly migrating individuals may be observed between the North West Cape and the Montebello Islands between August to early September (Ref. 125; Ref. 127). The predicted peaks in Humpback Whale migration in the Montebello Islands region are late-July (northern migration) and early-September (southern migration) (Ref. 125). Females and calves are known to stop and rest in Exmouth Gulf and Shark Bay (Ref. 125).

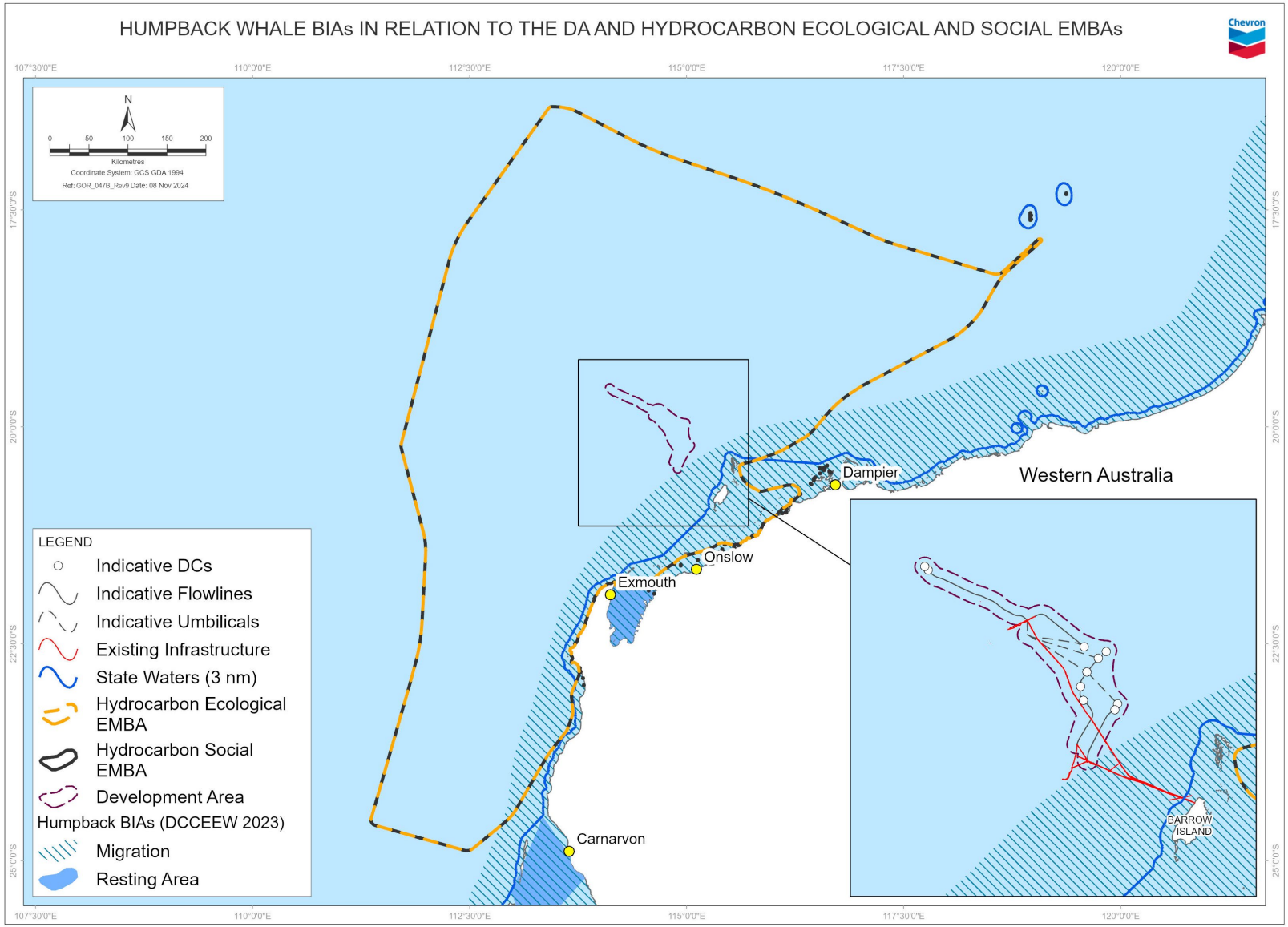


Figure 6-14: Humpback whale BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.1.2 pygmy blue whale

The pygmy blue whale (*Balaenoptera musculus brevicauda*) is a subspecies of the blue whale. The blue whale is listed as endangered and migratory under the EPBC Act. A migration BIA for the pygmy blue whale overlaps the DA and Hydrocarbon Ecological and Social EMBAs (Table 6-10; Figure 6-16). A 'possible foraging area' BIA (off the North West Cape) overlaps with the Hydrocarbon Ecological and Social EMBAs (Table 6-10; Figure 6-16).

It was estimated by McCauley and Jenner (Ref. 134) that 662–1,559 pygmy blue whales migrated south past Exmouth in 2004. This is similar to abundance estimates of 532–1,754 blue whales at the Perth Canyon between 1999/2000 to 2004/2005 (Ref. 20). A more recent preliminary abundance estimate by McCauley et al (Ref. 644) indicated that ~3,554 pygmy blue whales migrated north through the NWS region during 2022. It is unknown what proportion of the total population these seasonal migratory estimates encompass (Ref. 20; Ref. 134).

migration

Pygmy blue whales migrate along the west coast of Australia in the northern direction to their breeding grounds near the Indonesian Archipelago from approximately January to August (passing through the Perth Canyon region earlier [January to May] than Exmouth [April to August] before continuing north); then south to their feeding grounds in the Southern Ocean from approximately mid-November to early-January (Ref. 129; Ref. 134). Information collected from satellite tags shows that the Banda and Molucca seas in Indonesia are the likely destination for the northern migration of whales that feed off the Perth Canyon (Ref. 130; Ref. 131; Ref. 132). These seas are considered the northern terminus of the migration and potentially the whales' breeding and calving ground, but may also act as a feeding area (Ref. 128; Ref. 133).

Acoustic monitoring analysed by McCauley and Jenner (Ref. 134), including sites off the North West Cape and north of Montebello Islands, identified pygmy blue whales migrating south pass the Exmouth area through November to late-December with a comparatively short burst of animals passing (Ref. 134). The pygmy blue whales migrate north passing the Exmouth–Montebello Islands area over a more protracted period ranging from April to August (Ref. 134). The shorter southbound compared to northbound migratory period suggests the animals are swimming purposely through the area to reach southern feeding areas (Ref. 134). A difference in travel speed for pygmy blue whales was also reported by Thums et al (Ref. 135), where median speed during northward migration was 2.4 km/h (<0.1–15.4 km/h, n=22), and southward migration was 4.0–5.0 km/h (n=2).

CAPL passive acoustic loggers deployed over 2019–2023 (29 instruments; adjacent to existing Jansz field infrastructure and more broadly over the region[45]) have detected pygmy blue whales migrating south past the Jansz location from early-October to late-January of the following year (peak late-November to early-December); and north from late-March to mid-September (peak late-May to June) (Ref. 644). These migration periods are in agreement with McCauley and Jenner (Ref. 134), Double et al. (Ref. 128) and McCauley et al. (Ref. 487). During the 2019 soundscape monitoring pygmy blue whale song was detected on more days than any other type of mysticete (baleen whale) sound (Ref. 123). Higher numbers of singers were detected during the northern migration compared to southern migration (Ref. 644). The presence of migratory whales was also observed to vary temporally and spatially each year (Ref. 644; Ref. 659).

[45] Refer to soundscape survey area shown in Figure 6-16.

Predictions from modelling based on passive acoustic data indicate greatest numbers of pygmy blue whales during April and June/July (northern migration), and November and December (southern migration) (Ref. 135). Monthly spatial predictions indicated higher densities around the Montebello Island region during May and June (northern migration) and November and December (southern migration) (Ref. 135).

Previous descriptions, including within the Conservation Management Plan for the Blue Whale, of the migration route for pygmy blue whales along the WA coast are that they "tend to pass along the shelf edge at depths between 500 m to 1,000 m" (Ref. 20; Ref. 102). These descriptions appear to have been sourced from acoustic data for a southerly migration of pygmy blue whales past Exmouth, where it was observed that most pygmy blue whales pass along the shelf edge out to water depths of 1,000 m but centred near the 500 m depth contour (Ref. 134). The use of the continental slope habitat in WA is in contrast to southern Australia where use of the continental shelf and shelf break predominates (Ref. 135).

Literature (e.g. Ref. 128; Ref. 129; Ref. 134) supports that many pygmy blue whales follow the continental shelf edge when south of the North West Cape on their north and south migrations. However, north of the North West Cape the pygmy blue whales are more likely to transit through deeper and further offshore waters (e.g. Ref. 128; Ref. 129; Ref. 644).

Double et al (Ref. 128) described tagged pygmy blue whales (2009, 2011) during their northern migration as travelling relatively near to the Australian coast (100±1.7 km) in water depths of 1,369.5±47.4 m, until reaching the North West Cape, after which they travelled further offshore (238±14 km) into progressively deeper water (2,617±143.5 m). Data from tagged pygmy blue whales (2020) also indicated that during their northern migration, the width of the migration corridor increases north of Montebello Islands from ~175 km to ~690 km at its widest point (Ref. 135). Gavrilov et al. (Ref. 129) conducted a study using an array of ocean bottom seismographs to detect pygmy blue whales traversing the area to the north-west of the North West Cape during their southern migration. This study found that pygmy blue whales migrated southward much further from the WA coast compared to the northbound migration, at distances of up to 400 km from the coast (Ref. 129).

Based on analysis of CAPL's passive acoustic monitoring data (2019–2023) the northern migration corridor through the Jansz region is broad (i.e. extends further west than the survey area) and had two focal points: one just west of the continental shelf edge[46], and one ~65 km west of Jansz field infrastructure[47] (Ref. 644). The focal point for the southern migration corridor was also detected ~65 km to the west of the Jansz field infrastructure (Ref. 644). The results of this passive acoustic monitoring data are consistent with previous studies indicating broader migration corridors north of the North West Cape.

Ferreira et al. (Ref. 505) analysed available satellite tracking data for pygmy blue whales (n=38) and environmental data to predict habitat suitability for migration. The analyses determined that areas of high relative habitat suitability for migration were identified along the shelf break (200 m bathymetry contour) and slope between Windy Harbour and Scott Reef, and also in deep areas offshore of Rowley Shoals. From Cape Leeuwin to Ningaloo Reef, the suitable habitat was associated predominantly with the continental slope. North of Ningaloo Reef (and

[46] Where 'continental shelf edge' is defined as the 200 m water depth contour.

[47] This is indicated by the ~260 km distance from mainland in Figure 6-16.

extending to Ashmore Reef) there was a separation of suitable migration habitat between the deep ocean basin area and slope habitat (Ref. 505). Parts of the DA that occur on the slope and shelf do intersect with areas 'validated as suitable habitat' for migration (Figure 6-15); the offshore deeper areas of the DA do not.

Thums et al. (Ref. 135) incorporated data collected from both passive acoustic monitoring (46 instruments, 2006 to 2019) and satellite telemetry data (22 tag deployments, 2009 to 2021) to determine the 'most important areas' for migration[48] along the WA coast. This analysis identified an almost continuous area from southern WA to around the latitude of Rowley Shoals; and thereafter was more dispersed (Ref. 135). Parts of the DA do intersect with these 'most important areas' for migration (Figure 6-16).

Therefore, while the DA intersects with the migration BIA for pygmy blue whales, it is expected based on satellite tracking and acoustic detection studies that pygmy blue whales have a broader migration corridor at this latitude (i.e. extending further offshore than the defined BIA).

foraging

Blue whales aggregate in productive upwelling or frontal regions worldwide to prey on dense but patchy drill aggregations which occur (Ref. 136).Pygmy blue whales aggregate in the Austral summer to feed at known locations on or adjacent to the continental shelf including the Perth Canyon, Great Southern Australian Coastal Upwelling System, and the sub-tropical convergence zone (Ref. 135). The areas around the Perth Canyon and Australian Coastal Upwelling System correspond to 'Foraging Areas'[49] and 'Known Foraging Areas' within the Conservation Management Plan for the Blue Whale (Ref. 20). Blue whales have the highest known prey requirements of any predator, and Foraging Areas are therefore generally associated with areas of high primary productivity that can support sufficient densities of krill, such as oceanographic upwelling or frontal systems (Ref. 20). The Conservation Management Plan for the Blue Whale (Ref. 20) also identifies 'Possible Foraging Areas'[50], including two in WA, one off the Ningaloo coast, and another around Scott Reef. These 'Possible Foraging Areas' have been characterised as foraging BIAs and occur ~172 km south-west and ~877 km north-east of the DA respectively.

Analyses by Ferreira et al. (Ref. 505) determined that suitable habitat for foraging was identified as a large semi-continuous area from the southern extent (28°S) to the north-eastern edge of the modelled region (11.5°S). The model indicated high habitat suitability extending out from the continental shelf break (200 m bathymetry contour) in the north-west of WA; with the highest relative suitability occurred from just south of Shark Bay to Scott Reef along the continental shelf break and slope, and also extending to the Exmouth Plateau (Ref. 505). The study indicates suitable habitat is related to dynamic and localised oceanic processes that may occur at different temporal scales (Ref. 505). The DA does occur within areas 'validated as suitable habitat' for foraging (Figure 6-15).

[48] Grid cells with overlap between two metrics: largest percentage of whales and high move persistence, were designated as the 'most important areas' for migration (Ref. 135).

[49] The Conservation Management Plan for the Blue Whale (Ref. 20) defines a Foraging Area as "Blue whales are regularly observed on a seasonal basis", and a Known Foraging Area is "[k]nown foraging occurs in these areas but is highly variable both between and within seasons".

[50] The Conservation Management Plan for the Blue Whale (Ref. 20) defines a Possible Foraging Area as "[e]vidence of feeding is based on limited direct observations or through indirect evidence, such as occurrence of krill in close proximity to whales, or satellite tagged whales showing circling tracks. Blue whales travel through on a seasonal basis, possibly as part of their migratory route".

Thums et al. (Ref. 135) determined that pygmy blue whale movement off north-west WA was predominantly relatively fast, directed travel (high move persistence) interspersed with relatively short (median 28 h) periods of low move persistence (Ref. 135). This high move persistence is indicative of migration, while the low move persistence is generally indicative of foraging (Ref. 135). Data collected from both passive acoustic monitoring and satellite telemetry data, was analysed and determined the 'most important areas' for foraging[51] along the WA coast included the Perth Canyon and vicinity, the shelf edge off Geraldton, and discontinuous use of the shelf edge from Ningaloo Reef to Rowley Shoals (Ref. 135). These spatially non-continuous foraging areas may be used by pygmy blue whales during their migration north in the Austral winter (Ref. 643). Although foraging areas are described as static, they are likely to be dynamic given their dependence on presence of prey (Ref. 135; Ref. 349). Feeding behaviour appears to be largely a function of prey availability and their associated oceanographic drivers (i.e. surface currents, light attenuation, upwellings, and seabed features) (Ref. 505; Ref. 551; Ref. 552). The DA does not intersect with these most important areas for foraging (Figure 6-17).

Thums et al. (Ref. 643) analysed diving behaviour of nine tagged pygmy blue whales to determine where foraging actually occurs during their northern migration. Three main foraging areas were identified based on where foraging and feeding dives occurred: Perth Canyon to offshore of Jurien Bay; adjacent to Geraldton and the Abrolhos Islands, and offshore of Ningaloo (extending from near Coral Bay to offshore of the Montebello Islands) (Ref. 643). However, it was noted that more opportunistic foraging occurred off north-west Australia where foraging dives were shallower, horizontal travel rates faster, and there was an absence of a diurnal pattern in diving (Ref. 643). This suggests a reliance on more ephemeral prey in north-west Australia than off south-west Australia where whales have high residency. The foraging/feeding behaviours observed in this study provide support for use of a mixed breeding strategy (income and capital) in pygmy blue whales (Ref. 643).

A review by UWA demonstrated that there were no oceanographic features (including bathymetry, currents and eddies, chlorophyll concentrations) within the Jansz area that may lead to higher primary productivity and/or an increased likelihood of pygmy blue whale foraging in the area (Ref. 651). Sonar surveys to determine the presence of sufficient biomass of prey to support foraging pygmy blue whales were undertaken by CMST (Ref. 653). This study indicated that the Jansz area may be able to support opportunistic feeding in surface waters (<100 m water depth) for short durations (hours); however, in comparison to known prey aggregations observed at Perth Canyon, the biomass observed at the Jansz area is unlikely to represent a consistent and reliable feeding area (Ref. 653). Therefore, the DA and surrounding area are not considered to represent a Foraging Area, but may provide opportunistic foraging if the environmental conditions provide for the aggregation of prey at sufficient quantities at the time a pygmy blue migrates through the area. This is consistent with studies of tagged pygmy blue whales that demonstrated more opportunistic foraging in north-west Australia, compared to southern areas (e.g. Perth Canyon, Ningaloo) (Ref. 643).

Owen et al. (Ref. 645) deployed a multi-sensor tag on a single pygmy blue whale and tracked its movement from the Perth Canyon region to Geraldton. The whale completed a total of 1,677 dives over the duration of the tag was attached

[51] Grid cells with overlap between three metrics: greatest time spent, largest percentage of whales, and lowest move persistence, were designated as the 'most important areas' for foraging (and/or resting/breeding) (Ref. 135).

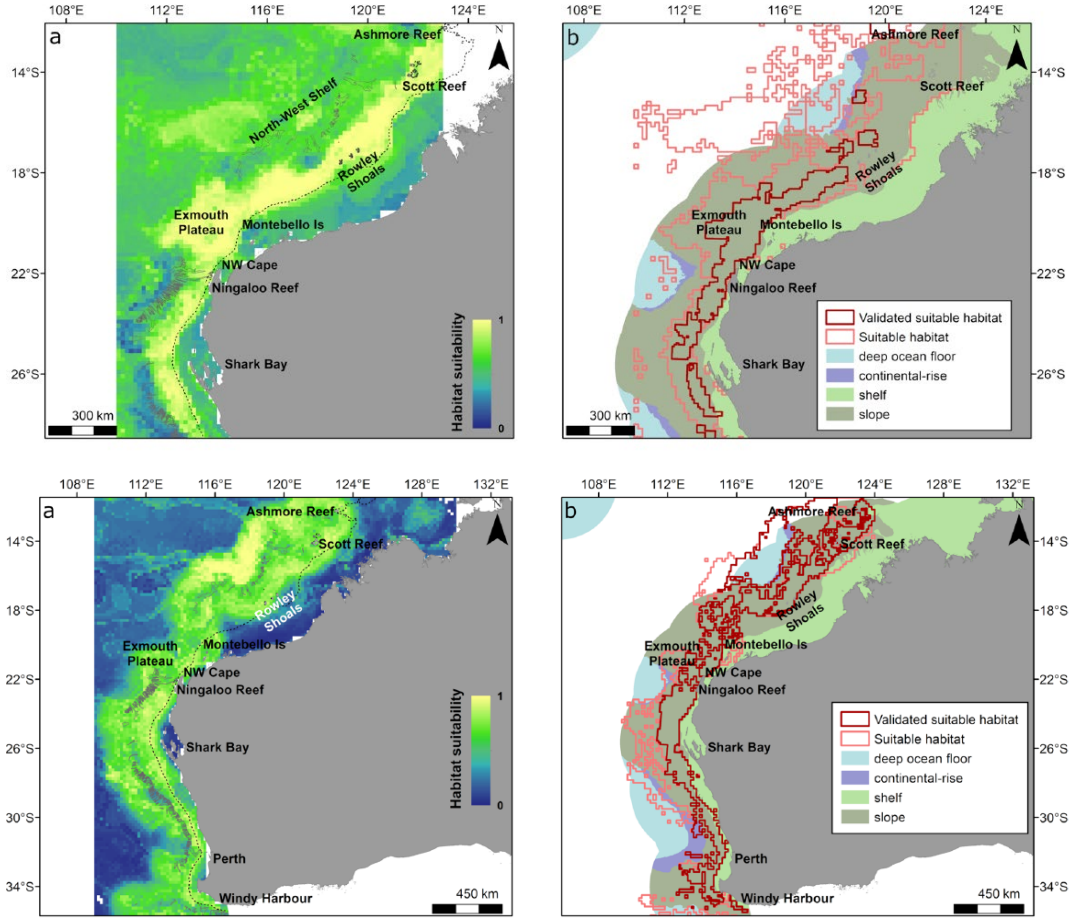
(7.6 days). Three types of movement behaviour (migratory, exploratory dives, and feeding [lunge dives] were identified. The feeding behaviours (lunge dives) were characterised by a mean maximum depth of 129±183 m (range 13–505 m) and a mean dive duration of 5.2 minutes for shallow feeding and 11.4 minutes for deep feeding.

Based on analysis of nine tagged pygmy blue whales (eight at Perth Canyon, one at Ningaloo), Thums et al. (Ref. 643) determined that maximum dive depths of foraging and lunge feeding dives were deeper in the Perth (321 m, 31–540 m) and Geraldton (338 m, 64–483 m) regions, followed by Savu Sea (176 m, 42–259 m), with Ningaloo being the shallowest (99 m, 39–306 m) (Ref. 643). As part of a different study, Thums et al. (Ref. 135) also describes 10 of the 24 pygmy blue whales that were encountered during a 2020 field trip off the North West Cape were observed to be surface feeding (implied by the visible baleen and pleats on the surface).

Biologically, surface feeding is an optimal behavioural response for pygmy blue whales, given the significantly reduced energetic costs associated with this strategy over lunge feeding at depth, which requires a significant oxygen and energetic demand (Ref. 646). Studies have demonstrated that feeding at depth is thought to only be energetically efficient if krill density at depth is three times higher than in surface waters (Ref. 646). Studies in several locations where pygmy blue whales are known to aggregate (southern Australia [Ref. 647], New Zealand [Ref. 646]; California [Ref. 648], Canada [Ref. 649]; Chile [Ref. 650]) have demonstrated evidence of surface or sub-surface (<100 m) foraging, determined through visual observations of lunge feeding and/or analysis of tagged data. In these instances, surface foraging was driven by the aggregation of krill at the surface (or sub-surface). Torres et al. (Ref. 646) noted that surface foraging adheres to the principles of the ‘optimal foraging theory’, which states that to maximise fitness, an animal adopts a foraging strategy that provides the most benefit (i.e. energy) for the lowest cost, thereby maximising the net energy gained.

Pattiaratchi (Ref. 651) demonstrated that chlorophyll production within the Pilbara region was highest in <100 m of water depth (particularly in summer), where sufficient light still penetrates to allow for photosynthesis and nutrients are highest within the thermocline (80–100 m). In winter the data demonstrated that the chlorophyll was mixed throughout the upper 80–100 m, corresponding to the well-mixed conditions in the upper surface waters. There is a generally accepted correlation between increased chlorophyll production (i.e. phytoplankton biomass) and increased krill density (Ref. 652). Furthermore, a krill biomass survey undertaken by McCauley and Erbe (Ref. 653) demonstrated that around the Jansz field region, aggregations of krill dense enough to support opportunistic feeding by pygmy blue whales were only found within surface or sub-surface waters (<100 m).

In summary, a range of evidence (i.e. visual observations of feeding individuals, diving data from tagged whales, prey biomass surveys and biological theory) indicates that pygmy blue whales within the Pilbara region preferentially forage at the surface or sub-surface, where studies demonstrates that productivity is concentrated within the photic zone (<100 m).



Source: Ref. 505

Figure 6-15: Predicted habitat suitability for foraging (top panel) and migration (bottom panel)

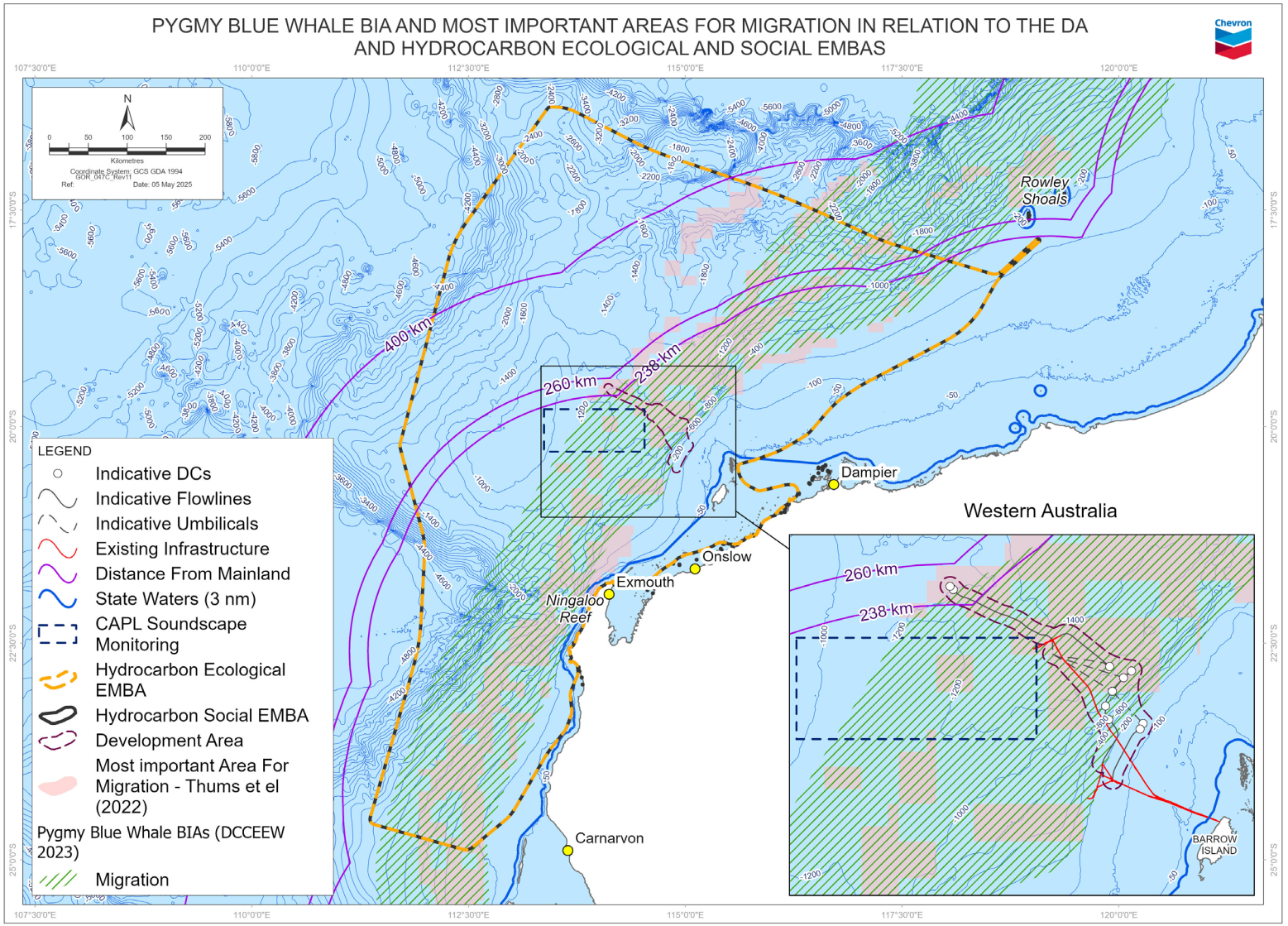


Figure 6-16: Pygmy blue whale BIA and most important areas for migration in relation to the DA and Hydrocarbon Ecological and Social EMBAs

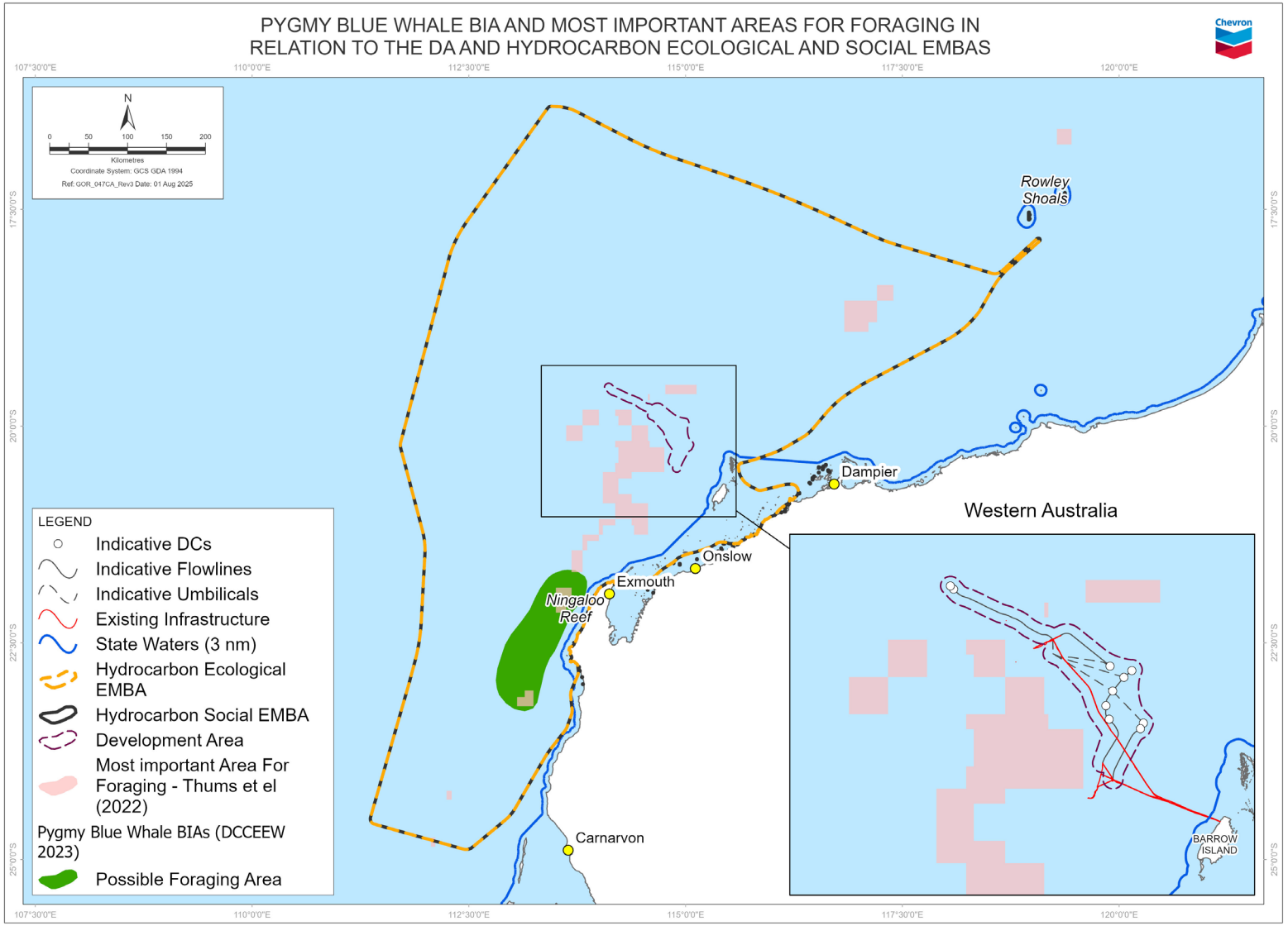


Figure 6-17: Pygmy blue whale BIA and most important areas for foraging in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.1.3 southern right whale

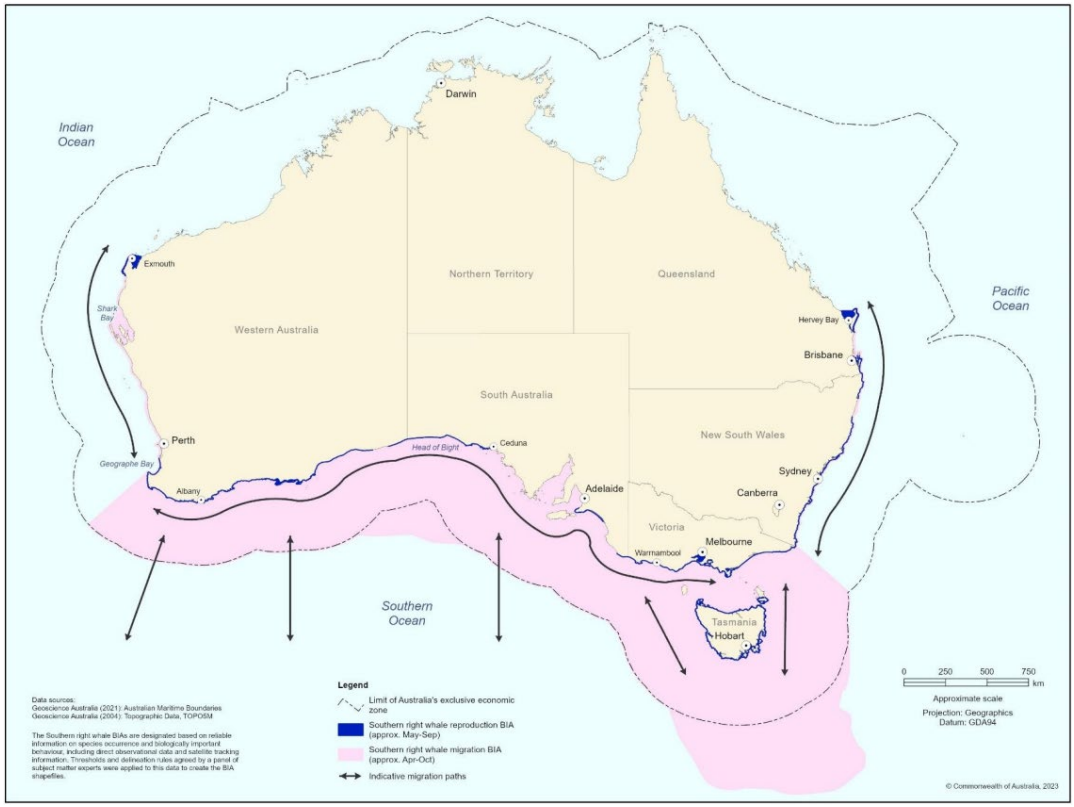
The southern right whale (*Eubalaena australis*) is listed as endangered and migratory under the EPBC Act (Table 6-8).There are no BIAs intersecting the DA, but there are migration and reproduction BIAs that intersect with part of the Hydrocarbon Ecological and Social EMBAs for the southern right whale (Table 6-10; Figure 6-19; Ref. 23). The National Recovery Plan for the southern right whale (Ref. 23) also defines HCTS of the species as being any reproductive BIA; therefore, both the Hydrocarbon Ecological and Social EMBAs also intersect with HCTS (Table 6-9).

Southern right whales have a circumpolar distribution in the southern hemisphere approximately between latitudes 20°S and 65°S; and have a seasonal presence in Australian coastal waters (Ref. 23). The distribution range for southern right whales in WA extends north to Exmouth/Ningaloo Reef (21°S) (Ref. 23). Within the distribution range, southern right whales predominantly occupy nearshore coastal areas and around oceanic islands. The western population of southern right whales occur in greatest numbers between Cape Leeuwin (WA) and Ceduna (South Australia) (Ref. 23). As capital breeders, southern right whale reproductive cycles are closely tied to their migratory behaviour (Ref. 23). Migration occurs between habitat used for foraging and breeding. Indicative migration paths are shown in Figure 6-18.

The seasonal presence of southern right whales in Australian waters typically occurs from May to October (but can occur from early-April to November), and they predominantly occupy shallow coastal areas, <10 m deep, usually within 1 km of the coast, where they calve and nurse their young (Ref. 23). Peak period of abundance is typically late-July and August; however, there is within season variability that differs between females with calves and unaccompanied whales (Ref. 23). Females with a calf generally occupy the calving ground for 2–3 months between June and September. Unaccompanied whales (males and females without a calf) are more variable in their occupancy of coastal areas throughout the reproductive season (Ref. 23). The preferred habitat for breeding generally includes shallow sloping sandy bottom bays that provide protection from prevailing wind and weather (Ref. 23). Southern right whales demonstrate strong fidelity to feeding and breeding areas (Ref. 23). Coastal foraging in Australian waters has not been observed, and foraging ecology remains poorly understood (Ref. 23).

Foraging and feeding occurs between at least 30°S and 65°S latitude, and particularly in offshore areas associated with large-scale features (e.g. sub-tropical and polar fronts) (Ref. 23). Feeding has not been observed in coastal Australian waters, although other parts of the Australian EEZ may be utilised for feeding (Ref. 23).

There is evidence of population increase in the western population; however, southern right whale abundance is still below estimated historic abundance (Ref. 23).



Source: Ref. 23

Figure 6-18: Indicative migration paths for southern right whales

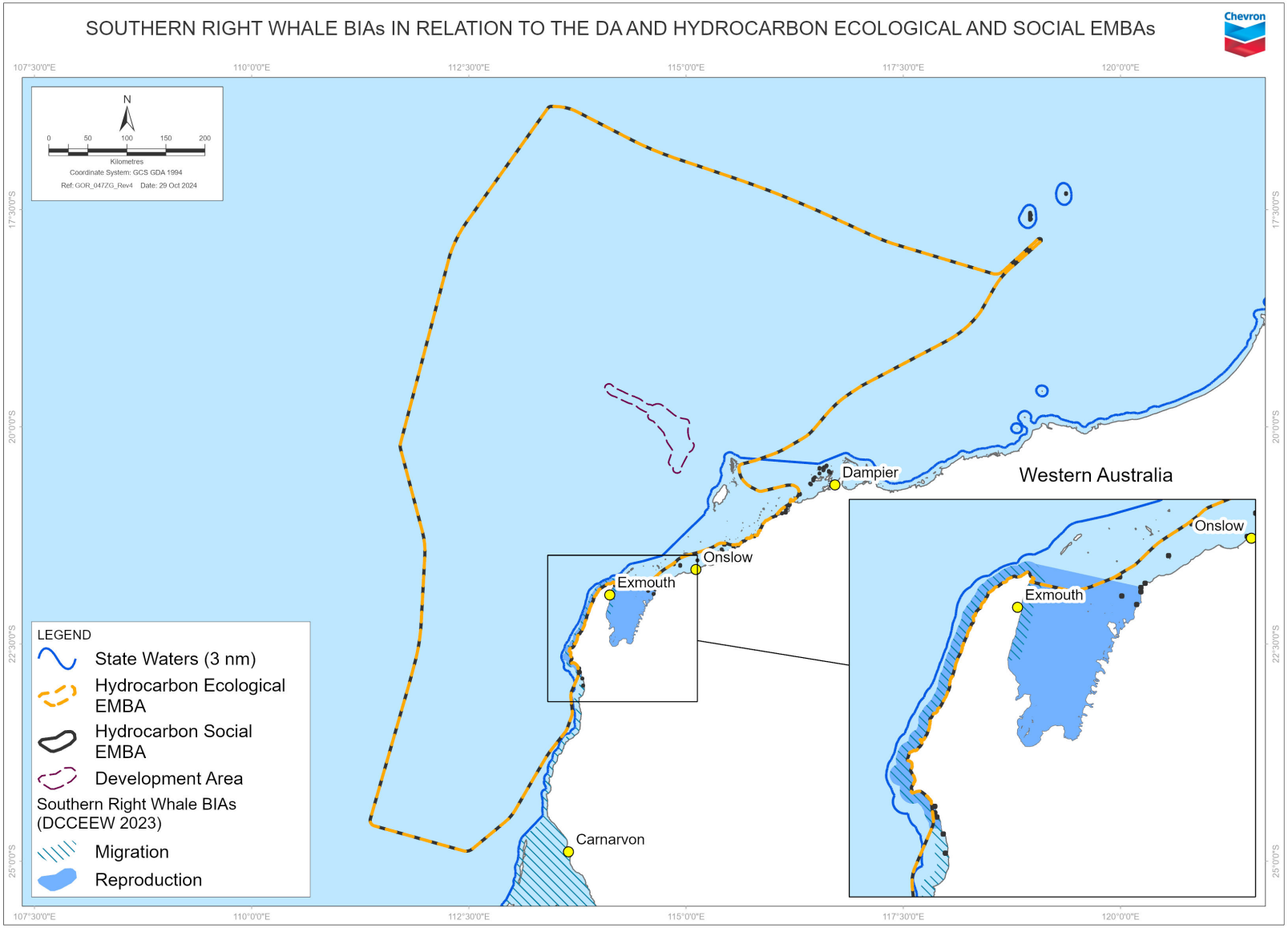


Figure 6-19: Southern right whale BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.1.4 dugong

The dugong (*Dugong dugon*) is listed as marine and migratory under the EPBC Act. There are no dugong BIAs overlapping the DA; however, several BIAs overlap the Hydrocarbon Ecological and Social EMBAs (Figure 6-20). BIAs overlapping the Hydrocarbon Ecological and Social EMBAs are for breeding, nursing, calving and foraging (high-density seagrass beds) (Table 6-10). These BIAs are in the Exmouth Gulf and along the coast from North West Cape to Coral Bay (Figure 6-20).

Dugongs inhabit seagrass meadows in coastal waters, estuarine creeks and streams, and offshore at Ashmore Reef (Ref. 103). Dugongs are predominantly distributed in coastal and island waters from Shark Bay in Western Australia to Moreton Bay in Queensland (Ref. 138). Specific areas supporting dugongs in WA include Shark Bay; Ningaloo and Exmouth Gulf; the Pilbara coast (Exmouth Gulf to De Grey River (Ref. 138); and Eighty Mile Beach and Kimberley Coast Region, including Roebuck Bay (Ref. 138). Their distribution range in Australia is broadly coincident with the distribution of seagrasses in tropical and sub-tropical waters (Ref. 138).

The maximum depth at which seagrasses occur along the coast is variable (controlled by turbidity and light availability), but they can occur down to depths of 50–60 m. However, the majority of seagrasses are found in shallow inshore and intertidal zone areas to water depths of around 25 m.

Dugongs are highly migratory and are capable of moving over relatively large distances, with the maximum recorded movement of more than 400 km in around 40 days (Ref. 103). Although dugong migration patterns are not well known in WA, it is believed that water temperature and the presence of seagrass can influence their movements (Ref. 103). Most seagrasses occur in shallow inshore and intertidal zone areas (≤25 m water depth); but can occur in water depths up to 50–60 m depending on light availability (Ref. 138). However, these deeper seagrass meadows occur at depths beyond the dugong's known diving range (up to ~35 m) (Ref. 138).

Dugongs have low breeding rates and long-term care of calves. Female dugongs give birth to a single calf at long intervals of between three to seven years and calves stay with their mother until one or two years of age. Dugongs can reach full adult size between four and 17 years old (Ref. 139).

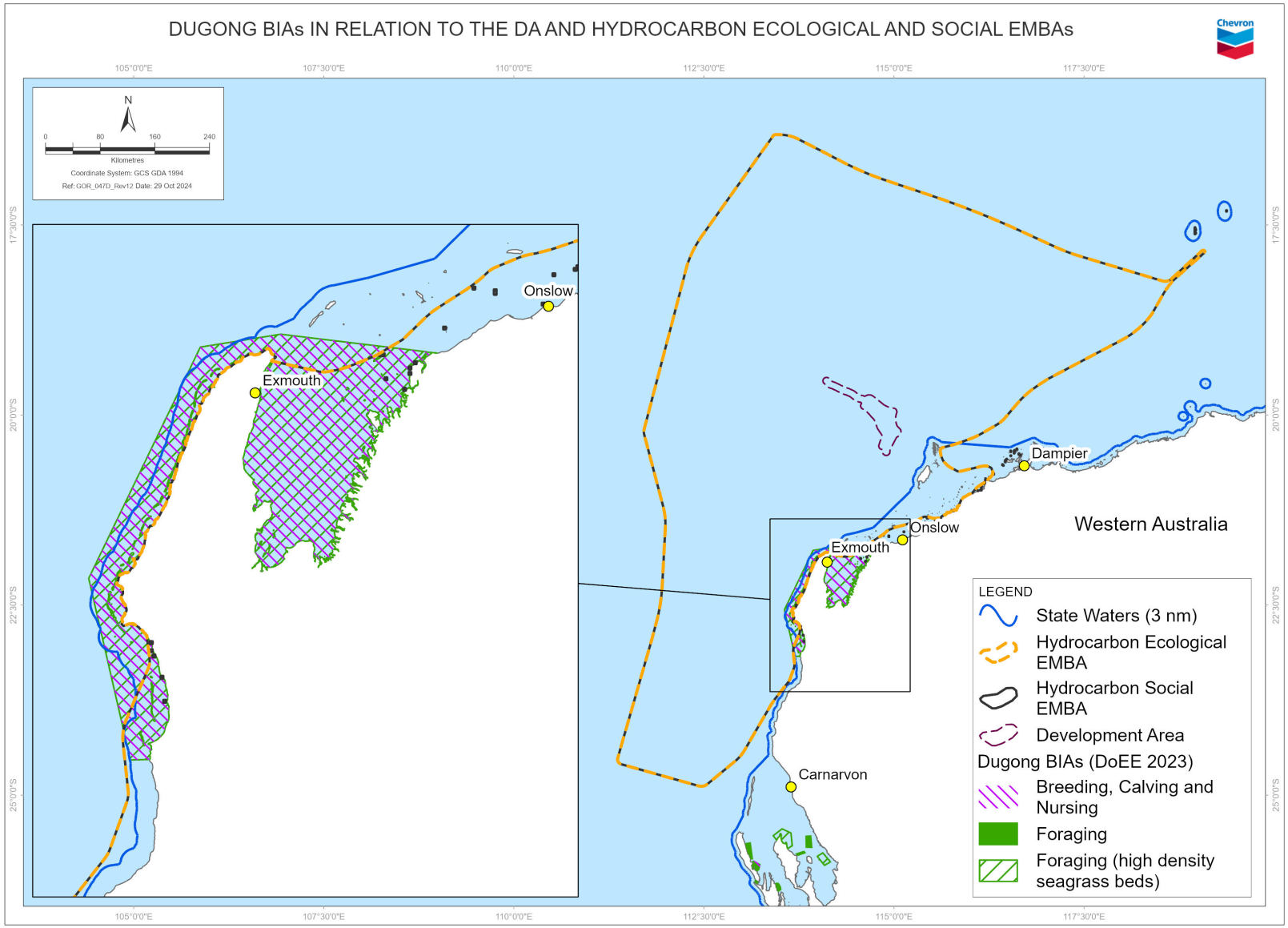


Figure 6-20: Dugong BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.2 reptiles

Based on searches of the EPBC Act protected matters database (Ref. 122; appendix b), the threatened and/or migratory reptile species shown in Table 6-11 may be present within the DA and Hydrocarbon Ecological and Social EMBAs. The full list of marine species identified from the protected matters database is provided in appendix b. HCTS of a species and BIAs associated with marine reptile species are listed in Table 6-12 and Table 6-13 respectively.

While the short-nosed sea snake was identified within the PMST as potentially being present within the DA, this species is not considered likely to be present. The short-nosed sea snake occurs primarily on reef flats or in shallow waters of the outer reef edges to depths of 10 m (Ref. 27). The DA occurs in water depths >100 m with no emergent reef features.

Similarly, the salt-water crocodile was identified within the PMST as potentially being present within the DA, however this species is not considered likely to be present. The salt-water crocodile inhabits Australian coastal waters, estuaries, lakes, inland swamps, and marshes (Ref. 537). The DA occurs offshore and is ~50 km northwest of the Montebello Islands. There are no islands or other emergent features within or adjacent to the DA.

Table 6-11: Presence of threatened and/or migratory reptiles

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Turtles							
Flatback turtle	*Natator depressus*	AKO	BKO	V	✓	✓	V
Green turtle	*Chelonia mydas*	KO	BKO	V	✓	✓	V
Hawksbill turtle	*Eretmochelys imbricata*	KO	BKO	V	✓	✓	V
Leatherback turtle	*Dermochelys coriacea*	LO	FKO	E	✓	✓	V
Loggerhead turtle	*Caretta caretta*	KO	BKO	E	✓	✓	E
Sea snakes							
Brown-lined sea snake	*Aipysurus tenuis*	–	MO	–	–	✓	–
Dubois' sea snake	*Aipysurus duboisii*	MO	MO	–	–	✓	–
Eastern turtle-headed sea snake	*Emydocephalus annulatus*	MO	MO	–	–	✓	–
Elegant sea snake	*Hydrophis elegans*	MO	MO	–	–	✓	–
Fine-spined sea snake, geometrical sea snake	*Hydrophis czeblukovi*	MO	MO	–	–	✓	–
Horned sea snake	*Hydrophis peronii*	MO	MO	–	–	✓ (as *Acalyptophis peronii*)	–
Leaf-scaled sea snake	*Aipysurus foliosquama*	–	KO	CE	–	✓	CE
MacDowell's sea snake, smallheaded sea snake	*Hydrophis macdowelli*	–	MO	–	–	✓	–
Mangrove sea snake	*Ephalophis greyae*	MO	MO	–	–	✓ (as *Ephalophis greyi*)	–

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Mosaic sea snake	*Aipysurus mosaicus*	MO	MO	–	–	✓ (as *Aipysurus eydouxii)*	–
Olive sea snake	*Aipysurus laevis*	MO	MO	–	–	✓	–
Olive-headed sea snake	*Hydrophis major*	MO	MO	–	–	✓ (as *Disteira major)*	–
Port Darwin sea snake, black-ringed sea snake	*Hydrelaps darwiniensis*	–	MO	–	–	✓	–
Shark Bay sea snake	*Aipysurus pooleorum*	–	MO	–	–	✓	–
Short-nosed sea snake	*Aipysurus apraefrontalis*	MO	KO	CE	–	✓	CE
Spectacled sea snake	*Hydrophis kingii*	MO	MO	–	–	✓ (as *Disteira kingii)*	–
Spotted sea snake, ornate reef sea snake	*Hydrophis ornatus*	MO	MO	–	–	✓	–
Stokes' sea snake	*Hydrophis stokesii*	MO	MO	–	–	✓ (as *Astrotia stokesii)*	–
Yellow-bellied sea snake	*Hydrophis platurus*	MO	MO	–	–	✓ (as *Pelamis platurus)*	–
Crocodiles							
Salt-water crocodile, estuarine crocodile	*Crocodylus porosus*	MO	MO	–	✓	✓	MI

Likely Presence
AKO: Congregation or aggregation know to occur within area
BKO: Breeding known to occur within area
FKO: Foraging, feeding or related behaviour known to occur within area
KO: Species or species habitat known to occur within area
LO: Species or species habitat likely to occur within area
MO: Species or species habitat may occur within area

Conservation Status:
CE: Critically Endangered
E: Endangered
V: Vulnerable
MI: Migratory

Table 6-12: HCTS of marine turtles

Common name	Nesting location	Internesting buffer	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Flatback turtle	Barrow Island, Montebello Islands, coastal islands from Cape Preston to Locker Island	60 km	Oct–Mar	✓	0	✓
	Dampier Archipelago, including Delambre Island and Hauy Island	60 km	Oct–Mar	–	85.4	✓
Green turtle	Barrow Island, Montebello Islands, Serrurier Island, and Thevenard Island	20 km	Nov–Mar	–	26.6	✓
	Dampier Archipelago	20 km	Nov–Mar	–	125.4	✓
	Exmouth Gulf and Ningaloo Coast	20 km	Nov–Mar	–	137.8	✓
Hawksbill turtle	Cape Preston to mouth of Exmouth Gulf including Montebello Islands and Lowendal Islands	20 km	Oct–Feb	–	26.6	✓
	Dampier Archipelago	20 km	Oct–Feb	–	125.4	✓
Loggerhead turtle	Exmouth Gulf and Ningaloo Coast	20 km	Nov–May	–	137.8	✓
	Gnaraloo Bay and beaches	20 km	Nov–May	–	348	

Table 6-13: Presence of BIAs for reptiles

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Flatback turtle	Aggregation	(Not defined in database)	–	44.5	✓
	Foraging	(Not defined in database)	–	44.5	✓
		Early in Summer	–	44.5	✓
		October to November for Solitary, Steamboat, Carey, Preston Islands and Cape Preston.	–	95.5	✓

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
		Year round[52]	–	150	✓
	Internesting	(Not defined in database)	–	44.5	✓
		Summer[22]	–	150	✓
	Internesting buffer	Early summer	✓	0	✓
		January	–	132.2	✓
		Summer	–	10.2	✓
	Mating	(Not defined in database)	–	44.5	✓
		Early summer	–	46.7	✓
		Year round[22]	–	150	✓
	Migration corridor	(Not defined in database) [22]	–	150	✓
	Nesting	Early in summer	–	46.7	✓
		Short summer nesting season, predominantly November- March with peak in January	–	46.5	✓
		Summer[22]	–	89.9	✓
Green turtle	Aggregation	(Not defined in database)	–	44.5	✓
	Basking	Summer	–	47.6	✓
	Foraging	(Not defined in database)	–	44.5	✓
		Early summer	–	46.7	✓
		October to November for Solitary, Steamboat, Carey, Preston Islands and Cape Preston.	–	95.0	✓
		Summer around Montebello Islands, Year round within inshore tidal and shallow subtidal areas around Barrow Island	–	41.9	✓
		Year round	–	44.7	✓
	Internesting	(Not defined in database)	–	44.5	✓
		Summer	–	41.9	✓
	Internesting buffer	Early summer	–	26.2	✓
		Summer	–	23	✓
	Mating	(Not defined in database)	–	44.5	✓
		Early summer	–	46.7	✓
		Summer	–	41.9	✓
		Year round[22]	–	150	✓

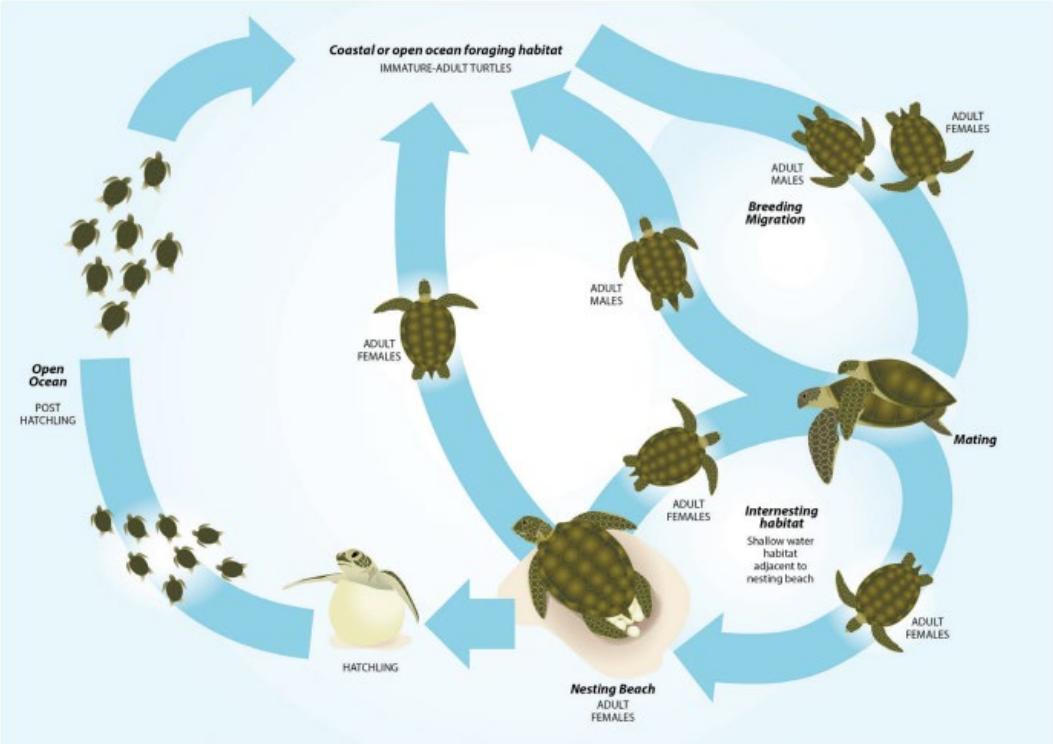
[52] Identified only in the Hydrocarbon Social EMBA around Dampier Archipelago (islands to the west of the Burrup Peninsula).

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
	Migration corridor	(Not defined in database) [22]	–	150	✓
	Nesting	Early summer	–	46.7	✓
		Summer	–	41.9	✓
Hawksbill turtle	Foraging	Early summer	–	44.5	✓
		October to November for Solitary, Steamboat, Carey, Preston Islands and Cape Preston.	–	95.0	✓
		Spring and early summer, peak nesting October	–	60.5	✓
		Year round	–	46.5	✓
	Internesting	Spring and early summer, peak nesting October	–	58.8	✓
		Summer[22]	–	150	✓
	Internesting buffer	(Not defined in database)	–	46.5	✓
		Early summer	–	27.6	✓
		Peak nesting in spring and early summer	–	30.1	✓
		Spring and early summer, peak nesting October	–	37.3	✓
		Year round	–	74.9	✓
	Mating	Early summer	–	44.5	✓
		Spring and early summer, peak nesting October	–	59.4	✓
		Year round	–	46.5	✓
	Migration corridor	Year round[22]	–	150	✓
	Nesting	(Not defined in database)	–	66.8	✓
		Early summer	–	44.5	✓
		Peak nesting in spring and early summer	–	46.5	✓
		Spring and early summer, peak nesting October	–	55.4	✓
		Summer[22]	–	150	✓
		Year round	–	100.4	✓
Loggerhead turtle	Internesting buffer	(Not defined in database)	–	31.4	✓
	Nesting	(Not defined in database)	–	50.4	✓

6.3.3.2.1 flatback turtle

The flatback turtle (*Natator depressus*) is listed as vulnerable and migratory under the EPBC Act. An internesting buffer BIA and HCTS (internesting buffer) for the flatback turtle overlaps the DA and Hydrocarbon Ecological and Social EMBAs (Figure 6-22 and Figure 6-23). Aggregation, foraging, internesting, mating and nesting BIAs overlap the Hydrocarbon Ecological and Social EMBAs. The migration corridor BIA only overlaps the Hydrocarbon Social EMBA (Figure 6-22 and Figure 6-23).

Marine turtles, including flatbacks, share a broadly similar life cycle (Ref. 24; Figure 6-21). During non-breeding periods, adults inhabit coastal or open ocean foraging habitats. Breeding adults migrate from these foraging areas to mating grounds, which may or may not be near nesting beaches (Ref. 696). After mating, males return to foraging areas, while females remain in internesting habitats close to the nesting beach or rookery (Ref. 24). Once the last clutch is laid, females also return to foraging areas to building up their fat reserves before the next breeding migration (Ref. 24).



Source: Ref. 24

Figure 6-21: Life cycle of marine turtles

Female flatback turtles nest on Barrow Island beaches during the wet season, generally from November - January (Ref. 727). Peak hatchling emergence occurs during February and March (Ref. 290; Ref. 727). Hatchlings typically emerge from the nest at night and orient toward the sea using topographic and brightness cues, orienting to the low elevation light horizon (Ref. 697).

Upon entering the water, hatchlings undergo a period of intense, continuous swimming known as the frenzy. This phase, lasting ~24–48 hours, is characterised by rapid and sustained offshore movement to reduce predation risk in nearshore waters (Ref. 719). During the frenzy, hatchlings primarily use wave direction as an orientation cue to reach deeper water (Ref. 24; Ref. 355; Ref. 719; Ref. 739).

Once the frenzy ends, they reduce active swimming and transition to passive drifting, using ocean currents as their primary orientation cue and floating seaweed for refuge (Ref. 740). Unlike other marine turtle species, flatback turtles do not have a known oceanic development phase; instead, hatchlings are considered to develop in shallow coastal waters without leaving the Australian continental shelf (Ref. 698; Ref. 699 cited in Ref. 290).

Flatback turtles have been reported foraging over the Australian continental shelf into continental waters off Papua New Guinea and Indonesia (Ref. 140). The exact locations of mating, post-hatching, and juvenile foraging grounds for flatback turtles are not well understood (Ref. 290). Limited observations suggest they feed on small animals living in the water column (Ref. 24). Flatback turtles nesting are only found in the tropical waters of northern Australia (Ref. 140).

Flatback turtles require sandy beaches for nesting, with sand temperatures between 25°C and 33°C needed for egg incubation (Ref. 140). Most females return to the same beach in successive breeding seasons and show a fidelity to the area where they were born. This means that a first-time nesting turtle might return to their 'predetermined' nest site that they emerged from, regardless of the nesting suitability of the location (Ref. 141). Flatback turtles make long reproductive migrations; however, these movements are restricted to the continental shelf (Ref. 140). Satellite tracking of adult female flatback turtles indicate that they move large distances between multiple geographically distinct areas, ranging from the Pilbara coast to the Gulf of Carpentaria (Ref. 290). However, there are knowledge gaps regarding migratory corridor information (Ref. 24).

Five flatback turtle stocks are recognised in Australia, with the south-west Kimberley and Pilbara stocks occurring in WA (Ref. 24). The Montebello and Barrow islands (~50 km and 60 km, respectively, of the DA) are identified as nesting habitat critical to the survival of the Pilbara stock. The DA overlaps the 60 km internesting buffer BIA and HCTS around Barrow Island and the Montebello Islands (Figure 6-22; Figure 6-23). Typically, flatback turtle nesting on Barrow Island occurs between October and March, with peak nesting activity occurring between November and January (Ref. 290). On Barrow Island, nesting activity is concentrated on the east coast on sandy, low-sloped, low-energy beaches with wide, shallow intertidal zones (Ref. 142; Ref. 143). Limited nesting activity has also been recorded on the south-west, north, and north-east beaches of Barrow Island (Ref. 144).

During internesting, turtles remain close to the nesting beach or rookery (Ref. 24). The 60 km internesting buffer defined within the *Recovery Plan for Marine Turtles in Australia* (Ref. 24) is based primarily on the movements of tagged internesting flatback turtles in WA (Ref. 145). The study tracked 56 turtles from four different rookeries, which demonstrated varying internesting movements, with distances ranging from 3–62 km, with some turtles at all four rookeries remaining within 10 km of their nesting beaches. However, tracking data showed these movements were largely longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland, which represent the greater distances (Ref. 145). There is no evidence to suggest that flatback turtles move to deep offshore waters during internesting periods.

A habitat suitability modelling study for internesting flatback turtles in the NWS region of WA (Ref. 146) was conducted to identify areas of suitable flatback turtle internesting habitat and determine overlap with identified industrial hazards. The study used a turtle tracking dataset of 47 nesting female turtles from five important rookeries in the NWS study area, including Barrow Island. The results showed

internesting flatback turtles from all rookeries remained within water depths of <44 m, with a mean depth of <10 m (Ref. 146). Results also showed internesting turtles from all rookeries remained within <28 km of the nearest coast, with a mean distance from the coast of <6.1 km. The habitat suitability modelling study defined suitable flatback turtle internesting habitat as water depths of between 0 and 16 m, within 5 –10 km of the coast. Unsuitable flatback turtle internesting habitat was defined as waters >25 m deep and >27 km from the coast (Ref. 146). The DA is located in waters classified as unsuitable for internesting flatback turtles.

Other previous studies (e.g. Ref. 147; Ref. 148; Ref. 149) have also presented findings that internesting behaviour was only observed in water depths of <40 m. One of these studies (Ref. 149) further indicates that internesting flatback turtles have relatively shallow dives, with 85% of the time during spent in ≤20 m water depth, of which most was spent in 5–10 m (27±2.7%) and 10–15 m (22.3±3.5%) water depths.

The DA is located in water depths of >100 m and is at closest ~50 km from the west coast of Barrow Island, and ~45 km from the Montebello Islands, and as such, is located in deeper waters and further offshore than where previous studies have recorded internesting behaviour (Ref. 146, Ref.147; Ref. 148; Ref. 149) or hatchling dispersal (Ref. 398 cited in Ref. 290). Consequently, it is considered highly unlikely that hatchling dispersal or internesting flatback turtles will occur within the DA.

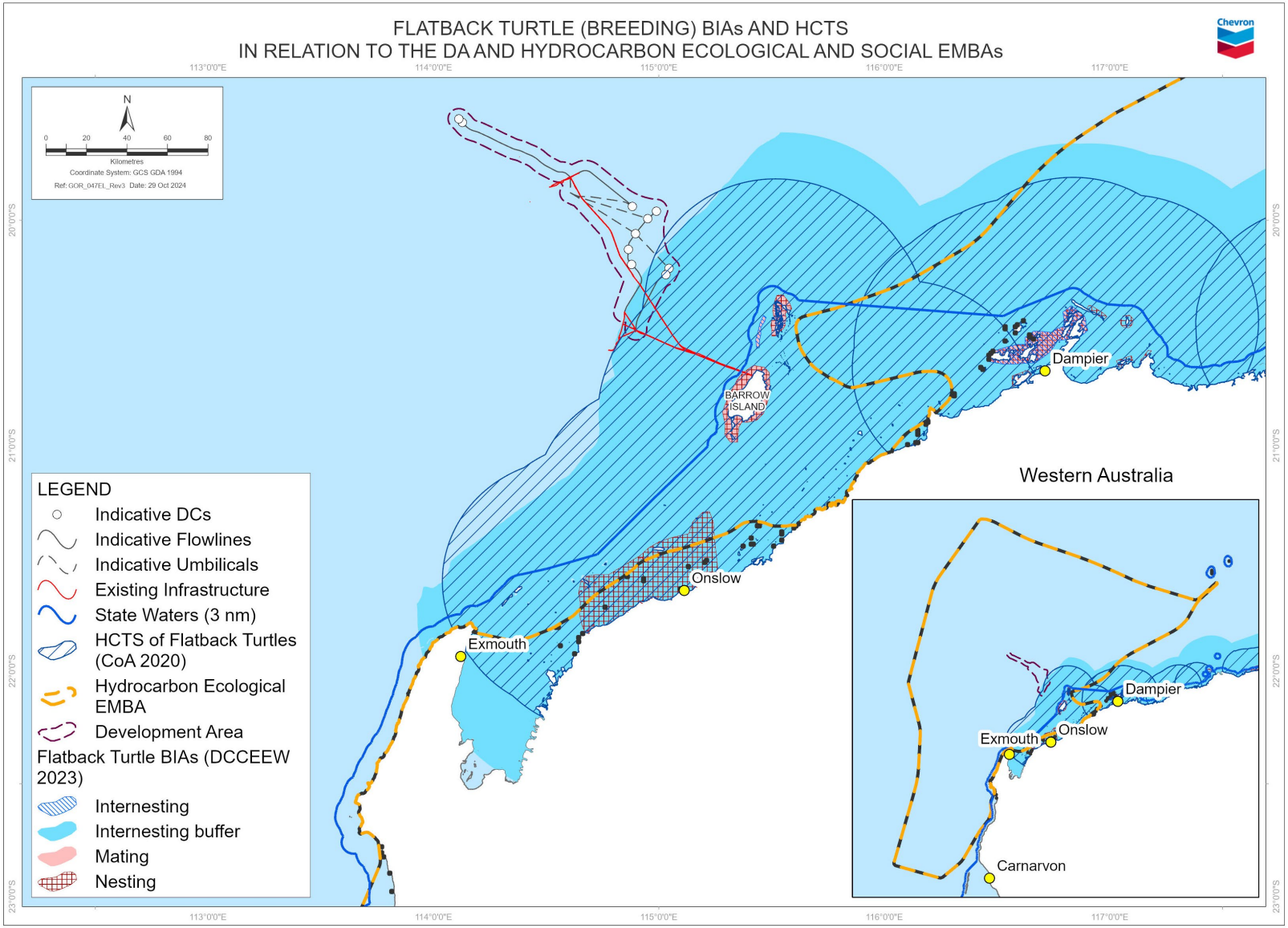


Figure 6-22: Flatback turtle (breeding) BIAs and HCTS areas in relation to the DA and Hydrocarbon Ecological and Social EMBAs

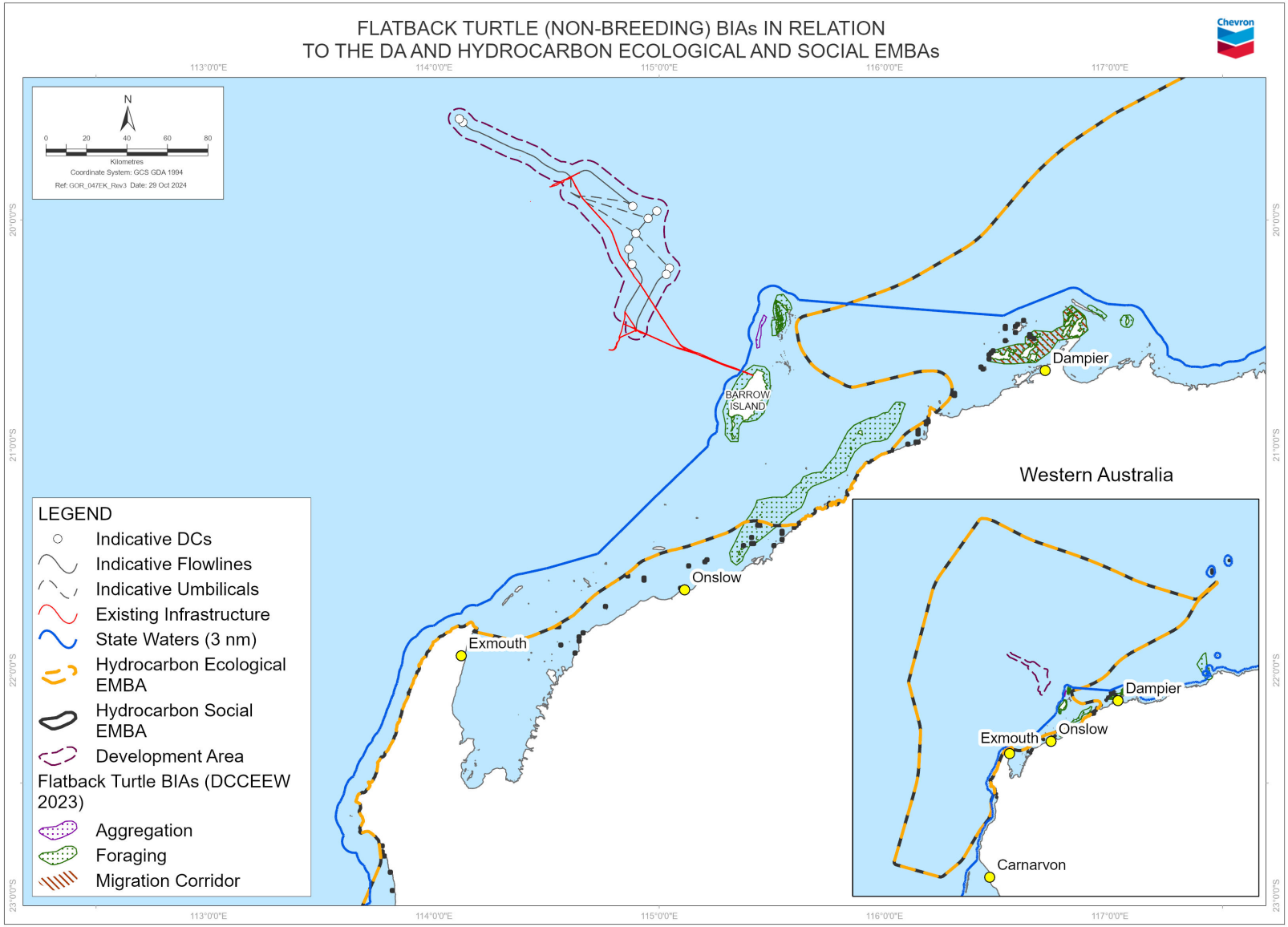


Figure 6-23: Flatback turtle (non-breeding) BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.2.2 green turtle

The green turtle (*Chelonia mydas*) is listed as vulnerable, marine, and migratory under the EPBC Act. There are no green turtle BIAs or HCTS overlapping the DA (Figure 6-24 and Figure 6-25). Aggregation, basking, foraging, internesting, internesting buffer, mating and nesting BIAs and HCTS overlap the Hydrocarbon Ecological and Social EMBAs (Figure 6-24 and Figure 6-25).

The life cycle of green turtles is similar to that of flatback turtles (see Section 6.3.3.2.1). However, green turtle hatchlings disperse into oceanic currents and gyres, where they remain in pelagic environments during their juvenile stage until they are large enough to settle in coastal feeding habitats (Ref. 700).

Green turtles are distributed across nine genetically distinct stocks (Ref. 24). The Northwest Shelf (NWS) stock is one of the largest green turtle stocks in the world and the largest in the Indian Ocean (Ref. 150 in Ref. 24). Nesting for the NWS stock occurs over a large geographic range with nesting on offshore islands and the mainland (Ref. 24). The Hydrocarbon Ecological and Social EMBAs overlap with BIAs and HCTS for the NWS stock, including key nesting and internesting areas as identified in Table 6-12. The seasonal presence for these areas is generally November to May (Ref. 24). The closest nesting areas to the DA are Barrow Island and Montebello Islands (Table 6-13). These are identified as nesting HCTS of the species, as is the 20 km internesting buffer surrounding the islands (Table 6-12).

Green turtle nesting usually occurs on the west and north-east coasts of Barrow Island between September and March each year, with a remigration interval of approximately five years (Ref. 151) and peak nesting activity occurring between December and February (Ref. 152; Ref. 142). During the internesting period, turtles remain close to the nesting beaches (Ref. 24). Satellite tracking data from Barrow Island shows that the internesting habitat for this area is found throughout the rocky intertidal and subtidal zones common on the west coast, and around north-eastern beaches and waters (Ref. 142). Internesting green turtles around Barrow Island were recorded to remain in the shallow waters, 5 km off Barrow Island, while tracking of post-nesting green turtles, around Barrow and Sandy Island, show that they feed between 200-1,000 km from the nesting beaches (Ref. 142). Following the nesting period on Barrow Island, these adult turtles were recorded to migrate to foraging grounds, ranging from Legendre Island in the Dampier Archipelago to waters around Southern Kimberley (Ref. 142, Ref. 702).

A satellite tracking study of 96 adult female green turtle in WA identified nesting, migration, and foraging behaviours for two genetic stocks: the NWS and Scott-Browse stocks (Ref. 702). Most turtles (86%) migrated to neritic foraging sites via coastal routes, while the remainder exhibited only internesting behaviour. Turtles from the NWS stock (Pilbara and Kimberley sub-stocks) primarily remained within WA, with most migrating in a northeasterly direction from the rookery. A smaller proportion (34%) migrated southwest or south (Ref. 702).Foraging habitat for juvenile and adult green turtles includes tidal/sub-tidal habitats with coral reef, mangrove, sand, rocky reefs and mudflats where there are algal turfs or seagrass meadows present (Ref. 24). Some turtles may remain in the open ocean (Ref. 153 in Ref. 24). The stock is classed as stable in the Recovery Plan for Marine Turtles (Ref. 24).Once the breeding and nesting periods are complete, green turtles return to their preferred foraging areas (Ref. 152).

Given the location (~50 km from the west coast of Barrow Island, and ~45km from the Montebello Islands), depth (>100 m), and considering that green turtle migration routes are typically shelf-bound and directed toward the mainland, it is

considered unlikely that green turtles would use the DA for migration, internesting, nesting, or foraging.

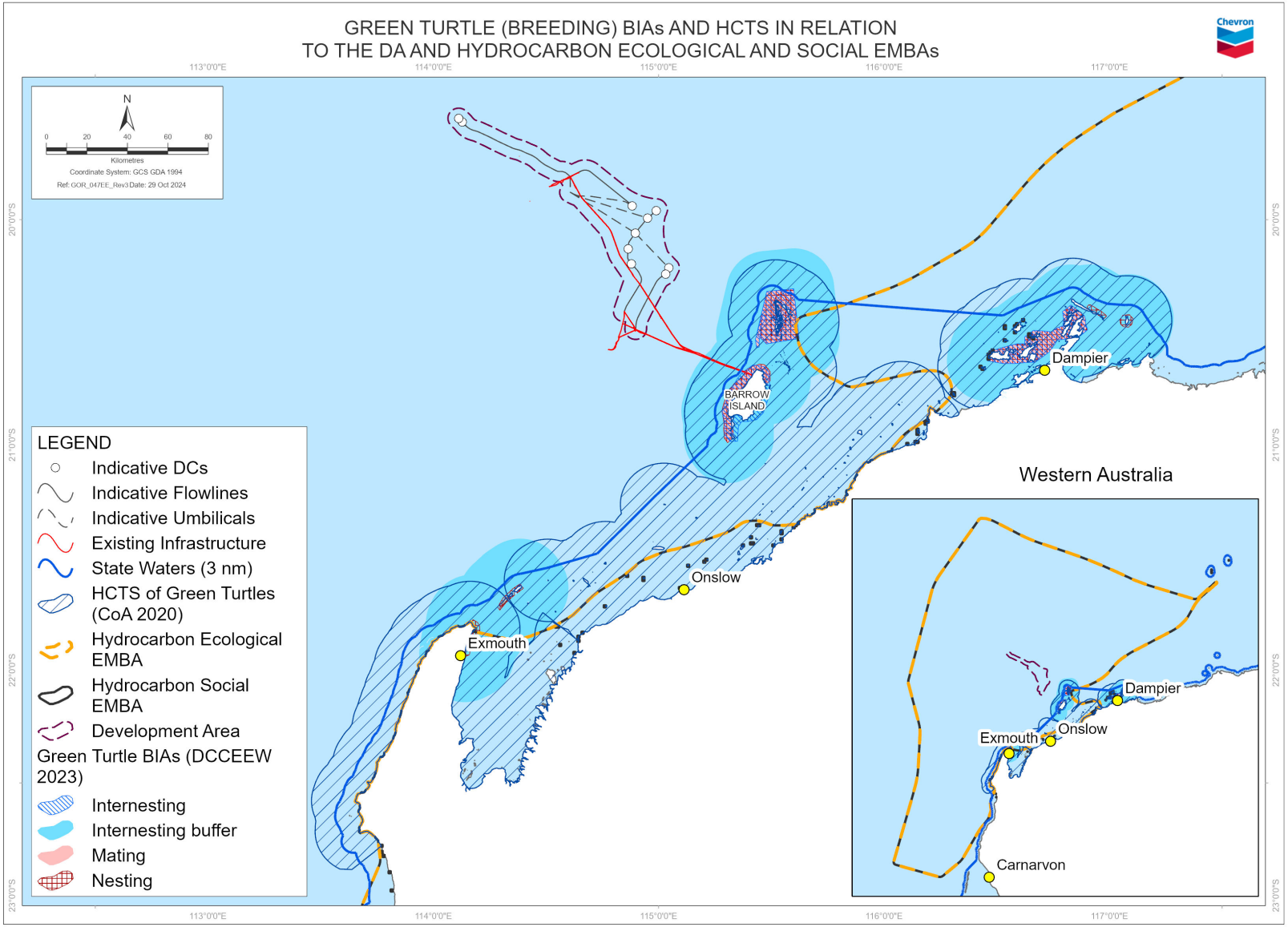


Figure 6-24: Green turtle (breeding) BIAs and HCTS areas in relation to the DA and Hydrocarbon Ecological and Social EMBAs

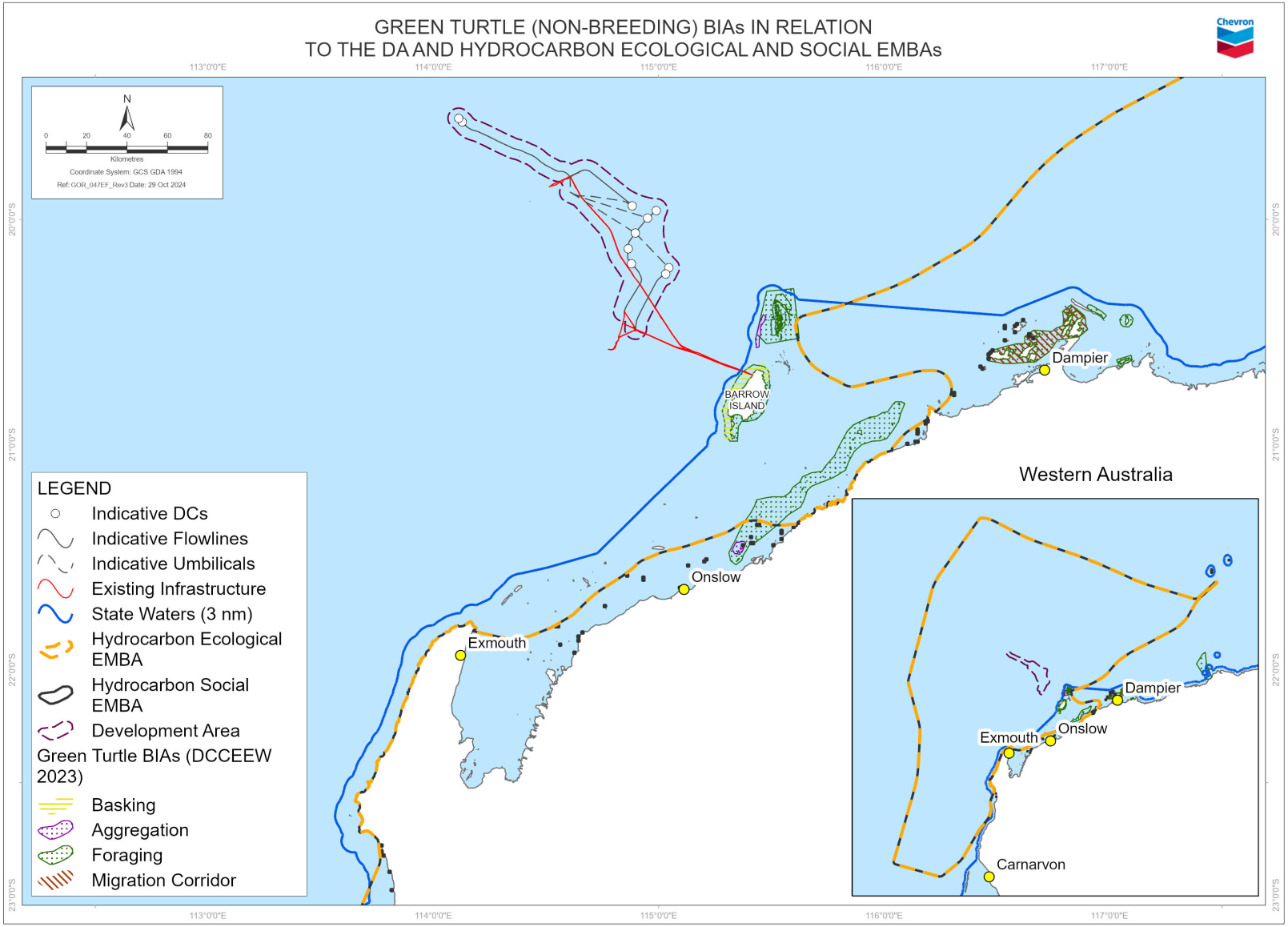


Figure 6-25: Green turtle (non-breeding) BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.2.3 hawksbill turtle

The hawksbill turtle (*Eretmochelys imbricata*) is listed as vulnerable, marine, and migratory under the EPBC Act. There are no hawksbill turtle BIAs or HCTS overlapping the DA (Figure 6-26 and Figure 6-27). Foraging, internesting buffer, internesting, nesting and mating BIAs and HCTS overlap the Hydrocarbon Ecological and Social EMBAs (Figure 6-26 and Figure 6-27).

The life cycle of hawksbill turtles is similar to that of green turtles (see Section 6.3.3.2.2). Hawksbill turtle hatchlings swim actively out to sea, and are then carried passively by currents during their pelagic phase (Ref. 154).

Australia supports the largest hawksbill turtle nesting aggregations worldwide, with approximately 2,000 females nesting annually in WA (Ref. 154). The majority of nesting for the WA hawksbill turtle stock is located in the Pilbara (Ref. 24). The key nesting and internesting areas in Australia include the Dampier Archipelago, the Ningaloo and Jurabi Coasts, and Thevenard, Barrow, Lowendal and Montebello Islands (Ref. 154). The estimated size of the reproductive population of WA stock is small (Ref. 290). For example, it has been estimated an overall reproductive population at Barrow Island of 100, an additional 1,000 in the Lowendal Islands, and 1,300 in the Montebello Islands exist (Ref. 142 Ref. 290).

Monitoring of Barrow Island hawksbill turtle nesting has found that nesting activity is more temporally and spatially diffuse than flatback and green turtle nesting activity and occurs predominantly on small, rocky, east coast beaches. Nesting on Barrow Island peaks in October (Ref. 398). The internesting interval for the hawksbill turtle is approximately 14.5 days with a remigration interval of approximately three years (Ref. 154). During internesting turtles remain close to the nesting beach or rookery (Ref. 24). Satellite tracking of hawksbill turtles supports this and found that individuals remained in shallow coastal waters (<10 m deep) post nesting (Ref. 142).

The hawksbill turtle is recorded to migrate up to 2,400 km between foraging areas and their nesting beaches (Ref. 155). Hawksbill turtles prefer shallow, tropical, and subtropical waters, settling and foraging in tropical tidal and sub-tidal coral and rocky reef habitats, although, they have also been found in seagrass habitats of coastal waters, as well as deeper waters (Ref. 156). In WA, reefs located west of Cape Preston and south of Onslow are recorded as important feeding grounds for the species (Ref. 24). Satellite tracking data shows that the turtles migrating between WA rookeries remained on the continental shelf, with majority following the coast and dispersing north-east, with some from the Montebello Archipelago and Lowendals moving south-west and stopping around Barrow Island (Ref. 157).

Although BIAs have been identified (Table 6-13), hawksbill turtle mating, internesting, and foraging grounds have not been identified for Barrow Island (Ref. 290). However, data from hawksbill turtles tracked from nearby Varanus Island indicate potential internesting habitat in waters north-east of Barrow Island (Ref. 142). This internesting is consistent with the internesting HCTS for the survival of the species that has been identified to overlap the Hydrocarbon Ecological and Social EMBAs (Table 6-12).

As hawksbill turtle nesting occurs predominantly on east coast beaches on Barrow Island, it is expected that any presence of these species within the DA would be of a transitory nature.

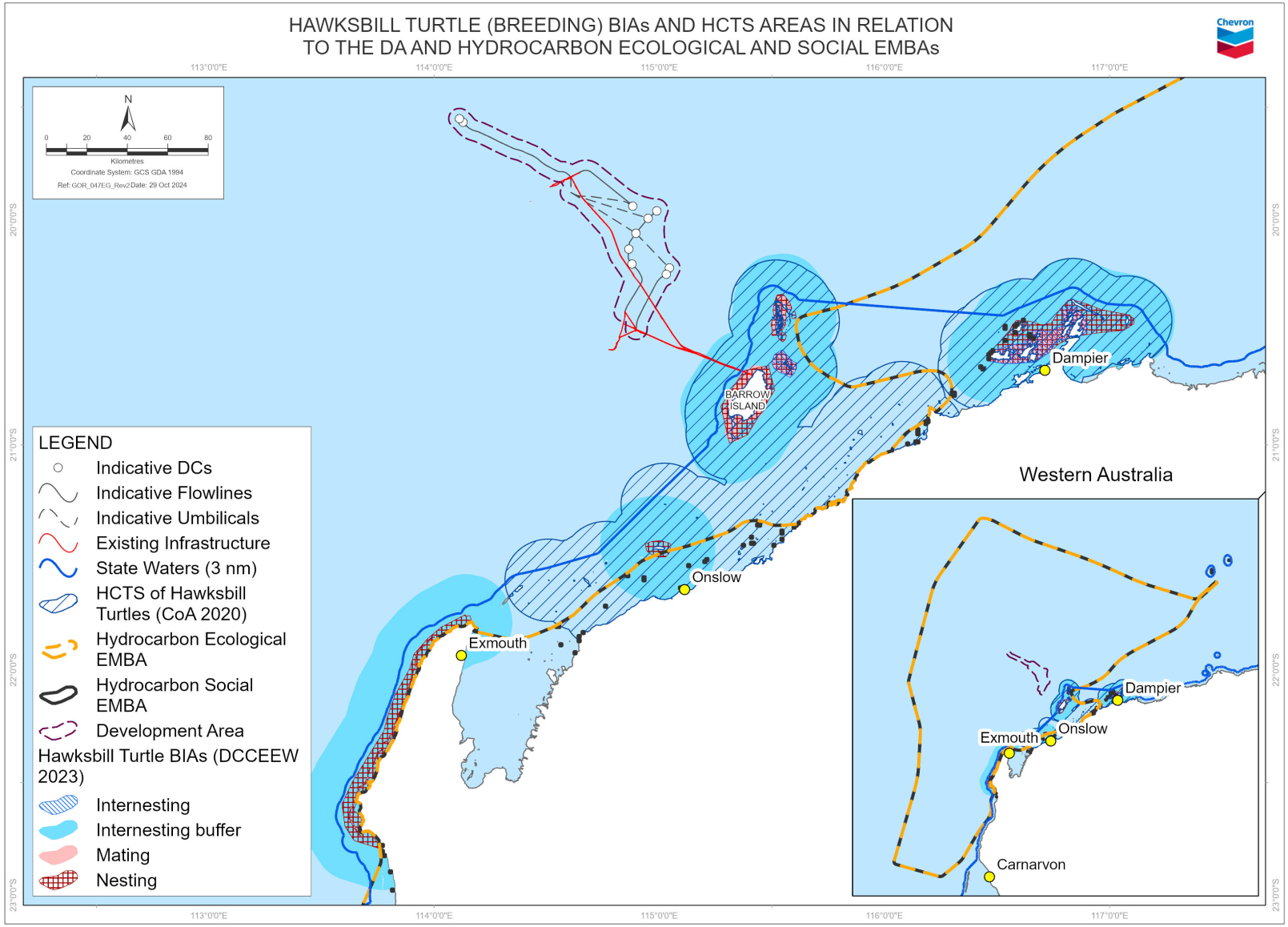


Figure 6-26: Hawksbill turtle (breeding) BIAs and HCTS areas in relation to the DA and Hydrocarbon Ecological and Social EMBAs

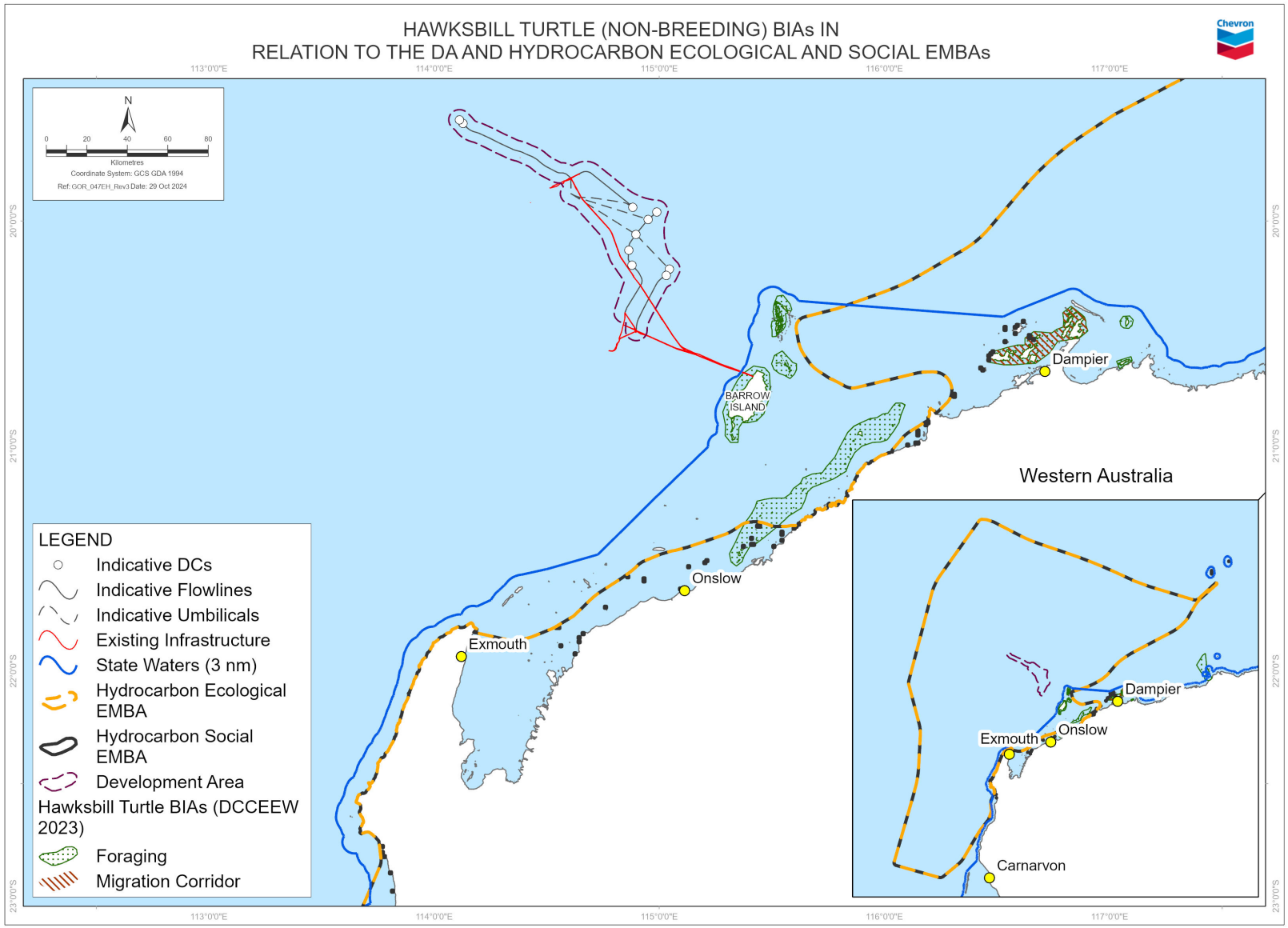


Figure 6-27: Hawksbill turtle (non-breeding) BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.2.4 loggerhead turtle

The loggerhead turtle (*Caretta caretta*) is listed as endangered, marine, and migratory under the EPBC Act. There are no loggerhead turtle BIAs or HCTS that overlap the DA (Figure 6-28 and Figure 6-29). Internesting buffer and nesting BIAs and HCTS overlap the Hydrocarbon Ecological and Social EMBAs (Figure 6-28 and Figure 6-29).

The life cycle of hawksbill turtles is similar to that of green turtles (see Section 6.3.3.2.2). Loggerhead turtles are globally distributed in tropical, sub-tropical and temperate waters. In Australia, the species can be found in eastern, northern, and western waters in coral and rocky reefs, seagrass beds, and muddy bays (Ref. 158). There are two genetically distinct stocks of loggerhead turtles that nest in Australia (Ref. 24): the south-west Pacific stock, that nest in southern Queensland, and the Western Australian stock, that nest between Shark Bay and North West Cape. Interbreeding between stocks does not occur.

The species nest on sandy beaches (Ref. 159). In WA nesting occurs from Shark Bay (including on the mainland near Steep Point) to the North West Cape, with major nesting at Dirk Hartog Island; Gnaraloo Bay; Muiron Island; and the beaches of the North West Cape (Ref. 160). Occasional late summer nesting crawls have also been recorded as far north as Barrow Island, the Lowendal Islands and Dampier Archipelago (Ref. 158). During internesting, turtles remain close to the nesting beach or rookery (Ref. 24). Once breeding and nesting is complete, turtles migrate back to their favoured foraging areas, sometimes over distances in excess of 1000 km, showing strong fidelity to their feeding and breeding areas (Ref. 161).

Loggerheads are carnivorous, feeding primarily on benthic invertebrates in habitats ranging from nearshore to 55 m depth (Ref. 162). Loggerhead turtles forage in all coastal states and the Northern Territory (Ref. 24).

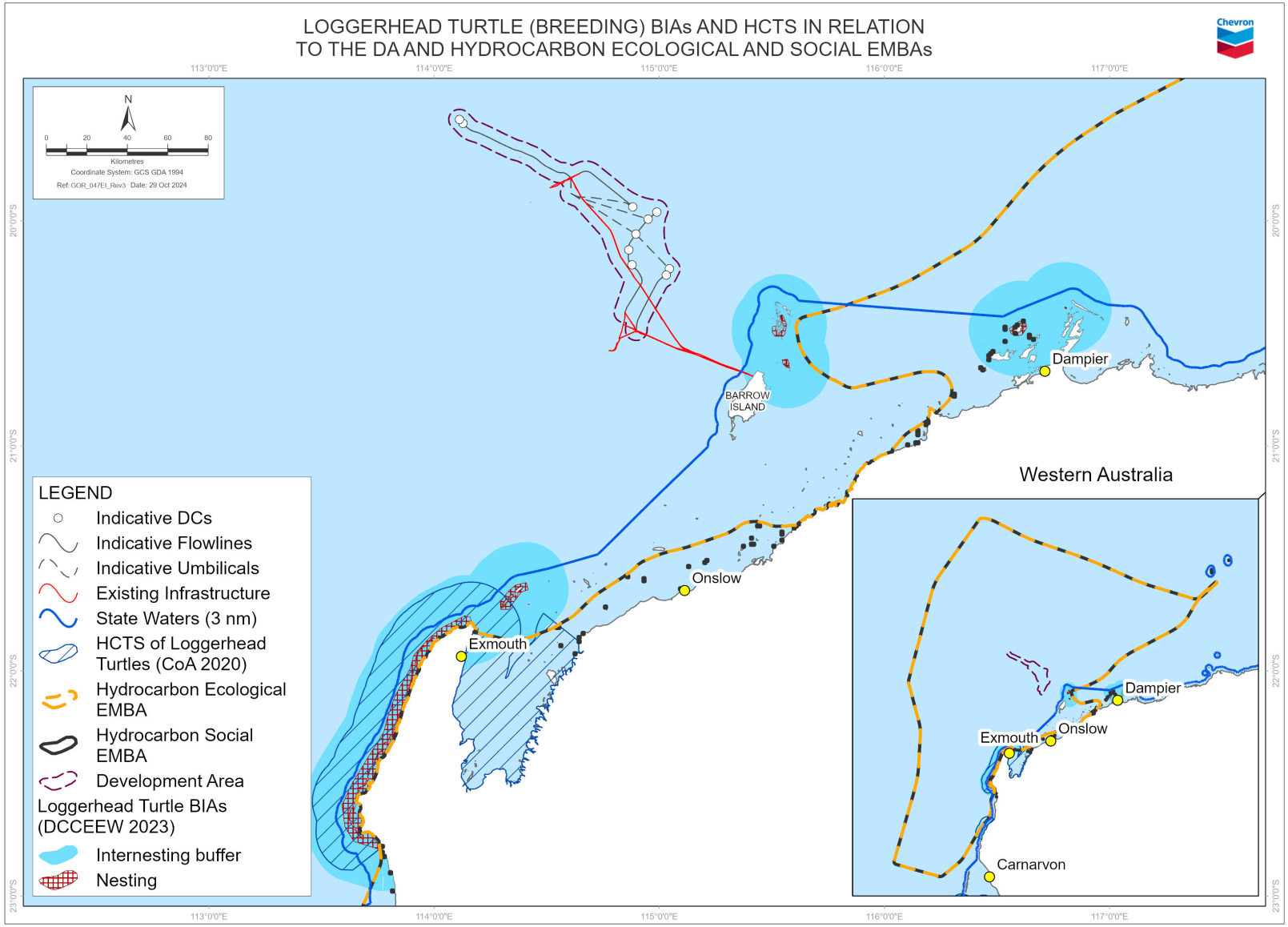


Figure 6-28: Loggerhead turtle (breeding) BIAs and HCTS in relation to the DA and Hydrocarbon Ecological and Social EMBAs

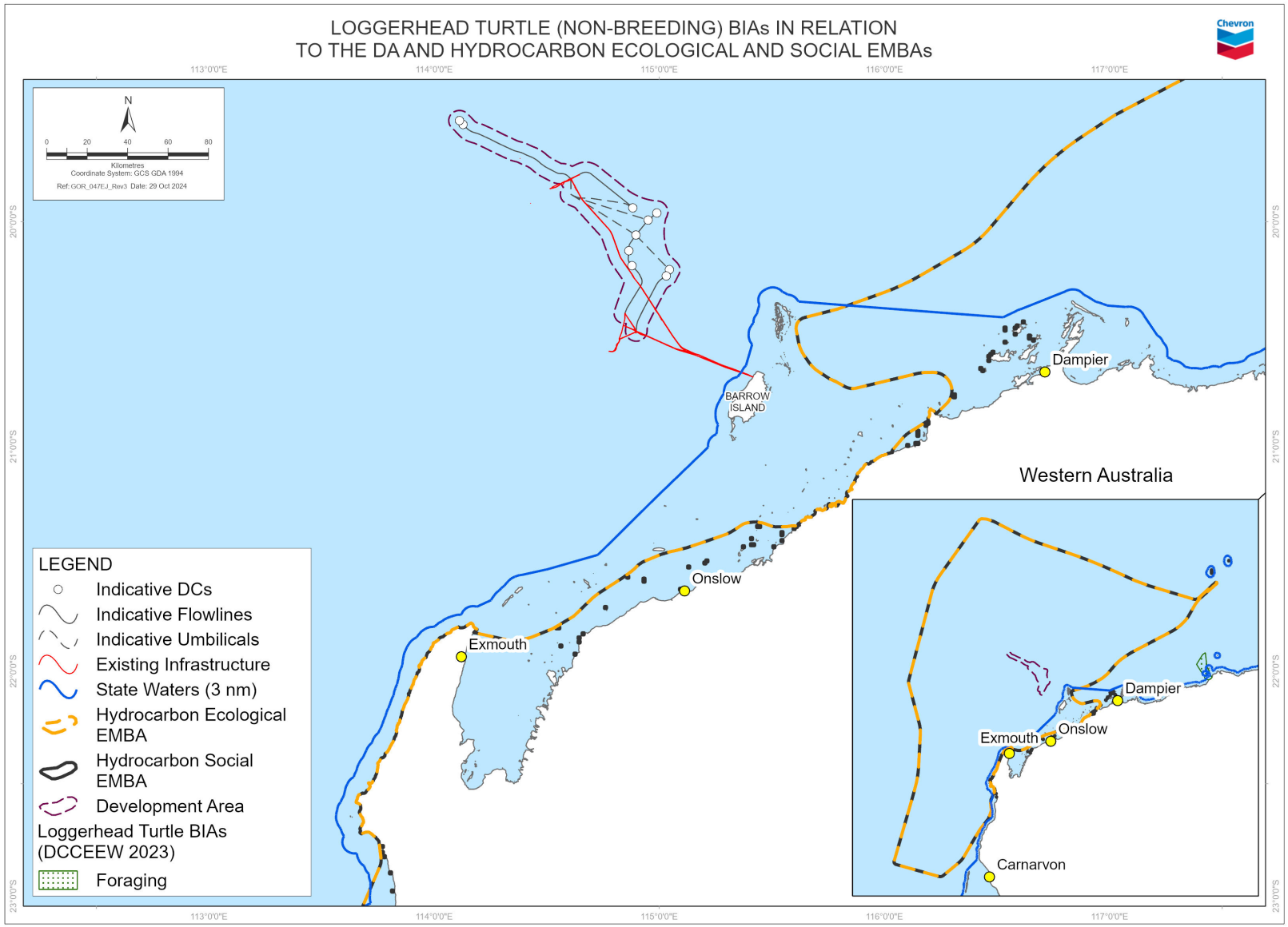


Figure 6-29: Loggerhead turtle (non-breeding) BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.3 fishes, including sharks and rays

Based on searches of the EPBC Act protected matters database (Ref. 122; appendix b), the threatened and/or migratory fish species shown in Table 6-14 may be present within the DA and Hydrocarbon Ecological and Social EMBAs. The full list of marine species identified from the protected matters database is provided in appendix b. BIAs associated with fish species are listed in Table 6-15.

A fish assemblage survey was undertaken as part of the benthic survey (Ref. 104; appendix a). Survey sites were selected across areas within the Chandon, C&D, Semele, and WTR fields, where video footage was collected. The results indicated the presence of distinct fish assemblages, which were strongly influenced by water depth and water masses (Ref. 104; appendix a). Shallower and warmer sites located in the tropical surface water mass within the ancient coastline at 125 m depth contour KEF had a greater number of fish (mean of 3,000 fish per transect) recorded than other sites (~1,700 fish per transect). The shallower sites were characterised by sharks and Carangidae such as yellowtail scad. The fish assemblages of the deeper continental slope were mostly dominated by Carangidae, Macrouridae (rat tails), Halosauridae (halosaurs) and unidentified anguilliform (eel-like) fishes. This zone was characterised by the Southern Indian central water mass and included the slope geomorphic feature and the continental slope demersal fish communities KEF (Ref. 104; appendix a).

In the KEFs, fish assemblages were recorded as follows (Ref. 104; appendix a):

- Exmouth Plateau KEF: a total of 165 individual fish from 14 taxa were identified. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois sp1* (family Ipnopidae), representing over 65% of the total number of individual fish recorded. Other abundant taxa included *Aldrovandia sp1, Aldrovandia sp2* (Halosauridae), and *Macrouridae sp2* (Macrouridae, rat tails)
- continental slope demersal fish communities KEF: a total of 468 fish belonging to 25 taxa were recorded. The fish assemblage was dominated by *Trevallies* (Carangidae) with four species from three genera accounting for 256 of the individuals observed. The five most abundant fish taxa were *Decapterus kurroides, Decapterus sp1* and *Seriola dumerili* (Carangidae), an unidentified bait fish, and *Synodontidae sp2* (Synodontidae). The fish assemblages of this KEF were significantly different to the fish assemblages at the Exmouth Plateau KEF and outside any KEFs.
- ancient coastline at 125 m depth contour KEF: recorded a total of 18,011 individuals from 13 fish taxa. The fish assemblage was dominated by *Trevallies* (Carangidae) with three species representing 14,231 of the total individuals. The most abundant fish taxa were *Carangoides sp1* and *Seriola dumerili* (Carangidae), an unidentified baitfish, *Carcharhinus sp1* (Carcharhinidae), and *Rachycentron canadum* (Rachycentridae).

The patterns of assemblage composition, abundance and number of taxa identified in fish sampled support that there is a different fauna associated with the deeper waters of >800 m depth and the Antarctic intermediate water mass. This change in fauna is likely linked to the Antarctic intermediate water, as the cold deep-water and lower saline current has a strong influence on the distribution of fish communities as seen in the south-west region between the Great Australian Bight and north of the Ningaloo Reef (Ref. 104; appendix a).

Table 6-14: Presence of threatened or migratory fishes, including sharks and rays

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Fish, sharks and rays							
Barrow cave gudgeon[53]	*Milyeringa justitia*	–	KO	E	–	–	E
Blind cave eel[54]	*Ophisternon candidum*	–	KO	V	–	–	V
Cape Range cave gudgeon, blind gudgeon[54]	*Milyeringa veritas*	–	KO	V	–	–	V
Dwarf sawfish, Queensland sawfish	*Pristis clavata*	KO	KO	V	✓	–	MI & P1
Freshwater sawfish, largetooth sawfish, river sawfish, Leichhardt's sawfish, northern sawfish	*Pristis pristis*	MO	LO	E	✓	–	MI & P3
Giant manta ray, Chevron manta ray, Pacific manta ray, pelagic manta ray, Oceanic manta ray	*Mobula birostris*	LO	KO	–	✓	–	MI
Green sawfish, dindagubba, narrowsnout sawfish	*Pristis zijsron*	KO	KO	V	✓	–	V
Grey nurse shark	*Carcharias taurus*	LO	AKO	–	✓	–	V
Grey nurse shark (west coast population)	*Carcharias taurus* (west coast population)	LO	AKO	V	–	–	–
Little gulper shark	*Centrophorus uyato*	–	LO	CD	–	–	–
Longfin mako	*Isurus paucus*	LO	LO	–	✓	–	MI
Narrow sawfish, knifetooth sawfish	*Anoxypristis cuspidata*	MO	KO	–	✓	–	MI
Oceanic whitetip shark	*Carcharhinus longimanus*	LO	LO	–	✓	–	MI
Porbeagle, mackerel shark	*Lamna nasus*	–	MO	–	✓	–	MI
Reef manta ray, coastal manta ray, inshore manta ray, Prince Alfred's ray, resident manta ray	*Mobula alfredi*	LO	KO	–	✓	–	MI
Scalloped hammerhead	*Sphyrna lewini*	LO	KO	CD	–	–	–

[53] The Barrow cave gudgeon is a subterranean species restricted to the aquatic subterranean habitat of Barrow Island (Ref. 792).

[54] The blind cave eel and Cape Range cave gudgeon are subterranean species found in caves and underwater waters on the Cape Range peninsula (Ref. 35; Ref. 36).

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Shortfin mako, mako shark	*Isurus oxyrinchus*	LO	LO	–	✓	–	MI
Whale shark	*Rhincodon typus*	FKO	FKO	V	✓	–	MI
White shark, great white shark	*Carcharodon carcharias*	MO	KO	V	✓	–	V
Pipefish / Pipehorse / Seahorse							
Australian messmate pipefish, banded pipefish	*Corythoichthys intestinalis-*	–	MO	–	–	✓	–
Banded pipefish, ringed pipefish	*Doryrhamphus dactyliophorus*	MO	MO	–	–	✓	–
Beady pipefish, steep-nosed pipefish	*Hippichthys penicillus*	MO	MO	–	–	✓	–
Bentstick pipefish, bend stick pipefish, short-tailed pipefish	*Trachyrhamphus bicoarctatus*	MO	MO	–	–	✓	–
Black rock pipefish	*Phoxocampus belcheri*	MO	MO	–	–	✓	–
Bluestripe pipefish, Indian blue-stripe pipefish, Pacific blue-stripe pipefish	*Doryrhamphus excisus*	MO	MO	–	–	✓	–
Bonyhead pipefish, bony-headed pipefish	*Nannocampus subosseus*	–	MO	–	–	✓	–
Braun's pughead pipefish, pug-headed pipefish	*Bulbonaricus brauni*	MO	MO	–	–	✓	–
Brock's pipefish	*Halicampus brocki*	MO	MO	–	–	✓	–
Cleaner pipefish, Janss' pipefish	*Doryrhamphus janssi*	MO	MO	–	–	✓	–
Corrugated pipefish	*Bhanotia fasciolata*	–	MO	–	–	✓	–
Double-end pipehorse, double-ended pipehorse, alligator pipefish	*Syngnathoides biaculeatus*	MO	MO	–	–	✓	–
Fijian banded pipefish, brown-banded pipefish	*Corythoichthys amplexus*	–	MO	–	–	✓	–

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Flagtail pipefish, Masthead Island pipefish	*Doryrhamphus negrosensis*	MO	MO	–	–	✓	–
Flat-face seahorse	*Hippocampus planifrons*	MO	MO	–	–	✓	–
Gale's pipefish	*Campichthys galei*	–	MO	–	–	✓	–
Glittering pipefish	*Halicampus nitidus*	MO	MO	–	–	✓	–
Gunther's pipehorse, Indonesian pipefish	*Solegnathus lettiensis*	MO	MO	–	–	✓	–
Hedgehog seahorse	*Hippocampus spinosissimus*	MO	MO	–	–	✓	–
Helen's pygmy pipehorse	*Acentronura larsonae*	MO	MO	–	–	✓	–
Ladder pipefish	*Festucalex scalaris*	MO	MO	–	–	✓	–
Many-banded pipefish	*Doryrhamphus multiannulatus*	MO	MO	–	–	✓	–
Mud pipefish, Gray's pipefish	*Halicampus grayi*	MO	MO	–	–	✓	–
Muiron Island pipefish	*Choeroichthys latispinosus*	MO	MO	–	–	✓	–
Pacific short-bodied pipefish, short-bodied pipefish	*Choeroichthys brachysoma*	MO	MO	–	–	✓	–
Pallid pipehorse, Hardwick's pipehorse	*Solegnathus hardwickii*	MO	MO	–	–	✓	–
Pig-snouted pipefish	*Choeroichthys suillus*	MO	MO	–	–	✓	–
Prophet's pipefish	*Lissocampus fatiloquus*	–	MO	–	–	✓	–
Red-hair pipefish, Duncker's pipefish	*Halicampus dunckeri*	–	MO	–	–	✓	–
Reticulate pipefish, yellow-banded pipefish, network pipefish	*Corythoichthys flavofasciatus*	MO	MO	–	–	✓	–
Ribboned pipehorse, ribboned seadragon	*Haliichthys taeniophorus*	MO	MO	–	–	✓	–

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation status
Robust ghost pipefish, blue-finned ghost pipefish,	*Solenostomus cyanopterus*	MO	MO	–	–	✓	–
Roughridge pipefish	*Cosmocampus banneri*	MO	MO	–	–	✓	–
Schultz's pipefish	*Corythoichthys schultzi*	–	MO	–	–	✓	–
Spiny seahorse, thorny seahorse	*Hippocampus histrix*	MO	MO	–	–	✓	–
Spiny-snout pipefish	*Halicampus spinirostris*	MO	MO	–	–	✓	–
Spotted pipefish, gulf pipefish, peacock pipefish	*Stigmatopora argus*	–	MO	–	–	✓	–
Spotted seahorse, yellow seahorse	*Hippocampus kuda*	MO	MO	–	–	✓	–
Straight stick pipefish, long-nosed pipefish	*Trachyrhamphus longirostris*	MO	MO	–	–	✓	–
Three-keel pipefish	*Campichthys tricarinatus*	MO	MO	–	–	✓	–
Three-spot seahorse, low-crowned seahorse, flat-faced seahorse	*Hippocampus trimaculatus*	MO	MO	–	–	✓	–
Tidepool pipefish	*Micrognathus micronotopterus*	MO	MO	–	–	✓	–
Tiger pipefish	*Filicampus tigris*	MO	MO	–	–	✓	–
Western spiny seahorse, narrow-bellied seahorse	*Hippocampus angustus*	MO	MO	–	–	✓	–

Likely Presence
AKO: Congregation or aggregation know to occur within area
FKO: Foraging, feeding or related behaviour known to occur within area
KO: Species or species habitat known to occur within area
LO: Species or species habitat likely to occur within area
MO: Species or species habitat may occur within area

Conservation Status:
CD: Conservation Dependent
P1: Priority 1, Poorly-known species
P3: Priority 3, Poorly-known species
MI: Migratory
V: Vulnerable

Table 6-15: Presence of BIAs for fishes, including sharks and rays

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological and Social EMBAs
Whale shark	Foraging	Spring	✓	0	✓
	Foraging (high-density prey)	Apr–Jun, autumn	–	166.5	✓

6.3.3.3.1 whale shark

The whale shark (*Rhincodon typus*) is listed as vulnerable and migratory under the EPBC Act. The DA and Hydrocarbon Ecological and Social EMBAs overlap a foraging BIA for the whale shark (Table 6-15; Figure 6-30). This BIA is associated with foraging behaviours during northward migration from Ningaloo Reef / North West Cape along the 200 m isobath during July to November (Ref. 33). In addition, a foraging (high-density prey) BIA that is present offshore from the North West Cape overlaps the Hydrocarbon Ecological and Social EMBAs (Table 6-15; Figure 6-30).

The whale shark has a global distribution in tropical and warm temperate seas (Ref. 163); they migrate to and from these oceanic seascapes to seasonal aggregations in coastal waters (Ref. 717 cited in Ref. 695). In Australian waters, whale sharks have shown year-round presence in WA's North West (Ref. 716); and also form seasonal coastal aggregations at Ningaloo Reef (March to July), Christmas Island (December to January), and in the Coral Sea (November to December) (Ref. 33). Ningaloo Reef is considered the main known seasonal aggregation area (Ref. 164). Whale sharks aggregate off Ningaloo Reef each year to feed (Ref. 165; Ref. 166); with this seasonal presence linked to mass coral spawning timing (Ref. 165). The population during this period is dominated by juveniles that amass for feeding purposes (Ref. 716). The Ningaloo population is part of a broader East Indian Ocean stock (Ref. 705; Ref. 695).

Based on satellite tagging undertaken between 2005 and 2008, when leaving Ningaloo Reef after the seasonal aggregation period, whale sharks generally headed south before migrating on three broad trajectories (Ref. 167; Ref. 704):

- north-west into the Indian Ocean (towards Christmas Island)
- north towards Sumatra and Java
- north-east, passing through the NWS region, travelling along the shelf break and continental slope towards the Timor Sea.

This is also consistent with further satellite tracking analysis (2005 to 2019) that found that after leaving coastal sites (Ningaloo Reef and Shark Bay), whale sharks movements were mostly along the continental shelf break of WA but also into deeper offshore areas and waters off the southern coast of Indonesia (Ref. 695). Satellite tagging of whale sharks (between 2015 and 2018) indicates that females may leave Ningaloo earlier, and spend more time in offshore waters, compared to males (Ref. 718).

The foraging BIA that overlaps the DA runs northward from Ningaloo along the 200 m isobath. Migration from Ningaloo towards the north-east broadly follows the 200 m isobath and typically occurs between July and November (Ref. 33). A review of satellite tracking data from 78 whale sharks tagged between 2005 and 2019 at either Ningaloo Reef or Shark Bay during their seasonal aggregations in austral autumn and winter was analysed to determine habitat use and connectivity

at local (hundreds of kilometres; North West Australia) and regional (thousands of kilometres; East Indian Ocean) scales (Ref. 695). The analysis showed that movement patterns and high-use areas for whale sharks were influenced by both natural geomorphic features and anthropogenic features (petroleum platforms). Natural features associated with abrupt changes in seafloor topography, such as escarpments, pinnacles, seamounts, and canyons, were found to have the greatest influence on habitat use and connectivity; and the petroleum platforms influenced movement dynamics and connectivity in a comparable way to natural features (Ref. 695).

At the regional East Indian Ocean scale, movement paths were identified that linked Ningaloo Reef to Indonesia, Shark Bay, and to the south-west region of WA; at the local North West Australia scale, the most common movement pathway away from Ningaloo Reef was north towards pinnacle features and south to Shark Bay (Ref. 695). Note: These pinnacle features occur to the north-east and north of Montebello Islands; and are outside of the DA (see inset of Figure 6-30).

Pinnacles had the highest effect on habitat use at both East Indian Ocean and North West Australia scales (Ref. 695). Whereas seamounts and escarpments, and canyons and escarpments, were the features with highest effects on habitat connectivity at the East Indian Ocean and North West Australia scales respectively (Ref. 695). The DA does not overlap with any pinnacle, seamount, escarpment, or canyon features as used in this analysis (see inset of Figure 6-30). Movement pathways across North West Australia that involved petroleum platforms also had similar effects to those of natural feature types (Ref. 695). The petroleum platform most used by whale sharks during this study was north of Ningaloo, in similar vicinity to the pinnacle features (see inset of Figure 6-30).

The whale shark is a suction filter feeder, with a diet comprising planktonic and nektonic prey, and feeds at or close to the water's surface by swimming forward with mouth agape, sucking in prey (Ref. 165). Although the species is generally encountered close to or at the surface, it will regularly dive and move through the water column. Research has found that whale sharks at Ningaloo Reef move between the sea surface and deeper water, spending 40% of their time in the upper 15 m of the water column and 50% of their time at 30 m or less (Ref. 168; Ref. 165). Off the outer NWS, whale sharks spend much of their time swimming near the seabed and can dive to around 1,000 m (Ref. 165). Deep dives are thought to be primarily for prey, such as krill, lantern fish, squid and jellyfish (Ref. 165). Analysis of 39 tagged whale sharks tracked on migratory routes from Ningaloo showed they spent >90% of time in waters ≤200 m and dived to a maximum depth of 1,906 m (Ref. 718).

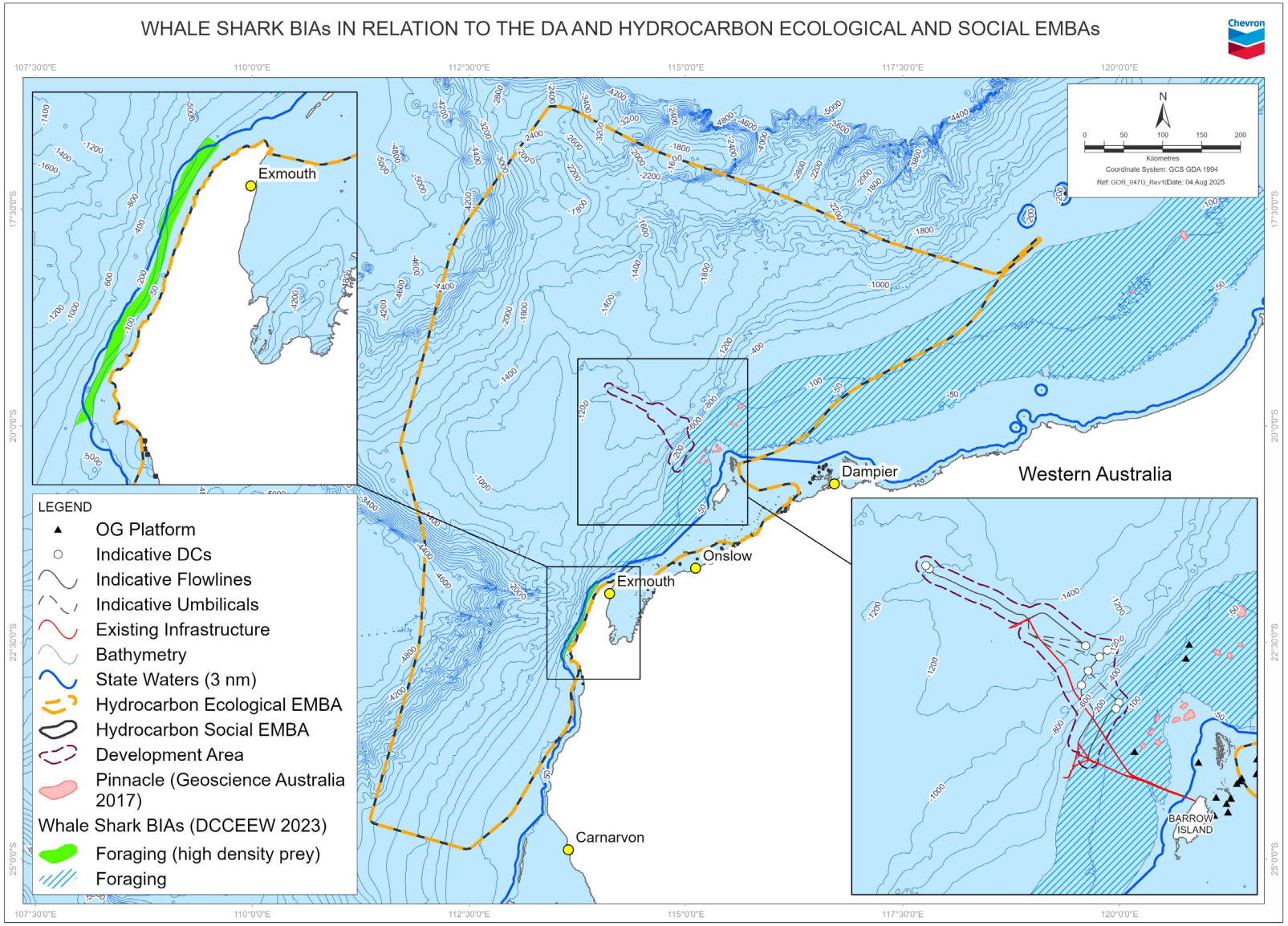


Figure 6-30: Whale shark BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.4 seabirds and shorebirds

Based on searches of the EPBC Act protected matters database (Ref. 122; appendix b), the threatened and/or migratory seabird and shorebird species shown in Table 6-16 may be present within the DA or Hydrocarbon Ecological or Social EMBAs. BIAs associated with seabird and shorebird species are listed in Table 6-17[55].The BIAs are shown in the following figures:

- wedge-tailed shearwater—Figure 6-31
- lesser frigatebird and white-tailed tropicbird—Figure 6-32
- fairy tern—Figure 6-33
- lesser crested tern—Figure 6-34
- roseate tern—Figure 6-35.

[55] The protected matters reports (appendix b) also identify BIAs for the lesser frigatebird as present within the Hydrocarbon Ecological and Social EMBAs. However, review of the BIA spatial dataset (Ref. 519) and DCCEEW Australian Marine Spatial Information System (Ref. 137) shows no overlap with the EMBA for the Development

Table 6-16: Presence of threatened or migratory seabirds and shorebirds

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation Status
Abbott's booby	*Papasula abbotti*	–	MO	E	–	✓	–
Asian dowitcher	*Limnodromus semipalmatus*	–	KO	V	✓	✓	MI
Australian fairy tern	*Sternula nereis nereis*	FLO	BKO	V	–	–	V
Australian painted snipe	*Rostratula australis*	–	LO	E	–	✓ (as *Rostratula benghalensis (sensu lato)*)	E
Barn swallow	*Hirundo rustica*	–	MO	–	✓	✓	MI
Bar-tailed godwit	*Limosa lapponica*	–	KO	–	✓	✓	MI
Black-browed albatross	*Thalassarche melanophris*	–	MO	V	✓	✓	E
Black-eared cuckoo	*Chalcites osculans*	–	KO	–	–	✓ (as *Chrysococcyx osculans)*	–
Bridled tern	*Onychoprion anaethetus*	–	BKO	–	✓	✓ (as *Sterna anaethetus*)	MI
Campbell albatross, Campbell black-browed albatross	*Thalassarche impavida*	–	MO	V	✓	✓	V
Caspian tern	*Hydroprogne caspia*	–	BKO	–	✓	✓ (as *Sterna caspia*)	MI
Cattle egret	*Bubulcus ibis*	–	MO	–	–	✓ (as *Ardea ibis*)	–
Christmas Island white-tailed tropicbird, golden bosunbird	*Phaethon lepturus fulvus*	MO	MO	E	–	✓	–
Common greenshank, greenshank	*Tringa nebularia*	–	LO	E	✓	✓	MI

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation Status
Common noddy	*Anous stolidus*	MO	LO	–	✓	✓	MI
Common sandpiper	*Actitis hypoleucos*	MO	KO	–	✓	✓	MI
Curlew sandpiper	*Calidris ferruginea*	MO	KO	CE	✓	✓	CE
Eastern curlew, far eastern curlew	*Numenius madagascariensis*	MO	KO	CE	✓	✓	CE
Fairy tern	*Sternula nereis*	–	BKO	–	–	✓ (as *Sterna nereis*)	V (as *Sterna nereis nereis*)
Flesh-footed shearwater	*Ardenna carneipes*	–	LO	–	✓	✓ (as *Puffinus carneipes*)	V
Fork-tailed swift	*Apus pacificus*	–	LO	–	✓	✓	MI
Great frigatebird, greater frigatebird	*Fregata minor*	–	MO	–	✓	✓	MI
Greater crested tern	*Thalasseus bergii*	–	BKO	–	✓	✓ (as *Sterna bergii*)	MI
Greater sand plover, large sand plover	*Charadrius leschenaultii*	–	KO	V	✓	✓	V
Grey falcon	*Falco hypoleucos*	–	KO	V	–	–	V
Grey wagtail	*Motacilla cinerea*	–	MO	–	✓	✓	MI
Indian yellow-nosed albatross	*Thalassarche carteri*	–	MO	V	✓	✓	E
Lesser crested tern	*Thalasseus bengalensis*	–	BKO	–	–	✓ (as *Sterna bengalensis*)	–
Lesser frigatebird, least frigatebird	*Fregata ariel*	LO	KO	–	✓	✓	MI
Little tern	*Sternula albifrons*	–	BKO	V	✓	✓ (as *Sterna albifrons*)	MI

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation Status
Night parrot[56]	*Pezoporus occidentalis*	–	MO	CE	–	–	CE
Northern Siberian bar-tailed godwit, russkoye bartailed godwit	*Limosa lapponica menzbieri*	–	KO	E	–	–	CE
Oriental plover, oriental dotterel	*Charadrius veredus*	–	MO	–	✓	✓	MI
Oriental pratincole	*Glareola maldivarum*	–	MO	–	✓	✓	MI
Osprey	*Pandion haliaetus*	MO	BKO	–	✓	✓	MI
Pacific gull	*Larus pacificus*	–	BKO	–	–	✓	–
Pectoral sandpiper	*Calidris melanotos*	MO	MO	–	✓	✓	MI
Rainbow bee-eater	*Merops ornatus*	–	MO	–	–	✓	–
Red goshawk	*Erythrotriorchis radiatus*	–	MO	E	–	–	E
Red knot	*Calidris canutus*	MO	KO	V	✓	✓	E
Red-tailed tropicbird	*Phaethon rubricauda*	MO	KO	–	✓	✓	MI & P4
Red-tailed tropicbird (Indian Ocean)	*Phaethon rubricauda westralis*	MO	KO	E	–	–	MI & P4 (as *Phaethon rubricauda*)
Roseate tern	*Sterna dougallii*	–	BKO	–	✓	✓	MI
Sharp-tailed sandpiper	*Calidris acuminata*	MO	KO	V	✓	✓	MI
Shy albatross	*Thalassarche cauta*	–	MO	E	✓	✓	E
Silver gull	*Chroicocephalus novaehollandiae*	–	BKO	–	–	✓ (as *Larus novaehollandiae*)	–

[56] Species distribution for the night parrot occurs through arid and semi-arid regions of Australia (Ref. 51).

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			WA BC Act
		DA	Hydrocarbon Ecological and Social EMBAs	Threatened	Migratory	Marine	Conservation Status
Soft-plumaged petrel	*Pterodroma mollis*	–	FLO	V	–	✓	–
Sooty tern	*Onychoprion fuscatus*	–	BKO	–	–	✓ (as *Sterna fuscata*)	–
Southern giant petrel	*Macronectes giganteus*	MO	MO	E	✓	✓	MI
Southern whiteface	*Aphelocephala leucopsis*	–	MO	V	–	–	V
Streaked shearwater	*Calonectris leucomelas*	LO	LO	–	✓	✓	MI
Wedge-tailed shearwater	*Ardenna pacifica*	–	BKO	–	✓	✓ (as *Puffinus pacificus*)	MI
White-bellied sea-eagle	*Haliaeetus leucogaster*	–	KO	–	–	✓	–
White-capped albatross	*Thalassarche steadi*	–	MO	V	✓	✓	–
White-tailed tropicbird	*Phaethon lepturus*	MO	KO	–	✓	✓	MI
White-winged fairy-wren (Barrow Island), Barrow Island black-and-white fairy-wren	*Malurus leucopterus edouardi*	–	LO	V	–	–	V
Yellow wagtail	*Motacilla flava*	–	MO	–	✓	✓	MI

Likely Presence
BKO: Breeding known to occur within area
FLO: Foraging, feeding or related behaviour likely to occur within area
KO: Species or species habitat known to occur within area
LO: Species or species habitat likely to occur within area
MO: Species or species habitat may occur within area

Conservation Status:
CE: Critically Endangered
E: Endangered
MI: Migratory
P4: Priority 4, Rare, Near Threatened and other species in need of monitoring
V: Vulnerable

Table 6-17: Presence of BIAs for seabirds and shorebirds

Common name	BIA behaviour	Seasonal presence	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Fairy tern	Breeding	Jul–late Sep	–	36.1	✓	✓
Lesser crested tern	Breeding	Mar–Jun	–	34	✓	✓
Little tern	Resting	Breeding recorded in June, July and October	–	471.2	-	✓
Roseate tern	Breeding	Mid-Mar–Jul. Birds from South-west Marine Region dispersing north in winter	–	39.8	✓	✓
Wedge-tailed shearwater	Breeding	Mid-Aug–Apr (Pilbara) or mid-May (Shark Bay)	✓	0	✓	✓
White-tailed tropicbird	Breeding	May and Oct	–	376.7	✓	✓

6.3.3.4.1 wedge-tailed shearwater

The wedge-tailed shearwater (*Ardenna pacifica*) is listed as migratory under the EPBC Act. A breeding BIA for the wedge-tailed shearwater overlaps the DA and Hydrocarbon Ecological and Social EMBAs (Figure 6-31). The BIAs for this species are buffers around islands that this species is known to nest on (Figure 6-27). Bird species may forage in the waters surrounding the islands during nesting seasons. The wedge-tailed shearwater 'foraging in high numbers BIA' is much further south (outside of the Hydrocarbon EMBAs and >610 km from the OA), near Carnarvon.

Wedge-tailed shearwaters are a pelagic, migratory visitor to WA; estimates indicate more than one million shearwaters migrate to the Pilbara islands each year (Ref. 169) out of an estimated global population of five million (Ref. 170). The wedge-tailed shearwaters typically begin arriving at their WA rockeries around August each year and will excavate burrows on vegetated islands for nesting. Peak egg laying typically occurs during November and they will typically leave nests between early-April and early-May and travel north (Ref. 171; Ref. 172). Migration from the rockery is very synchronous, but the return is less so (Ref. 172). Once adults cease returning to feed their young, the young (fledgling) wedge-tailed shearwaters fledge and depart nests (Ref. 187; Ref. 540).

Breeding behaviours are nocturnal in wedge-tailed shearwaters. Adults return to and depart the colony at night, and fledglings depart the colony at night. Adults may not return to feed chicks each night. In the lead up to fledging, chicks also leave their burrows to exercise their wings outside burrows. Known breeding locations within the EMBA include Dampier Archipelago, Passage Island, Lowendal Island, islands off Barrow Island (Mushroom, Double and Boodie islands) and islands in the Onslow area (including Airlie, Bessieres, Serrurier, North and South Muiron and Locker islands (Ref. 170).

When foraging, wedge-tailed shearwaters fly <10 m above the water, and dive to depths around 2–3 m. They have been observed to settle on the surface of the water after feeding or before migration. They mostly consume fish, cephalopods, insects, jellyfish and prawns (Ref. 173). One of the closest colonies to the DA is Double Island (east of Barrow Island). Baseline monitoring (during pre-construction of the GFP) recorded ~20–50 wedge-tailed shearwater nesting burrows on North Double Island and ~300 on South Double Island (Ref. 174; Ref. 175). CAPL (Ref. 1; Ref. 175) estimated 500 burrows over a 2 ha portion of the north-eastern corner of South Double Island, supporting 5,000–10,000 pairs of wedge-tailed shearwaters.

This species forages relatively close to breeding islands; however, more recent studies have indicated bimodal foraging. A study on foraging behaviour of wedge-tailed shearwaters during the 2018 nesting season on the Muiron Islands showed a bimodal foraging strategy that incorporated both short (<4 days) and long (>7 day) trips (Ref. 172). The foraging trips of the wedge-tailed shearwaters from the Muiron Islands were recorded over a large area, extending from the Cape Range Canyon to the Indonesian Archipelago; a consistent pattern of foraging near seamounts was observed (Ref. 172). This area is also part of the foraging extent used by the wedge-tailed shearwaters from both Pelsaert and Houtman Abrolhos islands (Ref. 176; Ref. 172). The use of a bimodal foraging strategy suggests that prey availability close to the colony (i.e. areas that would be used on short trips) is inadequate for the large numbers of breeding shearwaters (Ref. 172).

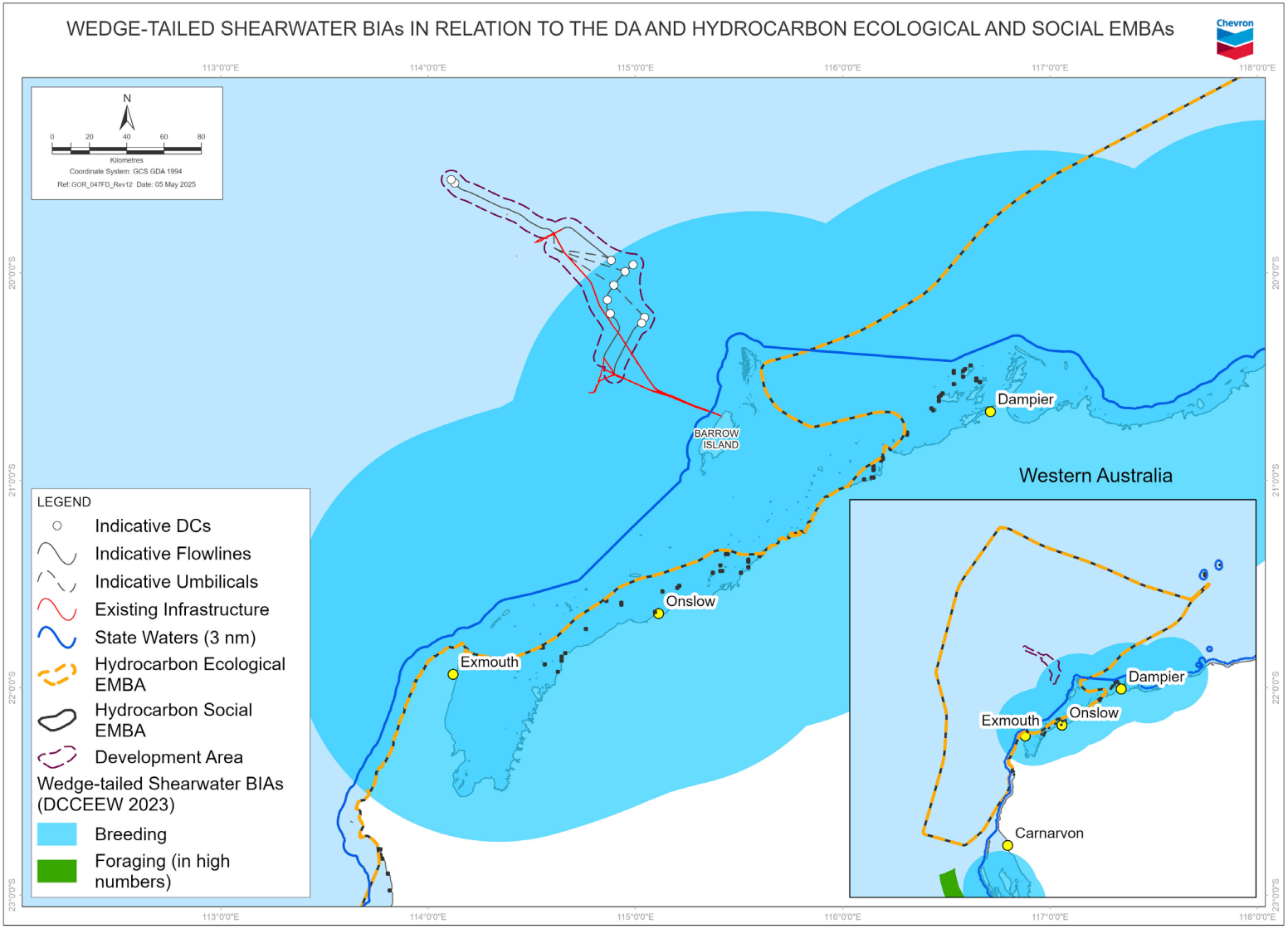


Figure 6-31: Wedge-tailed shearwater BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.4.2 white-tailed tropicbird

The white-tailed tropicbird (*Phaethon lepturus*) is listed as marine and migratory under the EPBC Act and BC Act. There are no BIAs for the white-tailed tropicbird that overlap the DA (Figure 6-32). A breeding BIA for the white-tailed tropicbird overlaps the Hydrocarbon Ecological and Social EMBAs (Figure 6-32).

The global population is estimated at over 50,000 individuals, with the Australian population poorly known (Ref. 38). The species is pantropical and tends to breed in many locations in low numbers (Ref. 38). The white-tailed tropicbird can be found most commonly off northern WA and occasionally around the Coral Sea and east coast of Australia. Although the species is mostly oceanic, it comes inshore to breed. A variety of habitats are used during nesting, including rainforest canopies, sandy beaches, and rocky terrain (Ref. 38). Adults breed throughout the year with breeding periodicities around 10 months (Ref. 177). Both parents share the incubation of the egg, with the nesting cycle from egg laying to fledgling taking approximately 18 weeks. White-tailed tropicbird breeds for the first time around four years of age (Ref. 178).

White-tailed tropicbirds are plunge divers in deep water and feed on fish and cephalopods. The foraging patterns in Australia, including distance from breeding sites, are not well known (Ref. 179). However, based on observations in Puerto Rico, white-tailed tropicbirds when breeding foraged up to 89 km away from their nesting location and moved further distances when not breeding (Ref. 180). Further, it has been noted that birds originating from Christmas Island foraged between 1,400 and 1,600 km south-east of the island (Ref. 181).

The overlapping white-tailed tropicbird BIA is located in the NWMR. The BIA is used as a breeding and foraging area for the species with resident and visitor birds.

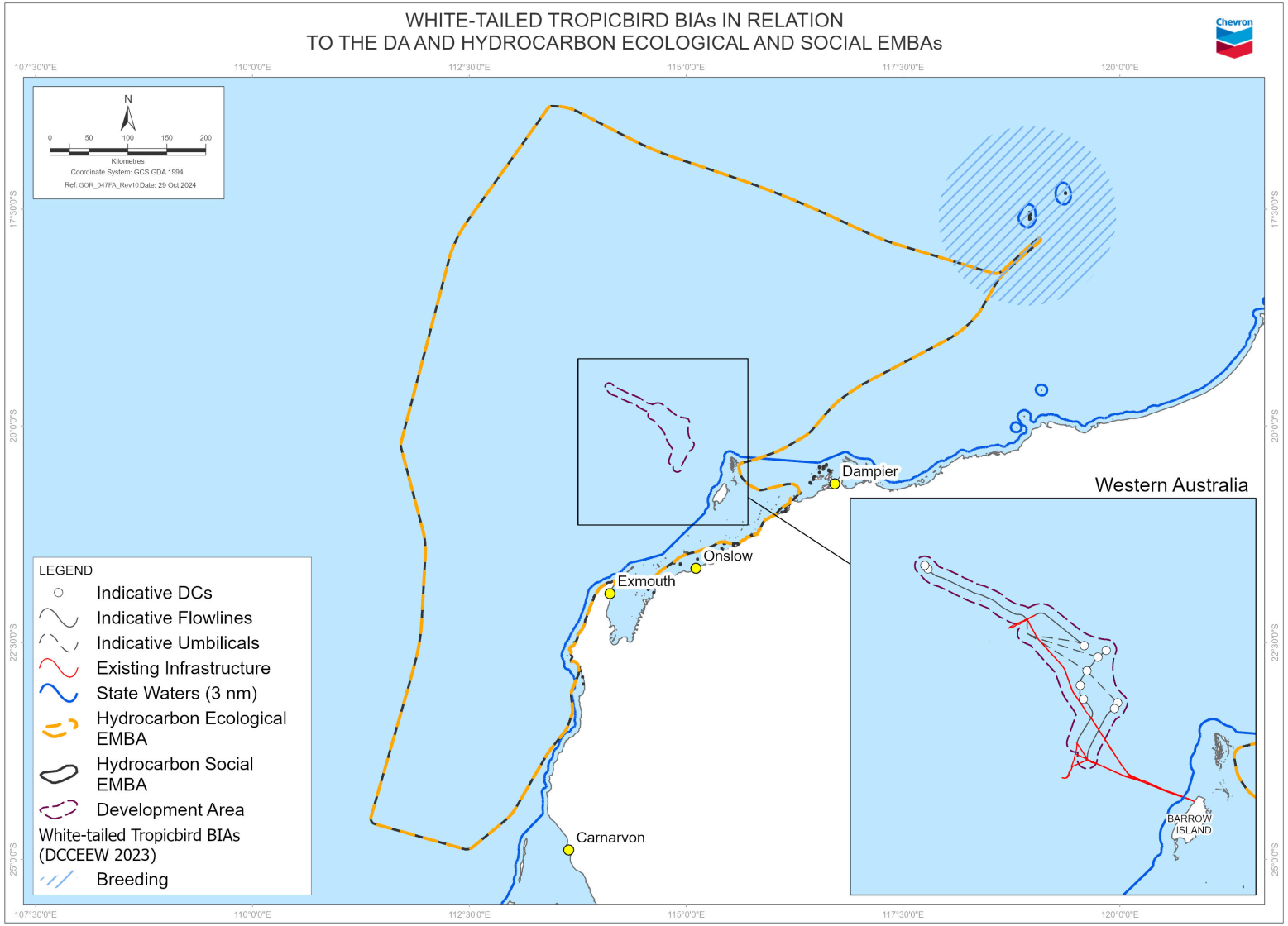


Figure 6-32: White-tailed tropicbird BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.4.3 fairy tern

The fairy tern (*Sternula nereis*) is listed as marine under the EPBC Act. There are no BIAs for the fairy tern that overlap the DA (Figure 6-33). A breeding BIA for the fairy tern overlaps the Hydrocarbon Ecological and Social EMBAs (Figure 6-33).

The fairy tern has a large geographical range between Australia, New Zealand and New Caledonia. Three subspecies have been identified based on phenotypic, genotypic and geographic differences (Ref. 182), only one of which (the Australian fairy tern) occurs in WA. The Australian fairy tern subspecies is listed as vulnerable under the EPBC Act. However, no BIAs have been identified for the Australian fairy tern subspecies in Australia.

The Australian fairy tern has been found in embayments of a variety of habitats including offshore, estuarine, or lacustrine (lake) islands, wetlands, and mainland coastline (Ref. 183). The Australian fairy tern nests on sheltered sandy beaches, spits and banks above the high tide line and below vegetation (Ref. 182). Typically, fairy terns lay between one and three eggs with an incubation period of around 18 days (Ref. 184).

Within WA, there appear to be two subpopulations:

- a sedentary population based along the Pilbara and upper Gascoyne coasts from Exmouth Gulf to the Dampier Archipelago, including Barrow, Montebello, and Lowendal islands; these Australian fairy terns nest from late-July to late-September
- a migratory population that disperses south along the coast from Shark Bay to breed between the Houtman Abrolhos Islands to the Recherche Archipelago between September and May, with active breeding flocks appearing at various locations between October and February (Ref. 44).

Australian fairy terns are reported from Barrow Island throughout the year and primarily from the south-east to south-west of the island, with high counts between November and April (Ref. 175). Australian fairy terns may nest on offshore islands between Barrow Island and the Montebello Islands (Ref. 185), including intermittently nesting on North and/or South Double Island (Ref. 175).

Australian fairy terns are diurnal plunge diving feeders that predate exclusively on small (<60 mm) surface schooling bait fishes throughout their range. Australian fairy terns feed almost entirely on fish in near-shore waters adjacent to nesting colonies and around island archipelagos (Ref. 44).

Behaviours used to define BIAs for seabirds in Commonwealth marine areas include breeding with a foraging buffer, and roosting (Ref. 182). The BIAs for this species represent buffers around islands that the species is known to nest on as they may forage in the waters surrounding the islands during nesting seasons.

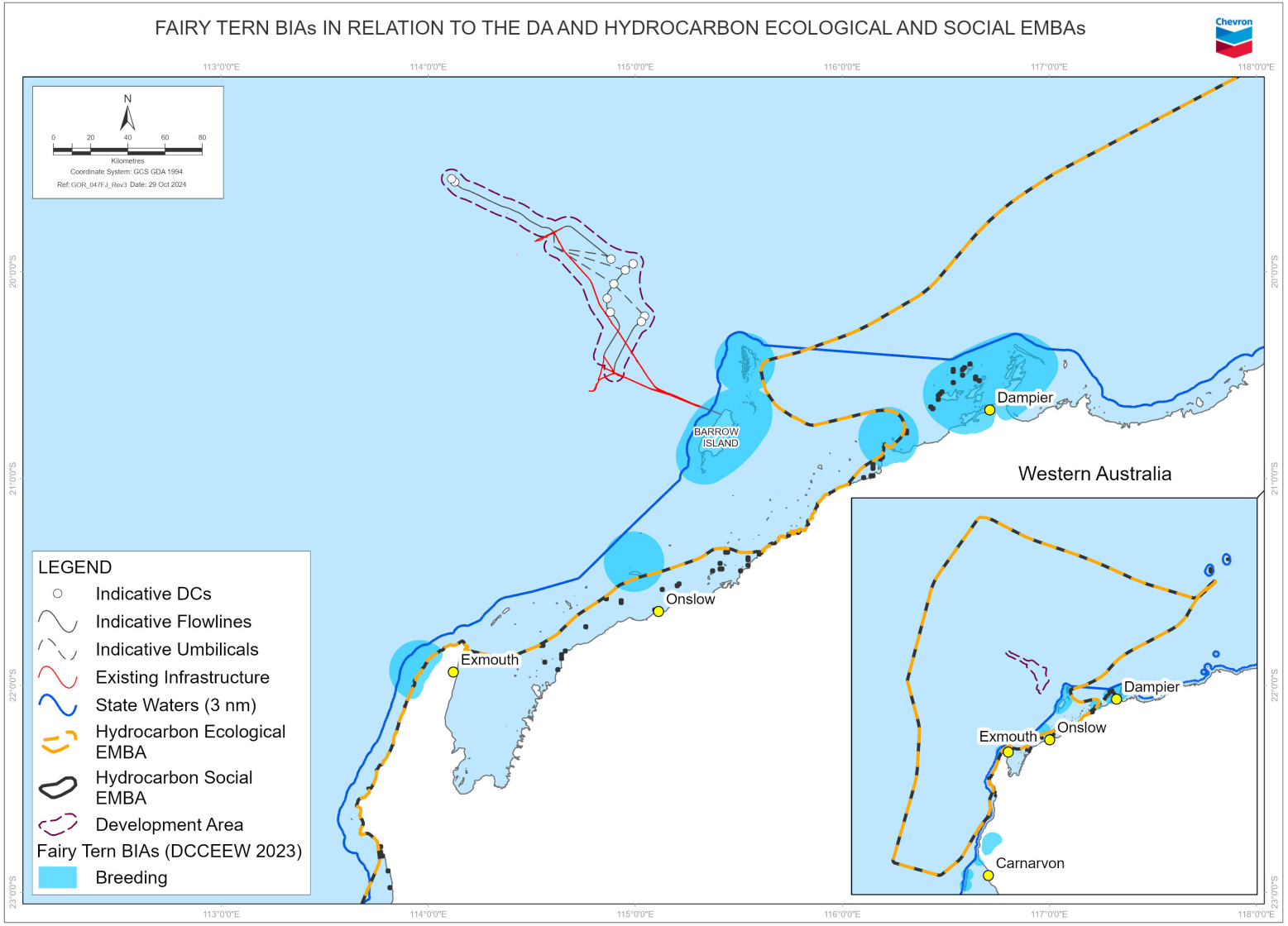


Figure 6-33: Fairy tern BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.4.4 lesser crested tern

The lesser crested tern (*Thalasseus bengalensis*) is listed as marine under the EPBC Act. There are no BIAs for the lesser crested tern that overlap the DA (Figure 6-34). A breeding BIA for the lesser crested tern overlaps the Hydrocarbon Ecological and Social EMBAs (Figure 6-34).

The population size is large and stable with the global population estimate for lesser crested tern sitting around 225,000 pairs, more than half of which are found in Australia (Ref. 38). The species breed in subtropical coastal areas, generally from the Red Sea across the Indian Ocean to the western Pacific Ocean and Australia. The species inhabits tropical and subtropical coasts and estuaries, breeding on low-lying offshore islands (Ref. 38). The species breeds on low-lying offshore islands, coral flats, sandbanks, and flat sandy beaches, and forages in the surf and offshore waters (Ref. 183).

Since 1996, this species has nested regularly at the Lowendal Islands, where up to 200 pairs nest among larger colonies of crested terns (Ref. 170). Additional nesting sites within state waters adjacent to the NWMR include Sterna Island in the Kimberley and, Bedout Island and potentially the Montebello Islands in the Pilbara (Ref. 170). Breeding records also exist for Ashmore Reef, various Kimberley islands (including Low Rocks and Adele Island), and islands extending south to Shark Bay (Ref. 170; Ref. 178). The breeding season is between March and June (Ref. 137). During the breeding season, lesser crested terns prefer to nest in colonies on bare sand or shingle, where they are protected from terrestrial predators. Outside the breeding season, they roost on coastal rocks and sandbars (Ref. 541).

Lesser crested terns forage in the surf of the ocean and on the surface of offshore waters feeding primarily on small pelagic fish and shrimp (Ref. 186). Lesser crested terns are highly social, particularly during the breeding season, when they form colonies that often include other seabird species (Ref. 183).

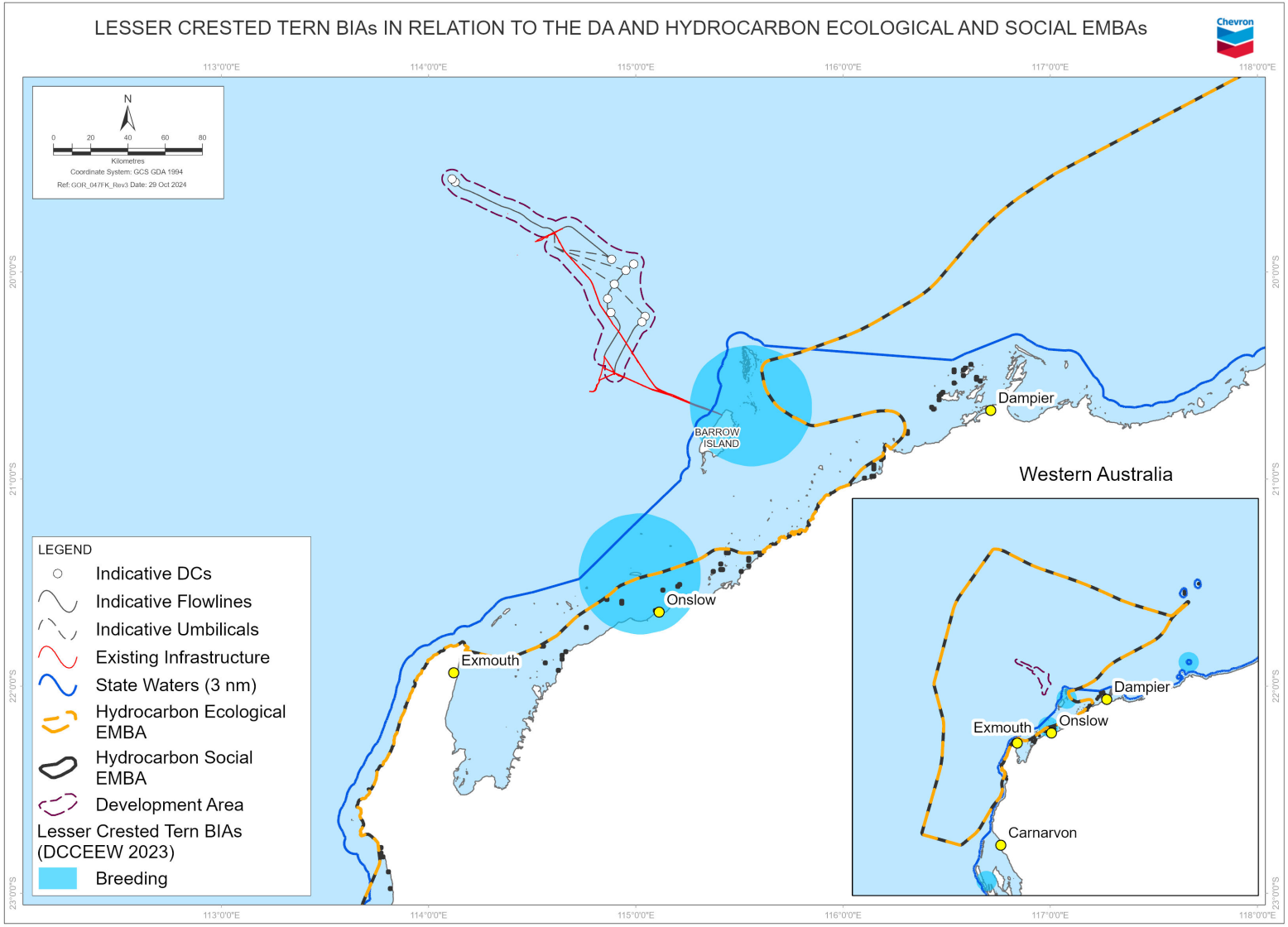


Figure 6-34: Lesser crested tern BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.4.5 roseate tern

The roseate tern (*Sterna dougalli*) is listed as marine and migratory under the EPBC Act and BC Act. There are no BIAs for the roseate tern that overlap the DA (Figure 6-35). A breeding BIA for the roseate tern overlaps the Hydrocarbon Ecological and Social EMBAs (Figure 6-35).

The roseate tern occurs in coastal and marine areas in subtropical and tropical seas. The species inhabits rocky and sandy beaches, coral reefs, sand cays and offshore islands (Ref. 183). The roseate tern is a migratory species, though the movement patterns are not well known. Birds are known to usually move away from breeding colonies following breeding; however, their non-breeding range is not well defined (Ref. 183).

In the NWMR breeding populations of roseate terns have been recorded at Ashmore Reef, Napier Broome Bay, Bonaparte Archipelago, Lacepede Island, Bedout Island, Dampier Archipelago, Lowendal Island, Frazer Island, Koks Island, Mary Anne Island and Meade Island (Ref. 170).

The largest breeding colony in WA is located in the Houtman Abrolhos Islands (Ref. 187). Other large colonies breed within the Lowendal Island and Montebello Island region, and a large breeding colony has also been recorded on Goodwyn Island on the Dampier Archipelago (Ref. 183). Roseate Terns breed in the Pilbara region from March to July and October (Ref. 188; Ref. 189).

Different islands can be chosen for the breeding colony from year to year. As roseate terns do not forage widely from their breeding colonies, suitable nesting islands may be chosen because of nearby aggregations of their pelagic fish prey (Ref. 190). The roseate tern mainly forages on fish and sometimes crustaceans. The species forages during the day up to 60 km from their colony and tend to favour deeper waters rather than shallow water closer to the shore (Ref. 191).

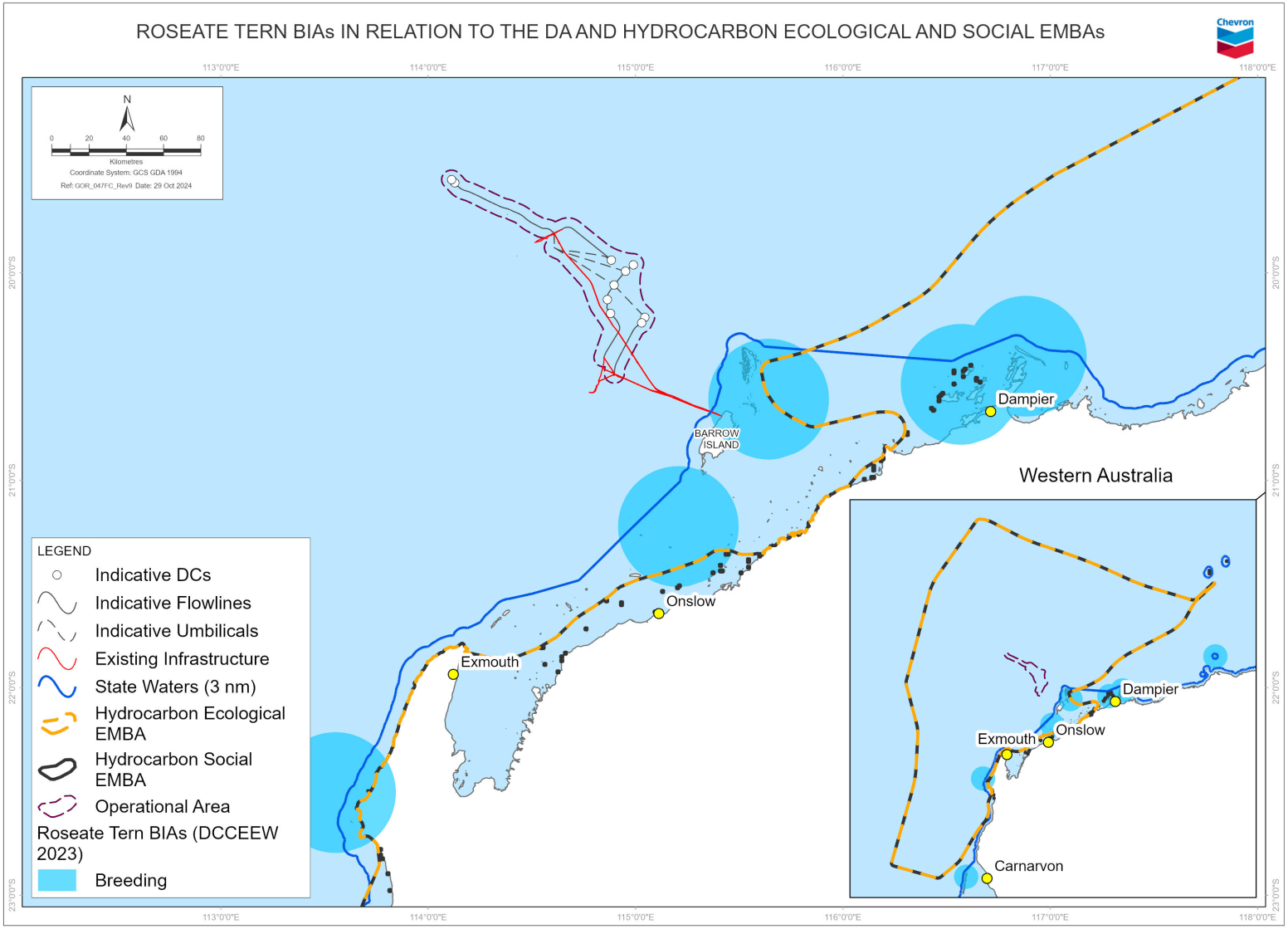


Figure 6-35: Roseate tern BIAs in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.3.3.5 summary of marine fauna seasonal sensitivities

Periods of the year coinciding with key biologically important behaviours for EPBC Act listed threatened and/or migratory species that may potentially be present within the DA and Hydrocarbon Ecological and Social EMBAs are presented in Table 6-18.

Table 6-18: Seasonal presence of marine fauna with biologically important behaviours within the DA and Hydrocarbon Ecological and Social EMBAs

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	DA	Hydrocarbon Ecological and Social EMBAs
Humpback whale														
Migration[57]													✓	✓
Resting[58]													-	✓
Pygmy blue whale														
Northern migration[59]													✓	✓
Southern migration[59]													✓	✓
Foraging[60]													✓	✓
Southern right whale														
Migration[61]													–	✓
Reproduction[61]													–	✓
Dugong														
Breeding, Calving and Nursing[62]													–	✓
Foraging (high-density seagrass beds) [62]													–	✓

[57] Humpback whale migration along the WA coast typically occurs between May and November (Ref. 192; Ref. 126). Humpback whale presence within the Jansz region has been recorded from July to October (Ref. 123; Ref. 682).

[58] Important resting areas have been identified during the southern migration including, but not limited to, Exmouth Gulf and the southern Kimberly region (Ref. 192; Ref. 126). Resting typically occurs in winter (Ref. 189).

[59] Pygmy blue whales presence during northern migrations along the WA coast have been detected between approximately January and August (Ref. 129; Ref. 134) and during southern migrations between November and January (Ref. 129; Ref. 134). Pygmy blue whale presence within the Jansz region has been recorded from late-March to mid-September (peak late-May to June) during northern migration, and from early-October to late-January (peak late-November and early-December) for the southern migration (Ref. 667).

[60] Habitat suitability modelling indicates that foraging habitat may exist along the continental shelf break and slope in north-west WA (Ref. 522). Utilisation of the 'most important areas' for foraging for the pygmy blue whale were identified to be correlated to the species northern and southern migrations (Ref. 135).

[61] Southern right whale migration in WA typically occurs from April to October and reproduction from May to September (Ref. 189).

[62] Dugong breeding, foraging and nursing occurs along the Ningaloo coast year-round (Ref. 519).

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	DA	Hydrocarbon Ecological and Social EMBAs
Flatback turtle														
Internesting and nesting[63]	■	■	■							■	■	■	✓	✓
Mating aggregations[63]	■								■	■	■	■	–	✓
Foraging[64]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Green turtle														
Internesting and nesting[65]	■	■	■								■	■	–	✓
Mating aggregations[65]									■	■	■	■	–	✓
Foraging[66]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Basking[67]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Hawksbill turtle														
Internesting and nesting[68]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Mating[68]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Foraging[69]	■	■	■	■	■	■	■	■	■	■	■	■	–	✓
Loggerhead turtle														
Internesting and nesting[70]	■	■	■								■	■	–	✓
Whale shark														
Foraging[71]							■	■	■	■	■		✓	✓

[63] Nesting locations is predicted to occur between October and March each year with peak nesting to occur between November and January (Ref. 24). Further, mating has been defined to occur between September and January (Ref. 24).

[64] Flatback turtle foraging behaviour may occur year-round based on the nesting location (Ref. 189).

[65] Nesting locations is predicted to occur between November and March each year with peak nesting to occur between December and February (Ref. 24). Further, mating has been defined to occur between September to December (Ref. 24).

[66] Following the breeding and nesting periods, green turtles return to preferred foraging areas (Ref. 152). Foraging behaviour may occur year-round based on the location (Ref. 189).

[67] In WA, at least some of the basking appears to coincide with courtship time (Ref. 193), however, basking areas may also be located close to preferred foraging areas to allow for relatively undisturbed periods (Ref. 194). Therefore, it is assumed basking may occur year-round.

[68] Nesting is predicted to occur all year with peak nesting to occur between October to January (Ref. 24). Further, mating has also been defined to occur year-round (Ref. 24).

[69] Foraging behaviour may occur year-round based on the location (Ref. 189).

[70] Nesting locations for the Loggerhead Turtle WA genetic stock is predicted to occur between November to March each year with peak nesting to occur in January (Ref. 24).

[71] Migration occurs mainly between July and November along the 200 m isobath (Ref. 33). A foraging BIA for whale sharks is associated with the area around this isobath.

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	DA	Hydrocarbon Ecological and Social EMBAs
Fairy tern														
Breeding[72]													–	✓
Lesser crested tern														
Breeding[73]													–	✓
Roseate tern														
Breeding[74]													–	✓
White-tailed tropicbird														
Breeding[75]													–	✓
Wedge-tailed shearwater														
Migration[76]													✓	✓
Breeding[77]													✓	✓
	Species may be present and display biologically important behaviour in the region													
	Predicted peak period													
	Species presence detected during CAPL's soundscape monitoring													

6.3.4 marine environmental quality

The term 'environmental quality' refers to the level of contaminants, or changes to the physical or chemical properties relative to a natural state (Ref. 195). Sediment and water quality were surveyed in the Gorgon Backfill Fields Benthic Survey (Ref. 104; appendix a).

6.3.4.1 oceanography

The major surface currents influencing WA flow towards the poles and include the Indonesian Throughflow, the Leeuwin Current, the South Equatorial Current, and the Eastern Gyral Current (Figure 6-36). The Ningaloo Current, the Holloway Current, the Shark Bay Outflow, and the Capes Current are seasonal surface currents in the region. Below these surface currents are several subsurface currents, the most important of which are the Leeuwin Undercurrent and the West Australian Current. These subsurface currents flow towards the equator in the opposite direction to surface currents (Ref. 102). Water circulation in WA is strongly influenced by the southward-flowing Indonesian Throughflow, whose

[72] The Pilbara and upper Gascoyne sedentary population of Australian fairy terns nests from late-July to late-September (Ref. 44).

[73] Lesser crested terns breed in the Pilbara region from March to June (Ref. 188; Ref. 189).

[74] Roseate terns breed in the Pilbara region from March to July and October (Ref. 188; Ref. 189).

[75] Breeding has been recorded in Western Australia in May and October (Ref. 179).

[76] Wedge-tailed shearwaters typically begin arriving at their WA colonies around August; and then leave nests in early-April to early-May (Ref. 171; Ref. 172). Once adults cease returning to feed their young, the young (fledging) wedge-tailed shearwaters fledge and depart nests (Ref. 187).

[77] Wedge-tailed shearwaters breed in the Pilbara region from November to April (Ref. 188); peak egg laying typically occurs during November (Ref. 171; Ref. 172).

strength varies seasonally with the northwest monsoon (Ref. 102). Currents in the North-west WA are principally driven by semi-diurnal tidal forcing (Ref. 1).

The NWMR large scale surface currents are subject to strong seasonal variations, largely due to annual variation in the alongshore pressure gradient. The South Equatorial Current and Eastern Gyral Current intensify during July-September. The Leeuwin Current is strongest in autumn, and diminishes during the Northwest Monsoon (Dec–March) (Ref. 110).

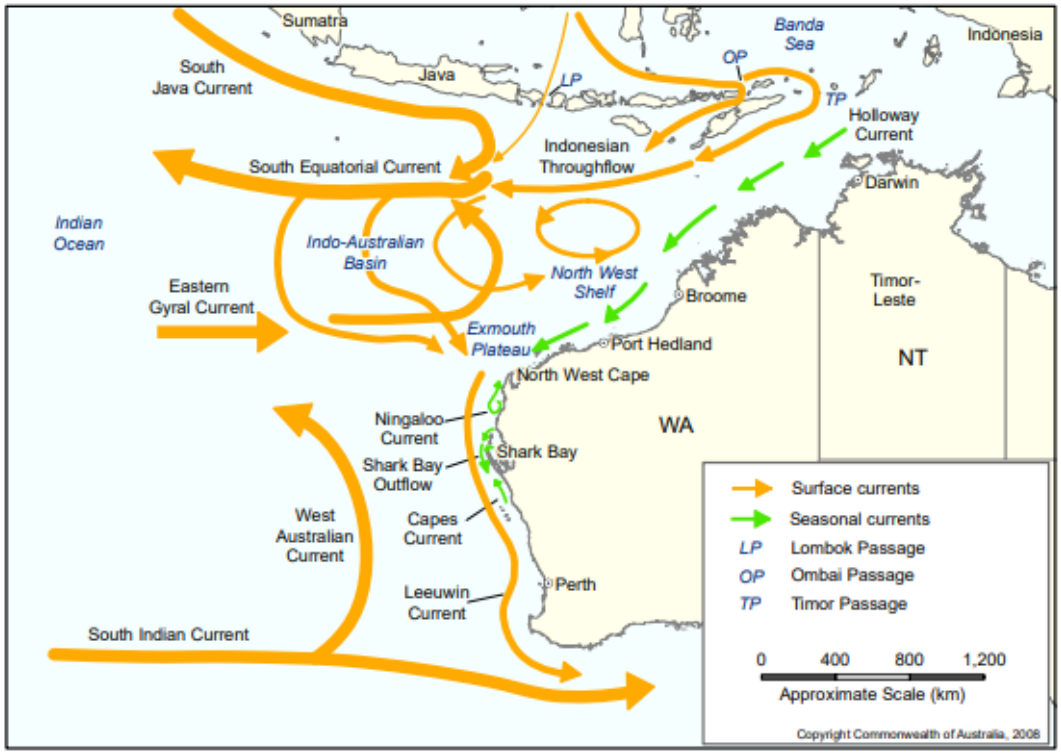


Figure 6-36: Regional oceanography – surface currents

In addition to seasonal variability, the oceanography of the NWMR demonstrates significant inter-annual variability, evident between El Niño/Southern Oscillation (ENSO) and La Niña years (Ref. 110). Wind changes associated with ENSO modulate the thermocline depth in the western Pacific Ocean. During El Niño events, the thermocline moves to shallower depths, sea level drops, sea surface temperatures fall and the Indonesian Throughflow and Leeuwin Current are relatively weak. During La Niña years, higher sea level anomalies, warmer sea surface temperatures and deeper thermoclines result in a stronger Indonesian Throughflow and Leeuwin Current (Ref. 110).

The NWMR is notable for large internal waves which facilitate the mixing of surface waters with nutrient-rich deeper waters. Key sites of internal wave activity include the Exmouth Plateau and the slope adjacent to the NWS (Ref. 102); however, there is no evidence of this occurring within the DA. A review of available datasets (bathymetry, ocean currents and eddies, sea surface temperature, sea surface chlorophyll, mooring time series, ocean gliders and particle tracking techniques) concluded there were no specific oceanographic features that may lead to higher primary productivity within the DA (Ref. 651). In addition, as described in Section 6.3.4.2 below, the field survey of the DA recorded slightly higher concentrations of nutrients near the seafloor compared to the sea surface, which further suggests there are no evidence of physical

processes such as upwelling (wave or current-induced) of deeper waters occurring in the DA.

Ocean surface current speeds in the DA range between 0.16 m/s and 0.27 m/s. Maximum current speeds typically occur in summer, ranging between 0.54 m/s and 2.18 m/s (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462).

Nearshore waters exhibit larger and stronger tidal movements than offshore waters. Tides in the region are broadly categorised as semidiurnal (i.e. two high tides and two low tides per day) with a spring/neap cycle (Ref. 102). Tides range from ~4 m at Exmouth to ~10 m at Broome (Ref. 110).

In the shallow waters around Barrow Island, ~47 km southeast of the DA, within the Hydrocarbon EMBAs, higher turbidity levels and light attenuation coefficients indicate that there are naturally more turbid than deeper offshore waters (Ref. 543). In the waters off the east coast of Barrow Island, turbidity and concentrations of suspended sediments were generally low (<5 mg/L) and indicative of clear water environments (Ref. 542).

The cyclone season in north-west WA runs from November to April, with an average of five tropical cyclones per year (Ref. 216).

6.3.4.2 water quality

Water clarity on the NWS is variable according to movement, depth and sediment; however, nearshore waters in the NWS may have high turbidity due to local current-induced resuspension of fine sediments and episodic run-off from adjacent rivers (Ref. 196).

Wenziker et al. (Ref. 197) estimated natural background concentrations for potential contaminants in waters around the Dampier Archipelago, which provided baseline water quality information for the nearshore waters of the NWS. The survey identified low background concentrations of metals and organic chemicals, with localised elevations of some contaminants (metals) near coastal industrial centres and ports (e.g. Dampier). Except for a few select constituents, such as relatively high natural levels of cadmium, the concentrations of metals were low (Ref. 197).

Further offshore, in the waters off the west coast of Barrow Island (~47 km southeast of the DA, within the Hydrocarbon EMBAs), turbidity and concentrations of suspended sediments were generally low (Ref. 544).

Similarly, water quality data collected in the DA benthic survey described background concentrations of marine water quality near indicative infrastructure locations (Ref. 104; appendix a). Concentrations were compared to the Australian and New Zealand Guidelines (ANZG) default guideline values (DGVs) for 99% species protection (Ref. 66). Metal and hydrocarbon (total recoverable hydrocarbons [TRH], benzene, toluene, ethylbenzene and xylenes [BTEX] and polycyclic aromatic hydrocarbons [PAH]), concentrations were mostly below laboratory limits of reporting (LoR) or, where applicable, below 99% species protection DGVs, which is typical of an undisturbed offshore tropical environment. A small subset of sites recorded concentrations of copper (surface samples at Chandon DC-1 and Gorgon MPTS) above the 99% DGVs and cobalt (seabed samples at Gorgon MPTS) above the 99% DGVs; however, reminded below 95% species protection DGVs. These results could either reflect natural background levels or a result of sampling contamination (Ref. 104; appendix a).

Dissolved and total barium concentrations were notably higher in water samples near the seabed at all of the deeper sites (i.e. all sites except WTR DC-1 and

Gorgon MPTS). Nutrient concentrations were consistently low across the survey area (Ref. 104; appendix a).

Total dissolved solids ranged from 37,000 to 39,900 mg/L in both surface and seabed samples. Total phosphorus (TP) concentrations ranged from 0.01 to 0.12 mg/kg, while total nitrogen (TN) concentrations ranged from 0.10 to 0.75 mg/kg. At all sites, water samples near the seabed had higher mean TP concentrations compared to surface samples. A similar trend was observed for mean TN concentrations, with higher values near the seabed compared to surface samples, except at sites within the WTR field (Ref. 104; appendix a).

6.3.4.2.1 water temperature and salinity

Waters in north-west WA are tropical year-round, with sea surface temperature in open shelf waters reaching ~26°C in summer, and dropping to ~22°C in winter. Nearshore temperatures of north-west WA fluctuate through a higher temperature range from ~17°C in winter to ~31°C in summer (Ref. 1).

Salinity is expected to be low in the north-west WA as a result of freshwater inputs through runoff from high rainfalls over Indonesia (Ref. 110). The salinity in waters off west Barrow Island (~47 km southeast of the DA, within the Hydrocarbon EMBA) was recorded between 34.9-35.1 PSU in both near surface and near seabed (Ref. 544). Within the nearshore waters of Barrow Island, temperature stratification is infrequent and there is little evidence of salinity stratification. However, rainfall events are expected to cause localised salinity stratification in coastal waters adjacent to discharging watercourses (Ref. 542).

Water quality data collected in the DA benthic survey identified background concentrations of marine water quality near indicative infrastructure locations (Ref. 104; appendix a). Profiles of the water column were collected at 35 sites across the five fields. Temperatures in the top 50 m of water across all sampling sites ranged from 27.7°C to 29.2°C, decreasing gradually with increasing depth. Water temperatures dropped to minimum of ~3.9–4.2°C in depths ~1,350 m. Salinity was relatively consistent with depth, ranging from 32.3 to 36.3 PSU. Conductivity showed a similar trend to temperature, in which conductivity ranged from 52.9 to 57.4 mS/cm between the surface and 50 m, and gradually declined with depth, reaching a minimum of ~33.1 mS/cm at ~1,350 m.

Temperature-salinity profiles for the deepest surveyed site at each field were relatively consistent across the DA and typical for the region (Ref. 104; appendix a). Across the DA, three separate water masses within the water column were identified:

- low salinity surface water ranging from 34.6 – 35.3 PSU with a temperature range of ~18 – 28°C; upper ~180 m of water column
- higher salinity mid-waters with a salinity and temperature range of 35.4 – 36 PSU and 15 – 20°C, respectively; centred between 185 and 250 m depth
- lower salinity bottom waters with a salinity and temperature range of 34.7 – 35.4 PSU ~3.5 – 15°C, respectively; between 250 to ~1,310 m depth.

Water quality profiles indicate that surface waters correspond with the southward-flowing Leeuwin Current and the deeper south Indian central water mass along with the subsurface Leeuwin Undercurrent, which moves towards the equator along the WA coast at deeper depths (Ref. 104; appendix a).

6.3.4.3 sediment quality

Sediment chemistry data collected during the DA benthic survey identified background concentrations of sediment quality (Ref. 104; appendix a). The concentrations of hydrocarbons (TRH, BTEX and PAH), metals and metalloids within the sediment at the indicative DC and tie-in locations were below ANZG DGVs (Ref. 66) at all sites and for all parameters tested[78], except for nickel at Chandon DC-1, which was above the ANZG DGV. Nickel concentrations across the remaining sites were slightly below the ANZG DGV. Given that this was a baseline study and no previous activities have occurred in the indicative DCs and tie-in locations, the concentration of nickel recorded likely represents natural background levels (Ref. 104; appendix a).

While below ANZG DGV concentrations of total metals (aluminium, arsenic, barium, cobalt, copper, iron, manganese, lead, zinc and mercury) in sediments at Chandon DC-1 were slightly higher compared to the other sites; WTR DC-1 had notably and consistently lower concentrations for all metals (Ref. 104; appendix a). This trend is likely attributed to the particle size distributions, Chandon DC-1 location had the highest clay-sized fraction whereas WTR DC-1 had the lowest clay-sized fraction (refer to Section 6.3.4.3.1). There were no other discernible trends in for metal concentrations across the sites.

6.3.4.3.1 particle size

Sediment samples data collected at indicative DC and tie-in locations[46] during the DA benthic survey identified particle size (Ref. 104; appendix a). Samples were predominantly comprised of clays (<2 µm), silts (2–60 µm) and sands (0.06–2 mm). Most sites were dominated by silt fraction ranging from 29 to 65%, and clay-sized fractions ranged from 31 to 58%, except for Chandon DC-1 (dominated by clay [58%]) and WTR DC-1 (dominated by sand [56%]).

6.3.4.4 air quality

Air quality within the DA and EMBAs is expected to be representative of the typically high air quality found in offshore areas, away from industrial point sources.

As part of the Ambient Air Quality Monitoring Program on Barrow Island, there were no recorded exceedances for nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), hydrogen sulfide (H_2S) or aromatic hydrocarbons (benzene, toluene, ethylbenzene and xylene) against the relevant National Environment Protection Measure (NEPM) standards (Ref. 198). There have been elevations of PM_{10} levels around facilities on Barrow Island, however these are likely associated with vehicle traffic and regional weather events (Ref. 198).

It is expected that these low levels of contamination would continue throughout the EMBA, unless within the immediate vicinity of an offshore point source such as a vessel or offshore petroleum activity where presence of atmospheric emissions would be slightly elevated.

6.3.5 people and communities

People and communities, and specifically their social, economic, and cultural features, are included within the definition of environment within the OPGGS(E)R.

[78] The site testing includes DC representative sites within the DA, covering all DCs listed in Table 4-1 except for Chandon DC-2, C&D DC-1, and WTR DC-2.

People and communities have been identified and described to the extent that they directly affect or are affected by the existing physical and biological environments in the DA and EMBAs.

The NWMR supports a range of economic, social, and cultural activities. At present, industries within the NWMR include petroleum exploration and production, commercial and recreational fishing, tourism, ports, and shipping (Ref. 102). These uses of the NWMR make an important economic and social contribution to settlements along the coast (Ref. 102). Section 6.4 identifies and describes the industrial, recreational, and traditional activities that occur within the Hydrocarbon Social EMBA.

6.3.5.1 land use

The DA occurs offshore and does not have any overlap with coastline. As described in Section 6.3.2, the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA overlap with some coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Muiron Islands, Passage Islands, Cape Range National Park and around the Point Cloates / Ningaloo Station area (Figure 6-1 and Figure 6-2). The Hydrocarbon Social EMBA includes additional shoreline points dispersed along the coast from North West Cape to islands in the Dampier Archipelago (including Enderby Island and Rosemary Island) (Figure 6-2). The Hydrocarbon Social EMBA typically only extends landward to the high-water mark (HWM).

The land uses that may be present within the Hydrocarbon Social EMBA are summarised below.

The Montebello Islands are protected under WA jurisdiction; the islands are a Conservation Park (International Union for Conservation of Nature classification II [IUCN II]) (Section 6.5.3), and they are surrounded by the Montebello Islands Marine Park (IUCN II) (Section 6.5.2). The Conservation Park is gazetted to the HWM. Because of the natural values of the islands and surrounding waters, recreational activities may occur, such as shore-based fishing, beach walking, picnics, and wildlife viewing (Ref. 199). Camping is permitted on some islands (with some restrictions during turtle nesting season) (Ref. 199).

Barrow, Double, Middle and Boodie islands are also protected under WA jurisdiction; the islands are Nature Reserves (IUCN Ia) (Section 6.5.3) and are surrounded by the Barrow Island Marine Park (IUCN Ia) and Barrow Island Marine Management Area (IUCN VI) (Section 6.6.1). These nature reserves are gazetted to the low water mark. Access to Barrow, Double, Middle, and Boodie islands is not encouraged due to numerous natural and artificial hazards, including the operation of an oilfield and the Gorgon Gas Development (Ref. 199). Camping is not permitted on any of these islands (Ref. 199).

The Ningaloo Coast is protected as part of the World Heritage property and National Heritage place (Section 6.6.1). The waters surrounding the coast are protected under WA jurisdiction as the Nyinggulara (Ningaloo) Marine Park (IUCN II) (Section 6.5.2). Because of the natural and heritage values of the coast, recreational activities may occur, such as shore-based fishing, beach walking, and wildlife viewing (Ref. 200).

The Dampier Archipelago islands have rich Traditional Owner culture and history. Today, the islands are used for recreational activities such as boating, camping, canoeing, and kayaking, fishing, scuba diving, snorkelling, and swimming (Ref. 201). The Hydrocarbon Ecological EMBA and the DA do not overlap the

Dampier Archipelago islands. Of the 41 islands in the Dampier Archipelago, the Hydrocarbon Social EMBA overlaps the west coast of Rosemary Island, West Lewis Island, Goodwyn Island, Enderby Island, Egret Island, Brigadier Island, and Kendrew Island, all of which are Nature Reserves (IUCN Ia) (Section 6.5.3).

The Pilbara islands comprise over 170 islands, islets, rocks and cays between Exmouth Gulf and Regnard Islands (Ref. 202). This includes 20 nature reserves with 92 islands. None of these islands overlap the DA, but some do overlap the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA, including Great Sandy Island Nature Reserve and Muiron Islands (IUCN Ia) (Section 6.5.3). These islands have a rich cultural history and are important to Traditional Owners. The islands have high conservation value for turtle nesting and for hosting migratory and resident shorebirds (Ref. 202). They are also used for recreational activities, including fishing, scuba diving, snorkelling, and camping (Ref. 202).

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA overlap two native title determinations (WCD2019/016 and WCD2018/006). WCD2019/016 extends over the Ningaloo Coast area and WCD2018/006 runs across Mardie and Gnoorea coast (Section 6.6.5). The Hydrocarbon Social EMBA also has a small section of shoreline contact in two other native title determinations (WCD2015/007 across the Dampier Archipelago and WCD2008/003 just outside Exmouth Gulf). The determination areas contain places of special significance, such as mythological and ceremonial sites and natural resources (Ref. 203) (Section 6.6.5).

6.3.5.2 heritage

Australia's heritage includes places, values, traditions, events, and experiences that capture and give context to where the community has come from, where they are now and where they are headed (Ref. 204).

Places on the World Heritage, National Heritage and Commonwealth Heritage Lists as well as Underwater Cultural Heritage protected by the UCH Act, Indigenous Protected Areas and Registered Aboriginal Sites are described in Section 6.6. The following subsections summarise other known heritage values identified within the Hydrocarbon Social EMBA.

6.3.5.2.1 first nations cultural activities, connections, and obligations

The land adjacent to the NWMR has been inhabited by Traditional Owners for at least 50,000 years, and they continue to use the NWMR and adjacent coastal resources with an ongoing connection to these areas (Ref. 102).

While outside the EMBA, Australia's first confirmed First Nations underwater archaeological sites were identified in 2020 in waters offshore from Murujuga (Burrup Peninsula) during the Deep History of Sea Country Project (Ref. 205). These findings confirmed an understanding that First Nations people would have lived on lands that are now submerged in water from rising seas after the last glacial maximum (LGM). The period of the LGM in Australia is described as 24,000 to 18,000 years ago (Ref. 206). At the LGM sea level was ~125 m below present (Ref. 207), which coincides with the ancient coastline at 125 m depth KEF (Section 6.3.6.1).

Archaeological deposits from Boodie Cave on Barrow Island, reveal some of the oldest evidence for human occupation of Australia, as well as illustrating the early use of marine resources (Ref. 208). First occupation on Barrow Island has been dated as occurring between 51,100 and 46,200 years ago, overlapping with earliest dates for occupation of Australia (Ref. 208). There is evidence of marine

resources (e.g. shellfish, fish) being incorporated into dietary assemblages by 42,500 years ago on Barrow Island, which continued through all periods of occupation (Ref. 208). The caves on Barrow Island (including Boodie Cave) and others on nearby Montebello Islands were abandoned by 6,800 years ago when rising sea levels reached their present levels (Ref. 208).

Recent studies at Murujuga have demonstrated that archaeological material remains on the seabed, predating inundation by rising seas (Ref. 205; Ref. 209). Previous geomorphological work (which was based on the analysis of available 3-dimensional [3D] seismic data) on the mid to outer shelf regions proximal to Barrow Island, demonstrated the presence of a highly complex and geomorphically mature coastal landscape preserved at depths of 70–75 m below sea level, including coastal barrier dunes, lagoonal systems, tidal flats, and estuarine channels (Ref. 207). Such feature preservation has significant geoheritage value (Ref. 207).

Traditional Owners have a culture that relates to a connectedness of land and sea in a holistic way (Ref. 210). The term ‘Country’ refers to more than just a geographical area, and includes values, places, resources, stories, and cultural obligations associated with that geographical area (Ref. 211). For Traditional Owners, the term ‘Country’ includes both land and sea, and coastal areas are connected with the traditional Country of a group or clan. Both Country and Sea Country contain evidence of the ancient events by which all geographic features, animals, plants and people were created (Ref. 210).

There are several coastal language groups or clans in northwest WA, including Thalanyji (associated with the Ashburton coastal plain, Exmouth Gulf, and surrounding areas). Based on engagement with Traditional Owner groups, CAPL understands that Thalanyji (represented by the Buurabalayji Thalanyji Aboriginal Corporation RNTBC for native title rights and interests) and Mardudhunera and Yaburara people (represented by the Wirrawandi Aboriginal Corporation RNTBC for native title rights and interests) have connections to Barrow Island (Table 6-19).

It should be noted that the archaeological research discussed above is primarily concerned with the identification of tangible UCH and Aboriginal Sites. Tangible values are those with a physical nature (such as artefacts and engravings); while intangible values are those that do not have a physical component (such as songlines and dances). Songlines are a feature of Traditional Owner culture, linking people, places, and practices (Ref. 212). Certain songlines are referred to as ‘Dreaming pathways’ because of the tracks forged by Creator Spirits during the Dreaming. These Dreaming songlines have specific ancestral stories attached to them (Ref. 213).

First Nations oral traditions have documented sea level rise over the last 7,000 years (Ref. 214). Seabed mapping near Murujuga (Burrup Peninsula) identified two submerged waterholes that were identified by local senior elders as belonging to the Kangaroo songline (Ref. 215).

The cultural, customary, and spiritual significance of species and the ecological communities they form are diverse and varied for Traditional Owners and their stewardship of Country (Ref. 23). For example, some First Nations people have a strong connection to whales, which has significance as totemic ancestors to some groups (Ref. 23). The arrival of whales along Australia's coast marked the arrival of the "elders of the sea", which follows a songline that traces the journeys of ancestral spirits as they created the land, animals, and lore (Ref. 23).

Traditional Owners in northwest WA continue to rely on coastal and marine environments and resources of the region for their cultural identity, health and wellbeing, and their domestic and commercial economies (Ref. 211). Their commitment to their Sea Country is demonstrated through their native title claims and their many initiatives to regain their role as managers of the cultural and natural values of northwest WA (Ref. 211).

The Traditional Owners of northwest WA engage in a diverse range of marine resource use activities, including hunting, egg collecting, fishing and gathering shellfish. Activities also continue on lands and waters where they have ceremonial and spiritual connections (Ref. 211).

Consultation with Traditional Owner groups and individuals has identified that Sea Country is of importance to their people (Table 6-19). These values include coastal areas, offshore islands, marine fauna, and traditional stories (e.g. it is believed that the Dreamtime serpent which created the rivers and inland springs is now in its resting place off the Pilbara coast; and as such, if the sea is protected, then the serpent is also being protected). It is acknowledged that Traditional Owners who are the custodians of this knowledge have the rights to decide how it is shared and used.

Table 6-19: Cultural values or features identified through consultation

Source	Cultural value or feature
Baiyungu Aboriginal Corporation (BAC)	Protecting land and Sea Country is a significant focus to the Baiyungu people. The Baiyungu coastal area, Sea Country, and adjacent islands are highly valuable to the Baiyungu people.
Buurabalayji Thalanyji Aboriginal Corporation	The Thalanyji people have a deep connection to Sea Country north of Onslow, extending out into the islands off the coast of the Pilbara including the Montebello Islands, Barrow Island, Mackerel Islands, Direction Island, Airlie Island, Weld Island, North and South Islands, Ashburton Island, Twin Islands, any island or atoll proximate to the above islands and a general radius of 150 km from Onslow.
Kariyarra Aboriginal Corporation (KAC)	KAC have noted the importance of protecting marine fauna during an emergency event. KAC are interested in flatback turtles and the impact of rubbish in the sea.
Malgana Aboriginal Corporation	Malgana Aboriginal Corporation identified Shark Bay seagrass as significant.
Mardathoonera Cultural Heritage Pty Ltd	Consultation with Mardathoonera representatives for other CAPL activities has identified a connection with Barrow Island and surrounding waters; specific values described include: • the creation story starts on Barrow Island • Barrow Island is a place that connects saltwater and freshwater together • Barrow Island is connected to Murujuga; both are considered by Coastal Mardudhunera as women's places • Biggada Creek is significant and connected to the Fortescue River; and that the rock formations in the creek are protectors • women's sites and ancestor spirits are present on Barrow Island • identified that Barrow Island was a hill in ancient times and is a sister hill to two hills on the mainland, and Old people would walk across before the sea levels rose and the island drifted; because of this, there will be artefacts and stories underwater • identified cultural importance of traditional stories, songlines, ocean, and marine fauna:

Source	Cultural value or feature
	– the sea is the source of energy for all life, it holds the codes that are encrypted in each person's body, the songlines, and is the lifeforce for the world – the places where the saltwater from the sea and the freshwater from the land connect are where the biggest energy lines are, and that connection is a force of creation relevant to a Dreaming story – songlines extend out from the land, through the sea, and around the globe – songlines connect places, people, and animals to each other, creating migratory patterns for animals and telling animals of the right time to birth and eat – freshwater that flows underneath the seabed carries the songlines – there is a large energy line that exists off the coast of Murujuga and runs through the area that CAPL operates in – there are songlines that go through Barrow Island and offshore and connect Barrow Island to the mainland; this includes a whale songline – Mardudhunera people are connected to songlines—if the songlines are disrupted, their widdart (heart) is disconnected, like the whales, their feet get lost, and they don't know where to go anymore • Country owns people and we are all connected by energy – different frequencies connect all beings on earth and everything on earth is connected – if you protect country, it will protect you – women hold the energy connected to water
Murujuga Aboriginal Corporation (MAC)	No specific areas have been identified through consultation however MAC has noted the cultural importance of Sea Country and the need to ensure it is protected.
Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC)	No specific areas have been identified through consultation however NTGAC has noted the cultural importance of Sea Country and the need to ensure it is protected. In addition, CAPL understands the Ningaloo Coast is culturally significant to the groups NTGAC represents.
Ngarluma Aboriginal Corporation (NAC)	NAC has noted that offshore islands are culturally significant.
Ngarluma Yindjibarndi Foundation Ltd	• The people from the land speak for and care about the marine animals, even if they are far out to sea. • Identified that marine fauna, specifically whales, dugongs, and turtles are species of importance. • The nature of many traditional narratives have origins and connection to the seascape, and impacts to the seascape, can have cultural repercussions. • Identified the presence and importance of intangible values, such as Barrimirndi (the serpent), which is an important part of dreaming for Ngarluma and Yindyibarndi people. • Identified the interconnectedness of the cultural landscape, whereby Traditional Owners from the western Pilbara are held to account by other Nyambali (cultural bosses) when proponents impact land and sea. • Cultural responsibilities transcend Native Title and other boundaries.
Robe River Kuruma Aboriginal Corporation	The waters extending seaward from the Jajiwurra (Robe River) river mouth. Values beyond the Hydrocarbon Social EMBA boundary included: • Jajiwurra (Robe River)

Source	Cultural value or feature
	• ecological integrity of Jajiwurra • the area within their Kuruma Marthudunera native title claim.
Wirrawandi Aboriginal Corporation	The coastal area, Sea Country, and adjacent islands are highly valuable to the Yaburara and Mardudhunera people. Identified a connection to Barrow Island.

6.3.5.2.2 european heritage

Early European exploration of the NWMR and adjacent coast occurred in the 1600s; however, explorers concluded at the time that resources and conditions were not appropriate for settlement (Ref. 102). British colonisation did not begin in the Pilbara until 1860s, with pastoralism as the first major industry, followed by small ports and service centres (Ref. 102). The pearling industry began in the late 1800s and remains a significant contributor to the economy of north-west WA (Ref. 102). Similarly, small fishing fleets were common from the 1860s onwards; the commercial fishing industry also remains a significant economic input for north-west WA, particularly from prawn and demersal finfish fisheries (Ref. 102). Petroleum discovery and development started in the 1950s, with both onshore and offshore discoveries (Ref. 102).

The marine and coastal industries that still exist and operate within the NWMR are further described in Section 6.4.

6.3.6 commonwealth marine area

The Commonwealth marine area is an MNES under the EPBC Act, and a relevant value and sensitivity under the OPGGS(E)R. The DA, Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA for this activity occur within waters off WA that are part of the NWMR.

The NWMR comprises the Commonwealth waters and seabed from the WA–Northern Territory border south to Kalbarri (Ref. 102). The NWMR is characterised by shallow-water tropical marine ecosystems with high species richness. Most of the region's species are tropical and are also found in other parts of the Indian and western Pacific oceans (Ref. 102). The region is a tropical carbonate margin that comprises an extensive area of shelf, slope, and abyssal plain/deep ocean floor, as well as complex areas of bathymetry such as plateau, terraces, and major canyons (Ref. 102).

The region experiences a tropical monsoonal climate towards its northern extent, transitioning to tropical arid and subtropical arid within its central and southern areas (Ref. 102).

Conservation values of the Commonwealth marine area include:

- protected species and/or their habitat (Section 6.3.3)
- protected places including AMPs (Section 6.5.1) and heritage places (Section 6.6)
- KEFs (Section 6.3.6.1).

6.3.6.1 key ecological features

Key ecological features (KEFs) are elements of the Commonwealth marine environment that are considered to be of importance for a region's biodiversity or its ecosystem function and integrity. KEFs are not MNES and have no legal status

in their own right; however, they may be considered as components of the Commonwealth marine area.

KEFs meet one or more of these criteria (Ref. 217):

- a species, group of species, or a community with a regionally important ecological role (e.g. a predator or prey that affects a large biomass or number of other marine species)
- a species, group of species, or a community that is nationally or regionally important for biodiversity
- an area or habitat that is nationally or regionally important for:
  - enhanced or high productivity (such as predictable upwellings—an upwelling occurs when cold nutrient-rich waters from the bottom of the ocean rise to the surface)
  - aggregations of marine life (such as feeding, resting, breeding or nursery areas)
  - biodiversity and endemism (species that only occur in a specific area)
- a unique sea floor feature, with known or presumed ecological properties of regional significance.

The Australian Government has identified KEFs based on scientific advice about the ecological processes and characteristics of the area (Ref. 217).

Table 6-20 describes the values of KEFs within the DA and EMBAs. Results of the Gorgon Backfill Fields Benthic Survey (Ref. 104; appendix a), which describes the presence of benthic KEF values within the DA, are further detailed in Section 6.3.1.1. Figure 6-37 shows the KEFs which are in the vicinity of or overlap the DA and EMBAs.

Table 6-20: Key ecological features in the vicinity of the DA and EMBAs

Key ecological feature	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Ancient coastline at 125 m depth contour	✓	**0**	✓	✓
Parts of the ancient coastline, particularly rocky escarpments, 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 (Ref. 102). The ancient, submerged coastline provides areas of hard substrate and therefore may provide sites for higher diversity and enhanced species richness relative to surrounding areas of predominantly soft sediment. According to the *Marine bioregional plan for the North-west Marine Region* (Ref. 102), little is known about fauna associated with the hard substrate of the escarpment across the entire KEF, but it is likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the NWS. For details of biota in the DA, refer below and to Section 6.3.1.1.1. **Values:** Unique sea floor feature with ecological properties of regional significance (Ref. 102). **DA benthic survey:** Key findings from the benthic survey within the DA identified (Section 6.3.1.1.1; Ref. 104; appendix a): • that BCH at Gorgon MPTS and the DA within this KEF is predicted to be comprised of smooth seabed with bioturbation and bare substrate and appeared to be devoid of epibenthic				

Key ecological feature	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
biota. This may indicate a layer of soft substrate over consolidated hard substrate, which is unlikely to provide significant habitat to biota • a total of 18,011 individuals from 13 fish taxa. The fish assemblage was dominated by *Trevallies* (Carangidae) with three species representing 14,231 of the total individuals.				
Continental slope demersal fish communities	✓	0	✓	✓
The diversity of demersal fish assemblages on the continental slope in the Timor Province, the Northwest Transition and the Northwest Province is high compared to elsewhere along the continental slope. The continental slope between 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 Australia (Ref. 218). According to the *Marine bioregional plan for the North-west Marine Region* (Ref. 102), the demersal fish species occupy two distinct demersal community types associated with the upper slope (water depths: 225–500 m) and the mid-slope (750–1,000 m). Bacteria and fauna present on the continental slope are the basis of the food web for demersal fish and higher-order consumers in this system (Ref. 102). For details of biota in the DA, refer below and to Section 6.3.1.1.1. **Values:** High levels of endemism with a diversity of fish assemblages (Ref. 102). **DA Benthic survey:** Key findings from the benthic survey within the DA found (Ref. 104; appendix a): • the most dominant BCH identified in the habitat mapping was irregular and smooth seabed with bare substrates, and discrete depressions of bioturbated sediments • topographically complex scarps were also predicted to be present traversing through the DA between ~400–800 m depths. Ground-truthing transects verified the presence of cnidarians, echinoderms, sponges, and a mixture of these biotic groups in the scarps in varying percent cover (from low [<10%] to high cover [>80%]) • a total of 468 fish belonging to 25 taxa, with the fish assemblage dominated by Trevallies (Carangidae) with four species from three genera accounting for 256 of the individuals observed In comparison to the other KEFs within the DA, there was no significant difference in the mean number of fish taxa within the continental slope demersal fish communities KEF.				
Exmouth Plateau	✓	0	✓	✓
The Exmouth Plateau is a regionally and nationally unique deep-sea plateau (water depths: 800–4,000 m) in tropical waters. The plateau is a very large topographic obstacle that may modify the flow of deep waters, generating internal tides and may contribute to upwelling of deeper-water nutrients closer to the surface, thus serving an important ecological role (Ref. 102). The topography of the plateau (with valleys and channels), in addition to potentially comprising a range of benthic environments, may provide conduits for moving sediment and other material from the plateau surface through the deeper slope to the abyss. The Exmouth Plateau is generally an area of low habitat heterogeneity; however, it is likely to be an important area of biodiversity as it provides an extended area offshore for communities adapted to water depths of ~1,000 m. Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna (Ref. 102). Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (Ref. 106). For details of biota in the DA, refer below and to Section 6.3.1.1.1. **Values:** Unique sea floor feature with ecological properties of regional significance (Ref. 102). **DA benthic survey:** Key findings from the benthic survey found (Ref. 104; appendix a): • the most dominant BCH were identified as relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota with significant habitat				

Key ecological feature	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
• two scarps cross through the indicative Chandon flowline route from east to west. A third one was identified north of Chandon DC-1. These scarps, however, are devoid of epibenthic fauna as observed in the ground-truthing videos • a total of 165 individual fish from 14 taxa were identified. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois sp1* (family Ipnopidae), representing over 65% of the total number of individual fish recorded.				
Commonwealth waters adjacent to Ningaloo Reef	–	143.5	✓	✓
The Commonwealth waters adjacent to Ningaloo reef include Ningaloo Commonwealth Marine Reserve (Commonwealth waters) and encompass an area of 2,435 km². This feature lies adjacent to the Ningaloo Marine Park (state waters) margin at the 3 nm limit. **Values:** The Commonwealth waters adjacent to Ningaloo Reef and associated canyons and plateau are interconnected and support the high productivity and species richness of Ningaloo Reef. The Leeuwin and Ningaloo currents interact on the seaward side of the reef, leading to areas of enhanced productivity which support aggregations and migration pathways of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds (Ref. 219; Ref. 220; Ref. 221; Ref. 222). Detrital input from phytoplankton production in surface waters and from higher-trophic consumers cycles back to the deeper waters of the shelf and slope (Ref. 106). Deepwater biodiversity includes fish, molluscs, sponges, soft corals and gorgonians. Some of these sponge and filter-feeding communities appear to be significantly different to those of the Dampier Archipelago and Abrolhos Islands, indicating that the Commonwealth waters of Ningaloo Marine Park have some particular areas of potentially high and unique sponge biodiversity (Ref. 223).				
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	–	101.2	✓	✓
The canyons on the slope of the Cuvier Abyssal Plain and Cape Range Peninsula are connected to the Commonwealth waters adjacent to Ningaloo Reef and may also have connections to Exmouth Plateau. **Values:** The canyons are thought to interact with the Leeuwin Current to produce eddies inside the heads of the canyons, resulting in waters from the Antarctic intermediate water mass being drawn into shallower depths and onto the shelf (Ref. 106). These waters are cooler and richer in nutrients and strong internal tides may also aid upwelling at the canyon heads (Ref. 106). The narrow shelf width (about 10 km) near the canyons facilitates nutrient upwelling. This nutrient-rich water interacts with the Leeuwin Current at the canyon heads. Aggregations of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds are known to occur in this area and are related to productivity (Ref. 224; Ref. 225).				
Glomar Shoals	–	165.3	✓	✓
The Glomar Shoals are a submerged littoral feature located ~150 km north of Dampier on the Rowley shelf at depths of 33–77 m (Ref. 226; Ref. 109). **Values:** 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 (Ref. 226; Ref. 109; Ref. 227). These species have recorded high catch rates associated with the Glomar Shoals, indicating that the shoals are likely to be an area of high productivity.				

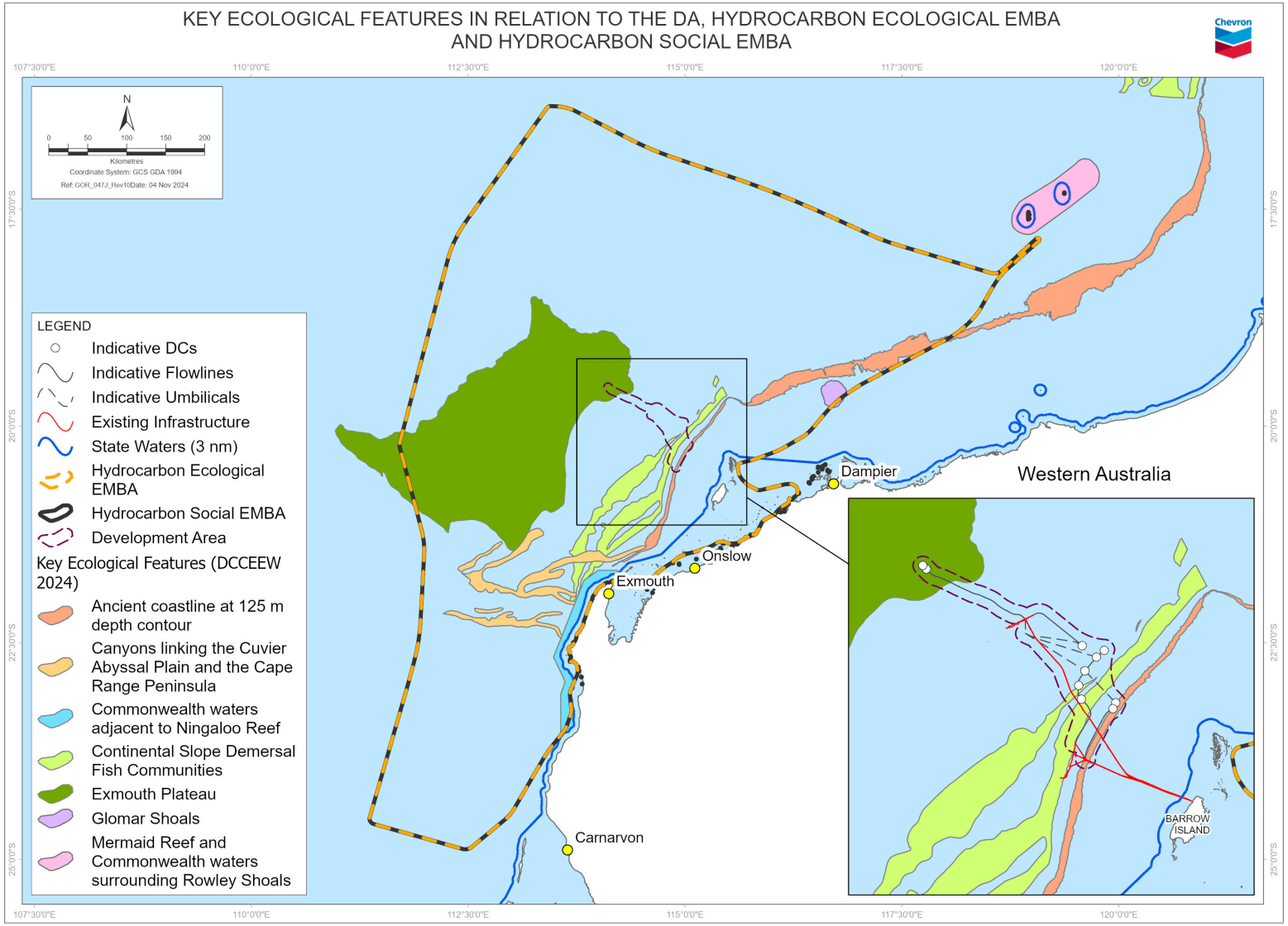


Figure 6-37: Key ecological features in relation to the DA and Hydrocarbon Ecological and Social EMBA

6.3.7 commonwealth land area

Commonwealth land[79] is a relevant value and sensitivity under the OPGGS(E)R. No Commonwealth lands overlap the DA. Based on spatial review and searches of the EPBC Act protected matters database (Ref. 122; appendix b), Commonwealth lands that overlap the Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA are outlined in Table 6-21.

Table 6-21 Commonwealth land areas in the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

Commonwealth Land Area	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Defence—Exmouth VLF transmitter station	✓	✓
Defence—Exmouth administration and HF transmitting	–	✓
Defence—Learmonth radar site—Vlamingh Head	✓	✓
Defence—Learmonth—air weapons range	✓	✓
Commonwealth land ID 52236 (unknown agency).	✓	✓
Commonwealth land ID 50385 (unknown agency).	–	✓
Commonwealth land ID 51104 (unknown agency).	–	✓

6.4 natural and physical resources

Natural and physical resources are described as substances occurring in nature that can be exploited for economic gain—these may include such resources as fishing stocks, petroleum reservoirs, or values of the Commonwealth marine area. Marine and coastal industries have been developed based on natural and physical resources. These industries are described in relation to the EMBA in the following subsections.

6.4.1 commercial fisheries

6.4.1.1 commonwealth-managed fisheries

The Commonwealth-managed commercial fisheries with fishery management areas that intersect the DA or Hydrocarbon Ecological and Social EMBAs, and that have fishing effort recorded during 2013–2022 (Ref. 228) are listed in Table 6-22.

Data for the Commonwealth-managed fisheries are supplied in two formats: relative fishing intensity and maximum area fished. Where <5 vessels were operating data are considered confidential (as advised by the DAFF) (Ref. 229) and relative fishing intensity is not available. The maximum area fished shows the total area where fishing occurred at a reporting grid resolution of one degree

[79] Commonwealth land includes land owned or leased by the Commonwealth or a Commonwealth agency, land in the Jervis Bay Territory, land in the Christmas Island, Ashmore and Cartier Islands, Coral Sea Islands, Cocos (Keeling) Islands, Australian Antarctic Territory and Heard and McDonald Islands external territories, and any other area of land that is included in a Commonwealth reserve.

(~111 × 111 km). Table 6-22 identifies the fisheries with reporting grids (maximum area fished) overlapping the DA and EMBAs.

Table 6-22: Presence of fishing effort within reporting grids overlapping the DA and EMBAs recorded within Commonwealth-managed commercial fisheries (2013–2022)

Fishery	DA	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
North-West Slope Trawl Fishery	✓	✓	✓
Western Deepwater Trawl	-	✓	✓
Western Tuna and Billfish Fishery	✓	✓	✓

6.4.1.1.1 north west slope trawl fishery

The North West Slope Trawl Fishery (NWSTF) uses bottom (or demersal) trawl methods to target deepwater prawn and scampi, typically in water depths of 350–600 m. The primary species landed in the NWSTF is the Australian scampi (*Metanephrops australiensis*), with smaller quantities of velvet scampi (*M. velutinus*), Boschma's scampi (*M. boschmai*) and mixed scampi (*Metanephrops spp.* and *Nephropsis spp.)* also landed. A quantity of prawns is also harvested each season, and squid is becoming an increasingly significant component of the catch. Mixed snappers (*Lutjanidae*) and redspot emperor (*Lethrinus lentjan*) have historically been an important component of the NWSTF catch. Fishing for scampi occurs over soft, muddy sediments or sandy habitats, using demersal trawl gear on the continental slope.

Fishing intensity data for the NWSTF is only available for the 2020 reporting period and this data does not overlap the DA or Hydrocarbon EMBAs. All other reporting periods had <5 vessels operating and therefore data are considered confidential. The maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km).

The DA and Hydrocarbon Ecological and Social EMBAs overlap multiple reporting grids with recorded fishing effort for the NWSTF (Figure 6-38). The inset shows the actual reporting periods with fishing effort data for the grids that overlap the DA during the 2013-2022 ten-year period (Figure 6-38). The majority of the DA has not been regularly fished, with two reporting grids only having one year of activity each; most of the fishing effort occurs to the east (Figure 6-38).

The total catch for the 2022-2023 season was 85.4 t (similar to the 85.8 t in the previous 2021-2022 season), with three vessels operating over 218 days. According to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) Fishery Status Report 2024, the NWSTF is not subject to overfishing (Ref. 230).

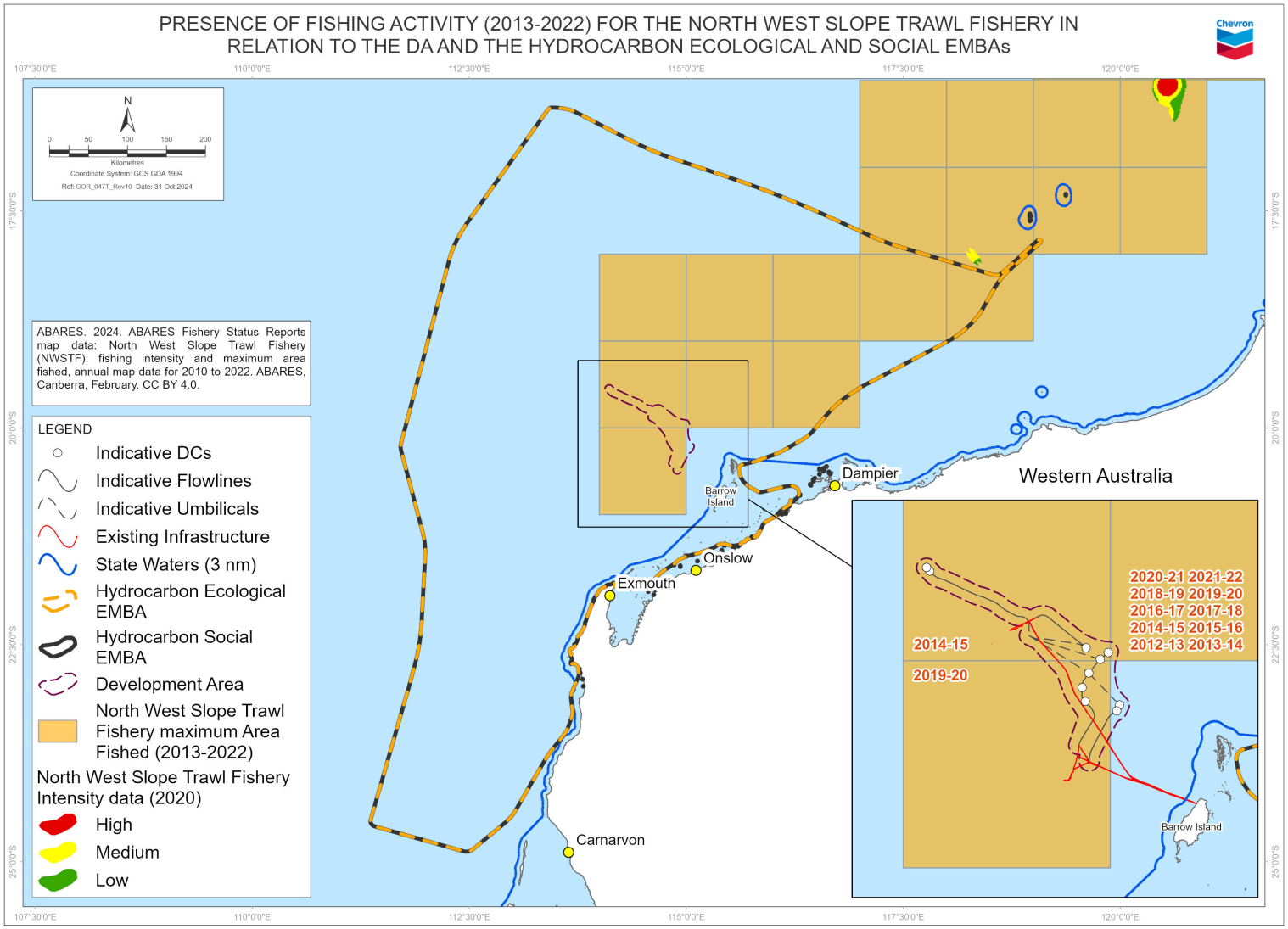


Figure 6-38: Presence of fishing activity (2013–2022) for the North West Slope Trawl Fishery in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.4.1.1.2 western deepwater trawl fishery

Operators within the Western Deepwater Trawl Fishery (WDTF) use demersal trawl methods and catch more than 50 species in waters seaward of a line approximating the 200 m isobath (Ref. 231).

There is no available fishing intensity data for the WDTF as all reporting periods had <5 vessels operating, and therefore data are considered confidential. As previously stated, the maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km).

The DA is outside of the management area for the WDTF, and as such no fishing effort occurs within the DA (Figure 6-39). The EMBAs overlap multiple reporting grids of the WDTF (Figure 6-39).

No catch or effort as recorded in the 2022-2023 season. The total catch for the previous 2021-2022 season was 12 t, up from 5 t in the 2020-2021 season. The number of vessels active in the fishery and total hours trawled have been variable but relatively low since 2005-2006. According to the ABARES Fishery Status Report 2024, the WDTF is not subject to overfishing (Ref. 231).

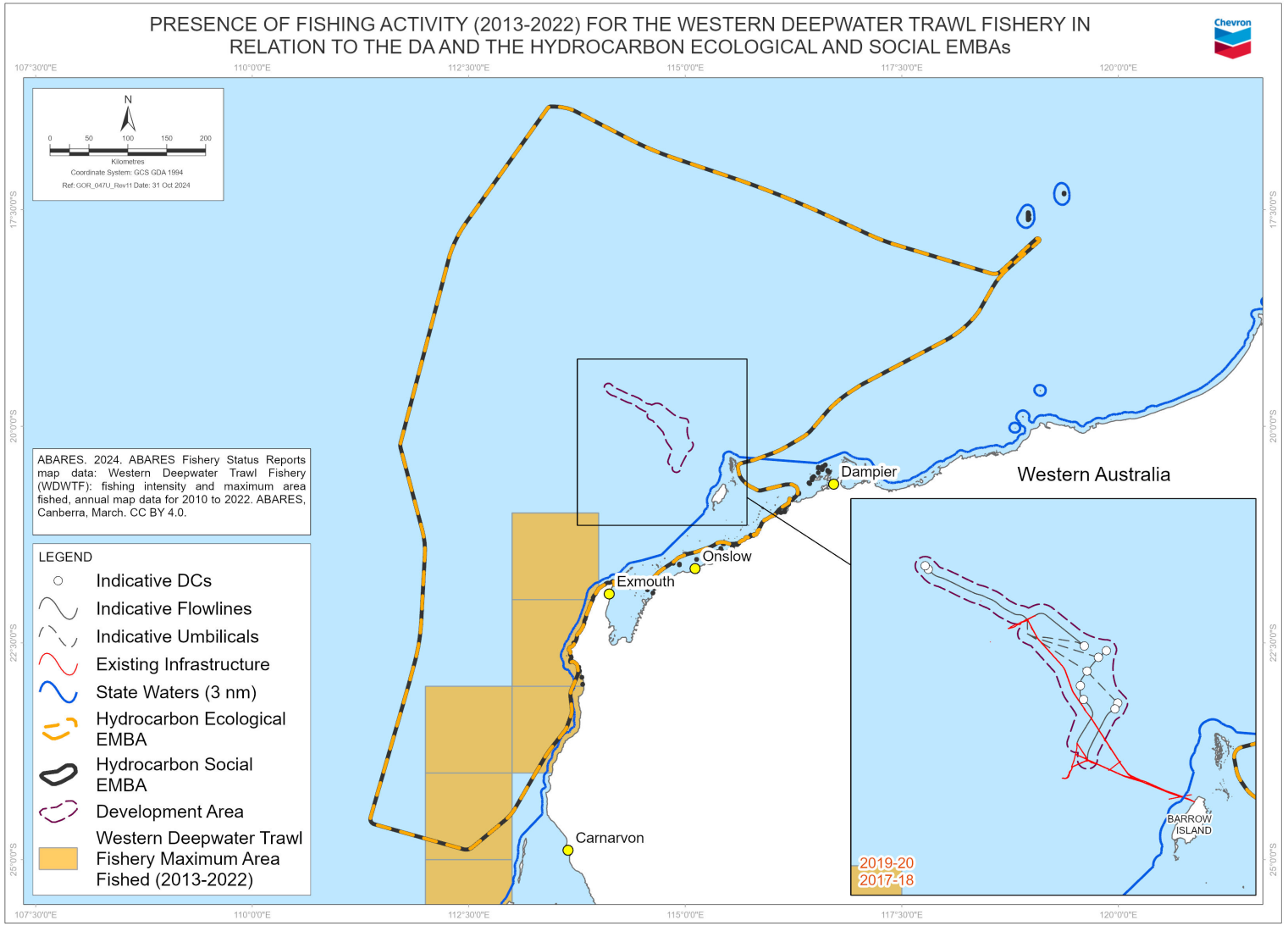


Figure 6-39: Presence of fishing activity (2013-2022) for the Western Deepwater Trawl Fishery in relation to the DA, Hydrocarbon Ecological and Social EMBAs

6.4.1.1.3 western tuna and billfish fishery

The main fishing gear in the Western Tuna and Billfish Fishery (WTBF) is pelagic longline, with low levels of minor-line fishing (Ref. 232). The species targeted include bigeye tuna (*Thunnus obesus*), Swordfish (*Xiphias gladius*) and yellowfin tuna (*Thunnus albacares*). striped marlin (*Kajikia audax* or *Tetrapturus audax*) is a minor component of the catch. Catch of albacore (*Thunnus alalunga*), a non-quota species, can approach levels similar to yellowfin tuna catch in some years.

There is no available intensity data for the WTBF as all reporting periods had <5 vessels operating, and therefore data are considered confidential. As previously stated, the maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km).

The DA and Hydrocarbon Ecological and Social EMBAs overlap multiple reporting grids with recorded fishing effort for the WTBF (Figure 6-40). The inset shows the actual reporting periods with fishing effort data for the grids that overlap the DA during the 2013-2022 ten-year period (Figure 6-40). The DA has not been regularly fished with the reporting grids only having one year (2013) of activity each (Figure 6-40).

The total catch for the 2023 season was 196 t, up from 139 t in the previous 2022 season. There were three active vessels (two pelagic longline, and one minor line) during 2023. According to the ABARES Fishery Status Report 2024, of the five indicator species within the WTBF, the bigeye tuna, striped marlin and yellowfin tuna are classified as overfished. The swordfish and albacore are not subject to overfishing (Ref. 232).

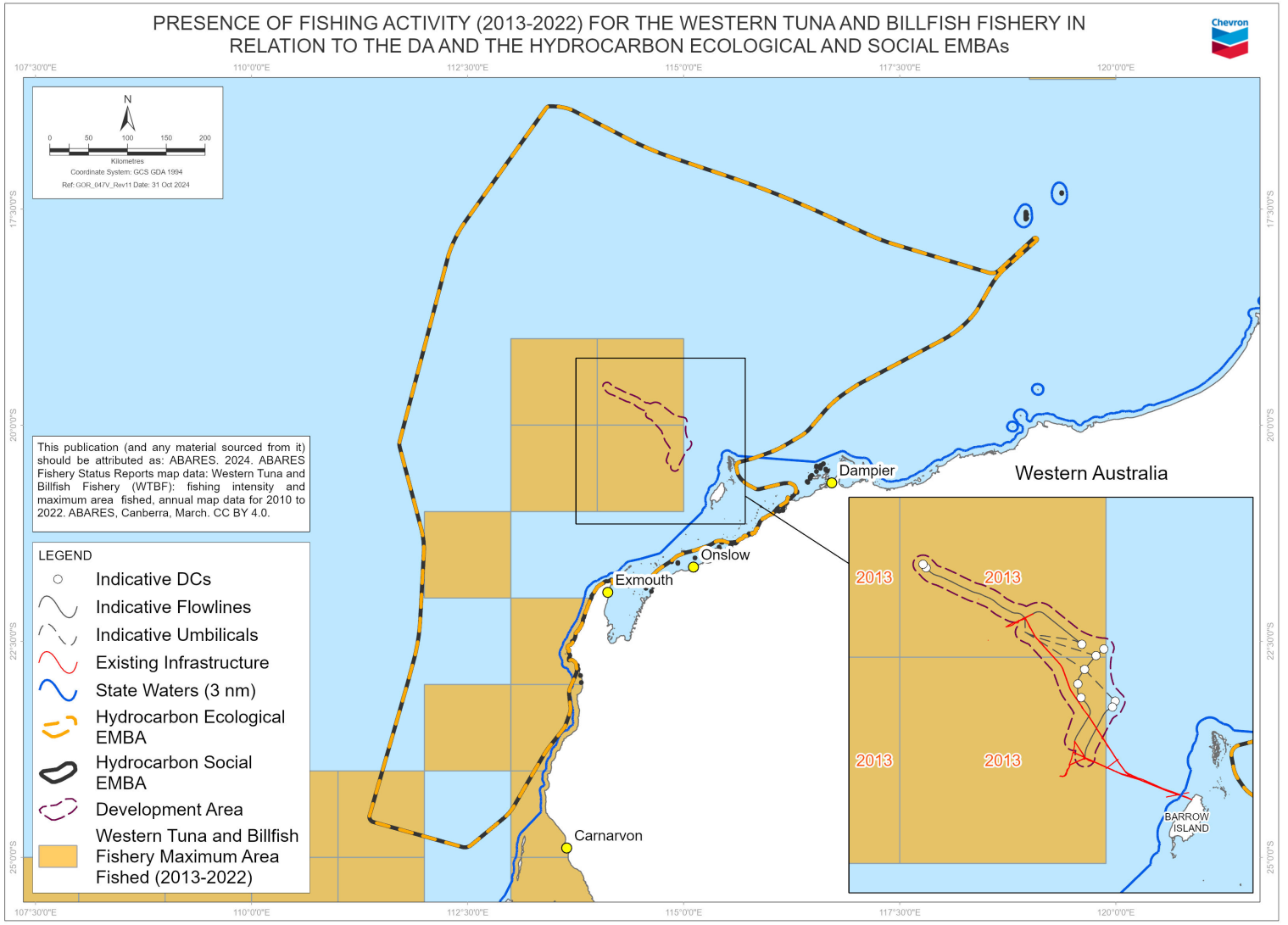


Figure 6-40: Presence of fishing activity (2013-2022) for the Western Tuna and Billfish Fishery in relation to the DA, Hydrocarbon Ecological and Social EMBAs

6.4.1.1.4 southern bluefin tuna fishery

The southern bluefin tuna Fishery is active within waters in the Great Australian Bight and south-eastern Australia (i.e. not within the DA or Hydrocarbon Ecological or Social EMBAs); however, the spawning grounds for southern bluefin tuna (*Thunnus maccoyii*) are in the north-east Indian Ocean (Ref. 230). This indicative spawning ground for the southern bluefin tuna (based on geospatial data provided by ABARES, and as shown in annual Commonwealth fishery status reports) extends into the DA and EMBAs. Two peaks have been observed in southern bluefin tuna spawning activity: September–October and February–March (Ref. 545; Ref. 546). Spawning typically occurs near the water surface. The fish then regularly dive into deeper waters to thermoregulate as they are cold-water fish and cannot tolerate warm waters for extended periods (Ref. 545). Individual fish probably stay in the spawning area for one month or so (Ref. 545; Ref. 547). The larvae drift passively before becoming entrained in the southwards flowing South Java and Leeuwin Currents and carried down the coast of WA (Ref. 545). One to two-year old juveniles then head east to the Great Australian Bight, or west to the waters off South Africa (Ref. 546).

6.4.1.2 state-managed fisheries

The State-managed commercial fisheries with fishing management areas that overlap the DA and EMBAs, and that have fishing effort recorded over a 10-year period (2014–2023) (Data supplied to CAPL by DPIRD) are listed in Table 6-23. Data are reported either via 60 x 60 nm or 10 × 10 nm reporting grids.

Four fisheries (Mackerel Managed Fishery, Pilbara Crab Managed Fishery, Pilbara Line Fishery, and Pilbara Trap Managed Fishery) were identified as having reporting grids indicating activity within the DA over the 10 years between 2014-2023(Figure 6-41 to Figure 6-44). Fishing effort records obtained from DPIRD (Ref. 394) for State-managed commercial fisheries indicate that fishing effort within the DA varies each year:

- Mackerel Managed Fishery—<3 active vessels per year, fishing effort recorded in 2014, 2016, 2017 and 2018
- Pilbara Line Fishery—active vessels varied between <3 to 6 per year, fishing effort recorded all years
- Pilbara Trap Managed Fishery—≤3 active vessels per year, fishing effort recorded all years
- Pilbara Crab Managed Fishery—<3 active vessels, with fishing effort only recorded in 2016.

Table 6-23: Presence of fishing effort recorded during 2014–2023 within State-managed commercial fisheries

Fishery	DA	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
North Coast Bioregion			
Mackerel Managed Fishery	✓	✓	✓
Nickol Bay Prawn Managed Fishery	–	✓	✓
Onslow Prawn Managed Fishery	–	✓	✓
Pilbara Crab Managed Fishery	✓	✓	✓
Pilbara Fish Trawl (Interim) Managed Fishery	–	✓	✓

Fishery	DA	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Pilbara Line Fishery	✓	✓	✓
Pilbara Trap Managed Fishery	✓	✓	✓
West Australian Sea Cucumber (Beche-De-Mer) Fishery	–	✓	✓
Open Access in the North Coast, Gascoyne Coast and West Coast Bioregions	–	✓	✓
Gascoyne Bioregion			
Exmouth Gulf Prawn Managed Fishery	–	✓	✓
Gascoyne Demersal Scalefish Fishery	–	✓	✓
West Coast Deep Sea Crustacean Fishery	–	✓	✓
State-wide			
Marine Aquarium Fish Managed Fishery	–	✓	✓
Specimen Shell Managed Fishery	–	✓	✓
Hermit Crab Fishery	–	✓	✓

The Mackerel Managed Fishery extends from the West Coast Bioregion to the WA/NT border. The Mackerel Managed Fishery utilises near-surface trolling or jig fishing methods, with vessels primarily active during May to November (Ref. 506). The bulk of the catch typically is typically taken in Kimberley and Pilbara waters, with smaller proportions in the Gascoyne/West Coast bioregions (Ref. 506). The fishery targets are Spanish mackerel (*Scomberomorus commerson*), grey mackerel (*S. semifasciatus*) and other species from the genus *Scomberomorus.* There are three managed fishing areas (Kimberley, Pilbara, Gascoyne/West Coast) and during the 2022 season commercial effort was recorded by three vessels (439 days), seven vessels (189 days), and six vessels (95 days) in each management area respectively (Ref. 506). The total catch for the fishery in 2022 was 198 t and 14 t for Spanish and grey mackerel respectively (Ref. 506). The intersect between the DA and Hydrocarbon Ecological and Social EMBAs and recorded fishing effort over the 2014-2023 period is shown in Figure 6-41; the inset shows the most recent year fishing effort was recorded within the vicinity of the DA.

The Pilbara Line Fishery, Pilbara Trap Managed Fishery, and the Pilbara Fish Trawl (Interim) Managed Fishery are part of the Pilbara Demersal Scalefish Fishery. For the 2022 fishing season, the bulk of the catch within the Pilbara Demersal Scalefish Fishery was landed by the trawl sector (which does not occur within the DA); with smaller contributions from the trap (~24%) and line (~4%) sectors (Ref. 506).

The Pilbara Line Fishery (line fishing methods) operates on an exemption basis which restricts vessels to operating within a nominated 5-month block period each year (typically May to September). The Pilbara Line Fishery catch is made up around 45–50 different fish species. The main species targeted by the fishery are bluespotted emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*) and rankin cod (*Epinephelus multinotatus*), as well as some deeper offshore species such as ruby snapper and eightbar grouper. The total catch for the fishery in 2022 was 104 t (Ref. 506).

The Pilbara Trap Managed Fishery (trap methods) is managed through area closures and effort allocations. The main species targeted by the Pilbara Trap

Managed Fishery are bluespotted emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*) and rankin cod (*Epinephelus multinotatus*). The total catch for the fishery in 2022 was 597 t (Ref. 506).

The intersect between the DA and Hydrocarbon Ecological and Social EMBAs and recorded fishing effort over the 2014-2023 period for the Pilbara Line Fishery and Pilbara Trap Managed Fishery is shown in Figure 6-42 and Figure 6-43 respectively. The insets shows the most recent year fishing effort was recorded within the vicinity of the DA.

The Pilbara Crab Managed Fishery utilises hourglass trap fishing methods, and primarily operated within inshore waters around Nickol Bay (Ref. 506). This fishery primarily targets blue swimmer crab (*Portunus armatus*) and mud crabs (*Scylla spp.*). The 2022 fishing season reported a commercial catch of 11.2 t and 2.4 t of blue swimmer and mud crab respectively (Ref. 506). The intersect between the DA and Hydrocarbon Ecological and Social EMBAs and recorded fishing effort over the 2014-2023 period is shown in Figure 6-44; the inset shows the most recent year (and the only year; 2016) fishing effort was recorded within the vicinity of the DA.

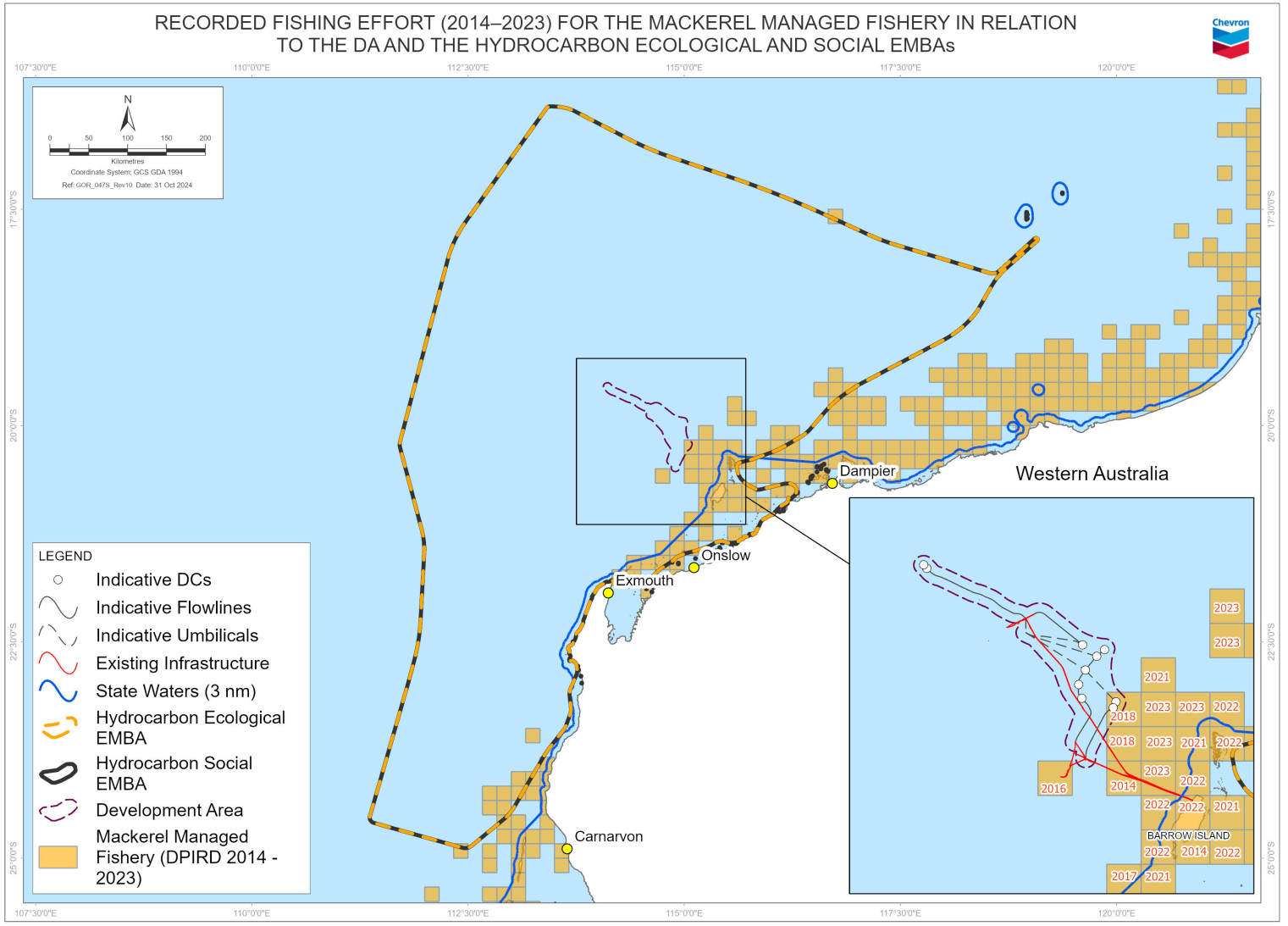


Figure 6-41: Recorded fishing effort (2014-2023) for the Mackerel Managed Fishery in relation to the DA and Hydrocarbon Ecological and Social EMBAs

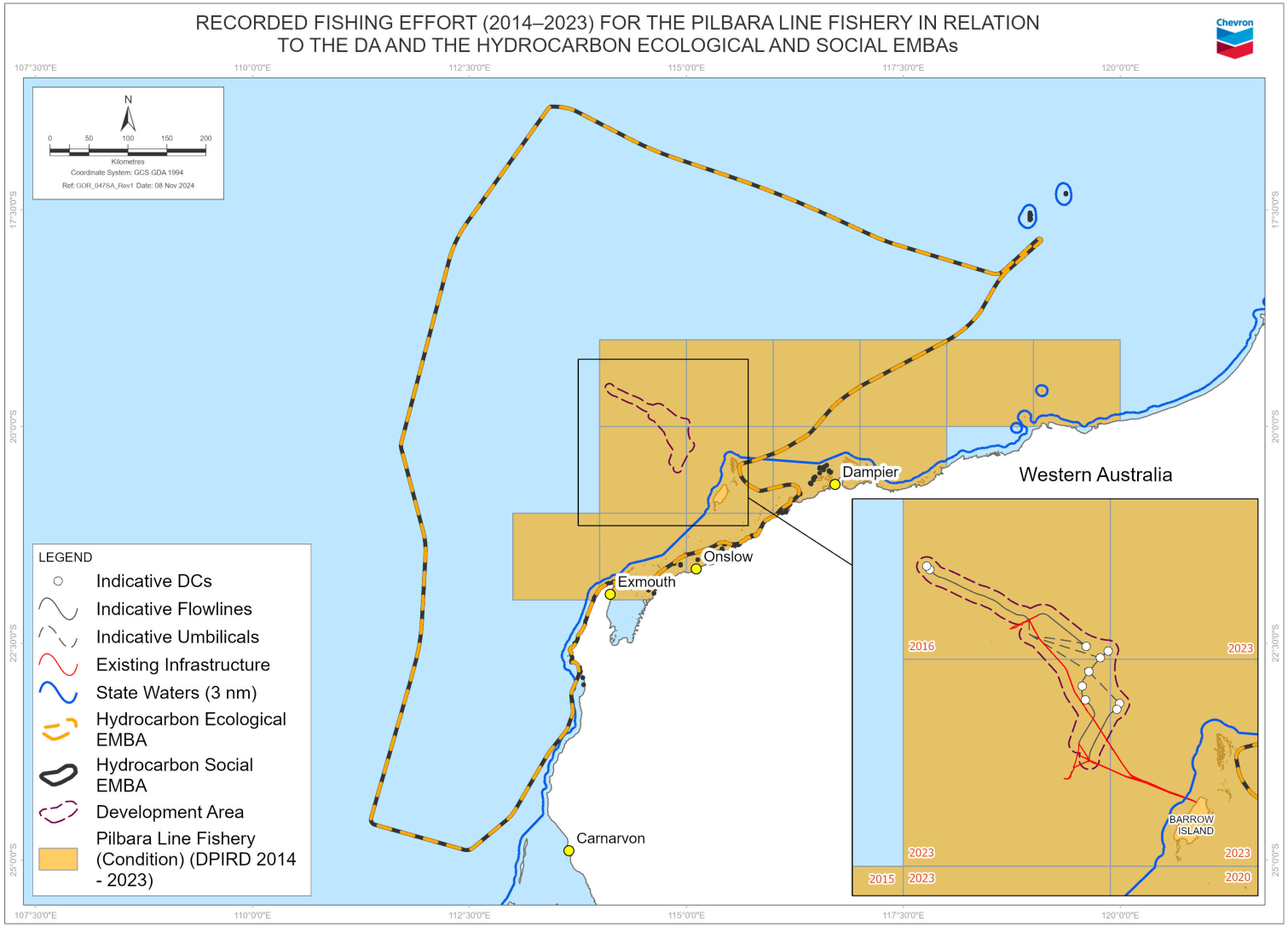


Figure 6-42: Recorded fishing effort (2014–2023) for the Pilbara Line Fishery in relation to the DA and Hydrocarbon Ecological and Social EMBAs

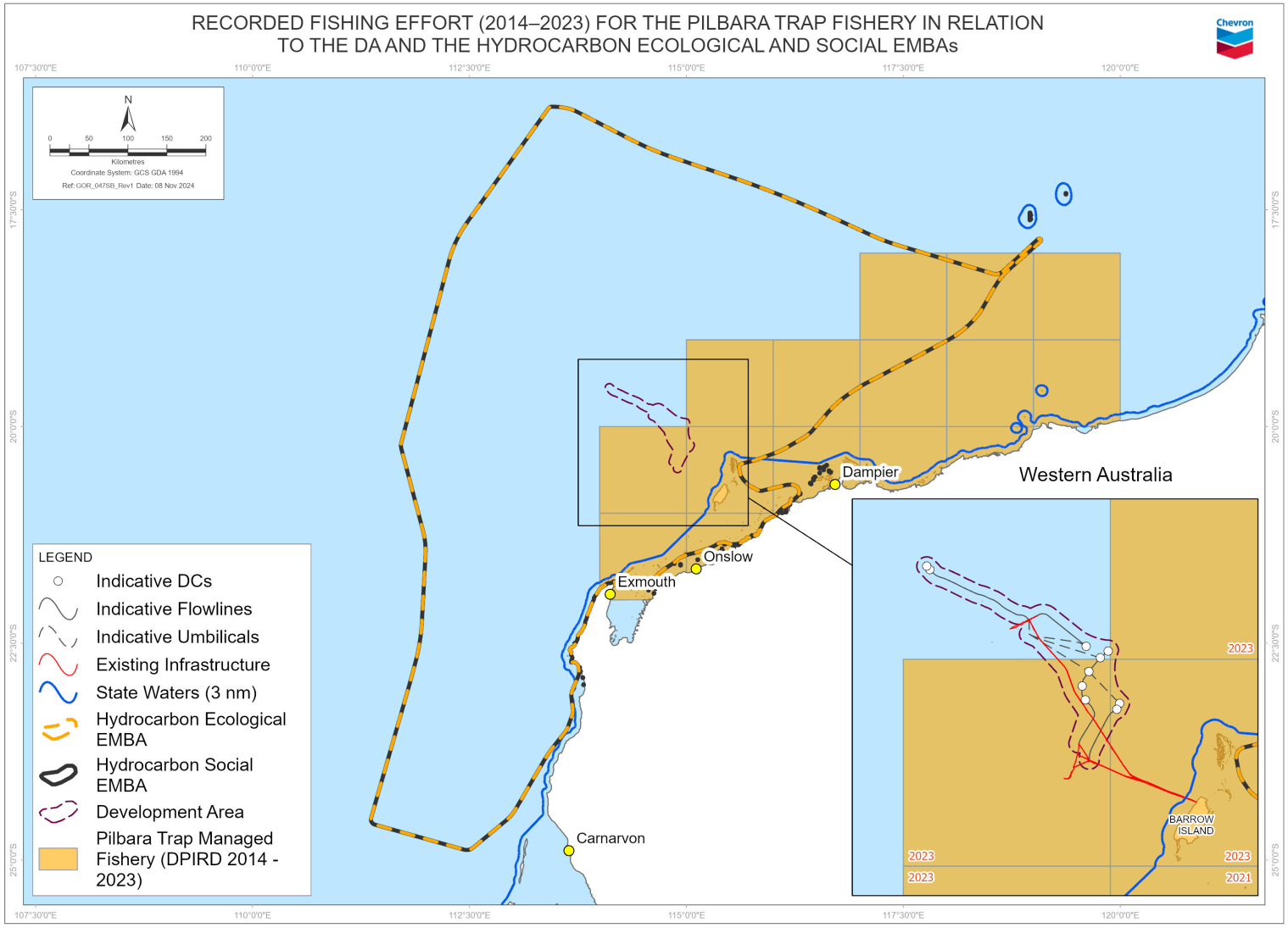


Figure 6-43: Recorded fishing effort (2014–2023) for the Pilbara Trap Fishery in relation to the DA and Hydrocarbon Ecological and Social EMBAs

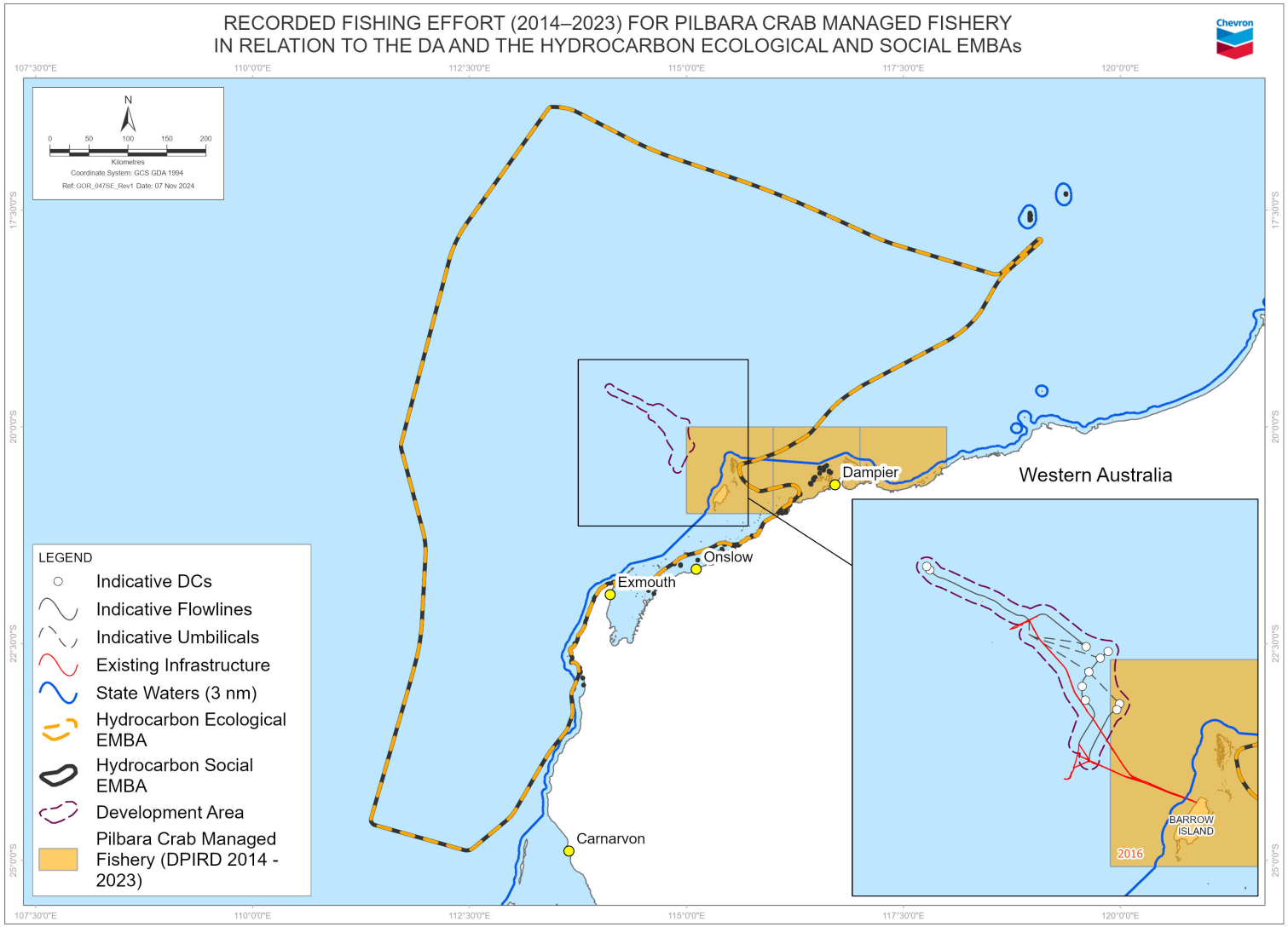


Figure 6-44: Recorded fishing effort (2014–2023) for the Pilbara Crab Managed Fishery in relation to the DA and Hydrocarbon Ecological and Social EMBAs

6.4.1.3 pearling and aquaculture

Pearling and aquaculture operations in the northwest are typically restricted to inland and shallow coastal waters.

The DA occur offshore and does not have any interface with the coast or shallow coastal waters, and therefore there is no overlap with any known licenced aquaculture or pearling operations.

The Hydrocarbon EMBAs interfaces with the coast, including Barrow Island, Pilbara inshore islands, and around the Point Cloates / Ningaloo Station area. The Hydrocarbon Social EMBA also includes additional shoreline contact dispersed along the coast from North West Cape to islands in the Dampier Archipelago (Figure 6-9 to Figure 6-12). Known pearl farm leases and sites exist in the nearshore waters around the Montebello and Sunday Islands. Additionally, there are aquaculture sites in the nearshore waters around the Airlie and Thevenard Islands within the Hydrocarbon EMBAs.

6.4.2 recreational fisheries

Recreational fishing is one of the most popular activities in WA—an estimated one-third of the population fishes recreationally (Ref. 233). DPIRD conducts state-wide recreational fishing surveys every two years, with the first survey completed in 2011. The survey collects information from more than 3,000 boat-based recreational fishers who record their catches in logbooks over a 12-month period. DPIRD also conducts interviews throughout the State and monitors the number of boat launches and retrievals using cameras at various boat ramps.

The DA and EMBAs are located in the North Coast and Gascoyne Coast bioregions. The September 2020–August 2021 survey report identified that most boat-based recreational fishing effort occurred in nearshore habitat (46% and 54% for North Coast and Gascoyne Coast respectively), followed by inshore demersal habitats (32% and 39% for North Coast and Gascoyne Coast respectively) (Ref. 234). Most fishing effort was attributed to line fishing (87% and 91% for North Coast and Gascoyne Coast respectively), during autumn for the Gascoyne Coast (36%) and during winter for the North Coast (42%) (Ref. 234).

Due to the offshore location of the Development, recreational fishing is not expected in the DA. Some shore-based fishing may occur within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA (Section 6.3.5.1).

6.4.3 traditional fisheries

A Customary Fishing Policy has been incorporated into the *Fish Resources Management Act 1994* (WA), which allows for customary fishing by applicable persons to occur within a sustainable fisheries management framework. According to the policy, customary fishing applies to a person of ‘aboriginal descent’ who is ‘fishing in accordance with the traditional law and custom of the area being fished’, and is ‘fishing for personal, domestic, ceremonial, educational or non-commercial needs’ (Ref. 235; Ref. 236). This customary fishing policy includes fish and does not apply to other species of marine fauna (e.g. crocodile, turtle, or dugong).

Under amendments made in 2012 to the *Conservation and Land Management Act 1984* (WA) Traditional Owners can undertake customary activities including hunting (except in marine sanctuary zones or marine nature reserves) for dugong, turtle, or crocodiles in WA.

As described in Section 6.3.5.2.1, ongoing use of marine and coastal resources, including fish, is expected to occur in the NWMR and adjacent coastal waters. Much of this activity is expected to occur in shallow coastal waters, so is not likely to overlap the DA; however, it may overlap the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA. Shore-based fishing may overlap the EMBAs.

The DA and EMBAs do not overlap the Memorandum of Understanding (MoU) Box that allows traditional Indonesian fishers to fish within Australian waters. The MoU Box is managed via a bilateral agreement between the Australian and Indonesian governments.

6.4.4 commercial shipping

AMSA collects vessel traffic data from various sources, including satellite shipborne automated identification system data, across Australia's search and rescue region. This data was used to develop Figure 6-45, which shows vessel traffic for 2023 within the vicinity of the DA and the Hydrocarbon Social EMBA. Figure 6-45 shows that the DA within the vicinity of the G&E to Jansz pipeline, and the indicative routes for the G&E, C&D, and Semele umbilicals, overlaps part of the NWS shipping fairway system.

The Hydrocarbon Social EMBA (Figure 6-45) covers several sections of the NWS shipping fairway system.

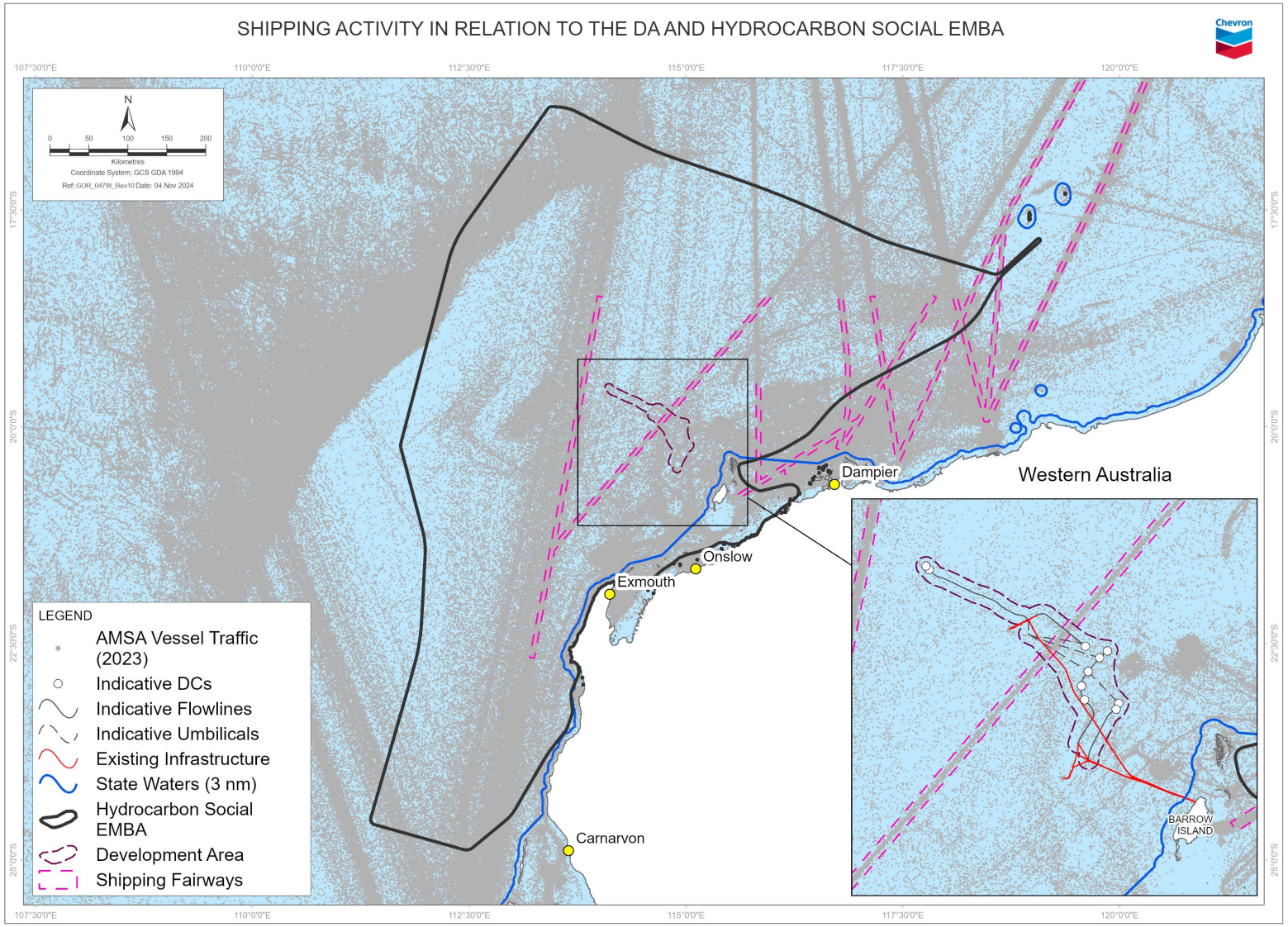


Figure 6-45: Shipping activity in relation to the DA and Hydrocarbon Social EMBA

6.4.5 tourism and recreation

Tourism is an important industry for WA, directly employing 56,300 people and indirectly employing a further 22,100 (Ref. 237). Charter fishing, diving, snorkelling, wildlife watching, and cruising are some of the commercial tourism activities in and adjacent to the NWMR (Ref. 102). Except for offshore charter fishing, most marine tourism activities occur in the shallower State waters (Ref. 102).

The DA occurs offshore and does not have any connection with nearshore waters or the mainland coast—no tourism and recreational activities are expected within the DA. The Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA do overlap with some coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Passage Islands, Cape Range National Park, Muiron Islands and around the Point Cloates / Ningaloo Station area (Figure 6-1 and Figure 6-2), as well as some shoreline points from North West Cape to islands in the Dampier Archipelago (see Section 6.3.2). As described in Section 6.3.5.1, tourism and recreational activities may occur around these shoreline areas, particularly the Montebello Islands, Point Cloates / Ningaloo Station, and the Dampier Archipelago islands.

The Gascoyne and Pilbara regions are popular visitor destinations for both Australian and international tourists. The main marine nature-based tourist activities within the Gascoyne Region are concentrated around and within the Ningaloo Coast World Heritage property (~127 km south-west of the DA; Section 6.6). Tourism activities include recreational fishing, snorkelling and scuba diving, wildlife watching and encounters (including whale sharks, manta rays, humpback whales, and turtles) (Ref. 238), as well as beach access, surfing and paddling sports. Recreational fishing within the Pilbara region tends to be concentrated in State waters adjacent to population centres. Charter vessels may also frequent the waters surrounding the Montebello Islands (Ref. 121).

6.4.6 other marine and coastal industries

Other marine and coastal industries may be present within the DA or Hydrocarbon Social EMBA (Table 6-24). No offshore renewable energy facilities, salt mines, or onshore processing facilities were identified within the DA or Hydrocarbon Social EMBA.

Table 6-24: Presence of industries

Industry	DA	Hydrocarbon Social EMBA
Petroleum exploration and production	✓	✓
Defence	-	✓
Ports	-	✓
Submarine cable	✓	✓

6.4.6.1 petroleum industry

The DA is located in the Northern Carnarvon Basin. The basin is Australia's premier hydrocarbon-producing province and contains an established network of oil, condensate and gas production infrastructure (Ref. 111) run by various operators. Petroleum activities that are approved or currently under assessment by NOPSEMA, and within the vicinity (≤50 km) of the DA are outlined in

Table 6-24. Submarine cables within the vicinity (≤50 km) of the DA are also shown in Figure 6-46.

Table 6-25: Petroleum activities overlapping the DA

Petroleum Activity	Key Characteristics	DA	Distance to DA (~km)
CAPL –GFP (Ref. 9; Ref. 10; Ref. 578)	• Initial commissioning and start-up activities occurred in 2015, and operations are expected to continue for the nominal operational design life of 50 years. • Ongoing operations for the Gorgon and Jansz-Io fields, including IMR and well interventions as required • The Development ties into the GFP.	✓	0
CAPL— Jansz-Io Compression (J-IC) (Ref. 14; Ref. 15; Ref. 10)	• J-IC will involve the construction and installation of a floating FCS, subsea compression infrastructure and a ~135 km submarine power cable linked to Barrow Island. It is considered part of the GFP. • Installation and pre-commissioning is indicatively scheduled to occur from late-2024 to mid-2027. • Commissioning is anticipated to commence from 2026, with start-up and operations expected from 2027 or 2028.	✓	0
CAPL – Wheatstone Project (Ref. 245; Ref. 577)	• The Wheatstone offshore facilities gather and partially process gas and associated condensate from the Wheatstone and Iago fields at the platform and then transport via trunkline to the GTP at Onslow. • The platform also receives fluids from Woodside's Julimar Development. • Part of the trunkline is within the DA, running along the south-eastern border. • Additional production well drilling within existing production licences for Wheatstone and Iago fields will occur in the future (drilling activities do not occur within the DA, indicative manifold locations are >22 km from the DA). • Indicative duration for Wheatstone Project operations until 2046, with operations 24 hours a day every day and IMR (including well intervention) activities when required.	✓	0
CAPL – Legacy Wellhead Decommissioning	• CAPL is planning to decommission several non-operational legacy wellheads and associated infrastructure. • An EP is currently in preparation.	✓	0
Woodside – Scarborough	• Development of Scarborough will include the installation of a floating	✓	0-85

Petroleum Activity	Key Characteristics	DA	Distance to DA (~km)
Development (Ref. 239; Ref. 575; Ref. 240; Ref. 670)	production unit (FPU) with eight wells drilled in the initial phase and thirteen wells drilled over the life of the Scarborough field, with all wells tied back to a semi-submersible FPU moored in 950 m of water close to the Scarborough field. • A trunkline runs ~430 km from the FPU to Pluto LNG on the Burrup Peninsula; the trunkline was installed in 2024. • The trunkline route crosses the Chandon flowline. • The Scarborough Offshore Facility and Trunkline (operations) EP includes hook, startup, commissioning and operations of the FPU. The FPU is ~85 km from the DA.		
Woodside – Goodwyn Area Infill Development (Ref. 576)	• The Goodwyn Area Infill Development will include multiple subsea tiebacks to existing Greater Western Flank subsea infrastructure. The OPP covers the life cycle (drilling, subsea installation, operations, and decommissioning) of the infill development.	–	39
Woodside – Julimar Development (Ref. 241; Ref. 242; Ref. 676)	• Initial start-up of production in 2016 with a field life of 25 years. • Ongoing operation of the subsea hydrocarbon system; also includes inspection, monitoring, maintenance and repair during operations. • Fluids from the Julimar and Brunello fields are transported to the Wheatstone Platform. • The western edge of WA-49-L overlaps the DA with several production wells and associated subsea infrastructure within the DA. • Julimar Development Phase 3 (JDP3): – drilling of additional wells and installation subsea infrastructure within the Julimar field and Penfolds prospect – start-up of JDP3 wells and associated infrastructure to commence H1 2026.	✓	0
Woodside – Pluto LNG Project (Ref. 244; Ref. 580)	• The Pluto offshore facility has been in production since 2012. Currently produces gas and condensate from the Pluto, Xena, and Pyxis gas fields which is transported via trunkline to the onshore Pluto Gas Plant • Estimated end of life of the Pluto, Xena and Pyxis fields is expected in	–	5

Petroleum Activity	Key Characteristics	DA	Distance to DA (~km)
	2032, subject to reservoir performance.		
Woodside – NWS and Julimar Exploration Wellhead Decommissioning (Ref. 579)	• Activities includes ongoing IMR. P&A, and removal of historical exploration wells. • Activities commenced June 2025 and may occur any time during in-force period of the EP. • Only one (Julimar South East-1) out of the 36 wells is within the southeastern section of the DA. An additional five wells are <50 km from the DA.	✓	0-185
Santos – Varanus Island Hub Operations (Ref. 243; Ref. 671)	• Consists of the John Brookes and Wonnich wellhead platforms (WHPs), and associated subsea infrastructure within the John Brookes, Spartan, Greater East Spar (GES), and Wonnich gas fields which export well fluids from the production wells to the processing facilities on Varanus Island. • Production is suspended from the Wonnich WHP. • Infrastructure includes WHPs, wells, umbilicals and flowlines for all fields. • Estimated EOFL for John Brookes is ~2043, Spartan ~2029, GES ~2025–2027.	–	15.6

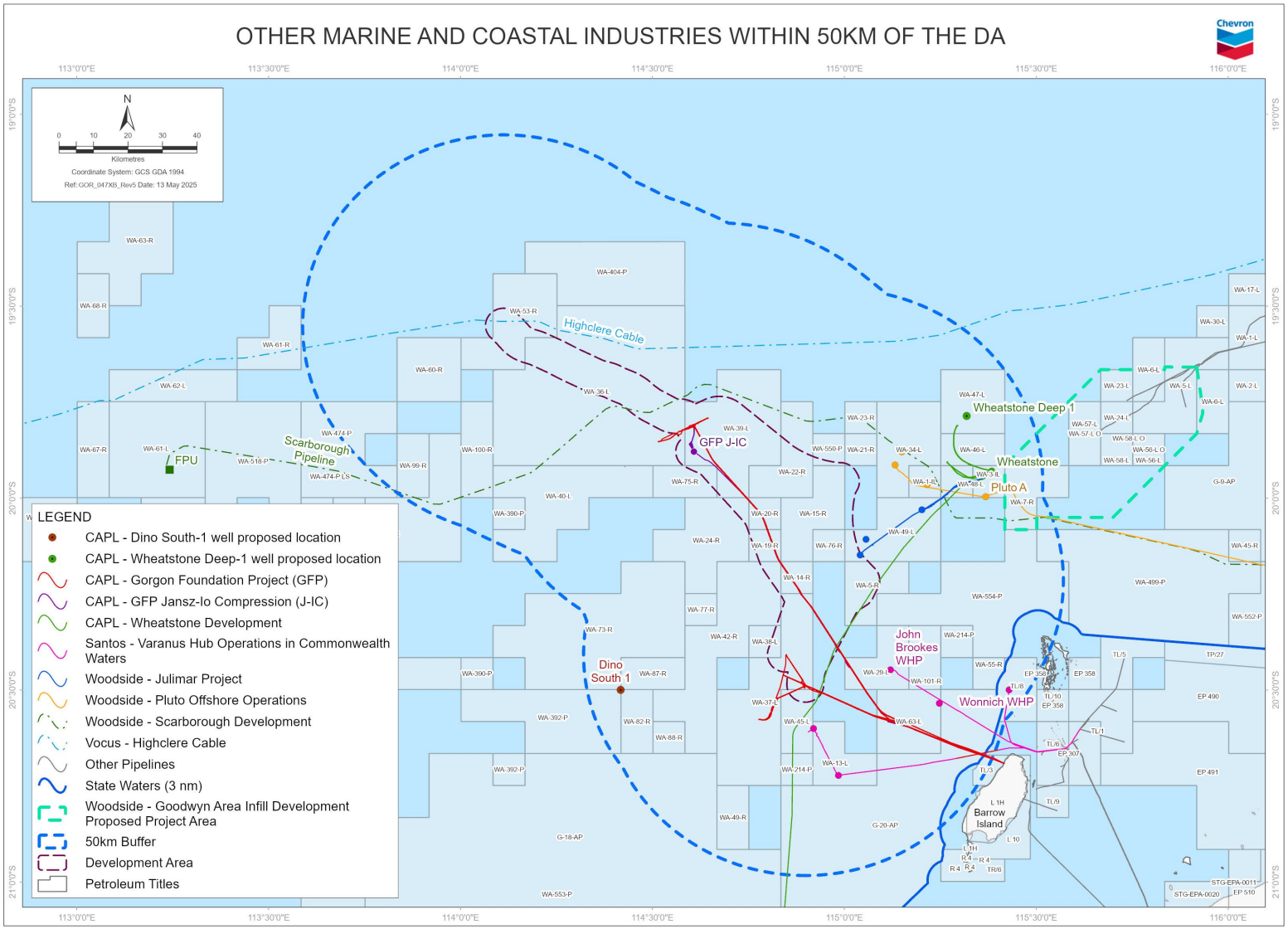


Figure 6-46: Petroleum activities and submarine cables within 50 km of the DA

6.4.6.2 defence

The Royal Australian Air Force has a base at Learmonth, and there is a designated maritime firing practices and exercise area associated with this base (Ref. 246).

The EPBC protected matters search identified the following defence areas that overlap the Hydrocarbon Social EMBA (Ref. 122; appendix b):

- Defence—Exmouth VLF transmitter station
- Defence—Exmouth admin and HF transmitting
- Defence—Learmonth radar site, Vlamingh Head
- Defence—Learmonth air weapons range.

There are no known sites of unexploded ordnance (UXO) within the DA; however, several potential UXO sites overlap the Hydrocarbon Social EMBA (Figure 6-47) (Ref. 247).

6.4.6.3 ports

The *Port Authorities Act 1999* (WA) governs Western Australia's port authorities, covering their functions, responsibilities, concept of operations and related matters. The Port of Ashburton, Port of Varanus Island and Cape Preston West are proclaimed ports managed under this Act, and the port areas extend within the Hydrocarbon EMBAs. The *Shipping and Pilotage Act 1967* (WA) governs shipping and pilotage in and about ports, boat harbours, and mooring control areas of WA. The Port of Barrow Island is a proclaimed port managed under this Act, and the port area extends within the Hydrocarbon EMBAs.

6.4.6.4 submarine cables

Submarine telecommunications cables are underwater infrastructure linking Australia with other countries; the submarine communications cables carry the bulk of Australia’s international voice and data traffic.

An offshore cable (Highclere Cable shown in Figure 6-46) has been installed as part of Vocus' fibre optic cable network, connecting the existing North West Cable System and Australia Singapore Cable. This connection is the final cable in establishing the Darwin-Jakarta-Singapore Cable system, a system of cables connecting Darwin, Port Hedland, Perth, Christmas Island, Jakarta, and Singapore. The Highclere Cable route overlaps the DA, ~2.2 km north of Chandon infrastructure.

Under Part 2 of the *Telecommunications Act 1997* (Cth), the Australian Communications and Media Authority can declare protection zones covering the cables to prohibit and/or restrict activities that may damage them. The protection zones are generally the area within 1.85 km (1 nm) either side of the cable and include both the waters and seabed within the area. No protection zone has been declared for the Highclere fibre optic cable identified within the DA.

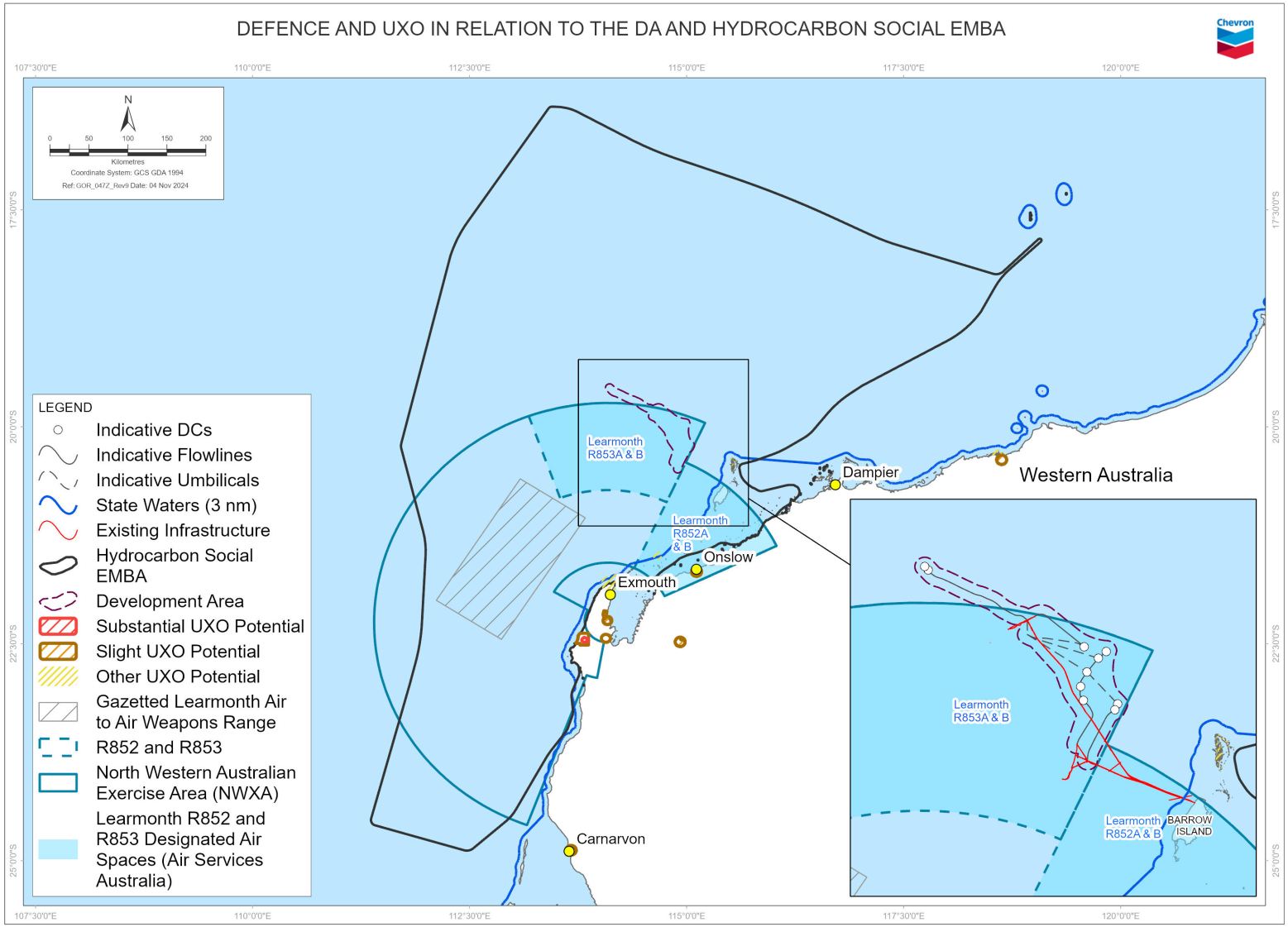


Figure 6-47: Defence and UXO in relation to the DA and Hydrocarbon Social EMBA

6.5 qualities and characteristics of locations, places and areas

The qualities and characteristics of the protected places present within the EMBA are described in the following sections.

6.5.1 australian marine parks

Marine parks help conserve marine habitats and the species that live within and rely on these habitats. Marine parks also provide places for people to watch wildlife, dive, and go boating, snorkelling, or fishing (Ref. 248).

The North-west Marine Parks Network Management Plan (Ref. 82) defines the following types of values for the Marine Parks in the North-west Network:

- natural values—habitats, species and ecological communities, and the processes that support their connectivity, productivity and function
- cultural values—living and cultural heritage recognising Indigenous beliefs, practices and obligations for Country, places of cultural significance and cultural heritage sites
- heritage values—non-Indigenous heritage that has aesthetic, historic, scientific or social significance
- socioeconomic values—the benefits for people, businesses and/or the economy.

The objectives of the North-west Marine Parks Network Management Plan (Ref. 82) are to provide for:

- the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network
- ecologically sustainable use and enjoyment of the natural resources within marine parks in the North Network, where this is consistent with objective (a)

AMPs occur within Commonwealth waters; they were proclaimed under the EPBC Act in 2007 and 2013. Table 6-26 describes the AMPs present within the DA and EMBAs and summarises their values (Ref. 82).

There are no AMPs within the DA; the closest is the Montebello Marine Park located ~16 km from the south-eastern edge of the DA. Australian Marine Parks in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-48.

Table 6-26: Presence and values of AMPs within the DA and EMBAs

Australian Marine Park	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Gascoyne (Multiple Use Zone [IUCN VI])], Habitat Protection Zone [IUCN IV])	**–**	**114**	✓	✓
The Gascoyne Marine Park is ~20 km off the west coast of the Cape Range Peninsula, adjacent to the Ningaloo Reef Marine Park and the WA Ningaloo Marine Park and extends to the limit of Australia's EEZ. The area of this marine park is 81,766 km² and its waters are 15 –6,000 m deep. **Natural values** This marine park includes examples of ecosystems that are representative of: • Central Western Shelf Transition—continental shelf with waters up to 100 m deep and a significant transition zone between tropical and temperate species				

Australian Marine Park	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
• Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises, and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species • Northwest Province—an area of continental slope comprising diverse and endemic fish communities. The marine park includes four KEFs characterised by seasonal and sporadic upwelling, nutrient-rich water and aggregations of marine life and a high diversity of demersal fish assemblages. The marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, and foraging habitat and migratory pathway for pygmy blue whales. **Cultural values** Sea country is valued for cultural identity, health and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Gnulli people have responsibilities for sea country in the Marine Park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region. **Heritage values** No international, Commonwealth or National Heritage listings apply to the marine park; however, it is adjacent to the Ningaloo Coast, which has international, Commonwealth and national heritage values. The Marine Park contains more than five known shipwrecks listed under the *Historic Shipwrecks Act 1976.* **Social and economic values** Commercial fishing, mining and recreation are important activities in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Montebello (Multiple Use Zone [IUCN VI])	**–**	**16.7**	✓	✓
The Montebello Marine Park is offshore from Barrow Island and 80 km west of Dampier extending from the State water boundary and is adjacent to the WA Barrow Island and Montebello Islands Marine Parks. The area of this marine park is 3,413 km² and its waters range from <15–150 m deep. **Natural values** This 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, and ancient coastline. The ancient coastline at the 125 m depth contour KEF overlaps the north-west boundary of the park, thought to be an important sea floor feature and migratory pathway for humpback whales (Section 6.3.6.1). The marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds; internesting, foraging, mating, and nesting habitat for marine turtles; a migratory pathway for humpback whales; and foraging habitat for whale sharks. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. At the time of writing there was limited information about the cultural significance of this marine park. **Heritage values** No international, Commonwealth or national listings apply to this marine park; however, it is adjacent to the WA Barrow Island and the Montebello–Barrow Island Marine Conservation Reserves, which have been nominated for National Heritage listing.				

Australian Marine Park	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Social and economic values Tourism, commercial fishing, mining and recreation are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Shark Bay (Multiple Use Zone [IUCN VI])	**–**	**456.2**	✓	✓
The Shark Bay Marine Park is ~60 km offshore from Carnarvon, adjacent to the Shark Bay World Heritage property and National Heritage place and extending out from the State water boundary. The area of this marine park is 7,443 km² and its waters are 15–220 m deep. **Natural values** This marine park includes examples of ecosystems representative of: • Central Western Shelf Transition—a predominantly flat, sandy and low-nutrient area, in waters 50–100 m deep; the bioregion is a transitional zone between tropical and temperate species • Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species. Ecosystems represented in the marine park are influenced by the Leeuwin, Ningaloo and Capes currents. This marine park supports a range of species including those listed as threatened, migratory, marine or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds, internesting habitat for marine turtles, and a migratory pathway for humpback whales. The marine park and adjacent coastal areas are also important for shallow-water snapper. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Gnulli and Malgana people have responsibilities for sea country in this marine park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region. **Heritage values** No international, Commonwealth or National Heritage listings applied to the marine park at the commencement of this plan, but it is adjacent to the Shark Bay, WA World Heritage Property and Shark Bay, WA National Heritage Place. This marine park contains ~20 known shipwrecks listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, commercial fishing, mining and recreation, including fishing, are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Ningaloo (Recreational Use Zone [IUCN IV], National Park Zone [IUCN II])	**–**	**143.5**	✓	✓
The Ningaloo Marine Park stretches ~300 km along the west coast of the Cape Range Peninsula and is adjacent to the Western Australian Ningaloo Marine Park and Gascoyne Marine Park. The area of this marine park is 2,435 km² and its waters are 30–500 m (or more) deep. **Natural values** This marine park includes examples of ecosystems representative of: • Central Western Shelf Transition—continental shelf of water up to 100 m deep, and a significant transition zone between tropical and temperate species • Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species				

Australian Marine Park	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
• Northwest Province—an area of continental slope comprising diverse and endemic fish communities • 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, and ancient coastline thought to be an important sea floor feature and migratory pathway for humpback whales. The marine park overlaps with three KEFs, valued for upwelling of nutrient-rich water, high biodiversity, and endemism. Ecosystems represented in the marine park are influenced by interaction of the Leeuwin Current, Leeuwin Undercurrent, and the Ningaloo Current. This marine park supports a range of species including those listed as threatened, migratory, marine or cetacean under the EPBC Act. BIAs within this marine park include breeding and or foraging habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, foraging habitat and migratory pathway for pygmy blue whales, breeding, calving, foraging, and nursing habitat for dugong and foraging habitat for whale sharks. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Gnulli people have responsibilities for sea country in this marine park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region. **Heritage values** This marine park is within the Ningaloo Coast World Heritage property, recognised for its outstanding universal heritage values, meeting World Heritage listing criteria vii and x. In addition to the marine park, the World Heritage area includes the WA Ningaloo Marine Park, the Muiron Islands, the WA Cape Range National Park and other terrestrial areas. The area is valued for high terrestrial species endemism, marine species diversity and abundance, and the interconnectedness of large-scale marine, coastal and terrestrial environments. The area connects the limestone karst system and fossil reefs of the ancient Cape Range to the nearshore reef system of Ningaloo Reef, to the continental slope and shelf in Commonwealth waters. The Ningaloo Coast overlaps this marine park and was established on the National Heritage List in 2010, meeting the National Heritage listing criteria A, B, C, D, and F. The Ningaloo Marine Area (Commonwealth waters) was established on the Commonwealth Heritage List in 2004, meeting Commonwealth heritage listing criteria A, B and C. The Ningaloo Marine Area overlaps the marine park. This marine park contains >15 known shipwrecks listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, commercial fishing, mining and recreation, including fishing, are important activities in this marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Argo–Rowley Terrace (Multiple Use Zone [IUCN VI])	**–**	**280**	✓	✓
The Argo–Rowley Terrace Marine Park is ~270 km north-west of Broome and extends to the limit of Australia's EEZ. The marine park is adjacent to the Mermaid Reef Marine Park and the WA Rowley Shoals Marine Park. The area of this marine park is 146,003 km^2 and its waters are 220–6,000 m deep. **Natural values** This marine park includes examples of ecosystems representative of: • Northwest Transition—an area of shelf break, continental slope, and the majority of the Argo Abyssal Plain. Key topographic features include Mermaid, Clerke and Imperieuse Reefs, which collectively are a biodiversity hotspot • Timor Province—an area dominated by warm, nutrient-poor waters. Canyons are an important feature in this area of the marine park and are generally associated with high productivity and aggregations of marine life.				

Australian Marine Park	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
The marine park overlaps two KEFs, valued for upwelling of nutrient-rich water and high species productivity. This marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include resting and breeding habitat for seabirds and a migratory pathway for the pygmy blue whale. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. As at the commencement of this plan there was limited information about the cultural significance of this marine park. **Heritage values** No international, Commonwealth or national listings apply to the Marine Park at commencement of this plan. This marine park contains two known shipwreck (Alfred [wrecked in 1908] and Pelsart [wrecked in 1908]) listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, recreation, and scientific research are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				

* *Source: Ref. 82*

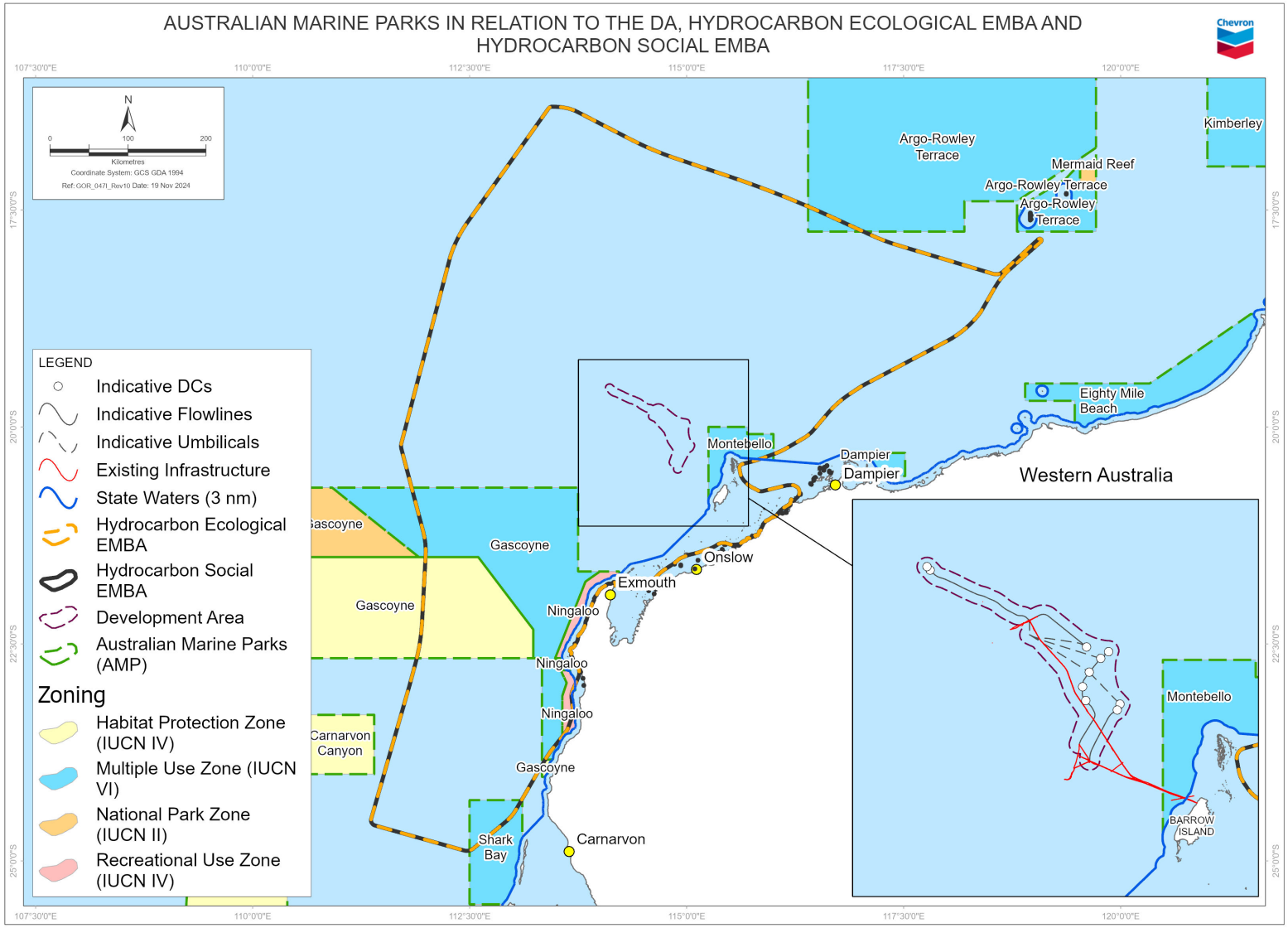


Figure 6-48: Australian Marine Parks in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.5.2 state marine protected areas

State marine parks, management areas, and reserves are proclaimed under the CALM Act, are located in State waters, and vested in the WA Conservation and Parks Commission.

There are no state marine parks, management areas and reserves within the DA; the closest is the Montebello Marine Park (General Use Zone IUCN II), which is ~40 km from the south-eastern edge of the DA. Table 6-27 lists the marine parks, management areas and reserves present within the DA and EMBAs. State Marine Protected Areas in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-49.

Table 6-27: Presence of State marine parks, management areas and reserves

State marine parks, management areas and reserves	Zone type (IUCN category)	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Barrow Island Marine Park	Unassigned (IUCN Ia)	–	44.2	✓	✓
Barrow Island Marine Management Area	Unassigned (IUCN VI)	–	40.9	✓	✓
Montebello Islands Conservation Park	Unassigned (IUCN II)	–	46.4	✓	✓
Montebello Islands Marine Park	General Use Zone (IUCN II)	–	38.6	✓	✓
	Sanctuary Zone (IUCN Ia)	–	40.7	✓	✓
	Special Purpose Zone – Pearling (IUCN VI)	–	48.5	✓	✓
	Recreation Zone (IUCN II)	–	52.6	✓	✓
	Special Purpose Zone (Benthic Protection) (IUCN IV)	–	39.3	✓	✓
Ningaloo Marine Park	General Use (IUCN II)	–	157.7	✓	✓
	Sanctuary Zone (IUCN Ia)	–	156.5	✓	✓
	Recreation Area (IUCN II)	–	157	✓	✓
	Special Purpose Zone (Shore-based Activities) (IUCN II)	–	155.7	✓	✓
	Unassigned (IUCN II)	–	172.5	✓	✓

State marine parks, management areas and reserves	Zone type (IUCN category)	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	Unassigned (IUCN IV)	–	268.4	✓	✓
	Special Purpose Zone (Benthic Protection) (IUCN IV)	–	200	✓	✓
Great Sandy Island Nature Reserve	Unassigned (IUCN Ia)	–	83.3	✓	✓
Thevenard Islands Nature Reserve	Unassigned (IUCN Ia)	–	101.1	✓	✓
Muiron Islands Marine Management Area	Conservation Area (IUCN Ia)	–	134	✓	✓
	Unassigned (IUCN VI)	–	127.2	✓	✓
Rowley Shoals Marine Park	Sanctuary Zone (IUCN Ia)	–	479.3	-	✓

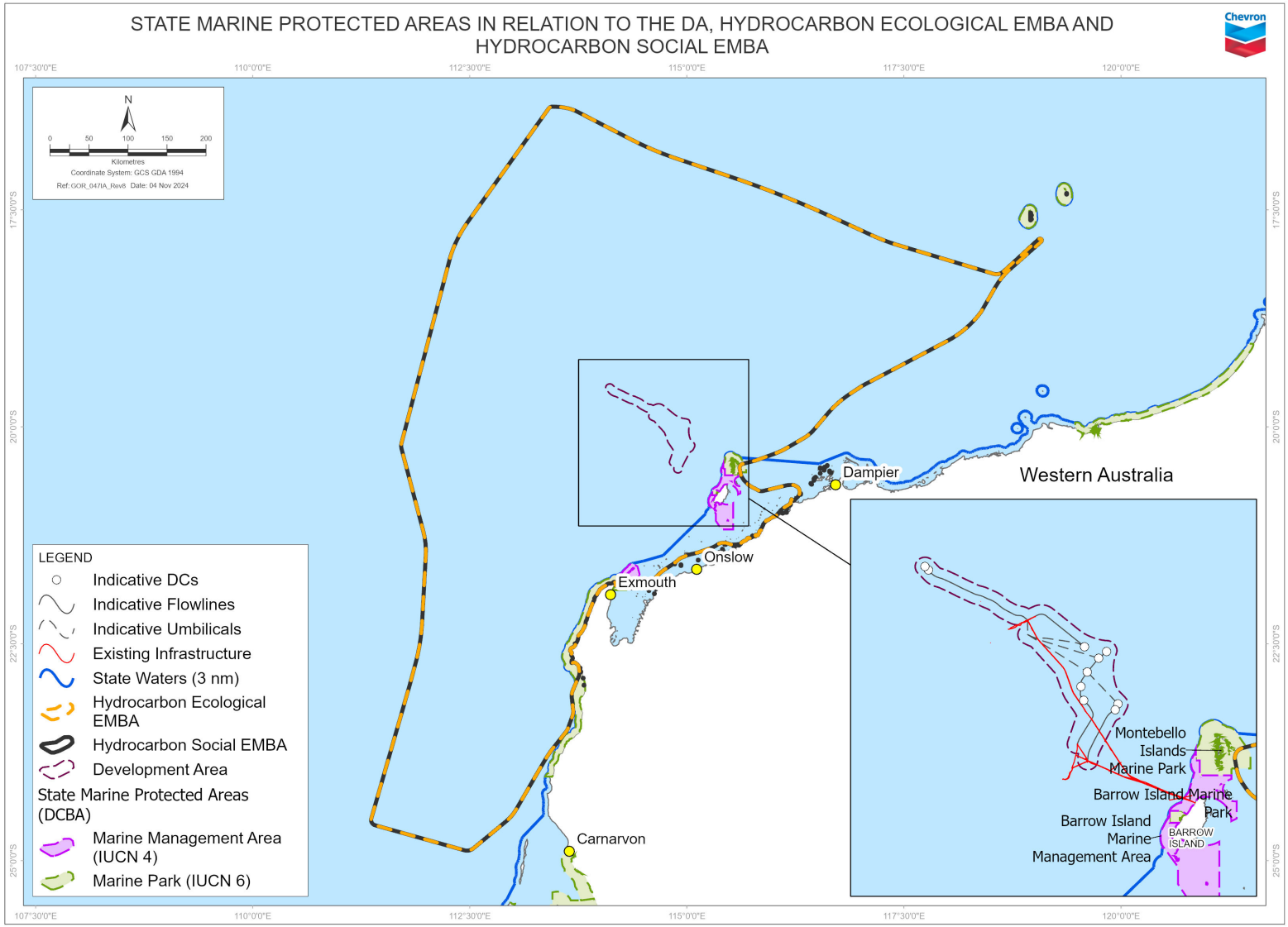


Figure 6-49: State Marine Protected Areas in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.5.3 state terrestrial protected areas

Terrestrial protected areas, proclaimed under the CALM Act, are located in State lands, and vested in the WA Conservation and Parks Commission.

The DA occurs offshore and does not have any overlap with the mainland coast. The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA do overlap with the coastal areas of islands (described in Section 6.3.2) (Figure 6-1 and Figure 6-2 respectively). Table 6-28 lists the State terrestrial protected areas that are present within the EMBAs. State terrestrial protected areas[80] in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-50.

Table 6-28: Presence of State terrestrial protected areas

State terrestrial parks, management areas and reserves	Zone type (IUCN category)	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Barrow Island Nature Reserve*	Nature Reserve (IUCN Ia)	-	50.6	✓	✓
Boodie, Double Middle Islands Nature Reserve*	Nature Reserve (IUCN Ia)	-	58.2	✓	✓
Montebello Islands Conservation Park^	Conservation Park (IUCN II)	-	46.6	✓	✓
Serrurier Island Nature Reserve^	Nature Reserve (IUCN Ia)	-	119.7	✓	✓
Muiron Islands Nature Reserve^	Nature Reserve (IUCN Ia)	-	131.7	✓	✓
Cape Range National Park^	National Park (IUCN II)	-	179.2	✓	✓
Cape Range National Park (South)^	National Park (IUCN II)	-	243.7	✓	✓
Lowendal Islands Nature Reserve^	Nature Reserve (IUCN Ia)	-	61.7	✓	✓
Jurabi Coastal Park^	5(1)(h) Reserve (IUCN II)	-	161	✓	✓
Airlie Island Nature Reserve*	Nature Reserve (IUCN Ia)	-	91.5	✓	✓
Little Rocky Island Nature Reserve^	Nature Reserve (IUCN Ia)	-	112.7	-	✓
Locker Island Nature Reserve^	Nature Reserve (IUCN Ia)	-	131.5	-	✓
North Sandy Island Nature Reserve*	Nature Reserve (IUCN Ia)	-	98.6	✓	✓
Nyinggulu (Ningaloo) Coastal Reserve^	5(1)(h) Reserve (IUCN II)	-	269.5	-	✓
Bessieres Island Nature Reserve*	Nature Reserve (IUCN Ia)	-	110.4	✓	✓

[80] Only state terrestrial protected areas with a coastal and/or marine interface have been identified.

State terrestrial parks, management areas and reserves	Zone type (IUCN category)	DA	Distance to DA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Round Island Nature Reserve^	Nature Reserve (IUCN Ia)	-	125.8	✓	✓
Unnamed WA36913^	Nature Reserve (IUCN Ia)	-	148	-	✓
Unnamed WA36915^	Nature Reserve (IUCN Ia)	-	145.4	-	✓
Unnamed WA36910^	5(1)(h) Reserve (IUCN II)	-	167.3	-	✓
Weld Island Nature Reserve^	Nature Reserve (IUCN Ia)	-	114.7	-	✓

** Protected area is landward of LWM.*

^ Protected area is landward of HWM.

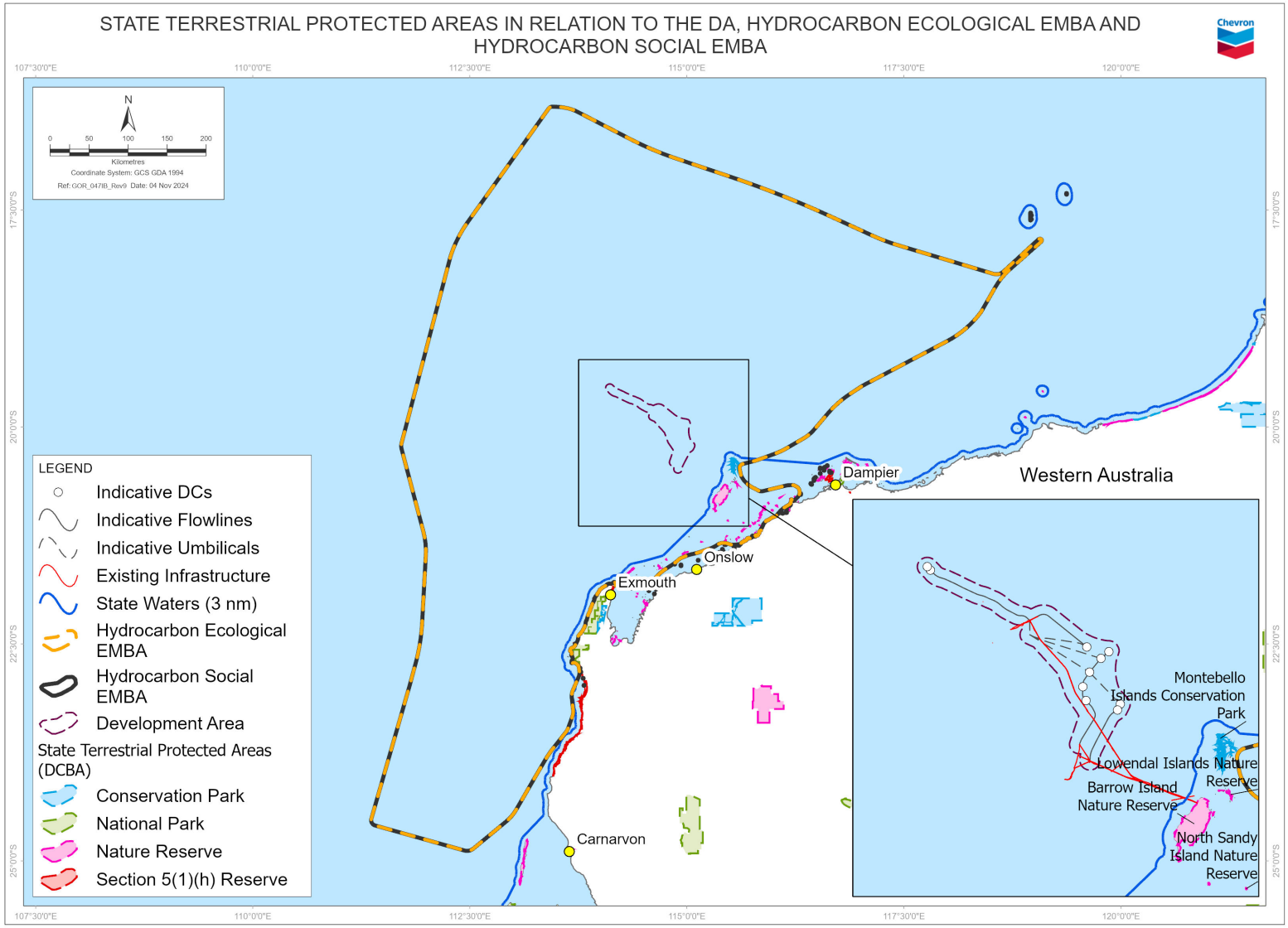


Figure 6-50: State terrestrial protected areas in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.6 heritage value of places

Listed World Heritage properties, National Heritage places, and Commonwealth Heritage places are MNES under the EPBC Act, and a relevant value and sensitivity under the OPGGS(E)R. Table 6-29 lists those heritage properties and other marine or coastal heritage protected places that are present within the DA and EMBAs. World, National, and Commonwealth listed heritage places in relation to the DA, Hydrocarbon Ecological and Social EMBAs are shown in Figure 6-51.

The ACHIS was searched for the DA and the Hydrocarbon Ecological and Social EMBAs (Ref. 249). No results were returned for the DA; the full results of the EMBA searches are available in appendix f.

Table 6-29: Presence of heritage properties within the DA and EMBAs

Feature	DA	Distance to DA (~km)	Hydrocarbon Social EMBA	Hydrocarbon Ecological EMBA
World Heritage property				
The Ningaloo Coast	–	127.2	✓	✓
Murujuga Cultural Landscape	–	143.3	✓	–
National Heritage place-				
The Ningaloo Coast	–	127.8	✓	✓
Dampier Archipelago	–	149.2	✓	–
Commonwealth Heritage				
Ningaloo Marine Area – Commonwealth Waters	–	143.5	✓	✓
Learmonth Air Weapons Range Facility	–	230.2	✓	✓
Indigenous protected areas				
N/A	(none identified within DA or EMBAs)			
Sites or artefacts protected under the *Underwater Cultural Heritage Act 2018* (Cth)				
Historic shipwrecks (>75 years old)	–	13.9	✓	✓
Shipwrecks	–	13.9	✓	✓
Sunken aircraft	(none identified within DA or EMBAs)			
In situ artefacts	(none identified within DA or EMBAs)			
Sites or artefacts protected under the *Aboriginal Heritage Act 1972* (WA)				
Determined areas under the *Native Title Act 1993* (Cth)	–	51.9	✓	✓
ACHIS registered sites[81]	–	51.9	✓	✓
ACHIS lodged places[82]	–	52.7	✓	✓
ACHIS historic records[83]	–	49.5	✓	✓

[81] Registered sites: Registered Aboriginal cultural heritage place or cultural landscape.

[82] Lodged places: Aboriginal cultural heritage place or cultural landscape with information in a verification stage.

[83] Historic records: Aboriginal heritage places determined to not meet the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.

Feature	DA	Distance to DA (~km)	Hydrocarbon Social EMBA	Hydrocarbon Ecological EMBA
Determined areas under the *Native Title Act 1993* (Cth)				
Native Title	–	–	✓	✓
Claim areas under the *Native Title Act 1993* (Cth)				
N/A	(none identified within DA or EMBAs)			

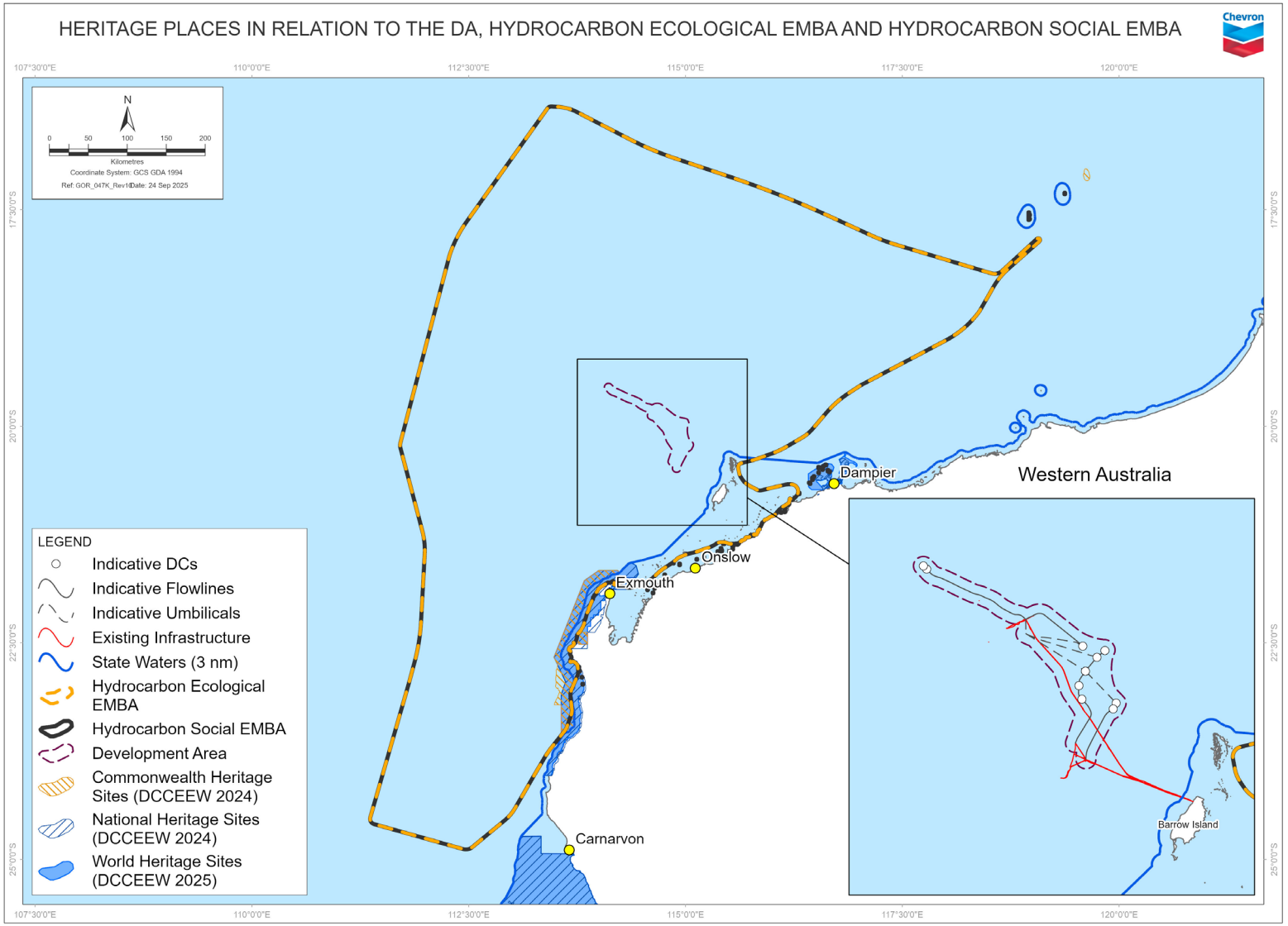


Figure 6-51: Heritage places in relation to the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.6.1 ningaloo coast

The Ningaloo Coast is located in WA adjacent to the eastern Indian Ocean. The area has a high level of terrestrial species endemism, and high marine species diversity and abundance (Ref. 250). The Ningaloo Reef and Exmouth Peninsula karst system is a cohesive limestone structure that is at the heart of the natural heritage significance of the Ningaloo Coast (Ref. 251).

The marine portion of the World Heritage property contains a high diversity of habitats that includes lagoon, reef, open ocean, the continental slope, and the continental shelf (Ref. 250). Intertidal systems such as rocky shores, sandy beaches, estuaries, and mangroves are also present (Ref. 250). The most dominant marine habitat is Ningaloo Reef, which sustains both tropical and temperate marine fauna and flora, including marine reptiles and mammals (Ref. 250).

The main terrestrial feature of the Ningaloo Coast is the extensive karst system and network of underground caves and water courses of the Cape Range (Ref. 250). The karst system includes hundreds of separate features such as caves, dolines, and subterranean water bodies and supports a rich diversity of highly specialised subterranean species (Ref. 250). Above ground, the Cape Range Peninsula belongs to an arid ecoregion recognised for its high levels of species richness and endemism, particularly birds and reptiles (Ref. 250).

In addition to the natural values of the Ningaloo Coast, values of Traditional Owners are identified under the National Heritage listing (Ref. 251). Archaeological deposits in the rock shelters on Cape Range show Traditional Owners had a sophisticated knowledge of marine resources between 35,000 and 17,000 years ago. The rock shelters are considered to provide the best evidence in Australia for the use of marine resources during the Pleistocene (Ref. 251).

6.6.2 murujuga cultural landscape

The Murujuga Cultural Landscape was inscribed on the UNESCO World Heritage List in July 2025. The World Heritage property encompasses areas of the Burrup Peninsula, Dampier Archipelago islands, and adjacent marine areas, and is an outstanding example of a continuing cultural landscape (Ref. 766; Ref. 767).

The Murujuga Cultural Landscape is shaped by Lore—rules and narratives that were put in place to create the Country—and the enduring presence of the Ngarda-Ngarli[84], Traditional Owners, and Custodians of the site (Ref. 766). The World Heritage property holds profound cultural and spiritual significance, reflecting over 50,000 years of continuous care and use, with traditions and knowledge expressed through a rich assemblage of tangible and intangible cultural attributes, including one of the densest and most diverse collections of petroglyphs in the world (Ref. 766; Ref. 767).

6.6.3 dampier archipelago

The Dampier Archipelago, including the Burrup Peninsula, lies on the Indian Ocean coast in the west Pilbara region of northern WA, ~1,550 km north of Perth (Ref. 548). The Archipelago consists of 42 islands, islets and rocks ranging in size from <2 ha to 3,29 ha covering a total area of ~400 km^2 (Ref. 548).

[84] Ngarda-Ngarli is a collective term for the Traditional Owners and Custodians who look after Murujuga today. They include the Ngarluma, Yindjibarndi, Yaburara, Mardudhunera and Wong-Goo-Tt-Oo groups (Ref. 795).

Formed 6,000–8,000 years ago by rising sea levels that flooded ancient coastal plains, the Archipelago is underpinned by some of the oldest rocks on Earth, dating back over 2.4 billion years to the Archaean period (Ref. 548; Ref. 549).

The region features diverse marine habitats, from wave-exposed, clear-water seaward areas with low sedimentation to sheltered coastal bays with turbid waters, as well as six species of mangroves (Ref. 548). Its warm tropical waters support abundant and highly diverse marine life, including rich coral species, bivalves, gastropods, crustaceans, worms, burrowing anemones, echinoderms, and brachiopods (Ref. 548). Additionally, the Dampier Archipelago is home to several species of shallow-water marine fish, including a rich reef assemblage (Ref. 548).

The Dampier Archipelago (including the Burrup Peninsula) are renowned for their rock engravings, boasting one of Australia's densest concentrations. Some sites feature thousands, even tens of thousands, of images. These engravings include an exceptionally diverse range of schematised human figures, with some arranged in intricate scenes of national significance (Ref. 548).

The area also contains a high density of stone arrangements. These include standing stones, stone pits, and circular stone formations. Standing stones range from solitary monoliths to extensive alignments of several hundred stones (Ref. 548).

The Ngarda-Ngarli people of this region have traditional accounts of the formation of the Dampier Archipelago. For them, ancestral beings formed the landscape of the Dampier Archipelago in the Dreamtime and the spirits of these beings and other spirits such as Ngkurr, Bardi, and Gardi continue to live in the area (Ref. 548). They have left their mark in features like the Marntawarrura, or 'black hills,' said to be stained from the blood of the creative beings (Ref. 549).

6.6.4 underwater cultural heritage

Australia's underwater cultural heritage (UCH) is protected under the *Underwater Cultural Heritage Act 2018* (Cth) (UCH Act). This legislation protects shipwrecks, sunken aircraft, and other types of underwater heritage, including Traditional Owners underwater cultural heritage in Australian waters. The UCH Act applies to all Australian waters, including both State waters (coastal waters) and Commonwealth waters (extending from coastal waters to the edge of continental shelf).

Under section 15 of the UCH Act, underwater cultural heritage is defined as 'any trace of human existence that has a cultural, historical, or archaeological character, and is located under water'. The UCH Act protects physical sites and artefacts; intangible heritage values with no physical component are not protected under the Act (Ref. 68).

A search of the online Australasian Underwater Cultural Heritage Database (Ref. 252) was undertaken to determine the presence of underwater cultural heritage within the Development EMBAs. Based on the search, both historic (>75 years old) shipwrecks and other shipwrecks were identified in the EMBAs. No sunken aircraft or other artefacts were identified within the EMBAs. No underwater cultural heritage was identified within the DA. The results of the search are listed in Table 6-29.

At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known underwater cultural heritage sites within the EMBA.

6.6.5 native title

Native Title recognises the rights and interests of Native Title Holders in land and waters according to their traditional laws and customs and is administered under the *Native Title Act 1993* (Cth), including their rights to maintain and protect cultural sites.

The Hydrocarbon Social EMBA overlaps two native title determinations (WCD2019/016 and WCD2018/006) and has a small section of shoreline contact in another native title determinations (WCD2008/003 just outside Exmouth Gulf) (Figure 6-52). Native Title WCD2018/006 runs across Mardie and Gnoorea coast and WCD2019/016 along the Ningaloo Coast area.

Cultural values and features were identified during consultations with representatives of these Native Tile Holders; summarised in Table 6-19.

6.6.5.1 native title WCD2019/016

The Gnulli, Gnulli # 2 and Gnulli # 3 – Yinggarda, Baiyungu and Thalanyji People Native Title determination (WCD2019/016) extends over the Ningaloo Coast area. The Yinggarda, Baiyungu, and Thalanyji people received recognition as Native Title holders over an area of 71,354 m^2. The determination area encompasses several pastoral leases, mining tenements, roads, and reserves, as well as portions of the Kennedy Range and Cape Range national parks, Ningaloo Marine Park, Lake MacLeod, and waters in the Exmouth Gulf and Ningaloo Marine Park (Ref. 203). The Yinggarda, Baiyungu and Thalanyji people have each maintained a physical presence in their respective part of the determination area and have a continuing physical or spiritual involvement in that area (Ref. 203). The determination area contains places of special significance, such as mythological and ceremonial sites and natural resources (Ref. 203).

The relevant Prescribed Bodies Corporate are the Nganhurra Thanardi Garrbu Aboriginal Corporation (representing the Baiyungu and Thalanyji people) and the Yinggarda Aboriginal Corporation.

6.6.5.2 native title WCD2018/006

The Yaburara and Mardudhunera People Native Title determination (WCD2018/006) extends over the Mardie coast area. The Yaburara and Mardudhunera people received recognition as a Native Title holder over an area of 5,683 km^2. The determination area encompasses several pastoral leases, mining tenements, roads, reserves, and unallocated Crown land. The Yaburara and Mardudhunera People have maintained a physical presence in their respective part of the determination area and have a continuing physical or spiritual involvement in that area (Ref. 253). The determination area contains places of special significance, such as cultural, spiritual, and ceremonial sites and natural resources.

The relevant Prescribed Bodies Corporate is the Wirrawandi Aboriginal Corporation.

6.6.5.3 native title WCD2008/003

The Thalanyji People Native Title determination (WCD2008/003) extends an area (18,432 km^2) of land and sea and is in the Pilbara region of Western Australia in the vicinity of Onslow. The determination area comprises of group and communal rights and interests held by the Thalanyji people, who have connection with the land and waters in the determination area, in accordance with the traditional laws

acknowledged and the traditional customs observed by the Thalanyji. The determination area encompasses pastoral leases, mining tenements, roads, and reserves. The determination confers non-exclusive rights of the Native Title holders to enter, travel, erect camps, gather traditional resources (hunt, fish, gather) and engage in ritual and ceremony on, and in relation to, the land and waters of the determination area.

The relevant Prescribed Bodies Corporate is the Buurabalayji Thalanyji Aboriginal Corporation RNTBC.

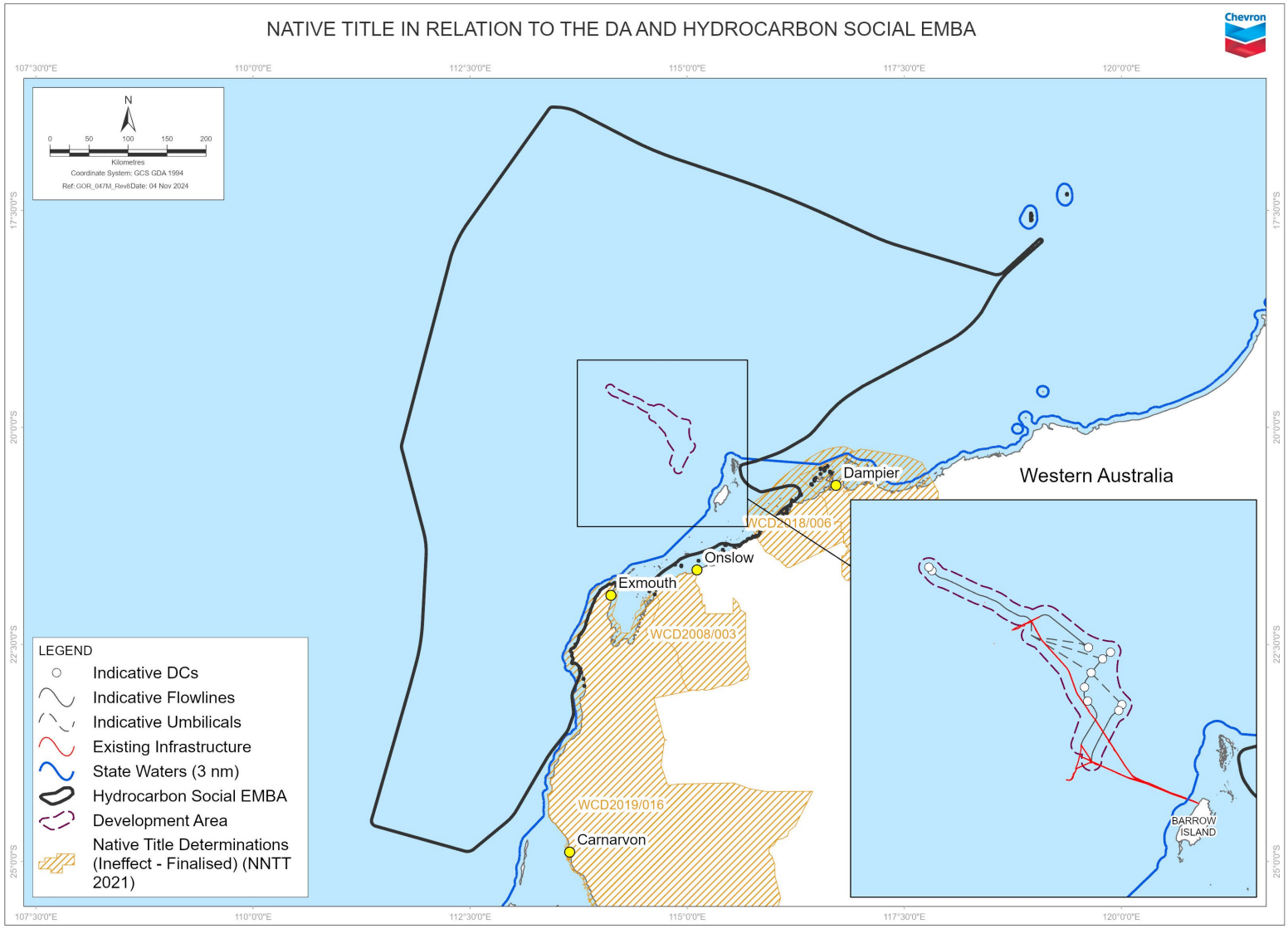


Figure 6-52: Native title in relation to the DA and Hydrocarbon Social EMBA

7 environmental impact and risk assessment methodology

This section describes the methods used to identify and evaluate the environmental impacts and risks associated with the Development.

Table 7-1 defines the common terms applied during the impact and risk assessment process (general terms used in this OPP and their definitions are defined in Section 11).

Table 7-1: Impact and risk assessment terms

Term	Definition
Acceptable level	The specified amount of environmental impact and risk that the Development may have (Ref. 16). Definitions of receptor-specific acceptable levels adopted in this OPP are provided in Section 7.6.
Aspect	The elements of the CAPL's products, services, and activities that interact with the environment while within the CAPL's operational control (Ref. 493).
Consequence	The possible effect of an event, accident scenario, or ongoing condition in terms of environmental impact (Ref. 257; Ref. 493).
Hazard	A chemical, biological, or physical condition that has the potential for causing harm to the environment (Ref. 257; Ref. 493).
Hydrocarbon Ecological EMBA	The Hydrocarbon Ecological EMBA (Figure 6-1) is relevant to the risk assessments for ecological receptors from unplanned hydrocarbon release events (for MDO and condensate) and is determined by the predicted spatial extent of hydrocarbon exposure at these thresholds: • surface/floating: ≥10 g/m^2 (moderate) • shoreline: ≥100 g/m^2 (moderate) • dissolved: ≥50 ppb (moderate) • entrained: ≥100 ppb (high). Further information on exposure thresholds is presented in Section 6.1 and Table 6-2.
Hydrocarbon Social EMBA	The Hydrocarbon Social EMBA (Figure 6-2) is relevant to the risk assessments for social, economic, and cultural receptors from unplanned hydrocarbon release events (for MDO and condensate) and is determined by the predicted spatial extent of hydrocarbon exposure at these thresholds: • surface/floating: ≥1 g/m^2 (low) • shoreline: ≥10 g/m^2 (low) • dissolved: ≥50 ppb (moderate) • entrained: ≥100 ppb (high). The Hydrocarbon Social EMBA incorporates lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil, but these thresholds are below concentrations at which ecological impacts are expected to occur. Further information on exposure thresholds is presented in Section 6.1 and Table 6-2.
Impact	Any change to the environment, whether adverse or beneficial, wholly or partly resulting from an environmental aspect (Ref. 493).
Likelihood	The chance of a consequence occurring (likelihood and probability are synonyms) (Ref. 257; Ref. 493).
DA	The area in which all petroleum activities associated with the Development occur. The DA extends to a 5 km radius around the outermost expected position of subsea infrastructure (Figure 4-2).
Planned activity	A planned petroleum activity as related to the construction, operations, and decommissioning of the Development.

Term	Definition
Risk	A measure of environmental impacts caused by environmental aspects in terms of both the likelihood and the consequence (magnitude) of the impact; i.e. risk is the product of the likelihood and the consequences (Ref. 257; Ref. 493).
Unplanned event	An event that results in some level of environmental impact and that may occur despite preventive safeguards in place. An unplanned event is not intended to occur during the Development.

7.1 identification and description of the petroleum activities that are part of the offshore project

All Development activities and potential emergency conditions relevant to the scope of this OPP are described and evaluated during the impact and risk assessment. For the purposes of description and evaluation, the petroleum activities associated with the Development were grouped into these phases:

- surveys
- drilling
- installation and commissioning
- operations
- decommissioning
- support activities (undertaken during all phases).

Support activities (Section 4.3.6) may occur throughout all phases of the Development and cover common activities on vessels, MODUs, helicopters, or ROVs/AUVs that are not process related, such as accommodation, sewage discharge, navigational lighting, and refuelling.

These common activities generated by support activities are considered separately to avoid repetition in the impact and risk assessment. For example, this avoids repetition in the assessment of vessel strike in the physical presence—marine fauna aspect (Section 8.10) for the numerous phases and activities that use vessels.

The activities described in this OPP are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

The Development is described in detail in Section 4.

7.2 identification of relevant values and sensitivities

The presence of environmental values and sensitivities within the DA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA is documented in Section 6. In accordance with regulation 7(2) and 7(3) of the OPGGS(E)R, relevant values and sensitivities include:

- the world heritage values of a declared World Heritage property
- the national heritage values of a National Heritage place
- the ecological character of a declared Ramsar wetland
- the presence of a listed threatened species or listed threatened ecological community

- the presence of a listed migratory species
- any values and sensitivities that exist in, or in relation to, part or all of a Commonwealth marine area or Commonwealth land.

Because many protected fauna have the potential to transit through the DA and/or Hydrocarbon Ecological and Social EMBAs, CAPL considers the habitat and/or temporal area that supports protected fauna (including areas defined as BIAs for these species) is part of the relevant value or sensitivity.

Environmental values and sensitivities are also considered to be associated with each of the receptor groups identified and described in Section 6 (i.e. in addition to those relevant values and sensitivities as identified under the OPGGS(E)R). All environmental values and sensitivities have been taken into consideration during the impact and risk assessments (Sections 8 and 9).

7.3 identification of relevant environmental aspects

CAPL defines an environmental aspect as an element of CAPL's products, services, or activities that interact with the environment while within the CAPL's operational control (Ref. 493).

After the Development was described, an assessment was done to identify potential interactions between the Development and the receiving environment by identifying the environmental aspects. The outcomes of stakeholder consultation also contributed to this scoping process.

Potential interactions with safety, health, and assets are outside the scope of this OPP.

Environmental aspects categorised for inclusion in the impact and risk assessment of this Development include:

- physical presence
- seabed disturbance
- air emissions
- GHG emissions
- light emissions
- underwater sound emissions
- invasive marine pests
- planned discharges
- unplanned releases.

Table 7-2 maps these environmental aspects against planned Development activities.

Table 7-2: Scoping of relationship between aspects and activities

Phase	Surveys		Drilling										Installation and commissioning								Operations					Decommissioning					Support activities (all phases)			
Activity / **Aspect**	Geophysical survey	Geotechnical survey	MODU positioning	Drilling top- and bottom-holes	Drilling fluids and cuttings	Cementing operations	Pressure-control equipment	Well suspension	Completions installation	Production tree installation	Well clean-up and testing	Well evaluation	Pre-lay works	Excavation and trenching	Installation of flowlines and pipelines	Installation of subsea structures	Post-lay works	Hydrotest & pre-commissioning	Commissioning	Start-up	Hydrocarbon system	Inspection	Maintenance and repair	Major repairs	Well intervention	Flush and clean	Well suspension and P&A	Flowline and MEG pipeline decommissioning	Umbilical decommissioning	Other subsea structures decommissioning	MODU operations	Vessel operations	Helicopter operations	ROV operations
Seabed disturbance		✓	✓	✓					✓				✓	✓	✓	✓	✓						✓	✓			✓	✓	✓	✓		✓		✓
Air emissions								✓			✓							✓							✓						✓	✓	✓	
GHG emissions								✓			✓								✓		✓				✓		✓				✓	✓	✓	
Light emissions											✓														✓						✓	✓		
Underwater sound emissions	✓		✓	✓								✓		✓							✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
Planned discharges—MODU and vessels																															✓	✓		
Planned discharges—Subsea operations																✓		✓	✓			✓	✓	✓				✓		✓				
Planned discharges—Drilling operations				✓	✓	✓	✓		✓	✓	✓													✓		✓								
Physical presence—Other marine users													✓								✓								✓	✓	✓			
Physical presence—Other marine users																		✓					✓								✓	✓	✓	
Physical presence—Marine fauna																		✓					✓								✓	✓	✓	
Invasive marine pests																														✓	✓	✓		
Unplanned release—Solid objects													✓			✓								✓				✓	✓	✓	✓	✓		
Unplanned release—Minor LOC																✓		✓					✓								✓	✓		✓
Unplanned release—Vessel collision (MDO)																															✓	✓		
Unplanned release—Hydrocarbon system (condensate)				✓			✓		✓												✓				✓	✓	✓							

7.4 identification of relevant environmental impacts and risks

Potential impacts and risks arising from the environmental aspects were identified during a scoping exercise and then evaluated in detail. Table 7-3 shows the credible interactions between aspects, impact and risks, and receptors.

A detailed evaluation of the impact or risk is provided in the corresponding assessment in Section 8.

Table 7-3: Scoping of relationship between aspects and receptors

	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
Aspects	**Impact/risk**	Water quality	Sediment quality	Air quality	Atmospheric GHG concentrations	Ambient light	Ambient sound	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
Seabed disturbance	Alteration of benthic habitats and associated communities							✓													
	Localised and temporary reduction in water quality	✓																			
	Change to behaviour										✓										
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Air emissions	Localised and temporary reduction in air quality			✓																	
GHG emissions	Contribution to the reduction of the global atmospheric carbon budget				✓																
	Contribution to the anthropogenic influence on the global climate system				✓																
Light emissions	Localised and temporary change in ambient light					✓															
	Attraction of light-sensitive species and in turn a change in predator–prey dynamics									✓	✓	✓									
	Change to values and sensitivities of AMPs																		✓		
	Change to cultural heritage values																				✓
Underwater sound emissions	Localised and temporary change in ambient underwater sound						✓														
	Change to behaviour										✓	✓	✓								
	Mortality or auditory impairment to marine fauna										✓	✓	✓								
	Change to values and sensitivities of AMPs																		✓		
	Change to cultural heritage values																				✓
Planned discharges—MODU and vessels	Localised and temporary reduction in water quality	✓																			
	Changes to predator–prey dynamics									✓	✓	✓	✓							✓	
Planned discharges—Subsea operations	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna							✓			✓	✓	✓								
	Changes to values and sensitivities of KEFs																			✓	

	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
Aspects	Impact/risk	Water quality	Sediment quality	Air quality	Atmospheric GHG concentrations	Ambient light	Ambient sound	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
	Change to the functions, interests and activities of other marine users													✓							
	Change to cultural heritage values		✓																		✓
Planned discharges—Drilling operations	Localised and temporary reduction in water quality	✓																			
	Localised and temporary reduction in sediment quality		✓																		
	Injury or mortality of marine fauna										✓	✓	✓								
	Alteration of benthic habitats and associated communities							✓													
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Physical presence—Other marine users	Change to the functions, interests and activities of other marine users													✓	✓	✓					
Physical presence—Marine fauna	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to cultural heritage values																				✓
Introduction of invasive marine pests	Displacement of, or competition with, endemic species							✓													
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Unplanned release—Solid objects	Alteration of benthic habitats and associated communities							✓													
	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to values or sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Unplanned release—Minor LOC	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna										✓	✓	✓								
Unplanned release—Vessel collision (MDO)	Alteration of coastal habitats and associated communities								✓												
	Localised and temporary reduction in water quality	✓																			

Aspects	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
	Impact/risk	Water quality	Sediment quality	Air quality	Atmospheric GHG concentrations	Ambient light	Ambient sound	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to the functions, interests and activities of other marine users													✓				✓			
	Change to values and sensitivities of AMPs																		✓		
	Change to values and sensitivities of KEFs																			✓	
	Change to values and sensitivities of the Ningaloo Coast																				✓
	Change to cultural heritage values																				✓
Unplanned release—Hydrocarbon system (condensate)	Alteration of coastal habitats and associated communities								✓												
	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to the functions, interests and activities of other marine users													✓	✓	✓	✓	✓			
	Changes to values and sensitivities of AMPs																		✓		
	Change to values and sensitivities of KEFs																			✓	
	Change to values and sensitivities of the Ningaloo Coast																				✓
	Change to cultural heritage values																				✓

7.5 evaluation of impacts and risks

After identifying the credible interactions between aspects, impact and risks, and receptors, each impact and risk was evaluated. This evaluation involved:

- determining the source of each impact and risk
- determining the consequence of each impact and risk
- for risks, determining the likelihood of the consequence occurring and corresponding residual risk level.

The consequence, likelihood, and residual risk levels were determined using Chevron Corporation's Integrated Risk Prioritization Matrix (Table 7-4).

Note: An environmental aspect can result in both environmental impacts and risks. Each impact and/or risk is defined and evaluated—an impact is ranked with a consequence level only, whereas a risk includes an evaluation of consequence, likelihood, and residual risk.

Table 7-4: Chevron Corporation's Integrated Risk Prioritization Matrix

1. The matrix shall only be applied by qualified personnel within an appropriate qualitative risk assessment framework
2. The matrix guidance is intended to assist users in the differentiation among consequence categories and factual circumstances or conditions of a particular scenario may warrant a different categorization than is presented in this guidance. In such circumstances, the consequence language of the matrix itself controls.

Likelihood Descriptions											
	Expected to occur *Once in 1–10 times the activity is performed*	Likely	**1**	6	5	4	3	2	1
	Conditions may allow to occur *Once in 10–100 times the activity is performed*	Occasional	**2**	7	6	5	4	3	2
	Exceptional conditions may allow to occur *Once in 100–1,000 times the activity is performed*	Seldom	**3**	8	7	6	5	4	3
	Reasonable to expect will not occur *Once in 1,000–10,000 times the activity is performed*	Unlikely	**4**	9	8	7	6	5	4
	Has occurred once or twice in the industry *Once in 10,000–100,000 times the activity is performed*	Remote	**5**	10	9	8	7	6	5
	Rare or unheard of *Once in 100,000–1,000,000 times the activity is performed*	Rare	**6**	10	10	9	8	7	6
Consequence Descriptions*				**6**	**5**	**4**	**3**	**2**	**1**
				Incidental	Minor	Moderate	Major	Severe	Catastrophic
				Limited impact	Localised, short-term impact	Localised, long-term impact or widespread, short-term impact	Localised, persistent impact or widespread long-term impact	Widespread, persistent impact or landscape-scale, long-term impact	Landscape-scale, persistent impact
Examples are given to help guide the user on assessing the appropriate consequence category and should not be interpreted as definitive bounds. *This guidance should be considered within the specific scenario context and supported by subject matter expert advice.*				*Negligible disturbance or impact, and/or the impact is reversable within a very short period of time (e.g. days to months).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, but the impact is recoverable in the short-term (e.g. <2 years).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, but the impact is recoverable in the long-term (e.g. 2-10 years),* ***or*** *impact affects a wide area, or affects a significant proportion of a habitat or population (e.g. >10%) but the impact is recoverable in the short-term (e.g. <2 years).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, and the impact is persistent (e.g. >10 years for recovery or never expected to fully recover),* ***or*** *impact affects a wide area, or affects a significant proportion of a habitat or population (e.g. >10%) but where the impact is recoverable in the long-term (e.g. 2-10 years).*	*Impact affects a wide area or affects a significant proportion of a species habitat or population (e.g. >10%) and the impact is persistent (e.g. >10 years or never expected to fully recover),* ***or*** *impact affects a very large area, or the majority or all of a habitat type or population and/or results in loss of ecosystem function, and lasts long-term (e.g. 2-10 years).*	*Impact affects a very large area or the majority or all of a species, habitat type.*
Definitions	An individual is an organism; a population is a group of individuals of one species that occupy a given area at the same time; a community is an association of interacting populations; and an ecosystem is the organisms (populations) in a community and the associated abiotic (non-living) factors with which they interact.								
***Note**	Consequence category needs to account for the resilience of the receptor. For example, impacts to long-lived, RTE (Rare, Threatened and Endangered) species with low resilience may be ranked higher than impacts to the same number of individuals of short-lived, common species with high resilience. Localized, widespread or landscape scale may be considered relative to the distribution and abundance of the receptors examined. For example, if a receptor is endemic to a small area and is impacted, this would potentially be considered a 'landscape-scale' impact for that receptor, rather than localized.								

7.5.1 source of impact or risk

The Development includes phases and associated petroleum activities that are common, well-understood situations, which are normal business for CAPL. CAPL is competent in applying these phases and has continuous proven experience undertaking these phases in accordance with current good practice.

Although the Development represents normal business for CAPL, the timing of each phase within each field is undefined and presents some uncertainty. This uncertainty is addressed by conservative assumptions of the source of each impact and risk for the Development, such that the precautionary approach is applied to define the source of each impact and risk (Ref. 254). The source of each impact and risk will be evaluated to determine the worst-case scenario that can be realised, such as the maximum number of vessels within the DA at one time or the longest duration for a phase for a field.

Similarly, as the exact location of infrastructure is not yet known, or multiple locations are under consideration; the DA has been defined based on a 5 km buffer around the outermost or longest routes (Section 4.1.3). This gives a conservative spatial extent to use for impact assessment.

The conservative assumptions for the source of each impact and risk is then used to evaluate the consequence of each impact and risk and likelihood for each risk. This approach will ensure, under the precautionary principle, the worst-case scenario is used for the characterisation of the source of the aspect to ensure confidence in the next stages of the impact and risk evaluation process.

7.5.2 consequence

The consequence levels, which are described in Chevron Corporation's Integrated Risk Prioritization Matrix (Table 7-4), are determined by considering:

- the spatial scale or extent of potential interactions within the receiving environment
- the nature of the receiving environment (within the spatial extent), including proximity to sensitive receptors, relative importance, and sensitivity or resilience to change
- the impact mechanisms (cause and effect) of the aspect within the receiving environment (e.g. persistence, toxicity, mobility, bioaccumulation potential)
- the duration and frequency of potential effects and time for recovery
- the potential degree of change relative to the existing environment or to acceptability criteria.

To inform the consequence evaluation, data may be drawn from engineering analysis, generic industry data, or operator-specific data to provide confidence in the assigned consequence level. Different techniques to inform the consequence evaluation may be required for complex aspects, such as modelling to define the spatial scale of an aspect relative to sensitive receptors (Ref. 254).

Values and sensitivities may be grouped together in the same impact or risk assessment in Sections 8 and 9, if they have the same consequence ranking and it is appropriate to nature and scale (e.g. 'marine fauna').

7.5.3 control measures

The OPGGS(E)R defines a control measure as:

> "a system, an item of equipment, a person or a procedure, that is used as a basis for managing environmental impacts and risk".

Under the OPGGS(E)R control measures are not required to be established within an OPP; they form part of the evaluation of impacts and risks in the subsequent activity-specific EPs (as per regulation 21(5)). However, if in the process of evaluating impacts and risks of the Development, control measures were required to manage the impacts and risks to acceptable levels these have been identified within this OPP.

Further consideration of control measures will be undertaken during the preparation of activity-specific EPs, where additional or different control measures may be identified and adopted to reduce the impacts and risks to ALARP and acceptable (Ref. 16).

7.5.4 likelihood

For environmental impacts likelihood is not considered.

For risks, where the environmental aspect or unplanned event may lead to environmental impacts under certain circumstances, the likelihood (probability) of the defined consequence occurring is determined. The likelihood is considered by assuming that all control measures are in place. The likelihood of a consequence occurring was identified using one of the six likelihood categories, as shown in Table 7-4.

7.5.5 quantification of the level of risk

The Integrated Risk Prioritization Matrix (Table 7-4) was applied during environmental risk assessment workshops. This matrix uses consequence and likelihood rankings of 1 to 6, which when combined, result in a residual risk level between 1 (highest risk) and 10 (lowest risk) (Table 7-5). Risk assessment outcomes are based solely on assessment of risk to the environment (as defined under the OPGGS(E)R).

Table 7-5: Residual risk descriptors

Residual risk level	1	2	3	4	5	6	7	8	9	10
Descriptor	Very High			High		Moderate	Low		Very Low	

7.6 acceptable levels

Regulation 13(4)(d) of the OPGGS(E)R requires that this OPP "demonstrates that the environmental impacts and risks of the project will be managed to an acceptable level".

NOPSEMA's guidance (Ref. 16) defines an acceptable level as "the specified amount of environmental impact and risk that the project may have" and "the maximum level of change in environmental parameters before the environmental effects become unacceptable". The guidance also notes that the acceptable level(s) of environmental impact and risk need to be defined before the evaluation of those impacts and risks can take place and the EPOs can be established (Ref. 16).

Acceptable level(s) should be defined having regard to all relevant contexts including, but not limited to:

- principles of ESD

- legislative and other requirements (including laws, policies, standards, conventions)
- environmental policy objectives from management documentation made or adopted under the EPBC Act (e.g. recovery plans, conservation advices, marine bioregional plans, AMP management plans)
- internal context (titleholder policy, culture, processes, standards and systems)
- external context (existing environment, stakeholder expectations).

If an environmental aspect associated with the Development is listed as a threat to a protected matter, or identified as an aspect of concern to a listed conservation value, under a document made or adopted under the EPBC Act, CAPL will define an acceptable level of impact and risk that is consistent with the objectives of those documents or plans. Receptors not considered protected matters under the EPBC Act will adopt the overall objective for the receptor in relevant legislative or environmental management documentation requirements.

Acceptable levels for the Development are described in Table 7-6.

Table 7-6: Acceptable levels for the Backfill Fields Development

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
Planned activities			
Seabed disturbance	Water quality	**AL-01**: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	The North-west Marine Bioregional Plan (Ref. 102) is made under section 176 of the EPBC Act. The conservation values of the Commonwealth marine area identified within the North-west Marine Bioregional Plan include KEFs. The marine environment is made up of numerous habitats, biological communities and ecosystems. An action is likely to have a significant impact on the Commonwealth marine environment if the action will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that there will be an adverse impact on marine ecosystem functioning or integrity in a Commonwealth marine area • result in a substantial change in air quality or water quality (including temperature) 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 (Ref. 102). Pressure analyses identified no 'pressures of concern' for the KEFs that intersect with the DA. Physical habitat modification was identified as 'of potential concern' for the continental slop demersal fish communities KEF. Consistent with the objectives of the EPBC Act, and in the context of the principles of ESD (as defined in the EPBC Act), the North-west Marine Bioregional Plan sets the following objectives for the for the NWMR: • conserving biodiversity and maintaining ecosystem health • ensuring the recovery and protection of threatened species • improving understanding of the region's biodiversity and ecosystems and the pressures they face. The acceptable levels (**AL-01** and **AL-02**) have been defined to not be inconsistent with the objectives for the management of the NWMR, and
	Benthic habitats and associated communities	**AL-02**: Impacts on benthic habitats and associated communities from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area. **AL-03**: Any damage to the seabed within title areas will not be inconsistent with the requirements under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth).	
	KEFs (benthic habitats and associated communities)		

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			have also been set at a smaller spatial scale (i.e. the Development Area) than the broader NWMR. As the objectives of the North-west Marine Bioregional Plan take into consideration the principles of ESD (e.g. Integration, Intergenerational, Biodiversity), these acceptable level(s) are also consistent with the principles of ESD.
			To be able to surrender a petroleum title associated with the Development, CAPL must satisfy the criteria in section 270 of the OPGGS Act, including but not limited to 270(3)(f): • made good any damage to the seabed or subsoil in the surrender area caused by any person engaged or concerned in the operations authorised by the permit, lease or licence. The acceptable level (**AL-03**) has been defined to not be inconsistent with the OPGGS Act. The acceptable level is also considered to be consistent with the principles of ESD (e.g. Biodiversity, Intergenerational) as the criteria to 'make good' would maintain biological diversity and ecological integrity, and not forego the health, diversity and productivity of the environment for future generations.
	Underwater cultural heritage	**AL-04**: No adverse impact[85] on declared or protected underwater cultural heritage[86] from the Development that would be inconsistent with the protection and conservation objects of the *Underwater Cultural Heritage Act 2018* (Cth).	The UCH Act is Australia's primary UCH legislation. The UCH Act provides protection from adverse impacts to underwater cultural heritage located within Australian waters. The acceptable level has been defined to not be inconsistent with the UCH Act. As the object of the UCH Act is the ongoing protection and conservation of UCH, the principles of ESD (e.g. Integration, Intergenerational) are inherently considered. Therefore, the acceptable level is also consistent with the principles of ESD. Note: No declared or protected UCH is currently known to exist in the DA. This acceptable level is intended to apply should this status change.

[85] Where 'adverse impact' is defined under section 30 of the UCH Act.

[86] Where underwater cultural heritage is defined under section 15 of the UCH Act.

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
	First Nations cultural heritage	**AL-05**: No injury or desecration[87] on declared areas or objects[88] from the Development that would be inconsistent with the preservation and protection purposes of the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cth).	The ATSIHP Act provides protection from injury or desecration to declared areas or objects of particular significance located in Australia or within Australian waters. The acceptable level has been defined to not be inconsistent with the ATSIHP Act. As the object of the ATSIHP Act is the ongoing preservation and protection of areas and objects of particular significance, the principles of ESD (e.g. Integration, Intergenerational) are inherently considered. Therefore, the acceptable level is also consistent with the principles of ESD. Note: No declared areas or objects are currently known to exist in the DA. This acceptable level is intended to apply should this status change.
		AL-06: No interference with native title rights or interests[89] within petroleum title areas to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder under section 280 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth).	Section 280 of the OPGGS Act describes the requirements regarding the interference with other rights within petroleum title areas. The acceptable level has been defined to not be inconsistent with the OPGGS Act. Note: No determination of native title, or claims for native title, are currently known to exist in the DA. This acceptable level is intended to apply should this status change.
		AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	Consultation with First Nations people and/or representative groups has identified that Sea Country is of importance (Section 6.3.5.2.1). These values include coastal areas, offshore islands, marine fauna, and traditional stories. The acceptable level has been defined consistent with the intent of section 280 of the OPGGS Act, but in acknowledgement that First Nations cultural values can exist in the absence of formal native title claims or determinations. The acceptable level also considered consistent with the principles of ESD (e.g. Integration, Intergenerational, Biodiversity) as the limit of

[87] Where 'injury or desecration' is defined under section 3(2) of the ATSIHP Act.

[88] Where areas and objects are defined under section 3(1) of the ATSIHP Act.

[89] Where 'the enjoyment of native title rights and interests' is within the meaning of the *Native Title Act 1993* (Cth).

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			reasonable interference is intended to ensure Sea Country values are maintained. The requirement for ongoing engagement with First Nations peoples and/or representative groups is described in control measures throughout Section 8.
Air emissions	Air quality	**AL-01** (see above).	Refer to source and justification description above for **AL-01**.
Greenhouse gas emissions	Atmospheric GHG concentration	**AL-08**: Greenhouse gas emissions from the Gorgon Gas Development[90,91,92] will be within limits as set by the *National Greenhouse and Energy Reporting Act 2007* (Cth) and *Environmental Protection Act 1986* (WA).	The NGER scheme (including the Safeguard Mechanism) is established under the NGER Act. The 'Gorgon Operations Facility' is registered as a facility under both the NGER and Safeguard Mechanism schemes. The scope of the Gorgon Operations Facility includes GHG emissions from both the GTP and associated facilities on Barrow Island, as well as from any activities or facilities in Commonwealth waters (i.e. including any activities in Commonwealth waters associated with the Development). As part of the 2023 reforms to the Safeguard Mechanism, a decline rate is now applied to the facilities baseline so that it is reduced over time (Section 8.3.5.3). GHG emissions for the GFP (including from the operation of the GTP on Barrow Island) have been estimated an approved under existing primary environmental approvals (Section 8.3.6). Current state environmental approval conditions (MS 1198) provide declining Net GHG Emissions limits over the life of the Gorgon Gas Development (Section 8.3.6.1). The acceptable level has been defined to not be inconsistent with State or Commonwealth legislative requirements in place at the time. As the second object of the NGER Act is to contribute to the achievement of Australia's GHG emissions reduction targets, the principles of ESD (e.g. Integration, Intergenerational, Biodiversity) are inherently considered. Similarly, the object of the EP Act is to protect the environment of WA by having regard to the principles of ESD

[90] The Gorgon Gas Development includes the GFP, the Development, and potential future development of other Greater Gorgon Area fields. GHG emissions from the Gorgon Gas Development incorporates direct (Scope 1) GHG emissions from the Gorgon GTP and Gorgon Operations Facility .

[91] The 'Gorgon GTP' includes all direct (Scope 1) GHG emissions from the current operational Gorgon Gas Development facilities (as outlined in MS 800) (Section 8.3.6.1).

[92] The 'Gorgon Operations Facility' is registered with the CER as a facility under both the NGER and Safeguard Mechanism schemes (Section 8.3.5.3). The reporting boundary of the Gorgon Operations Facility includes direct (Scope 1) emissions from the 'Gorgon GTP' as well as direct (Scope 1) emissions from any activities or facilities in Commonwealth waters.

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			(Precautionary, Intergenerational, Biodiversity). Therefore, the acceptable level is also consistent with the principles of ESD.
		AL-09: Net GHG emissions associated with the transport and third-party end use of products from the Development do not represent a significant proportion of cumulative global GHG emissions.	The Intergovernmental Panel on Climate Change (IPCC) states in the Assessment Report 6 (AR6) Synthesis Report: Summary for Policymakers (Ref. 756) that "[o]bserved increases in well-mixed GHG concentrations since around 1750 are unequivocally caused by GHG emissions from human activities over this period"[93] and WGI AR6 of the IPCC acknowledges that "[c]limate change is a global phenomenon, but manifests differently in different regions" (Ref. 271). GHG emissions from the Development do not individually represent a significant proportion of cumulative global GHG emissions. The IPCC states that "[h]istorical cumulative net CO_2 emissions from 1850 to 2019 were 2400±240 Gt CO_2"[93]. The total 'BFF secondary GHG emissions' over the operational life of the Development (~600.7 Mt CO_2-e) would be the equivalent of ~0.023–0.028% of these historical emissions. The IPCC Synthesis Report states "[g]lobal net anthropogenic GHG emissions have been estimated to be 59±6.6 Gt CO_2-e in 2019"[93]. Based on the long-term annual average of 'BFF secondary GHG emissions' (~15.8 Mtpa CO_2-e) this would represent ~0.024–0.030% of current annual global GHG emissions. As described in Section 8.3.13, the total 'BFF secondary GHG emissions' over the operational life of the Development (~600.7 Mt CO_2-e) represents a potential reduction to IPCC's remaining carbon budget (estimated to remain at the beginning of 2020) for a 50% likelihood to limit global warming to 1.5–2°C of ~0.04–0.12%. The above proportions are based on comparisons to the estimated total 'BFF secondary GHG emissions' from the Development and do not take into account any potential GHG emissions mitigations, reductions, or offset opportunities that may be undertaken by third-parties (e.g. refer to regulatory mechanisms for customer markets below in **AL-10** and **AL-11**). Therefore, the actual net GHG emissions for the transport and third-party end use of the Development's products

[93] IPCC AR6, Synthesis Report, SPM-4 (Ref. 784).

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			will be lower than these total estimates and are not considered to represent a significant proportion of cumulative global GHG emissions. Anthropogenic GHG emissions from the Development do not individually cause the physical effects of climate change, rather it is their cumulative effect, in combination with GHG emissions from all other anthropogenic and natural sources since the mid-1700's, that contribute to increased global temperature and global weather trends in the aggregate that may cause or contribute to physical effects. For the reasons above, the Development does not represent a significant proportion of either annual or historic global cumulative GHG emissions. Third-party emissions are ultimately driven by domestic and international demand for gas products and there are regulatory mechanisms by which customer markets manage their own GHG emissions. Therefore, GHG emissions from the transport and third-party end use of Development products are acceptable.
		AL-10: The Gorgon State Agreement establishes a commitment to reserve and market domestic gas from the Gorgon Gas Development. Therefore, the acceptable level of GHG emissions from third-party end use of this domestic gas supply is inherently set by the Agreement and domestic GHG emissions are managed under relevant Australian law.	As described in Section 8.3.7.1, the Gorgon Gas Processing and Infrastructure Project Agreement (Gorgon State Agreement) provides for the reservation of 2,000 PJ of gas for domestic supply, construction of the 300 TJ/day Gorgon domestic gas plant on Barrow Island and requires the production capacity of this plant is actively marketed to Western Australian customers. This represents the largest indicative domestic gas commitment of the eight existing agreements in place in WA (Ref. 565). Therefore, the acceptable level of GHG emissions from third-party end use of this domestic gas has been defined to not be inconsistent with the reservation requirements as per the Gorgon State Agreement. In addition, GHG emissions in Australia are managed under relevant Australian Government legislative mechanisms, including the *Climate Change Act 2022* (Cth) and the NGER Act. The *Climate Change Act 2022* (Cth) sets out Australia's GHG reduction targets, and the NGER Act contributes to achieving these targets. As described above, the NGER Act inherently considers the principles of ESD, and therefore, the acceptable level is also consistent with the principles of ESD.
		AL-11: Acceptable levels for GHG emissions occurring outside of Australia's jurisdiction from the transport and third-party end use of	Sections 8.3.7.2 and 8.3.7.3 describe the existing customer markets for Gorgon Gas Development's LNG and condensate, including both long-term sales agreements and spot markets. Chevron Australia has no operational control over either the transport or end use of its

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
		Gorgon Gas Development products are managed under relevant laws of the respective customer countries.	products beyond the point of sale, nor the marketing or sale of equity liftings by its joint venture partners. GHG emissions associated with the third-party end use of products would be direct emissions for these consumers who would operate under their own respective regulatory regimes to manage their own GHG emissions. Customer countries adopt their own regulatory mechanisms relating to GHG emissions based on various considerations, including energy policies, GHG emissions reduction ambitions, and international commitments. Therefore, the acceptable level of GHG emissions from the transport and third-party end use of Gorgon Gas Development products outside of Australia's jurisdiction defers to the regulatory mechanisms of the respective customer countries. In addition, Chevron Australia has obligations under petroleum production licenses, such as maintaining production in line with the approved Rate of Recovery and Field Development Plan, as administered by the NOPTA under the OPGGS Act and Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011.
Light emissions	Ambient light Marine reptiles Fishes, including sharks and rays Seabirds and shorebirds	**AL-12**: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species. **AL-13**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act. **AL-14**: Impacts from the Development will not decrease the availability or quality of marine fauna habitat to the extent that it interferes with the recovery of the population of an EPBC Act listed threatened species. **AL-15**: Impacts from the Development will not decrease the	The EPBC Act is the Australian Government's primary environmental legislation. The EPBC Act protects Australia's native species by providing for the identification and listing of species as threatened. Any person can nominate a native species for listing under the EPBC Act. Recovery plans for threatened fauna may be made under Part 13 Subdivision A of the EPBC Act. Under the EPBC Act an action must not be inconsistent with a recovery plan. Recovery plans include research and management actions with the intent of stopping the decline of, and supporting the recovery of, population so threatened species in the wild. For example, the Recovery Plan for Marine Turtles in Australia (Ref. 24) identifies light pollution as a threat to marine turtles, and has this relevant management action: • A8.1—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. Management actions from current in-force recovery plans are addressed in the 'demonstration of acceptability' and EPOs within the environmental impact and risk assessment for each aspect (see Section 8).

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
		availability or quality of important habitat [94] to the extent that it interferes with the survival of the population of an EPBC Act listed migratory species.	The acceptable levels (**AL-12** and **AL-13**) have been developed such that they are not inconsistent with the long-term recovery of listed threatened species or inconsistent with recovery plans. That is, the prevention of the recovery of a listed threatened species population is unacceptable. Criteria for determining if an action is likely to have a significant impact (under the EPBC Act) on threatened species include if there is a real chance or possibility that it will lead to a long-term decrease in the size of the population, or interfere with the recovery of the species (Ref. 72). These acceptable levels are considered to provide a level of environmental protection that would prevent these significant impact criteria from being met. The EPBC Act significant impact guidelines also describe that an action is likely to have a significant impact • to threatened species if it decreases the availability or quality of habitat to the extent that the species is likely to decline • to migratory species if it substantially modifies, destroys or isolates an area of important habitat (Ref. 72). The acceptable levels (**AL-14** and **AL-15**) have been developed to provide a level of environmental protection that would prevent these significant impact criteria from being met. As objects of the EPBC Act include providing for the protection of the environment and conservation of biodiversity, and the nomination and listing process incorporates public consultation, the principles of ESD (e.g. Integration, Intergenerational, Biodiversity) are inherently considered. Therefore, all these acceptable levels are also consistent with the principles of ESD.
	First Nations cultural heritage	**AL-07** (see above).	Refer to source and justification description above for **AL-07**.
	AMPs	**AL-16**: No impact on the natural values of the Montebello Marine Park[95] from the Development that	There are no AMPs within the DA; i.e. no Development activities occur directly within an AMP. The Montebello Mark Park is ~16 km from the DA (Section 6.5.1).

[94] Where important habitat for migratory species are defined within the MNES Significant Impact Guidelines (Ref. 72).

[95] Where the natural values of the Montebello Mark Park are described in the North-west Marine Parks Network Management Plan (Ref. 82).

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
		would prevent the conservation of biodiversity within the North-west Marine Parks Network.	The North-west Marine Parks Network Management Plan (Ref. 82) is made under section 370 of the EPBC Act. The natural values of the North-west Network are broadly defined as habitats, species and ecological communities within marine parks, and the processes that support their connectivity, productivity and function. The North-west Marine Parks Network Management Plan identifies habitat modification (which includes the modification of natural light) as a pressure for the North-west Network. Consistent with the objectives of the EPBC Act, and in the context of the principles of ESD (as defined in the EPBC Act), the objectives of the North-west Marine Parks Network Management Plan are to provide for: • the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network • ecologically sustainable use and enjoyment of the natural resources within marine parks in the North-west Network (where this is consistent with the above objective). The acceptable level has been defined to not be inconsistent with the objectives for the management of the North-west Network. As the objectives of the North-west Marine Parks Network Management Plan take into consideration the principles of ESD (e.g. Integration, Intergenerational, Biodiversity), this acceptable level is also consistent with the principles of ESD.
Underwater sound emissions	Ambient sound	**AL-12**, **AL-13**, **AL-14**, and **AL-15** (see above).	Refer to source and justification description above for **AL-12**, **AL-13**, **AL-14**, and **AL-15**.
	Benthic invertebrates		
	Marine mammals		
	Marine reptiles		
	Fishes, including sharks and rays		
	First Nations cultural heritage	**AL-07** (see above).	Refer to source and justification description above for **AL-07**.

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
	AMPs	**AL-16** (see above).	Refer to source and justification description above for **AL-16**.
Planned discharges—MODU and vessels	Water quality	**AL-01** (see above).	Refer to source and justification description above for **AL-01**.
	Marine mammals	**AL-12**, **AL-13**, **AL-14**, and **AL-15** (see above).	Refer to source and justification description above for **AL-12**, **AL-13**, **AL-14**, and **AL-15**.
	Marine reptiles		
	Fishes, including sharks and ray		
	Seabirds and shorebirds s)		
	KEFs (associated fish communities)	**AL-17**: Impacts to fish communities associated with key ecological features will not prevent the conservation of biodiversity and maintenance of ecosystem integrity of the North-west Marine Region.	The North-west Marine Bioregional Plan (Ref. 102) is made under section 176 of the EPBC Act. The conservation values of the Commonwealth marine area identified within the North-west Marine Bioregional Plan include KEFs. An action is likely to have a significant impact on the Commonwealth marine environment if the action will: • have a substantial adverse effect on a population of a marine species or cetacean, including its lifecycle (e.g. breeding, feeding, migration behaviour or life expectancy) and spatial distribution (Ref. 102). Pressure analyses identified no ‘pressures of concern’ for the KEFs that intersect with the DA. Further both chemical pollution/contaminants and nutrient pollution were categorised as ‘not of concern’ for the KEFs that intersect with the DA. Consistent with the objectives of the EPBC Act, and in the context of the principles of ESD (as defined in the EPBC Act), the North-west Marine Bioregional Plan sets the following objectives for the for the NWMR: • conserving biodiversity and maintaining ecosystem health • ensuring the recovery and protection of threatened species • improving understanding of the region’s biodiversity and ecosystems and the pressures they face. The acceptable level has been defined to not be inconsistent with the objectives for the management of the NWMR. As the objectives of the

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			North-west Marine Bioregional Plan take into consideration the principles of ESD (e.g. Integration, Intergenerational, Biodiversity), the acceptable level is also consistent with the principles of ESD.
Planned discharges—subsea operations	Water quality	**AL-01** (see above).	Refer to source and justification description above for **AL-01**.
	Marine mammals	**AL-12**, **AL-13**, **AL-14**, and **AL-15** (see above).	Refer to source and justification description above for **AL-12**, **AL-13**, **AL-14**, and **AL-15**.
	Marine reptiles		
	Fishes, including sharks and ray		
	KEFs (associated fish communities)	**AL-17** (see above).	Refer to source and justification description above for **AL-17**.
	First Nations cultural heritage	**AL-07** (see above).	Refer to source and justification description above for **AL-07**.
Planned discharges—drilling activities	Water quality	**AL-01** (see above).	Refer to source and justification description above for **AL-01**.
	Sediment quality		
	Benthic habitats and associated communities	**AL-02** (see above).	Refer to source and justification description above for **AL-02**.
	KEFs (benthic habitats and associated communities)		
	KEFs (associated fish communities)	**AL-17** (see above).	Refer to source and justification description above for **AL-17**.
	Marine mammals	**AL-12**, **AL-13**, **AL-14**, and **AL-15** (see above).	Refer to source and justification description above for **AL-12**, **AL-13**, **AL-14**, and **AL-15**.
	Marine reptiles		
	Fishes, including sharks and rays		
	First Nations cultural heritage	**AL-07** (see above).	Refer to source and justification description above for **AL-07**.

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
Unplanned events			
Physical presence—other marine users	Commercial fisheries Commercial shipping Petroleum activities	**AL-18**: No interference with other lawful marine users within the petroleum title areas to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder under section 280 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth).	Section 280 of the OPGGS Act describes the requirements regarding the interference with other rights within petroleum title areas. The acceptable level has been defined to not be inconsistent with the OPGGS Act. The acceptable level is also considered to be consistent with the principles of ESD (e.g. Intergenerational) as the limit of reasonable interference is intended to ensure the activities do not forego the health, diversity and productivity of the environment for future generations.
Physical presence—marine fauna	Marine mammals Marine reptiles Fishes, including sharks and rays Seabirds and shorebirds First Nations cultural heritage	**AL-19**: No death or injury to an EPBC Act listed threatened species, migratory species, marine species or cetacean species within the Commonwealth marine area attributable to the Development.	It is an offence under the EPBC Act for an action to result in the death or injury of an EPBC Act listed threatened species, migratory species, marine species or cetacean species within the Commonwealth marine area. Acceptable level (**AL-19**) has been developed to not be inconsistent with requirements under the EPBC Act. As objects of the EPBC Act include providing for the protection of the environment and conservation of biodiversity, and the nomination and listing process incorporates public consultation, the principles of ESD (e.g. Integration, Intergenerational, Biodiversity) are inherently considered. Therefore, all these acceptable levels are also consistent with the principles of ESD.
Introduction of invasive marine pests	Benthic habitats and associated communities KEFs (benthic habitats and associated communities) First Nations cultural heritage	**AL-20**: No introduction and establishment of an invasive marine pest attributable to the Development.	The introduction and establishment of an invasive marine pest attributable to Development activities within the DA is considered unacceptable. Further, the conservation values of the Commonwealth marine area identified within the North-west Marine Bioregional Plan (Ref. 102) include KEFs. An action is likely to have a significant impact on the Commonwealth marine environment if the action will: • result in a known or potential pest species becoming established in the Commonwealth marine area (Ref. 102). The acceptable level is also considered to be consistent with the principles of ESD (e.g. Intergenerational, Biodiversity) as the event not occurring would maintain biological diversity and ecological integrity,

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
			and not forego the health, diversity and productivity of the environment for future generations.
Unplanned release—solid objects	Water quality	**AL-21**: No unplanned release of solid objects to the environment from the Development.	The unplanned release of solid objects attributable to Development activities within the DA is considered unacceptable. The acceptable level is also considered to be consistent with the principles of ESD (e.g. Intergenerational, Biodiversity) as the event not occurring would maintain biological diversity and ecological integrity, and not forego the health, diversity and productivity of the environment for future generations.
	Benthic habitats and associated communities		
	Marine mammals		
	Marine reptiles		
	Fishes, including sharks and rays		
	Seabirds and shorebirds		
	KEFs		
	First Nations cultural heritage		
Unplanned release—minor LOC	Water quality	**AL-22**: No minor loss of containment of hydrocarbons or chemicals to the environment from the Development.	The unplanned minor loss of containment of hydrocarbon or chemicals attributable to Development activities within the DA is considered unacceptable. The acceptable level is also considered to be consistent with the principles of ESD (e.g. Intergenerational, Biodiversity) as the event not occurring would maintain biological diversity and ecological integrity, and not forego the health, diversity and productivity of the environment for future generations.
	Marine mammals		
	Marine reptiles		
	Fishes, including sharks and rays		
	Fish communities associated with KEFs		
	Commercial fisheries		
Unplanned release—vessel collision (MDO)	Water quality	**AL-23**: No unplanned release of hydrocarbons to the environment from the Development.	The unplanned release of hydrocarbons from a major spill event attributable to Development activities within the DA is considered unacceptable. The acceptable level is also considered to be consistent with the principles of ESD (e.g. Intergenerational, Biodiversity) as the event not occurring would maintain biological diversity and ecological integrity,
	Coastal habitats and associated communities		
	Marine mammals		

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
	Marine reptiles		and not forego the health, diversity and productivity of the environment for future generations.
	Fishes, including sharks and rays		
	Seabirds and shorebirds		
	KEFs		
	AMPs		
	Commercial fisheries		
	Tourism and recreation		
	First Nations cultural heritage		
	Listed heritage places		
Unplanned release—hydrocarbon system (condensate)	Water quality	**AL-23** (see above).	Refer to source and justification description above for **AL-23**.
	Coastal habitats and associated communities		
	Marine mammals		
	Marine reptiles		
	Fishes, including sharks and rays		
	Seabirds and shorebirds		
	KEFs		
	AMPs		
	Commercial fisheries		
	Commercial shipping		

Aspect	Environmental value or sensitivity	Acceptable level(s)	Source and justification
	Tourism and recreation		
	Petroleum activities		
	Defence		
	First Nations cultural heritage		
	Listed heritage places		

7.7 demonstration of acceptability

7.7.1 comparison with acceptable level

The predicted level of impact and risk will be compared against the acceptable level(s) to determine if additional actions (i.e. additional control measures; Section 7.5.3) are required (Ref. 16).

7.7.2 principles of ESD

The principles of ESD are considered in Table 7-7 in relation to acceptability demonstration.

Under the EPBC Act, the decision-maker must also consider the precautionary principle in determining whether to approve the taking of an action. The precautionary principle (section 391(2) of the EPBC Act) "is that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there may be threats of serious or irreversible environmental damage".

Table 7-7: Principles of ESD in relation to petroleum activity acceptability demonstration

Principles of ESD	How they have been applied
Integration Principle (a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social, and equitable considerations	CAPL's impact and risk assessment process integrates long-term and short-term economic, environmental, social, and equitable considerations. This is demonstrated through the Integrated Risk Prioritization Matrix (Table 7-4), which includes provision for understanding the long-term and short-term impacts associated with its activities. The impact and risk assessment process also provides for, and integrates any matters raised during stakeholder consultation (including public comment) into the evaluation of impacts and risks. A summary of relevant public comments and/or stakeholder feedback and how they have been addressed in the Development is demonstrated for each aspect against the external context acceptability criteria. As this principle is inherently met by applying the assessment process, it is not considered separately for each aspect's impact and risk evaluation.
Precautionary Principle (b) 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	CAPL considers if there is the potential for serious or irreversible environmental damage by assigning these as equivalent to a consequence level between Severe (2) and Catastrophic (1) from the Integrated Risk Prioritization Matrix (Table 7-4). Where a potential for serious or irreversible environmental damage is identified, then CAPL assess whether there is a lack of full scientific certainty associated with the aspect. Then, if there is a lack of full scientific certainty, CAPL will use a precautionary approach to implement control measures to eliminate, prevent, reduce, or mitigate the threat of serious or irreversible environmental damage.
Intergenerational Principle (c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or	CAPL considers if there is the potential to affect the maintenance of health, diversity, and productivity of the environment; by determining if there is potential for serious or irreversible environmental damage by assigning these as equivalent to a consequence level between Severe (2)

Principles of ESD	How they have been applied
enhanced for the benefit of future generations	and Catastrophic (1) from the Integrated Risk Prioritization Matrix (Table 7-4). If the impacts and risk are determined to be serious or irreversible, then the Precautionary Principle is implemented to ensure that impacts and risks are managed to an acceptable level to ensure that the environment is maintained for the benefit of future generations.
Biodiversity Principle (d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	Provide evidence that the impact and risk assessment of aspects during alternatives analysis considers the potential effects on biological diversity and ecological integrity.
Valuation Principle (e) improved valuation, pricing, and incentive mechanisms should be promoted	Not considered relevant for the Development acceptability demonstrations.

7.7.3 legislative and other requirements

Legislative and other requirements include:

- requirements from Australian legislation and regulations
- relevant Commonwealth government policies
- relevant Commonwealth government guidance
- relevant industry standards
- relevant international conventions.

Matters protected under Part 3 of the EPBC Act are also considered under this acceptability criterion such that impacts and/or risks are consistent with relevant environmental management documents made or adopted under the EPBC Act (e.g. threatened species recovery plans, AMP management plans, and so on).

Evaluation of this acceptability criterion against all aspects will confirm and recognise CAPL as a competent organisation with proven ability and experience to apply current good practice to manage well-understood impacts and risks arising from the Development.

7.7.4 internal context

The impact and risk assessment for this OPP was undertaken in accordance with CAPL's ABU OE Risk Management Process (Ref. 257) and using Chevron Corporation's Integrated Risk Prioritization Matrix (Table 7-4). This approach generally aligns with the processes outlined in ISO 31000:2018 Risk Management—Principles and Guidelines (Ref. 255) and the HB 203:2012 Managing Environment-related Risk (Ref. 256).

This approach will include a review of the aspect against requirements under CAPL's management systems and will ensure that impact and risk management is consistent with company policy, culture, and standards.

The impact and risk assessment process involved consulting with CAPL's Health, Safety and Environment (HSE), commissioning, start-up, operations, maintenance, engineering, and emergency response personnel who have gained

experience during the GFP, and more broadly from Chevron Corporation's operations globally.

7.7.5 external context

The impact and risk assessment process was also informed by stakeholder engagement (Section 3).

Existing and new stakeholders for the Development were consulted when developing this first iteration of the OPP, which is published for public comment (Stage 1 of the OPP assessment). Feedback received during the public comment period will be reviewed and summarised in the OPP during Stage 2 of the assessment by the regulator.

7.7.6 summary of acceptance criteria

Table 7-8 outlines the criteria that CAPL used to demonstrate that impacts and risks from each identified aspect are acceptable.

Table 7-8: Acceptability criteria

Criteria	Test
Acceptable level	Confirm that the predicted level of impact can be managed to provide an equal or better environmental outcome that the defined acceptable level.
Principles of ESD	Evaluate all aspects of the Development against ESD principles (b), (c), and (d) (Table 7-7).
Relevant environmental legislation and other requirements	Confirm that impact and risk management is consistent with relevant Australian environmental management laws and other regulatory or statutory requirements.
Internal context	Confirm that impact and risk management is consistent with CAPL's management systems, company policy, culture, and standards.
External context	Consider any feedback regarding this aspect made by stakeholders, and how they can be addressed.

7.8 environmental performance outcomes

The OPGGS(E)R defines an EPO for an activity as:

> "a measurable level of performance required for the management of environmental aspects of the activity to ensure that environmental impacts and risks of the activity will be of an acceptable level".

In accordance with NOPSEMA's guidance, EPOs should be representative of levels of environmental performance that are equal to or better than the defined acceptable level (Ref. 16).

EPs for petroleum activities submitted subsequent to this OPP will contain EPOs that are consistent with those set out in this OPP (Ref. 16). The EPOs presented in EPs may differ, but will need to achieve the same environmental outcome (or better) as that described in this OPP (Ref. 16). The EPs will also contain environmental performance standards (EPSs) set with appropriate measurement criteria to monitor the performance of the control measures and determine whether the EPOs and EPSs have been met during the activity.

Regulation 13(4)(e) of the OPGGS(E)R also requires that the EPOs "are consistent with the principles of ecologically sustainable development". The EPOs for the Development are consistent with the principles of ESD because:

- the acceptable levels (Section 7.6) take into consideration the principles of ESD
- the demonstration of acceptability process (Section 7.7), which is applied to each aspect in Section 8, also takes into consideration the principles of ESD
- the EPOs have been set at a level of environmental performance that is equal to or better than the defined acceptable level(s).

8 environmental impact and risk assessment and management strategy

Each environmental aspect assessment is organised into these subsections:

- source—describes the activities that may lead to the aspect occurring
- impact and risk evaluation—describes the potential impacts or risks arising from the aspect and the receptors that may be impacted
- determination of acceptability—provides justification for the determination of acceptability
- environmental performance—provides the EPOs and adopted control measures.

The impact and risk assessments in this OPP are based on conservative assumptions of Development activities, as understood at the time of writing. Evaluations in subsequent EPs will revalidate levels of impact and risk and acceptability, as needed.

Table 8-1 summarises the worst-case impacts and risks that were identified and evaluated for each aspect.

Table 8-1: Summary of impact and risk evaluation

Section	Aspect	Impact	Risk			Acceptable
		C	C	L	RR	
8.1	Seabed disturbance	4	4	4	7	Yes
8.2	Air emissions	6	–	–	–	Yes
8.3	Greenhouse gas emissions	6	–	–	–	Yes
8.4	Light emissions	6	5	5	9	Yes
8.5	Underwater sound emissions	5	5	2	6	Yes
8.6	Planned discharges—MODU and vessels	6	6	6	10	Yes
8.7	Planned discharges—Subsea operations	6	6	6	10	Yes
8.8	Planned discharges—Drilling operations	5	5	4	8	Yes
8.9	Physical presence—Other marine users	–	6	3	8	Yes
8.10	Physical presence—Marine fauna	–	6	3	8	Yes
8.11	Introduction of invasive marine pests	–	3	6	8	Yes
8.12	Unplanned release—Solid objects	–	5	5	9	Yes
8.13	Unplanned release—Minor LOC	–	5	5	9	Yes
8.14	Unplanned release—Vessel collision (MDO)	–	5	5	9	Yes
8.15	Unplanned release—Hydrocarbon system (condensate)	–	4	5	8	Yes

C = Consequence; L = Likelihood; RR = Residual Risk

8.1 seabed disturbance

8.1.1 source

Development activities on the seabed (including sampling, excavating, and placing equipment or infrastructure) have the potential to cause seabed disturbance.

Seabed disturbance is considered in this impact assessment as either long-term disturbance (e.g. from infrastructure likely to remain on the seabed long-term or for the life of the Development) or short-term disturbance (e.g. from anchoring).

The Development's exact direct disturbance footprint from placing subsea infrastructure is not yet finalised given the early stage in the Development process. CAPL will provide more precise areas of seabed disturbance and document these in activity-related EPs. To allow for environmental impact assessment in the OPP, CAPL has proposed a conservative long-term disturbance area, which is described in Section 8.1.1.7.

Table 8-2 identifies activities within each phase that have the potential for seabed disturbance in the DA.

Table 8-2: Phases and activities that have the potential for seabed disturbance

Phase	Activity
Surveys	Geotechnical survey
Drilling	MODU positioning Drilling top- and bottom-holes Completions installation
Installation and commissioning	Pre-lay works Excavating and trenching (including rock dumping) Installation of flowlines and pipelines Installation of subsea structures Post-lay works (including rock dumping)
Operations	Maintenance and repairs Major repairs
Decommissioning	Well suspension and P&A Flowline and MEG pipeline decommissioning Umbilical decommissioning Other subsea infrastructure decommissioning
Support activities	Vessel operations ROV operations

8.1.1.1 surveys

Geotechnical surveys comprise in situ testing and sampling of the sediments of the sea floor. This may include the short-term placement of equipment on the seabed (e.g. transponders), with an indicative footprint of ~2 m^2 per deployment. Multiple deployments may be required, giving a conservative footprint of ~20 m^2 per survey location.

If drilling cores are taken, the footprint for the borehole sampling unit is expected to be ~14 m^2 at each location. This will occur within the long-term disturbance area and therefore, is not discussed further in this section.

8.1.1.2 drilling

Drilling is done using a MODU, which will either be moored using drag embedment anchors, kept on location with DP using thrusters, or connected to the seabed via legs with spud cans (for a jack-up). A moored MODU, with up to 16 drag embedment anchors per DC, represents the largest disturbance footprint, estimated to be 0.02848 km^2, compared to the MODU on DP (no seabed disturbance) or jack-up rig (<0.001 km^2).

The wellhead will be installed on the seabed at each well. The total footprint of the wells at each field is estimated to be 0.00033 km^2. The disturbance for the well top-holes is included in the long-term disturbance area; however, the disturbance from MODU anchoring or Jack-up (if undertaken) is considered short-term (Section 8.1.1.7).

Discharge of drilling cuttings, fluids and cement to the seabed is also planned for the Development. The environmental impacts associated with planned drilling discharges is evaluated in Section 8.8.

8.1.1.3 installation and commissioning

Flowlines, MEG pipelines and other subsea infrastructure may remain on the seabed for the Development's whole life. Any stabilisation materials, such as concrete mattresses, placed on the seabed during pre- or post-lay works may also remain for the duration of the Development.

Mattresses, grout bags, foundations, adjustable pipe supports, and global buckling mitigation structures used in pre-lay and post-lay works have indicative footprints up to 0.0021 km^2 each, though most will be significantly smaller. The total number to be used is unknown at this stage.

Excavation and trenching will be required at the scarp crossing of the C&D flowline and MEG pipeline. This trench is estimated to be ~12 m wide, ~50 m long and ~8 m deep (~600 m^2 excavation). Spoil generated from the excavation will be left in situ. Excavation and trenching may also be required at other points along the flowline and MEG pipeline routes but is unlikely.

Rock stabilisation or rock dumping may be required as a contingency. The disturbance footprint will occur within the long-term disturbance area.

The largest flowline to be used in the Development will have a 24″ diameter. The diameters of MEG pipelines and umbilicals will be significantly smaller. The full description of the subsea infrastructure that will be placed on the seabed is described in Section 4.2.

A conservative area of direct seabed disturbance associated with the presence of subsea infrastructure and equipment has been adopted for the impact assessment. The long-term disturbance area (Section 8.1.1.7) is a 250 m radius around the DCs and tie-in locations of each flowline, and a 30 m wide corridor along flowline, MEG pipeline and umbilical routes, with a contingency built in. The total long-term disturbance area (including a 50% contingency) is ~18.85 km^2. The intent of the long-term disturbance area is to allow for the footprint of all these structures (e.g. pipeline termination structures, in-line tees, MEG pipelines) and flowline stabilisation equipment (e.g. concrete mattresses, grout bags).

An initiation anchor or suction pile will be deployed to fix the end of the flowline or MEG pipeline in place at the beginning of the lay; these are short-term as they will be recovered from the seabed at the end of the lay process. Initiation anchors and wires have an estimated footprint of ~0.03 km^2.per flowline or MEG pipeline. One

anchor and initiation wire per flowline or MEG pipeline is expected to be used and these will be positioned outside of the long-term disturbance area. The anchor or pile may need to be repositioned in the event that load testing prior to the commencement of pipelay is unsuccessful.

If a cyclone occurs during subsea infrastructure installation, some infrastructure may need to be temporarily stored on the seabed, so that installation vessels can safely demobilise (known as 'wet parking'). This is not a planned activity; however, if wet parking is required, the footprint of the largest individual structure (i.e. the slug catcher) is <0.0021 km^2. This may occur outside the long-term disturbance area.

8.1.1.4 operations

The maintenance and repair activities that may be required during the operations phase include installing foundations, grout bags and concrete mattresses, excavating alongside infrastructure, adding equipment adjacent to infrastructure, and water jetting to remove growth or deposits. The frequency and scale of such activities is unknown; however, disturbance footprint is expected to be similar or smaller to those described in Section 8.1.1.3.

In the unlikely event of major repairs, equipment may be stored temporarily on the seabed (wet parked) beside the area of flowline that needs to be repaired. It is estimated that the footprint of this disturbance would be <0.001 km^2. This area of short-term laydown would be outside the long-term disturbance area (Section 8.1.1.7).

If a battery system is required for temporary power supply, it will be positioned within the long-term disturbance area. If a vessel downline is used, the battery system footprint is estimated to be ~0.0136 km^2 and located outside the long-term disturbance area. The battery system will be retrieved after use (Section 4.2.5.1).

8.1.1.5 decommissioning

Well suspension and P&A may be carried out using a MODU similar to that used for drilling.

The footprint of seabed disturbance from decommissioning is estimated to be the same as for mooring activities (if the MODU is moored), and installation of flowlines, umbilicals, and other subsea structures (Section 8.1.1.3). These activities re-disturb an already disturbed area; therefore, this area was not included in the total seabed disturbance footprint in Section 8.1.1.7.

CAPL's decommissioning philosophy is described in Section 4.3.5.

8.1.1.6 support activities (all phases)

Vessels are required in all phases of the Development and typically use DP. In some unlikely circumstances, vessels may require anchoring, so it is included here as a contingency.

A vessel anchored with a swing anchor at a depth of 80 m could have a disturbance area of up to ~0.057 km^2. This conservative value is considered in the impact assessment. Anchoring is considered a short-term disturbance.

In the unlikely event that an ROV is required to park on the seabed, this will occur within the long-term disturbance area.

8.1.1.7 seabed disturbance area

To allow for environmental impact assessment in the OPP, seabed disturbance has been classified as either long-term disturbance or short-term disturbance.

As described in Section 4.1.3.1, given the Development's exact long-term infrastructure disturbance footprint is not yet known, a conservative disturbance area has been adopted for the impact assessment. The long-term disturbance area comprises the direct footprint of infrastructure that may remain on the seabed from installation through to decommissioning as well as a buffer area either side of the flowlines, pipelines and umbilicals, and an area around the DCs and tie-ins. Assigning this buffer to all corridors and tie-in points, even those requiring less infrastructure, provides a conservative estimate.

The long-term disturbance area has been calculated using the following assumptions:

- a 30 m wide lay corridor along the production flowline, MEG pipeline and umbilical routes (i.e. ~15 m either side from the centre point of the infrastructure). While the flowlines, pipelines and umbilicals range from approximately 5" – 24" wide, the corridor allows for all other infrastructure or equipment associated with the production flowlines, MEG pipelines and umbilicals, including:
  - concrete mattresses / grout bags / adjustable pipe supports
  - in-line tees, global buckling mitigation structures
  - spoil from trenching (if required)
  - rock dumping (if required).
- a 250 m radius around the DCs and GFP tie-in locations. This footprint is wider than the flowline/umbilical corridor to allow for associated infrastructure and equipment that may include:
  - foundations
  - manifolds
  - production trees and tie-in structures
  - pipeline end terminations (PLET), pipeline end manifolds (PLEM)
  - pipeline termination structures
  - jumpers/spools
  - CDUs
  - slug catchers
  - overpressure protection structures
  - some contingency power supply infrastructure (Section 4.2.5.1).

Short-term disturbance is caused when infrastructure or equipment has contact with the seabed during a particular phase but is removed at or before the end of that phase. Where short-term equipment will contact the seabed within the long-term disturbance footprint, it is implicitly accounted for in the long-term disturbance area. Hence, the short-term disturbance area includes only short-term disturbance that will occur outside of the long-term disturbance area described above. The activities and equipment that comprise the short-term disturbance footprint are summarised in Table 8-3.

As the Development is subject to refinement during the design process, CAPL has included a 50% contingency to calculate both the long-term and short-term disturbance areas to represent a conservative maximum extent. The long-term disturbance area contingency allows for additional infrastructure that may go beyond the radius at some tie-in locations and the potential for some MEG pipelines to run in a separate route to the production flowlines. The short-term disturbance area contingency allows for any changes to footprints or placement of short-term infrastructure or equipment. For clarity, it is not intended that the 50% contingency will be used at a single site within the DA but will be used, when required, across the Development activities.

Table 8-3 summarises the total area of seabed disturbance for the long-term and short-term disturbance areas.

Table 8-3: Total area of seabed disturbance – long-term and short-term

Phase	Description	Approx. disturbance footprint (km^2)
Long-term subsea infrastructure (long-term disturbance area)		
Drilling to decommissioning	Assumes 30 m corridor for flowlines, MEG pipelines and umbilicals, 250 m radius around DCs and GFP tie-in locations, Includes all installed equipment and infrastructure.	12.49
Contingency power supply (if required)	Downline umbilical to account for downline umbilical being deployed on seabed until power supply is stable (0.0136 km^2 at each field/ co-developed field).	0.07
Total long-term disturbance		12.56
Total long-term disturbance plus 50% contingency		18.85
Short-term disturbance (temporary disturbance outside long-term disturbance area)		
Drilling	MODU anchor spread per well, if a moored MODU is selected (largest seabed disturbance footprint): • assumes 16 anchors • 0.028 km^2 per DC, for 10 DCs.	0.28
Installation	Initiation anchors used during pipelay: • assumes 30,000 m^2 per anchor/pile • one anchor required per flowline or MEG pipeline.	0.30
Installation, operations, decommissioning	Contingency for temporarily storing equipment on the seabed (wet parking): • largest single structure is a slug catcher at 0.0021 km^2.	<0.01
Operations	Wet parking equipment on the seabed, if a major repair is needed.	<0.01
Support activities	Contingency vessel anchoring: • assumes 0.057 km^2 for an anchor spread.	0.06
Total short-term disturbance		0.65
Total short-term disturbance plus 50% contingency		0.98
Total seabed disturbance (long-term and short-term plus contingency)		19.84

8.1.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by seabed disturbance:

- water quality
- benthic habitats and associated communities
- fishes, including sharks and rays
- KEFs (benthic habitats and associated communities)
- cultural heritage values: underwater cultural heritage
- cultural heritage values: Traditional Owners.

The DA represents the boundary within which all final routes and infrastructure will be located post final design (Section 4.2.1). As identified in Table 8-3, the total long- and short-term disturbance footprint (including the 50% contingency) represents 19.84 km^2, which is only ~0.69% of the total DA area.

The benthic survey (Ref. 104; appendix a) and other baseline reports for the Development covering the extent of the DA were used to inform on the presence of receptors, ensuring that all impacts and risks within the DA are adequately assessed. Table 8-4 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to seabed disturbance in the DA.

Marine fauna associated with seabed disturbance include marine mammals, marine reptiles, fish, and benthic fauna (i.e. epibenthic invertebrates and infauna).

There are several species of marine mammals and marine reptiles that may interact (feed/rest) on the seabed, but they are not considered demersal species, but rather utilise the entire water column. No known aggregation areas for these species have been identified within the DA. Therefore, seabed disturbance is not expected to result in impacts to marine mammals and reptiles.

The benthic survey (Ref. 104; appendix a) identified distinct fish assemblages within the DA, which were strongly influenced by water depth and water masses (Section 6.3.3.3). This indicates that both pelagic and demersal fish populations are likely to be transient and variable, depending on environmental conditions and habitat type.

Across the DA, pelagic fishes accounted for 99% of observations (n = 33,594), and were significantly more abundant in the shallower water KEFs and areas of greater seabed heterogeneity than soft sediment areas (Ref. 104; appendix a). The lowest fish diversity and abundance was found within the deeper Antarctic Intermediate Water mass of the Exmouth Plateau KEF area (~0.4% of all observations, n = 134; Ref. 104; appendix a). .

As the seabed disturbance is expected to be highly localised, it is not expected to result in a change in the viability of the population of commercially important species. Four State- and two Commonwealth-managed fisheries have recorded historical fishing effort in the DA. Of these only three are trawl or trap-based fishing targeting demersal fish species (the Commonwealth NWSTF and the State Pilbara Trap Managed Fishery and Pilbara Crab Managed Fishery). However, the DA is not regularly targeted by commercial fishing effort in the NWSTF or Pilbara Trap and Crab Managed Fisheries (Sections 6.4.1.1 and 6.4.1.2).

Therefore, impacts to marine mammals, marine reptiles, and commercial fisheries from seabed disturbance are not expected, and are not evaluated further.

Table 8-4: Impact and risk evaluation for seabed disturbance

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Seabed disturbance may result in: • localised and temporary reduction in water quality	6	An alteration of BCH may result in: • change to values and sensitivities of KEFs	4	4	Low (7)
Seabed disturbance may result in: • alteration of benthic habitats and associated communities	4	Seabed disturbance may result in: • temporary changes in fish behaviour	6	4	Very Low (9)
		Seabed disturbance may result in: • change to cultural heritage values: underwater cultural heritage	–	–	–
		Seabed disturbance may result in: • change to cultural heritage values: Traditional owners	4	4	Low (7)

Impact evaluation

Water quality

Localised and temporary reduction in water quality

A reduction in water quality is expected to occur when sediment on the seabed is disturbed and becomes suspended in the water column when infrastructure or equipment (such as anchors) is placed on, or removed from the seabed, during excavation and trenching and from water jetting and MFE to unbury structures (if required during decommissioning). The impacts to water quality will be localised around the infrastructure, anchoring positions and trenching locations. These impacts will be intermittent and temporary, with increased suspended solids expected only during the relevant activities. After the activities are completed, sediments will gradually settle back to the seabed and water quality will return to background levels.

Trenching is likely to generate the highest levels of turbidity. Excavation and trenching may be undertaken where flowlines, pipelines or umbilicals are required to cross the scarp to create a suitable seabed profile. The trench required is estimated to be ≤12 m wide, 50 m long and 8 m deep (~600 m^2 excavation). Spoil generated from the excavation, estimated at ~4,800 m^3, will be left adjacent to the excavation site and not transported to a spoil ground.

There are limited studies of changes in turbidity impacts during subsea trenching. Gooding et al. (Ref. 728) studied the impacts of cutting a 2 m deep trench on ambient turbidity at an undisclosed location on the NWS, using an RT-1, the world's largest subsea, tracked trencher. The trials were conducted at four locations of varying seabed types, ranging from well cemented calcarenite to dense carbonate sands. They found that turbidity levels fell by 66.8% down-current and 65.4% up-current between 20 m and 50 m from the RT-1. It was estimated from these results that the turbidity level would fall to ambient levels within 66 m of the trencher (Ref. 728).

Trenching impacts were also monitored during trenching trials for the Wheatstone trunkline installation near Onslow, northwestern Australia, where trenching was also conducted using an RT-1 trencher (Ref. 258; Ref. 259) for trenching distances of 2.6 km and 1.5 km, respectively, and trench depths of ~3.6 m. Monitoring demonstrated that turbidity significantly decreased within a small distance (tens of metres) away from the location of the physical disturbance footprint and that ambient turbidity levels would likely be reached within ~65 m up current and to 70 m down current from the trencher, depending on environmental conditions. Within 2 hours of ceasing trenching operations, turbidity levels returned to background or very close to background level (Ref. 258; Ref. 259). These results were consistent with those of the Gooding et al. (Ref. 728) study.

Impact evaluation

The full trenching program undertaken for the Wheatstone trunkline installation involved an excavation depth of 3.6 m, over a distance of 36 km, using a combination of trenching methods (backhoe dredge, trailer suction hopper dredge, cutter suction dredge) and included removal of ~2.5 million m^3 of mostly fine silt and clay material and reinstatement of ~2.5 million m^3 of material (Ref. 729). Only minor and temporary increases in turbidity were observed during Wheatstone trunkline trenching and no detectable impacts to benthic receptors were observed beyond the disturbance footprint (Ref. 733).

Turbidity levels during the Wheatstone trunkline trenching trials and the full Wheatstone trunkline trenching program are considered to be similar or conservative representations of what may occur during pipeline route trenching at the scarp crossing associated with the Development Activities. Although Wheatstone trenching occurred in much shallower waters (~2-20 m) than the scarps (~200-600 m), the silt and clay fractions for the Wheatstone trunkline trenching (silt: 20 to 60%, clay 10-30%; Ref. 196) were similar to those at the sites throughout the DA, including sites that were sampled closest to the scarp (~50% silt and ~30% clay, along with observations of bare bedrock at some scarp locations Ref. 104; appendix a). Gooding et al. (Ref. 728) studied turbidity impacts associated with trenching in a range of sediment types, including well cemented calcarenite. Together, the Wheatstone and Gooding et al. (2012) studies covered a range of sediment types likely to be encountered at the Development trenching locations. Furthermore, current speeds at the Wheatstone trunkline trenching location (maximum 0.35 m/s, mean ~0.15 m/s; Ref. 196) are similar to those modelled 1 m above seabed at the scarp location (maximum 0.35 m/s mean ~0.1 m/s; Ref. 730). In addition, while the trenching methods for the Development are yet to be determined, turbidity changes during the Wheatstone trenching trials (Ref. 258; Ref. 259) and the Gooding et al. study (Ref. 728) are likely to be representative or conservative, since material from the RT-1 trencher is side-cast, resulting in similar or greater suspension of sediments than other trenching methods.

Given the results of the above studies, any changes to the water column from small scale trenching activities (i.e. within scarp areas) associated with the Development are expected to be minor (small increases to suspended solids) and localised (to within tens of meters of the site). The potential impacts associated with seabed disturbance are likely to be limited to direct disturbance within the DA as well as a temporary reduction in water quality within tens of metres of the Development's activities. No regional scale impacts to water quality are expected.

The consequence of seabed disturbance causing a change in water quality has been evaluated as Incidental (6).

Benthic habitats and associated communities

Alteration of benthic habitats and associated communities

Alteration of BCH occurs when infrastructure or equipment is placed on the seabed, or the seabed surface is disrupted.

The Development activities will generate a long-term and a short-term disturbance footprint of 19.84 km^2 which represents ~0.69% of the total DA (Section 8.1.1, Table 8-3). Results of the benthic survey (Section 6.3.1.1; Ref. 104; appendix a) predicted that the DA is mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity.

Overall, the proposed DCs and tie-in locations are considered to be relatively devoid of epifauna, as confirmed by ground-truthing (Ref. 104; appendix a). The dominant benthic category is bare substrate with no biota. Bioturbation in bare sediment was also observed. A limited number of benthic infauna were found, primarily around proposed DCs Semele DC-1 and Semele DC-2 in deep-sea sediments (1,100–1,200 m) , and at WTR DC-1 in shallower seabed (100–200 m). The benthic infauna collected included marine worms, polychaete worms and molluscs. No endemic benthic infauna was identified in the survey (Ref. 104; appendix a). The ground-truthing conducted at the indicative DCs confirmed the lack of complex seafloor structures, supporting a high level of confidence in the mapping (Ref. 104; appendix a). These findings are consistent with previous seabed surveys in the NWS region where infauna was sparse and generally dominated by polychaetes and crustaceans (Ref. 115; Ref. 109; Ref. 114; Ref. 539; Ref. 104; appendix a).

The benthic survey (Section 6.3.1.1) identified BCH in close proximity to the proposed flowline/umbilicals. Where biota were present during ground-truthing, they were sparsely distributed and limited to isolated individuals, including sponges, echinoderms, and cnidarians (Ref. 104; appendix a). The following was identified:

- Chandon DC-1 to Jansz MPTS corridor: characterised by low structural habitats. Within the Exmouth Plateau KEF, scarps with associated biota were predicted along this corridor; however, ground-truthing did not confirm their presence

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- Jansz to G&E corridors: characterised by low structural habitats. A scarp with patches of biota was predicted parallel to existing subsea infrastructure; however, ground-truthing did not detect epifauna
- C&D to Gorgon corridor: mainly characterised by low structural habitats. Within the continental slope demersal fish communities KEF, scarps and reef mosaics with presence of biota, and discrete patches of depressions over bare substrate were predicted. Ground-truthing identified sections of rock reef colonised by sponges and cnidarians, as well as biota near the Gorgon tie-in
- Semele to C&D corridor: characterised by low structural habitats. Scarps with biota were predicted close to C&D DC (~500 m south of the proposed flowline) and confirmed through ground-truthing
- WTR to Gorgon corridor: characterised by low structural habitats.

No canyon features and no endemic benthic infauna were identified in the survey (Ref. 104; appendix a). Ground-truthing transects along the indicative flowline have validated the presence/absence of benthic biota. While there is some residual uncertainty with the mapping reports (Ref. 104; appendix a), the BCH were representative of known regional and local habitats (Ref. 741; Ref. 108; Ref. 111; Ref. 112; Ref. 104; appendix a) providing confidence for the impact and risk assessment purpose.

Dernie et. al. (Ref. 260) identified that full recovery of soft sediment assemblages from anthropogenic physical disturbance could take 64–208 days following physical disturbances of different intensities. Even where sedimentation levels are extreme, such as at dredge spoil disposal grounds, sediment infauna were observed to recover within 1 year (Ref. 731). The benthic habitat in these studies were characterised by sandy sediment (Ref. 260) and clay, silt and fine sand (Ref. 731) dominated by worms and clams (phylum Annelida Mollusca, and Echinodermata, respectively), which is similar to the benthic habitat and infauna identified throughout the DA.

Filter feed communities, including sponges, echinoderms, cnidarians, and a mixture of these biotic groups were identified, typically along the scarps. While information on the tolerance of deep-water filter feeder communities to elevated turbidity and sedimentation is limited, the response of shallower-water filter feeders to elevated turbidity and sedimentation associated with the Wheatstone dredging and trenching campaigns was studied by Wahab et al. (Ref. 732) and Chevron (Ref. 733). These studies concluded that filter feeder communities were not affected by dredging and trenching, with densities either remaining consistent, or in some cases increasing, between pre- and post-development surveys, despite the massive scale of excavation (~45 million m^3 dredged and 2.5 million m^3 trenched).

Some sessile invertebrates, such as sponges, have the capacity to filter out or to physically remove particulates (Ref. 263). Laboratory studies on sponges of varying morphology types showed that they can tolerate turbidity of up to 10 mg/L for up to 28 days without ill effect (Ref. 734). In addition, smothering of sponges of various morphologies with sediments for up to 30 days did not cause mortality, visible signs of stress, lipid depletion or overall changes in sponge respiration rates (Ref. 660). While individual species present at the scarp and other deep-water locations are likely to be different to the shallow-water communities studied, the physiological mechanisms of dealing with sediment ingestion and sediment removal are likely to be similar. Additionally, the above studies encompassed a broad range of morphologies, which, overall, are likely to capture the responses of deeper water species.

Studies of echinoderms have identified that, although excessive turbidity negatively affects some echinoderms, they have adaptations that allow them to thrive in turbid environments (Ref. 661). Some echinoderms species are specifically adapted to tolerate or utilise conditions of high turbidity (Ref. 662).

As previously noted, monitoring of turbidity during trenching programs indicated plumes were highly localised and resulted in only short-term exposures (Ref. 258; Ref. 259; Ref. 728). Consequently, impacts to these BCH from seabed disturbance are expected to be localised and temporary. Furthermore, these sections of BCH within the proposed infrastructure are typically sparse and patchy in distribution. As such, ecosystem function or habitat connectivity is not expected to be affected.

In addition, the physical presence of artificial structures on the seabed are known to provide hard substrate that can provide habitat for algae, fish, and invertebrates (Ref. 724; Ref. 725). Analysis of habitats on wellheads and associated infrastructure in water depths between 78–825 m on the NWS indicates that the presence of fish assemblages and invertebrate habitats were strongly influenced by depth, age and height of the structures (Ref. 726). Older, taller wellheads in depths <135 m possessed greater abundances of fish species, while beyond 350 m depth, the number of

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species and total fish abundance declined markedly, as did the percent cover of invertebrates (e.g. ascidians, black/octocorals, sponges) (Ref. 726). A review of ROV video footage recorded between 2015 and 2018 across two separate areas, comprising a total of 37 sites (29 sites on existing infrastructure and eight sites away from Jansz–Io pipelines) in water depths ~700–1,360 m also indicated some spatial differences in assemblage between non-infrastructure and infrastructure sites, with greater overall abundances, species richness, and species diversity generally associated with infrastructure (Ref. 112). The review also indicated a decrease in richness, abundance, and diversity with depth as found in other studies both in the north-west of WA and elsewhere (Ref. 112). Given the water depth of the proposed infrastructure ranges from ~150–1,400 m, the infrastructure may provide a hard substrate for colonisation over time, with a greater diversity and abundance of benthic invertebrates within the shallower area (i.e. a change, albeit not considered a negative change).

In summary, the Development is expected to result in localised alteration to BCH, without affecting ecosystem function or habitat connectivity. This is supported by:

- a localised disturbance footprint (~0.69% of the total DA) and turbidity plume (within tens of metres)
- the depth of the proposed infrastructure (~150–1,400 m; Table 4-6), where richness, abundance, and diversity decrease with depth
- BCH characteristics (mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity)
- short-term recovery potential of low structural habitats (within days to months)
- expected short-term recovery of infauna (within 1 year)
- biota in high structural complexity habitats are expected to tolerate or adapt
- high structural complexity habitats are predicted to occur in isolated sections within the proposed infrastructure area, and are typically sparse and patchy in distribution.

However, given the long-term presence of infrastructure the impact was evaluated as Moderate (4). For the short-term disturbance, the impact was identified as highly localised and benthic habitat is expected to recover within months; consequently, it was evaluated as Incidental (6).

Risk evaluation

Fishes, including sharks

Seabed disturbance may lead to temporary changes in fish behaviour due to alteration of BCH.

The Development activities will generate a long-term and a short-term disturbance footprint of 19.84 km^2 which represents ~0.69% of the total DA (Section 8.1.1, Table 8-3). As previously noted, a reduction in water quality is expected to be highly localised and short-term.

As identified in Section 6.3.3.3, several listed threatened and/or migratory fish and shark species under the EPBC Act have the potential to occur within the DA. The values and sensitivities with the potential to be affected include:

- whale shark foraging BIA
- fish communities associated with the continental slope demersal fish communities KEF (risk assessment to the change to values and sensitivities of KEFs has been undertaken separately and therefore is not further discussed in this section).

The foraging BIA identified overlaps the southern section of the DA and is associated with foraging behaviours during northward migration from Ningaloo Reef towards the north-east broadly follows the 200 m isobath (Ref. 33). Consequently, whale shark presence is expected to be transitory. The whale shark is a suction filter feeder and feeds at or close to the water's surface by swimming forward with mouth agape, sucking in prey (Section 6.3.3.3.1; Ref. 165). Given these characteristics, the depth of waters of the development, and the highly localised and short-term extent, changes in whale sharks behaviour due to seabed disturbance are not considered credible, therefore, is not evaluated further.

The benthic habitat report indicated that the DA is predominantly characterised by low structural complexity, with isolated areas of high structural complexity, mainly identified in the shallow waters KEFs within the DA (Ref. 104; appendix a). Ground-truthing footage, undertaken across the proposed infrastructure, showed limited presence of epifauna (Section 6.3.1.1.1; Ref. 104; appendix a).

Risk evaluation

The fish assemblage survey conducted as part of the benthic survey (Ref. 104; appendix a) identified distinct fish assemblages within the DA, which were strongly influenced by water depth and water masses (Section 6.3.3.3). Pelagic fishes accounted for 99% of individuals observed (n = 33,594), and were significantly more abundant in the shallower water KEFs and areas of greater seabed heterogeneity than soft sediment areas (Ref. 104; appendix a). Pelagic fishes are generally considered mobile and/or transient in nature (Ref. 743). They can temporarily move to other areas to forage or may take advantage of the disturbance for increased foraging opportunities. Therefore, potential impacts from the Development to pelagic fishes are considered unlikely and have not been further evaluated.

Demersal fishes present throughout soft sediment habitats in the DA (Ref. 104; appendix a) are also generally mobile taxa without any site attachment (Ref. 743). Any disturbance to the seabed may result in these species moving away from unfavourable areas. However, given their mobility over soft sediment habitats and the homogeneity of these habitat types at any given depths (Ref. 104; appendix a), as well as limited presence of epifauna, localised seabed disturbances from the Development are unlikely to have any detectable effects on soft sediment-dwelling demersal fishes. This is supported by evidence from studies of deep-water demersal fish assemblages on the NWS (Ref. 744), where even large-scale disturbances from trawling activities have resulted in minimal change to assemblages.

A small proportion of the DA is predicted to consist of more complex habitat, in varying percent cover (from low [<10%] to high cover [>80%]) of epibenthic invertebrates (e.g. the scarp; Ref. 104; appendix a). The mapping report predicts that these BCH occur in isolated patches and are generally sparse. Ground-truthing observations confirmed the presence of biota primarily within shallow-water KEFs within the DA.

Studies of disturbances to demersal fishes in similar habitat types on the NWS revealed little to no impact on the composition, abundance, behaviour and movement of demersal fishes, despite an assumed, relatively large, disturbance from seismic airguns (Ref. 745). While this study (Ref. 745) focused on shallower areas of the NWS (~50-70 m) than the DA, habitats consisted of rocky reef outcrops and patches of filter feeder assemblages, similar to those at the scarp location in the DA (Ref. 104; appendix a). The species examined were also from families that are common in the rocky, filter feeder patches within the DA (e.g. lutjanid and serranid species; Ref. 104; appendix a).

Demersal fish species present in patches of rock and filter feeder habitat within the DA may frequent the same locations, however, they are not considered ‘site-attached’ in the same sense as shallow-water reef species, such as damselfish or coral-dwelling gobies (Ref. 746). Shallow-water, site-attached reef species often live their whole life within a very small area (e.g. a few m^2) and may suffer higher predation if moved away from their site, due to the intense competition for shelter sites on coral reefs (Ref. 747). Instead, deep-water species may frequent the same areas to shelter from currents and reduce energetic demands but will roam more widely for foraging (Ref. 748). Therefore, if a particular patch becomes temporarily unavailable due to seabed disturbance from the Development, deep-water demersal species are likely to move to other areas, which usually only need to be minor anomalies in topographic complexity to be used to shelter from currents (Ref. 745). Once the seabed disturbance from Development activities ceases, these species are likely to move back and utilise these areas again.

As previously noted, the proposed infrastructure may provide a hard substrate for colonisation over time, potentially increasing the diversity and abundance of benthic invertebrates and fish assemblages, particularly in shallower areas. This is consistent with the review of ROV video footage from Jansz–Io pipelines in water depths ~700–1,360 m (which overlaps the western section of the DA, Section 6.3.1.1). The footage revealed some spatial differences in assemblage between non-infrastructure and infrastructure sites, with greater overall abundances, species richness, and species diversity generally associated with infrastructure (Ref. 112). The review also indicated a decrease in richness, abundance, and diversity with depth as found in other studies both in the north-west of WA and elsewhere (Ref. 112).

Given the previous details, only limited displacement of individuals is expected. Consequently, changes in fish behaviour are assessed as Incidental (6). The likelihood of seabed disturbance leading to changes in fish behaviour is assessed as Unlikely (4). Overall, the risk of seabed disturbance to fishes, including sharks and rays is Very Low (9).

KEFs

Change to values and sensitivities

Seabed disturbance may result in changes to the values and sensitivities of KEFs through alteration of benthic habitats and associated communities or injury or mortality to marine fauna.

Risk evaluation

Three KEFs overlap some of the DA:

- ancient coastline at 125 m depth contour KEF (Ancient coastline KEF)
- Exmouth Plateau KEF
- continental slope demersal fish communities KEF.

The DA overlaps a small portion (<1%) of each KEF's total area. Proposed infrastructure that may overlap or is in close proximity to these KEFs includes:

- WTR DCs, WTR flowline and one of the Gorgon tie-in points: Ancient coastline KEF
- Chandon DCs and part of the Chandon flowline: the Exmouth Plateau KEF
- C&D DC-3, and sections of the C&D flowline, WTR umbilical and Gorgon tie-in points: continental slope demersal fish communities KEF.

The values of the Ancient coastline and Exmouth Plateau KEFs have been assessed due to their unique sea floor features with ecological properties of regional significance (Ref. 102). Benthic habitat surveys within the Ancient coastline KEF predicted that the entire DA is comprised of smooth seabed with bioturbation and bare substrate and appeared to be devoid of epibenthic biota (Section 6.3.1.1.1). For the Exmouth Plateau KEF, the most dominant BCH were predicted as relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota. Scarps were predicted to cross through the indicative Chandon flowline route and identified north of the Chandon DC-1 (Section 6.3.1.1.1). These scarps, however, were devoid of epibenthic fauna as observed in the ground-truthing videos (Ref. 104; appendix a). While there is some residual uncertainty with the mapping reports (Ref. 104; appendix a), the BCH were representative of known regional and local habitats (Ref. 741; Ref. 108; Ref. 111; Ref. 112; Ref. 104; appendix a) providing reasonable confidence for the impact and risk assessment purpose. As previously assessed, alteration to these BCH is expected to be localised with potential establishment due to the introduction of hard substrates (i.e. a change, albeit not considered a negative change).

The values for the continental slope demersal fish communities KEF were identified as high levels of endemism with a diversity of fish assemblages (Ref. 102). According to the fish assemblage survey undertaken as part of the benthic survey, fish assemblages were strongly influenced by water depth and water masses (Section 6.3.3.3; Ref. 104; appendix a). Pelagic fishes accounted for 99% of individuals observed and were significantly more abundant in the shallower water KEFs, including the continental slope demersal fish communities KEF. . Where the DA crosses this KEF the most dominant BCH identified in the habitat mapping were irregular and smooth seabed with bare substrates and discrete depressions of bare substrate. Topographically complex habitat, in varying percent cover (from low [<10%] to high cover [>80%]) of epibenthic invertebrate were predicted to be present traversing through the DA within this KEF (Ref. 104; appendix a), where demersal fishes may frequent these areas to shelter from currents and reduce energetic demands but will roam more widely for foraging (Ref. 748).. As previously assessed, potential impacts to pelagic fishes are considered unlikely, while only limited displacement of demersal fish individuals is expected.

The disturbance footprint represents ~0.69% of the total DA and therefore, corresponds to an even smaller percentage of disturbance within the KEFs. Furthermore, although the entire Ancient coastline and Exmouth Plateau KEFs are identified as having unique seafloor features comprising areas of hard substrate (Ref. 102), these values were not identified or predicted within the area of the KEFs that overlaps with the proposed infrastructure. Consequently, changes to values and sensitivities of these KEFs are not expected.

Despite the DA overlapping three KEFs, the potential impact to their values is limited. The extent of any potential impact is relatively localised and limited to activities related to specific fields, with the DA only covering <1% of each KEF.

Given the nature of the receiving environment, the characteristics of KEFs within the DA, changes to the values and sensitivities of relevant KEFs are not expected. However, limited impact to BCH within the KEFs may occur and was determined as Incidental (6) for the short-term disturbance. Due to the long-term presence of the infrastructure, impacts from localised and long-term disturbance were determined to be Moderate (4).

As the DA is expected to predominantly consist of a mixture of flat sediment terrain with bioturbation or bare sediment with limited epibenthic and infaunal invertebrates represented throughout the region, the likelihood is assessed as Unlikely (4).

Overall, the risk of seabed disturbance to KEFs is Very Low (9) from short-term disturbance and Low (7) from long-term disturbance.

Risk evaluation
Cultural heritage value: underwater cultural heritage
No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken.
Cultural heritage value: Traditional Owners
Change to cultural heritage values No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the DA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. archaeology) are expected; and no further evaluation has been undertaken. Based on the outcomes of Phase 1 stakeholder consultation (Section 6.3.5.2.1), CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur due to alterations to benthic habitats and associated communities. The consequence evaluations to these receptors are provided above, and the highest consequence level was evaluated as Moderate (4). As such, the consequence for cultural heritage values is evaluated as consistent with that for benthic habitat and associated communities, as Moderate (4). Any impact will be limited to the immediate vicinity of the disturbance, and thus the extent of potential impact is relatively localised. A significant adverse change to cultural values attributed to the offshore marine area is not predicted to occur, though the infrastructure will be in place for a long time. Therefore, the likelihood of the consequence occurring as Unlikely (4). The risk of seabed disturbance to Traditional Owner cultural heritage values is Low (7).

8.1.3 determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-5 details the determination of acceptability for seabed disturbance.

Table 8-5: Determination of acceptability for seabed disturbance

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-01**, **AL-02**, **AL-03**, **AL-04**, and **AL-07**, as defined in Table 7-6 and shown below in Section 8.1.4. As described in the impact and risk evaluation (Section 8.1.2), the predicted impacts range from a short-term, direct reduction in water quality within a localised area, to localised impacts to benthic habitats and communities. As such, these impacts are not expected to substantially affect the biodiversity, ecosystem function, or integrity of the DA. Therefore, the predicted level of impact for these receptors is better than **AL-01**, **AL-02**, and **AL-03**. In addition, no impacts to tangible seabed-based cultural heritage are expected. Therefore, the predicted level of impact is better than **AL-04**. As a significant adverse change to traditional owner cultural values attributed is not predicted to occur, the predicted level of impact is equal to or better than **AL-07**.
Principles of ESD	**(b) 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 highest consequence level for seabed disturbance was evaluated as Moderate (4). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that:

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">

The results of the benthic habitat survey (appendix a), which are supported by a literature review of previous surveys in the NWS region, provides scientific certainty to inform the impact and risk evaluation for seabed disturbance.
To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.

</td></tr>
<tr><td></td><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td></td><td colspan="2">
The Development is consistent with principle of ESD (c) for this aspect as:

The Development is committed to applying measures to prevent the impact and risk of seabed disturbance based on relevant environmental legislation and other requirements as listed below.
The regulation and management of seabed disturbance in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence level for seabed disturbance was evaluated as Moderate (4). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
Any relevant stakeholder feedback in relation to seabed disturbance has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">
Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.
</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>Environment Protection (Sea Dumping) Act 1981 (Cth)
A sea dumping permit is required if any objects are planned to be left in situ.</td><td rowspan="2">Legislative requirements to manage seabed disturbance are addressed by adopting these EPOs and control measures:
• EPO-06
• CM-03
• CM-04.</td></tr>
<tr><td></td><td>Offshore Petroleum Decommissioning Guideline (DISER) (Ref. 75)
Decommissioning options other than complete removal may be considered, if the titleholder demonstrates that the alternative decommissioning approach delivers equal or better environmental, safety</td></tr>
</table>

Determination of acceptability		
	and well integrity outcomes, and that the approach complies with all other legislative and regulatory requirements.	
	Section 572 Maintenance and removal of property Policy (NOPSEMA) (Ref. 80) • all property is designed, installed and operated with the intention of being removed when it is no longer in use • when a field permanently ceases production, all remaining property is removed if it is not to be used in connection with the operations • a comparative assessment may be used in an EP as a method to evaluate feasible alternatives to removing property • when an evaluation of impacts and risks are required by the OPGGS(E)R, they must incorporate a holistic evaluation of the impacts and risks of the alternative arrangements (including those impacts and risks that may arise from removing or relocating property outside the title area) and consider community interest.	
Internal context	This procedure was identified as relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included an adaptive management control measure for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to seabed disturbance from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.1.4 environmental performance

Table 8-6 lists the EPO defined for seabed disturbance and the adopted control measures to achieve the outcome.

Table 8-6: Environmental performance for seabed disturbance

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-01: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area. **AL-02**: Impacts on benthic habitats and associated communities from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area. **AL-03**: Any damage to the seabed within title areas will not be inconsistent with the requirements under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth).	**EPO-01**: Planned seabed disturbance within the Development Area will not cause lasting changes to water quality (total suspended solids). Water quality will return to ambient state within seven days following the cessation of the disturbance. **EPO-02**: Undertake seabed surveys of proposed wells and subsea infrastructure locations prior to final field layout design to ensure that: • infrastructure design footprints will be positioned to minimise disturbance to key ecological features • any emergent seabed features or other obstacles are avoided wherever practicable within technical and safety constraints. **EPO-03**: No planned seabed disturbance from the Development to any previously undisturbed exposed hard substrate within the 'ancient coastline at 125 m depth contour' key ecological feature. **EPO-04**: Long-term direct disturbance from the Development is limited to 18.85 km^2 within the Development Area **EPO-05**: Short-term direct disturbance from the Development is limited to 0.98 km^2 within the Development Area. **EPO-06**: Decommissioning of subsea infrastructure will not be inconsistent with obligations under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) and/or other relevant legislation in place at the time.	**CM-01**: Visual seabed inspections conducted prior to drilling, pipelay, or subsea installation ensures no previously undisturbed exposed hard substrate within the 'ancient coastline at 125 m depth contour' key ecological feature is within the proposed disturbance footprint. **CM-02**: Develop and maintain an inventory of subsea assets for the Development. **CM-03**: Remove all property above the mudline unless an alternative decommissioning approach has been accepted by NOPSEMA. **CM-04**: If property is accepted to be decommissioned in situ, a sea dumping permit will be acquired in accordance with the *Environmental Protection (Sea Dumping) Act 1981* (Cth).
AL-04: No adverse impact[96] on declared or protected underwater cultural heritage[97] from the Development that	**EPO-07**: Undertake an underwater cultural heritage assessment of proposed wells and subsea infrastructure	**CM-05**: Implement CAPL's Inadvertent Underwater Cultural Heritage Discovery Procedures (Ref. 691),

[96] Where 'adverse impact' is defined under section 30 of the UCH Act.

[97] Where underwater cultural heritage is defined under section 15 of the UCH Act.

Acceptable levels	Environmental performance outcomes	Adopted control measures
would be inconsistent with the protection and conservation objects of the *Underwater Cultural Heritage Act 2018* (Cth).	locations prior to final field layout design to identify and report any suspected underwater cultural heritage and to ensure these areas are avoided (unless a permit under section 23 of the *Underwater Cultural Heritage Act 2018* (Cth) is granted). **EPO-08:** No adverse impacts to declared underwater cultural heritage without a permit[98] from planned activities associated with the Development.	including processes for notification and response to suspected discoveries. **CM-06**: Discovery of suspected underwater cultural heritage is reported to the Minister within 21 days of discovery as per section 40 of the *Underwater Cultural Heritage Act 2018* (Cth).
AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

8.2 air emissions

8.2.1 source

The MODU, vessels and machinery produce air emissions that contain atmospheric pollutants. The atmospheric pollutants considered in this section include:

- nitrogen dioxide (NO_2), as representative pollutant for nitrogen oxides (NO_x), which is a generic term for the mono-nitrogen oxides, i.e. nitric oxide (NO) and NO_2
- airborne particulate matter (PM), which includes particulate matter of size 10 microns and lower
- sulfur dioxide (SO_2), as representative pollutant for sulfur oxides (SO_x), which include sulfur monoxide (SO), sulfur trioxide (SO_3), and other combinations of sulfur and oxygen
- non-methane volatile organic compounds (NMVOCs), including aliphatic hydrocarbons (propane and longer straight chain hydrocarbons) and aromatic hydrocarbons such as BTEX
- carbon monoxide (CO)
- mercury (Hg)

[98] Where a permit under section 23 of the UCH Act has been granted.

- ozone-depleting substances (ODS).

Table 8-7 lists the activities in each phase that have the potential to generate air emissions that contain the atmospheric pollutants listed above.

Table 8-7: Phases and activities that generate Air emissions

Phase	Activity
Drilling	Well suspension Well clean-up and testing
Installation and commissioning	Hydrotest and pre-commissioning
Operations	Well intervention
Support activities	MODU operations Vessel operations Helicopter operations

8.2.1.1 drilling

Flaring may be required as a contingency during flowback activities. Air emissions from gas flaring during flowback may contain NO_x, SO_2, NMVOCs, CO and Hg (Ref. 266).

If flaring is required, it may occur intermittently over ~1 day. Flaring will only occur from one well at a time. The indicative estimated volume of flared reservoir gas is 60 MMscf per well.

During well suspension, small volumes of reservoir gas may need to be handled back to the rig. The indicative estimated volume of cold vented reservoir methane gas is 0.1 MMscf per well.

8.2.1.2 installation and commissioning

During pre-commissioning, nitrogen gas and compressed air from the flowline may be vented at the sea surface via a downline. An estimated 5,250,000 m^3 of nitrogen gas or compressed air may be vented per event. This volume is based on estimates for the longest Chandon flowline, and volumes would be less at the other fields.

8.2.1.3 operations

Flaring and venting may be required as part of well intervention and well suspension, respectively. Emissions are not expected to be different to those described above (Section 8.2.1.1) for drilling.

8.2.1.4 support activities (all phases)

Vessels, helicopters and the MODU use diesel or gas to generate power for operation. Vessels will use MDO or MGO. Combustion of these fuels releases atmospheric pollutants including NO_x, PM, SO_2, NMVOCs and CO (Ref. 266).

Vessels and the MODU may also be a source of fugitive emissions from the diesel storage tanks on board. Fugitive emissions may contain NMVOCs and Hg.

Vessels and the MODU have low potential for ODSs to be present on board; ODSs are typically found in old refrigeration and air conditioning equipment.

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well

interventions). The MODU will move between fields but will spend most of the time at the DCs. The MODU may be kept on location using anchoring or DP. The impact evaluation for air emissions will consider the MODU using DP as the worst-case scenario for air emissions.

Vessels are present in the DA during all phases of the Development. A variety of vessels will be used. Up to ten vessels are estimated to be present. This may occur due to the presence of multiple vessels in the DA at any given time, and/or different activities (e.g. drilling, installation) occurring close to each other simultaneously.

Helicopters operate during drilling, installation and commissioning, operations and decommissioning phases, but are far less frequent during operations. During drilling, installation and commissioning, and decommissioning, helicopters may need to service the MODU ~5 times per week and ~15-16 times per week for larger vessels.

8.2.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified this receptor within the DA that may be impacted by air emissions:

- air quality.

CAPL has concluded that air emissions from the Development are not expected to pose a risk to marine fauna because exposure is limited to the immediate vicinity of the source, emissions are temporary, and the DA is located in the offshore marine environment where long-term air pollutant exposure to air-breathing marine fauna is not credible .

Therefore, impacts to marine fauna from air emissions are not expected, and are not evaluated further.

Table 8-8 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to air emissions in the DA.

Table 8-8: Impact and risk evaluation for air emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Air emissions may result in: • localised and temporary reduction in air quality.	6	N/A	–	–	–

Impact evaluation
Air quality
Localised and temporary reduction in air quality Air emissions containing atmospheric pollutants from the Development activities will result in localised and temporary reduction in air quality within the DA. MODU, vessel and helicopter operations will release exhaust air emissions containing atmospheric pollutants including NO_x, PM_{10}, SO_2, NMVOCs and CO. Modelling was undertaken for NO_x emissions for MODU power generation for another offshore project (Ref. 267). The modelling focused on NO_x based on larger predicted emission volumes compared to other pollutants (i.e. PM_{10}, SO_2, NMVOCs and CO). Modelling of PM_{10}, SO_2, NMVOCs and CO was not deemed necessary as concentrations are expected to be very low based on using low sulfur diesel for MODU operations. Although this modelling was carried out for a different MODU, the modelled distances provide a good measure of the order of magnitude over which an increase in ambient concentration could

Impact evaluation
be predicted for hourly rate of operation of a MODU and a conservative estimate for vessels and helicopter operations. The results of this modelling indicate that on an hourly average, there is the potential for an increase in ambient NO_2 concentrations of 0.0005 ppm within 10 km of the emission source and an increase of <0.1 µg/m^3 (0.00005 ppm) in ambient NO_2 concentrations >40 km away. NEPM ambient air quality standards [National Environment Protection (Ambient Air Quality) Measure] recommend that hourly exposure to NO_2 is <0.08 ppm with annual average exposure <0.015 ppm. The results of this modelling indicate the highest hourly averages (0.00039 ppm or 0.74 µg/m^3) were restricted to a distance of ~5 km from the MODU (Ref. 267), which is below NEPM standards [National Environment Protection (Ambient Air Quality) Measure]. The volume of fuel required for power generation for vessels and helicopters is expected to be significantly less than for MODU operations, and it is expected that the concentration of atmospheric pollutants generated from vessel and helicopter operations, even where multiple vessels are present at one time, is likely to be lower. Air emissions from MODU, vessel and helicopter movements across the DA are expected to disperse rapidly and are not expected to result in noticeable increases in atmospheric pollutants locally or regionally. Hydrocarbon storage tanks on vessels and subsea infrastructure may release fugitive emissions containing NMVOCs and Hg atmospheric pollutants. Fugitive emissions are not considered to be major sources of atmospheric pollutants due to the expected low emission rates (fugitive emissions) and limited overall volumes anticipated. Well clean-up is a once-off activity for each well. Well interventions will be infrequent during the operations phase (no more than once a year per well) and flaring may not be required. If flaring occurs, it may occur intermittently over ~1 day. Flaring will only occur from one well at a time. ODSs may be present on board vessels that have old refrigeration and air conditioning equipment. However, the release of ODSs during the Development is not planned or anticipated. Nitrogen gas, which is released during pre-commissioning, is not considered a pollutant, as it makes up ~78% of the atmosphere and is not expected to have any impact to the environment. Similarly, any compressed air released during pre-commissioning is not considered to have any impact on the environment. Air quality in the DA is expected to be high and typical of an unpolluted offshore marine environment. Wind patterns vary with the season, but average speeds are 6–13 m/s. Wind conditions experienced in the open offshore marine environment of the DA, which is >115 km from the Pilbara coast, are expected to rapidly disperse any air emissions temporarily generated during the Development. Air quality is expected to return to baseline levels after air emissions cease. The impact associated with air emissions is limited to a short-term reduction in air quality within a localised area. No regional scale impacts to air quality are expected. Therefore, the consequence of air emissions causing a change in air quality has been evaluated as Incidental (6).

8.2.3 determination of acceptability

The acceptable level of impact is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-9 details the determination of acceptability for air emissions.

Table 8-9: Determination of acceptability for air emissions

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-01**, as defined in Table 7-6 and shown below in Section 8.2.4. As described in the impact and risk evaluation (Section 8.2.2), the predicted impact to air quality is limited to a short-term reduction in air quality in a localised area. Therefore, the predicted level of impact is better than **AL-01**.
Principles of ESD	**(b) 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 highest consequence level for air emissions was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required.
Notwithstanding, CAPL also notes that:
• Prevention measures for air emissions are well regulated and managed in Australian waters (e.g. via implementation of MARPOL requirements).
• To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td></td><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the impact and risk of air emissions based on relevant environmental legislation and other requirements as listed below.
• The regulation and management of air emissions in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for air emissions was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to air emissions has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>AMSA Marine Order 97: Marine Pollution Prevention – Air Pollution
Sets out the requirements for preventing air pollution by vessels including certification requirements, reporting requirements, incineration on board a vessel, energy efficiency, servicing and record keeping.</td><td rowspan="2">Legislative requirements to manage air emissions are addressed by adopting this control measure:
• CM-09.</td></tr>
<tr><td></td><td>Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian</td></tr>
</table>

Determination of acceptability		
	waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.	
	***Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth)** Reduces emissions of ozone depleting substances (ODSs) and synthetic GHGs. It controls the manufacture, import and export of ODSs and synthetic GHGs and products containing these gases.	
Internal context	This environmental performance standard/procedure was deemed relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. No feedback was received in relation to air emissions from Phase 1 stakeholder consultation.	

8.2.4 environmental performance

Table 8-10 lists the EPO defined for air emissions and the adopted control measures to achieve the outcome.

Table 8-10: Environmental performance for air emissions

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-01: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	**EPO-10**: Planned air emissions within the Development Area will not cause lasting changes to air quality. Air quality will return to ambient state within seven days following the cessation of the emission.	**CM-09**: Vessels operating within the Development Area will comply with requirements within Marine Order 97—Marine pollution—air pollution.

8.3 greenhouse gas emissions

8.3.1 terminology

Within this OPP the following terminology has been adopted to describe greenhouse gas (GHG) emissions:

- **BFF GHG emissions**—these are GHG emissions that are a direct consequence of planned petroleum activities that comprise the Development (as described in Section 4) from sources within the DA in Commonwealth waters

- **BFF gas processing GHG emissions**—these are GHG emissions from sources outside the DA associated with CAPL's operation of the Gorgon Gas Development facilities (as outlined in MS 800)[99] and that are an indirect consequence of the Development
- **BFF secondary GHG emissions**—these are transport (shipping) and third-party end use GHG emissions that are a reasonably foreseeable consequence of the Development from sources outside the DA.

8.3.2 GHG inventory boundary

The GHG Protocol identifies 'relevance' as one of the principles of GHG accounting and reporting, of which an integral aspect is defining an appropriate GHG emissions inventory boundary that serves the decision-making needs of the users (Ref. 269).

The purpose of the GHG emissions inventory for the Development is to inform the environmental impact and risk assessment within this OPP. This OPP is the primary environmental approval for the GHG emissions resulting from the addition of the Development (i.e. BFF GHG emissions). Therefore, the GHG emissions inventory boundary for this OPP is bound by the scope of the planned petroleum activities as described in Section 4. Note: Unplanned events (including major repairs and responding to emergency events) are considered out of scope of the emissions inventory.

In having regard of the EPBC Act Policy Statement—'Indirect consequences' of an action: Section 527E of the EPBC Act (hereafter referred to as the EPBC Indirect Consequences Policy; Ref. 757), GHG emissions that constitute 'direct consequences' as well as GHG emissions that may constitute 'indirect consequences' of the Backfill Fields Development have been included in the GHG emissions inventory.

However, gas processing GHG emissions and secondary GHG emissions for the Gorgon Gas Development have been previously estimated and assessed under existing EPBC Act and EP Act primary environmental approvals (Section 8.3.6). A proportion of these Gorgon Gas Development GHG emission estimates (as being substantially caused by the Development) have been included in this inventory for completeness only and to inform the evaluation of impacts and risks associated with the Development in the OPP.

8.3.3 source

GHG emissions refer to any gas that absorbs infrared radiation in the atmosphere (Ref. 268). Greenhouse gases include, but are not limited to:

- carbon dioxide (CO_2)
- nitrous oxide (N_2O)
- methane (CH_4)
- sulphur hexafluoride (SF_6)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs).

[99] This includes emissions from operation of the Gorgon GTP for the processing of LNG and domestic gas, as well as emissions from Barrow Island support operations. This is consistent with the presentation of GHG emissions for the Gorgon Gas Development in existing environment approvals (e.g. Ref. 3; Ref. 6; Ref. 67).

8.3.3.1 BFF GHG emissions

Table 8-11 lists the petroleum activities within each phase of the Development that have the potential to generate BFF GHG emissions.

No emissions from consumption of a purchased energy commodity are associated with the Development. Power to the operate the offshore hydrocarbon system is supplied from the Gorgon GTP, and as such these emissions are captured within BFF gas processing GHG emissions (Section 8.3.3.2).

Table 8-11: Phases and activities that generate BFF GHG emissions

Phase	Activity
Drilling	Well suspension (venting) Well clean-up and testing (flaring)
Installation and commissioning	Commissioning (venting)
Operations	Operation of the hydrocarbon system (fugitive) Well intervention (flaring) Well suspension (venting)
Decommissioning	Well P&A (flaring, venting)
Support activities	MODU operations (fuel consumption) Vessel operations (fuel consumption) Helicopter operations (fuel consumption)

8.3.3.1.1 drilling

As described in Section 4.3.2.9, wells may be subject to flowback at the end of the completions phase (noting that not all wells may be subject to flowback). Flaring may be required as a contingency during well flowback activities. Based on CAPL's operational experience on the NWS a typical volume of reservoir gas flared during well flowback has been estimated at 60 MMscf per well, with this flaring occurring over ~1 day. Flaring may not be constant during well flowback (i.e. it may intermittently occur over ~1 day). Unforeseen circumstances such as weather events or a trip of safety systems, may cause the flowback and flaring to be done again. For each drilling campaign (i.e. per field or co-developed field), flowback and flaring will only occur from one well at a time.

Given that well flowback is not required to be undertaken at every well during a drilling campaign, an allowance of the equivalent of ~60 MMscf over one day for each of the 40 wells within scope of this OPP is considered conservative to estimate GHG emissions for both initial and any repeated flaring required.

As described in Section 4.3.2.6, during well suspension, small volumes of reservoir gas may need to be handled back to the rig and would be cold vented to the atmosphere. The indicative volume of cold vented reservoir gas is ~0.5 MMscf per well.

8.3.3.1.2 installation and commissioning

During commissioning of the production flowlines, there may be the requirement to purge nitrogen and methane gas (Section 4.3.3.7).

A gas dispersion study was undertaken by Wood Group to investigate the gas plume behaviour of a subsea release of nitrogen and methane in deep water (1,200 m) and shallow water (150 m) (Ref. 553). Based on the outcomes of this study (refer to summary in Section 8.7.1.1.2), no atmospheric release of methane

is predicted for deep-water sites, however some release to atmosphere would occur for a shallow-water release. Therefore, for the purposes of informing the impact and risk assessment, ~6,000 Sm^3 of methane is assumed to reach the surface and be released to the atmosphere at WTR; this volume is considered conservative as it is based on the longest flowline at WTR and is not allowing for any dissolution into the water column to occur.

8.3.3.1.3 operations

Fugitive GHG emissions may occur from the Development's subsea hydrocarbon system in Commonwealth waters; however, these would represent a minor contribution to the overall GHG emissions inventory. Fugitive emissions for the Gorgon Gas Development are estimated based on product throughput (as per accepted National Greenhouse and Energy Reporting [NGER] scheme methodology), and therefore, any offshore component for the Development cannot easily be separated. As such, fugitive emissions estimates for the Development are incorporated into the BFF gas processing GHG emissions inventory (Section 8.3.3.2).

Flaring may be required as part of well intervention activities (Section 4.3.4.5). For the purpose of the impact and risk evaluation within this OPP an allowance of 60 MMscf over ~1 day of flaring per well intervention has been carried. This rate and duration is consistent with estimates for flaring during well flowback.

Well intervention activities may include well suspension (Section 4.3.4.5). During well suspension small volumes of reservoir gas may need to be transferred back to the MODU. If the volume is too small to flare, it will be cold vented to atmosphere. Given well suspension is a contingency activity during both drilling and operations phases of the Development, GHG emissions have only been estimated once (under the drilling phase) as part of this GHG emissions inventory.

8.3.3.1.4 decommissioning

During well P&A, if any residual gas is returned to the MODU this may be flared, or where the volume of gas is too small to flare this will be cold vented (Section 4.3.5.8). Indicative volumes of flared or cold vented reservoir gas during well P&A is ~1.5 MMscf and ~0.5 MMscf per well respectively.

8.3.3.1.5 support activities (all phases)

Vessels, MODUs, and helicopters can use hydrocarbon-based fuels (e.g. diesel, gas, marine fuel, aviation fuel) to generate power for operation. Any equipment (e.g. ROVs, MBES, etc.) used during vessel-based activities are powered by the vessel itself, and as such these do not represent an additional emission source to that already accounted for by the vessel.

Vessels and the MODU have diesel storage tanks on board, which may also be a source of fugitive emissions. However, this is considered a negligible source of GHG emissions and has not been quantified as part of this inventory.

Note: The GHG emissions inventory presents these support activities as part of the relevant Development phase (i.e. survey, drilling, installation and commissioning, operations, and decommissioning).

8.3.3.2 BFF gas processing GHG emissions

The purpose of the Development is to maintain gas supply to the GTP on Barrow Island (part of the approved Gorgon Gas Development and constructed as part of

the GFP). Therefore, in having regard to the EPBC Indirect Consequences Policy the processing of the gas from the seven backfill fields at the GTP on Barrow Island has been assessed as an indirect consequence of the Backfill Fields Development.

As gas from the Development will not be the only feed gas supply for the Gorgon GTP, a proportion of production and hence a proportion of GHG emissions from the overall Gorgon Gas Development will be substantially caused by the Development. Therefore, this GHG emissions inventory has been prepared to estimate the proportion of Gorgon Gas Development's gas processing GHG emissions associated with the Development.

It is important to note that in addition to only a portion of these Gorgon Gas Development GHG emissions being substantially caused by the Development, all of the gas processing GHG emissions from the Gorgon Gas Development have previously been described and assessed in existing primary and secondary environmental approvals (e.g. Ref. 3; Ref. 6; Ref. 67; Ref. 9).

No change to previously approved GHG emissions is being sought under the Development OPP in relation to the overall Gorgon Gas Development gas processing GHG emissions. The proportion of emissions (as substantially caused by the Development) are provided as part of this GHG emissions inventory for completeness, and to inform the impact and risk evaluation within the OPP.

8.3.3.3 GFP secondary GHG emissions

For the purposes of the EPBC Indirect Consequences Policy, the transport and third-party end use of LNG, condensate and domestic gas products following processing at the Gorgon GTP on Barrow Island (part of the approved Gorgon Gas Development) have been assessed as reasonably foreseeable 'secondary actions' and the associated GHG emissions as reasonably foreseeable direct consequences of those 'secondary actions'. Accordingly, they are 'indirect consequences' of the Development.

As per the treatment of BFF gas processing GHG emissions, the BFF secondary GHG emissions presented in this inventory are a proportion of the overall Gorgon Gas Development GHG emissions.

All secondary GHG emissions for the Gorgon Gas Development have been described and assessed in existing primary and secondary environmental approvals (e.g. Ref. 1; Ref. 6; Ref. 67; Ref. 9). The proportion of emissions (as substantially caused by the Development), are provided as part of this GHG emissions inventory for completeness, and to inform the impact and risk evaluation within this OPP.

8.3.4 GHG modelling

A GHG Emissions Technical Note (Ref. 584) has been prepared and is provided in appendix e.

8.3.4.1 methodology

BFF GHG emissions have been calculated based on the methods described in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth) for the combustion of liquid fuels and flaring, and on methods described in the API Compendium of Greenhouse Gas Emissions Methodologies (Ref. 64) for cold venting. For further detail on the methods, inputs and assumptions refer to Section 2 of the GHG Emissions Technical Note (appendix e).

An overview of the methods for the estimation of BFF gas processing GHG emissions and BFF secondary GHG emissions (i.e. proportions of overall Gorgon Gas Development GHG emissions) are provided in Section 2 of the GHG Emissions Technical Note (appendix e).

Note: The below GHG emissions inventory for the Development does not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken for the Gorgon Gas Development or by third-parties. For example, there are regulatory GHG emission reduction requirements for the Gorgon Gas Development (e.g. Commonwealth Safeguard Mechanism [Section 8.3.5.3] and environmental approval conditions under the EP Act (WA) [Section 8.3.6.1]), or similarly any actions taken by third-parties in respect to transport or end use of products (Section 8.3.7).

8.3.4.2 BFF GHG emissions

Based on the GHG inventory boundary (Section 8.3.2) and methodology (Section 8.3.4.1), the estimate of total BFF direct GHG emissions over the life of the Development[100] is ~3.075 Mt CO_2-e (Table 8-12).

The proportion of estimated total GHG emissions generated during each phase of the Backfill Field Development varies, with the highest proportions associated with drilling, operations and decommissioning (Figure 8-1).

Table 8-12: Estimated BFF direct GHG emissions and BFF indirect GHG emissions over the life of the Development

Phase	Estimated total BFF GHG emissions over the life of the Development[100] (Mt CO_2-e)
Surveys	0.034
Drilling	0.855
Installation and commissioning	0.367
Operations	1.007
Decommissioning	0.812
Total	**3.075**

[100] Where 'life of the Development' is represented as FY2027–FY2070 (44 years). This period is based on indicative commencement of drilling activities for the first of the backfill fields (Table 4-2) and the indicative end of life of the Development (consistent with that for the overall Gorgon Gas Development; Section 4.1.4).

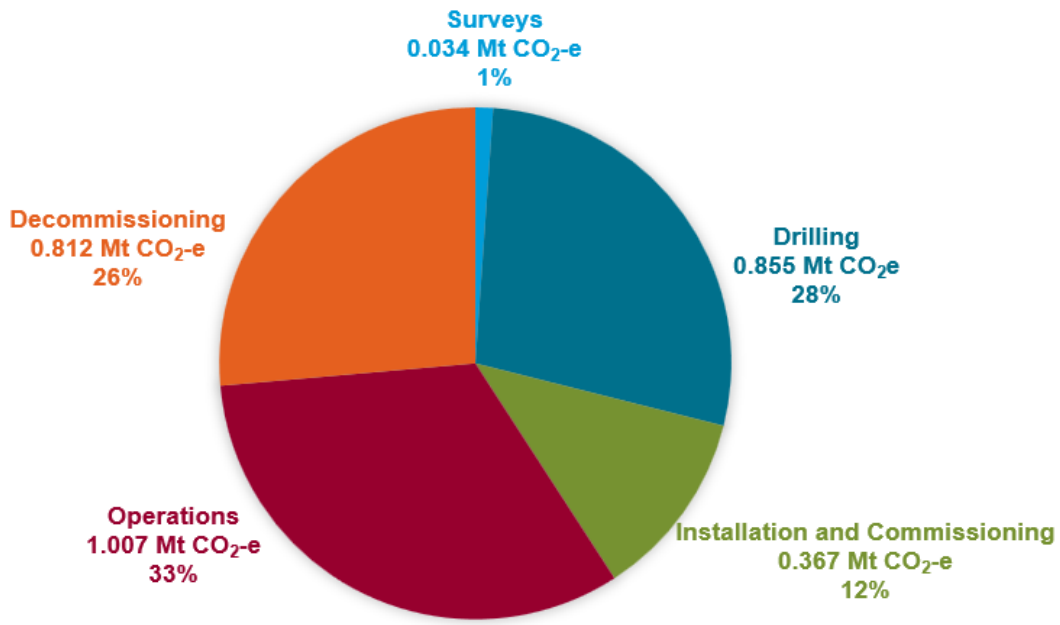


Figure 8-1: Estimated total BFF GHG emissions associated with different phases of the Development

8.3.4.3 BFF gas processing GHG emissions

The gas processing GHG emissions attributable to the Development has been estimated by considering the proportion of production forecast from the seven backfill fields, as a subset of the total Gorgon Gas Development production forecast[101], over the indicative operational life of the Backfill Fields Development[102] (appendix e).

The estimated total BFF gas processing GHG emissions over the operational life of the Development is ~107.8 Mt CO_2-e. When converted to an annual average over the operational life of the Backfill Fields Development this equates to an estimate of ~2.8 Mtpa CO_2-e[103].

8.3.4.4 BFF secondary GHG emissions

As per the treatment of BFF gas processing GHG emissions, the BFF secondary GHG emissions presented in the inventory represent a proportion of the overall Gorgon Gas Development secondary GHG emissions (appendix e).

The estimated total BFF secondary GHG emissions over the operational life of the Development[102] is ~600.7 Mt CO_2-e. When converted to an annual average over

[101] Forecast production rates were based on information available at the time of development of the Backfill Fields Development OPP and Gorgon GTP GHGMP, and may be subject to change as modelling improves or business decisions change.

[102] Where 'operational life of the Development' is represented as FY2029–FY2066 (38 years). This period is based on indicative RFSU for the first of the backfill fields (Table 4-2) and the indicative date of the start of decommissioning (consistent with the Gorgon GTP GHGMP; Ref. 67).

[103] This annual average is a long-term estimate based on the 'operational life of the Gorgon Gas Development' represented as FY2029–FY2066 (38 years). However, as the forecast production takes into consideration lower production in the latter years of the Gorgon Gas Development, the annual average for BFF gas processing GHG emissions over a 'nominal period of three-train operations' represented as FY2029–FY2050 (22 years) is estimated at ~4.4 Mtpa CO_2-e, being higher than the long-term operational life estimate.

the operational life of the Development this equates to an estimate of ~15.8 Mtpa CO_2-e[104].

8.3.4.5 summary

The estimated total GHG emissions for the Backfill Fields Development are summarised in Table 8-13.

These estimates correspond to the total GHG emissions for the Development and do not take into account any potential GHG emissions mitigations, reductions, or offset opportunities that may be undertaken by the Gorgon Gas Development or by third-parties.

At the time of writing this OPP there are two sets of regulatory GHG emission reduction requirements for the Gorgon Gas Development: EP Act approval conditions (Section 8.3.6.1) and the Safeguard Mechanism scheme (Section 8.3.5.3). Both sets of regulatory requirements have GHG emissions from the Gorgon Gas Development on a trajectory to net zero by 2050.

The Gorgon Gas Development supplies both Australian markets (domestic gas) and international markets (LNG and condensate). The primary long-term export markets have commitments in place to manage GHG emissions in their jurisdictions (Section 8.3.7).

Table 8-13: Estimated total GHG emissions for the Backfill Fields Development

Emission source	Emission location	Jurisdiction for GHG emissions management	Estimated total[105] GHG emissions for the Backfill Fields Development[106] (Mt CO_2-e)	Estimated annual average[105] GHG emissions for the Backfill Fields Development[106] (Mtpa CO_2-e)
BFF GHG emissions				
Fuel combustion (MODU, vessels)	Development Area (Commonwealth waters)	Australia	2.64	0.06
Fuel combustion (helicopters)			0.04	0.001
Flaring (MODU)			0.37	0.01
Cold venting (MODU)			0.02	0.004
BFF gas processing GHG emissions				
Gas processing at the GTP[107]	Barrow Island (State onshore)	Australia	107.8	2.8

[104] This annual average is a long-term estimate based on the 'operational life of the Gorgon Gas Development' represented as FY2029–FY2066 (38 years). However, as the forecast production takes into consideration lower production in the latter years of the Gorgon Gas Development, the annual average for BFF secondary GHG emissions over a 'nominal period of three-train operations' represented as FY2029–FY2050 (22 years) is estimated to be ~24.7 Mtpa CO_2-e, being higher than the long-term operational life estimate.

[105] All estimated GHG emissions presented in this table do not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken.

[106] For BFF GHG emissions this refers to the 'life of the Backfill Fields Development' as represented by FY2027–FY2070 (44 years). However, for BFF gas processing GHG emissions and BFF secondary GHG emissions this refers to the 'operational life of the Backfill Fields Development') as represented by FY2029–FY2066 (38 years).

[107] This includes emissions from operation of the Gorgon GTP for the processing of LNG and domestic gas, as well as emissions from Barrow Island support operations.

Emission source	Emission location	Jurisdiction for GHG emissions management	Estimated total[105] GHG emissions for the Backfill Fields Development[106] (Mt CO_2-e)	Estimated annual average[105] GHG emissions for the Backfill Fields Development[106] (Mtpa CO_2-e)
Purchased electricity[108]	N/A	N/A	0	0
BFF secondary GHG emissions				
Transport and third-party end use (LNG, condensate, and domestic gas)	Western Australia (domestic gas)	Australia	600.7	15.8
	Subject to consumer location (LNG, condensate)	Subject to consumer location		
		Total	**711.6**	**18.7**

8.3.5 relevant GHG legislative and policy framework

The following subsections are specifically relevant to the GHG emissions legislative framework and are intended to be read in combination with the information in Section 2.

8.3.5.1 paris agreement

Australia is a party to, and has ratified, the Paris Agreement. The Paris Agreement is an international treaty on climate change that entered into force in November 2016 (Ref. 514). Article 2 of the Paris Agreement states that it "aims to strengthen the global response to the threat of climate change, in the context of sustainable development and the efforts to eradicate poverty, including by" … "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change." (Article 2; Ref. 515).

Implementation of the Paris Agreement requires economic and social transformation, based on the best available science (Ref. 514). The Paris Agreement works on a 5-year cycle of increasingly ambitious climate action carried out by countries (Ref. 514). Countries submit their plans for climate action—these plans are known as NDCs. In their NDCs, countries communicate actions they will take to reduce their GHG emissions to reach the goals of the Paris Agreement. Countries also communicate in the NDCs actions they will take to build resilience to adapt to the impacts of climate change (Ref. 514).

Australia submitted its first NDC to the UNFCCC in 2015 and submitted an update in July 2022. The update commits Australia to reduce its emissions to 43% below 2005 levels by 2030 (Ref. 516). This 2030 commitment is both a single-year 'point' target to reduce emissions 43% below 2005 levels by 2030, and a multi-year 'emissions budget' from 2021–2030 (based on a 43% reduction by 2030, the

[108] There is no purchased electricity associated with the Gorgon Gas Development. All electricity is generated on Barrow Island (including any power required for subsea operations) and any associated emissions are therefore already incorporated into the 'BFF gas processing at the GTP' emissions estimate.

indicative emissions budget for this period is 4,353 Mt CO_2-e)[109]. Within the NDC submission, Australia also reaffirmed its target to achieve net zero emissions by 2050 (Ref. 516). In September 2025 Australia submitted its second NDC to the UNFCCC. Australia's 2035 commitment is a "[r]eduction in net national greenhouse gas emissions of 62–70% below 2005 levels by 2035, implemented as an emissions budget covering the period 2031–35" (Ref. 762).

Australia regularly reports to the UNFCCC on climate change policies and measures. The latest National Inventory Report (Ref. 517) was submitted to the UN Climate Change secretariat in May 2025. The estimated net annual GHG emissions for FY2023 were 453.4 Mt CO_2-e; this is a 25.9% decrease from 611.9 Mt CO_2-e in FY2005 (Ref. 517). Australia's net emissions peaked in FY2006 and have generally been on a long-term decline since that financial year (Ref. 517).

8.3.5.2 climate change act 2022

The *Climate Change Act 2022* (Cth) sets out Australia's GHG emissions reduction targets in a manner consistent with the Paris Agreement and Australia's 2030 NDC under that agreement[110].

Australia's GHG emissions reduction targets are:

- reduce net GHG emissions to 43% below 2005 levels by 2030, which is implemented as a point target as well as an emissions budget covering the period 2021–2030.
- reduce Australia's net GHG emissions to zero by 2050.

Under the *Climate Change Act 2022* (Cth) the Minister must prepare an annual climate change statement. The latest report, prepared by the Climate Change Authority and provided to the Minister in November 2024 stated that "emissions are falling but not yet at the rate required to meet Australia's 2030 emissions reduction target" (Ref. 518).

8.3.5.3 NGER and Safeguard Mechanism schemes

The NGER scheme is the Australian Government's national framework for reporting facility information about GHG emissions, energy production, and energy consumption. The scheme is administered through the NGER Act (Cth) and associated regulations.

The Safeguard Mechanism is the Australian Government's scheme that requires relevant industrial facilities to reduce their emissions in line with Australia's GHG emission reduction targets of 43% below 2005 levels by 2030, and net zero by 2050. The Safeguard Mechanism applies to industrial facilities that emit more than 100,000 tonnes of carbon dioxide equivalent (CO_2-e) in a year. The Safeguard Mechanism commenced in 2016 and was reformed in 2023. The Safeguard Mechanism is enacted through the NGER Act, as amended by *the Safeguard Mechanism (Crediting) Amendment Bill 2023* (Cth); and with additional scheme details as set out in the *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015* (Cth).

[109] Note: Following FY2024 revisions to Australia's historical GHG emissions estimates, Australia's implied GHG emissions budget is 4,377 Mt CO_2-e (Ref. 62; Ref. 534).

[110] The Australian Government has recently (September 2025) submitted its second NDC; refer to Section 8.3.5.1.

Safeguard Mechanism facilities have an annual net GHG emission limit known as a 'baseline'. As part of the 2023 reforms, a decline rate is now applied to a facilities baseline so that it is reduced over time on a trajectory consistent with achieving Australia's emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050 (Ref. 519). In general, baselines will decline by 4.9% each financial year from FY2024 through to FY2030. The subsequent decline rate will be set in 5-year blocks consistent with updates to Australia's NDC under the Paris Agreement (Ref. 519).

The 'Gorgon Operations Facility' is registered with the CER as a facility under both the NGER and Safeguard Mechanism schemes. The scope of the Gorgon Operations Facility includes GHG emissions from both the GTP and associated facilities on Barrow Island, as well as from any activities or facilities in Commonwealth waters (i.e. this would include any activities in Commonwealth waters associated with the Development). The Gorgon Operations Facility has a 'production-adjusted baseline' established under the reformed Safeguard Mechanism. This production-adjusted baseline for FY2024 was ~9.19 Mtpa CO_2-e, inclusive of the 4.9% decline.

All Safeguard facilities' net emissions must be at or below baselines by the annual deadline. Responsible emitters of facilities that exceed or expect to exceed their baselines must manage their excess emissions. Responsible emitters can:

- surrender of Australian carbon credit units (ACCUs) or Safeguard Mechanism credit units (SMCs)
- apply for the use of a flexibility measure under the scheme (e.g. borrowing baseline from the following year, or extending the facility's baseline under a multi-year monitoring period).

Each ACCU or SMC represents one tonne of CO_2-e that has been stored or avoided. These credit units are surrendered to the Australian National Registry of Emissions Units, and are then permanently cancelled, thereby removing them from circulation and preventing their reuse.

8.3.5.4 WA GHG emissions policy for major projects

The WA State Government released an amended *Greenhouse Gas Emissions Policy for Major Projects* in October 2024 (Ref. 520). The intent of this revised policy is to remove duplication in GHG emissions management by the State and Commonwealth governments. Where GHG emissions of a major proposal that is being (or has been) assessed under Part IV of the EP Act (WA), and that proposal is subject to alternative regulatory measures (i.e. the Safeguard Mechanism), the State will no longer apply conditions to reduce net GHG emissions

For existing projects, including the Gorgon Gas Development, the State Government has initiated a review of existing Ministerial Statements under section 46 of the EP Act (WA) to align requirements with the amended policy. At the time of writing this OPP, the section 46 process is underway for the Gorgon Gas Development; however, no changes to existing approval conditions have been finalised or published (i.e. the existing approval conditions remain in place).

8.3.6 primary environmental approvals

The scope of the Gorgon Gas Development, as described in the below environmental approvals, is the extraction and processing of hydrocarbons from the Greater Gorgon Area resources. The Greater Gorgon Area is defined within the *Barrow Island Act 2003* (WA) and Section 1.3.1 of the Draft Environmental

Impact Statement / Environmental Review and Management Programme for the Proposed Gorgon Development (Draft EIS/ERMP) (Ref. 1). The Gorgon and Jansz–Io gas fields are within the Greater Gorgon Area and were the fields selected for development under the GFP.

The two-train Gorgon Gas Development was referred, pursuant to the EPBC Act and EP Act, on 23 November 2003 and 19 November 2003, respectively. The Ministers' delegates set the assessment approach as assessment by environmental impact statement (EIS) under the EPBC Act, and an environmental review and management program (ERMP) under the EP Act. The scope of the proposed development included development of the Greater Gorgon Area gas resource base (Ref. 1). Section 13 of the Draft EIS/ERMP (Ref. 1) and the Final Environmental Impact Statement / Response to Submissions on the Environmental Review and Management Programme for the Proposed Gorgon Development (Ref. 2) set out the environmental impact assessment of GHG emissions. In that assessment it was estimated that the Gorgon Gas Development would emit ~4.01 Mtpa CO_2-e of GHG emissions. The Gorgon Gas Development was approved with conditions (EPBC 2003/1294 and MS 748) by the relevant Ministers on 3 October 2007 and 6 September 2007, respectively. The EPBC Act approval has effect until 1 January 2070.

The Development of Jansz–Io Deepwater Gas Field was referred, pursuant to the EPBC Act, on 22 June 2005. The Ministers' delegate set the assessment approach as assessment by preliminary documentation. The scope of this referral was all physical elements of the Jansz–Io Deepwater within the Commonwealth marine area. The Development of Jansz–Io Deepwater Gas Field was approved with conditions (EPBC 2005/2184) by the Minister on 22 March 2006. This approval was transferred from Mobil Exploration and Producing Australia Pty Ltd to CAPL on 8 September 2009. This EPBC Act approval has effect until 31 December 2050[111].

The Jansz Feed Gas Pipeline was referred, pursuant to the EP Act, on 26 October 2007. The Ministers' delegate set the assessment approach as assessment on referral information. GHG emissions were not identified as an environmental factor requiring assessment. The Jansz Feed Gas Pipeline was approved with conditions (MS 769) by the relevant Minister 30 May 2008.

The three-train Revised and Expanded Gorgon Gas Development was subsequently referred, pursuant to the EPBC Act and EP Act, on 14 April 2008 and 22 February 2008, respectively. The Ministers' delegate set the assessment approach as assessment by public environmental review (PER). Section 12 of the Gorgon Gas Development Revised and Expanded Proposal Public Environmental Review (Ref. 3) set out the environmental impact assessment of GHG emissions. The processing of gas from gas fields in the Greater Gorgon Area by the GTP was the development premise articulated in the PER. In that assessment it was estimated that the Gorgon Gas Development would emit ~5.45 Mtpa CO_2-e of GHG emissions. The Revised Gorgon Gas Development was approved with conditions (EPBC 2008/4178 and MS 800 [as amended from time to time[112]]) by the relevant Ministers on 26 August 2009 and 10 August 2009, respectively. The EPBC Act approval has effect until 26 August 2070. The approved life span for the

[111] CAPL intends to submit an application to extend the effective date of this EPBC Act approval to align with effective dates of other Gorgon Gas Development approvals.

[112] Since the Revised and Expanded Gorgon Gas Development was approved, further changes to the Gorgon Gas Development have been made and/or approved and are now also part of the Gorgon Gas Development. These include MS 865, MS 965, MS 1136, and MS 1198.

Revised and Expanded Gorgon Gas Development contemplated that backfill fields would be required in the future, and would be processed at the GTP, although development of those backfill fields was not assessed and approved as part of the Revised Gorgon Gas Development. Consequently, further assessment and approval steps are required, and this OPP constitutes the primary Commonwealth approval mechanism for the backfill fields (the Development).

The Gorgon Gas Development Fourth Train Expansion Proposal was subsequently referred, pursuant to the EPBC Act and EP Act, on 27 April 2011 and 28 April 2011, respectively. The Ministers' delegate set the assessment approach as assessment by EIS under the EPBC Act, and PER under the EP Act. Section 11 of the Gorgon Gas Development Fourth Train Expansion Proposal Public Environmental Review / Draft Environmental Impact Statement (Ref. 6) set out the environmental impact assessment of GHG emissions. In that assessment it was estimated that the Gorgon Gas Development would emit ~7.69 Mtpa CO_2-e (incorporating CO_2 reinjection estimates) of GHG emissions for four-trains. The Gorgon Gas Development Fourth Train Expansion was approved with conditions (EPBC 2011/5942 and MS 1002) by the Minister on 12 May 2016 and 30 April 2015, respectively. The EPBC Act approval has effect until 1 January 2070.

The GHG emissions estimate for the three-train proposal were revised to an average annual emissions footprint of ~9.47 Mtpa CO_2-e with no abatement in place, and ~6.07 Mtpa CO_2-e incorporating CO_2 reinjection estimates within the Fourth Train Expansion Proposal (approved by the respective Commonwealth and State Ministers on 12 May 2016 and 30 April 2015) and within the Gorgon Gas Development and Jansz Feed Gas Pipeline: Greenhouse Gas Abatement Program (Ref. 270), which was approved by the Minister's delegate of the WA Environmental Protection Authority in May 2015.

In October 2022, the WA Minister for Environment, pursuant to section 46 of the EP Act approved an amendment to the implementation conditions contained within MS 800 by way of MS 1198. These amendments included changes to condition 26 (Reservoir Carbon Dioxide Injection System) and condition 27 (Greenhouse Gas Management Plan). The amendments to condition 27 included setting Net GHG Emission reduction targets at 5-yearly intervals towards net zero GHG emissions by FY 2050) (Section 8.3.6.1). The Gorgon GTP GHGMP (Ref. 67) was developed to satisfy the requirements of condition 27 of MS 800 (as amended by MS 1198), and also included a revised estimate of secondary GHG emissions for the Gorgon Gas Development. This revised estimate is 49.8 Mtpa CO_2-e for a representative year of three-train production. This plan was approved by the Ministers delegate of the WA Environmental Protection Authority in February 2024.

Therefore, any Gorgon Gas Development gas processing GHG emissions should be considered in the context of the revised estimate for the three-train Revised and Expanded Gorgon Gas Development (i.e. average annual emissions of ~9.47 Mtpa CO_2-e[113]). Similarly, any secondary GHG emissions should be considered within the context of the revised estimate for a representative year of three-train production (~49.8 Mtpa CO_2-e[113]).

Note: The fields proposed to be developed as part of the Development are not contingent on the fourth LNG train or the additional Feed Gas Pipeline System that were described within the Gorgon Gas Development Fourth Train Expansion

[113] These GHG emissions estimates do not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken.

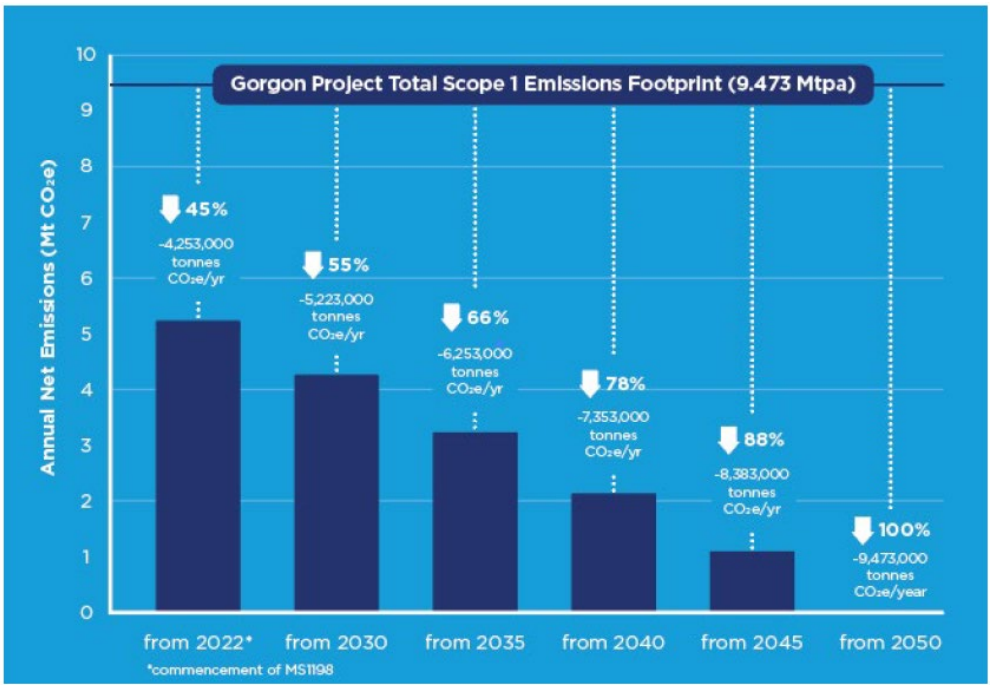
Proposal (Ref. 6). The Development (as described in the OPP) has been designed as a subsea tieback development to the existing GFP infrastructure (i.e. it will utilise the two existing Feed Gas Pipeline Systems and existing domestic gas and three-train LNG capacity at the Gorgon GTP).

8.3.6.1 GHG management plan

The Gorgon GTP GHGMP (Ref. 67) was developed to satisfy the requirements of condition 27 of MS 800 (as amended by MS 1198). The GHGMP is applicable to all GHG emissions from the current operational Gorgon Gas Development facilities (as outlined in MS 800), including the three LNG processing trains, domestic gas unit, and Carbon Dioxide Injection System. The objectives of the Gorgon GTP GHGMP are to outline:

- measures implemented through the design and early phase of operations to avoid or reduce GHG emissions
- measures to avoid, reduce and offset Proposal GHG Emissions[114] during operations over the life of the proposal
- emission limits, required by condition 27.1, for Net GHG Emissions[114] over the life of the proposal (Figure 8-2).

Note: As described in Section 8.3.5.4, the State Government has initiated a review of existing Ministerial Statements under section 46 of the EP Act (WA). At the time of writing this OPP, the section 46 process is underway for the Gorgon Gas Development; however, no changes to existing approval conditions have been finalised or published (i.e. the existing approval conditions, including this GHGMP, remain in place).



Source: Gorgon GTP GHGMP (Ref. 67).

Figure 8-2: Net GHG Emissions targets (per condition 27.1 of MS 1198) and associated percent reduction in emissions from the three-train Revised and Expanded Gorgon Gas Development GHG emissions estimate

[114] Proposal GHG Emissions and Net GHG Emissions are defined within MS 1198.

8.3.7 customer markets

Customer markets are key to understanding where secondary GHG emissions occur. As the Gorgon Gas Development supplies both the Australian domestic market and the international market, the secondary GHG emissions may occur across national and multiple global locations. These secondary “third-party end use” emissions would be direct emissions for the end consumers, who would operate under their own respective regulatory regimes to manage their GHG emissions and any associated impacts or risks.

8.3.7.1 domestic gas

The Gorgon State Agreement was ratified in 2003. The Gorgon State Agreement provides for the reservation of 2,000 PJ of gas for domestic supply, construction of the 300 TJ/day Gorgon domestic gas plant on Barrow Island, and requires the production capacity of this plant is actively marketed to Western Australian customers.

The Gorgon Gas Development has one of eight domestic gas agreements currently in place, and has the largest indicative domestic gas commitment of these existing agreements (Ref. 565). CAPL’s Wheatstone Project has the second largest indicative domestic gas commitment (Ref. 565). Of the 10 gas production facilities supplying the WA domestic gas market, the Gorgon Gas Development and Wheatstone Project supplied ~25% and ~19% respectively of WA’s total domestic gas supply in 2024 (Ref. 566).

As described in Sections 8.3.5, Australia is party to the Paris Agreement and has legislative mechanisms to manage GHG emissions within Australia’s jurisdiction.

8.3.7.2 LNG

Gorgon Gas Development LNG is marketed and sold on an equity lifting basis. This means each joint venturer is separately responsible for marketing and selling its LNG off-take, allocated based on respective ownership interests.

Most of CAPL’s Gorgon Gas Development’s LNG production is committed under binding long-term agreements with major utilities in Asia, with the remainder sold on the Asian spot LNG market (Ref. 585). This long-term sales agreement market is primarily Japan, with some exports to other countries including China, Taiwan, and the Republic of Korea (South Korea). All of these countries have Paris Agreement NDC or equivalent commitments in place to reduce and manage GHG emissions (Section 8.3.7.2.1).

There are emerging regional markets where demand for LNG is expected to grow in the future and could be the home market for future long-term agreements. These include India, Indonesia, Bangladesh, Thailand, Malaysia, Vietnam, and The Philippines. All these countries are party to the Paris Agreement and have NDCs in place (Ref. 586).

8.3.7.2.1 paris agreement (or equivalent) commitments from countries with main LNG sale purchase agreements

Japan is a party to, and has ratified, the Paris Agreement. Japan has submitted an NDC to reduce its GHG emissions by 60% in fiscal year 2035, and by 73% in fiscal year 2040 from its fiscal year 2013 levels (Ref. 521). Japan’s NDC submission stated that these targets “are on a straight pathway towards the achievement of net-zero by 2050” (Ref. 521). Japan’s long-term strategy includes driving decarbonisation of the energy and transport sectors (Ref. 522). The

strategy promotes the shift to decarbonised power sources (which includes using existing gas infrastructure [e.g. gas turbines] where relevant) and the development of "greener ships such as gas-fueled ships powered by LNG, hydrogen, ammonia and others" (Ref. 522).

The Republic of Korea is a party to, and has ratified, the Paris Agreement. In December 2021, the Republic of Korea submitted an updated NDC raising its emission reduction targets from 26.3% of 2018 levels to 40% from 2018 levels by 2030 (Ref. 523). South Korea's implementation plan includes to "dramatically phase down coal-fired power generation", shut down aged coal power plants or shift their fuels from coal to LNG, and focusing emission reduction efforts within the shipping sector on "distributing eco-friendly ships" (Ref. 523).

China is a party to, and has ratified, the Paris Agreement. In October 2021, China submitted revised NDC goals, which include: "aims to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060; to lower CO_2 emissions per unit of GDP by over 65% from the 2005 level" (Ref. 524). Part of China's implementation strategy includes the replacement and optimisation of transportation fuels; for water transportation this includes the use of LNG-powered ships (Ref. 524; Ref. 525).

Taiwan is not a formal member of the United Nations (UN) and is not a party to the Paris Agreement. However, Taiwan submitted an Intended NDC to the UNFCCC secretariat in 2015 and revised this Intended NDC in 2022; this revised target aims to reduce net GHG emissions by 23–25% from 2005 level by 2030 (Ref. 526). Under the periodic regulatory goals established as per Taiwan's *Climate Change Response Act*, this 2030 net GHG emissions reduction target was raised to a 28±2% reduction relative to the 2005 base year (Ref. 760). Additional reduction targets have also been drafted for 2032 (32±2%) and 2035 (38±2%) relative to the 2005 base year (Ref. 760). Future implementation plans refer to Taiwan's intention to submit a 2035 Intended NDC (Ref. 761).

8.3.7.3 condensate

Whilst Gorgon Gas Development's main export is LNG, a small volume of condensate is also produced. Based on historical trade, condensate from the Gorgon Gas Development will be exported to regional refineries likely in Singapore, Thailand and the Republic of Korea (South Korea).

Singapore, Thailand, and the Republic of Korea are all party to, and have ratified, the Paris Agreement. The commitments from the Republic of Korea are described above in Section 8.3.7.2.1. In November 2022, Thailand submitted a revised NDC to "reduce its greenhouse gas emissions by 30 percent from the projected business-as-usual (BAU) level by 2030" from reference year 2005 (Ref. 587). In February 2025, Singapore submitted their second NDC that "intends to reduce emissions to between 45 to 50 million tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2035" (Ref. 588).

8.3.8 projected WA energy trends

Natural gas is an integral component of energy supply and energy security for WA. Analysis by KPMG shows that natural gas currently provides 54% of WA's primary energy needs and 60% of the State's electricity (including supplying 51% of the energy consumed by the WA mining sector) (Ref. 568). Natural gas is projected to play an important role as a transitional energy source as both the domestic and global economies decarbonise (Ref. 569 as cited in Ref. 567).

The WA Government has also committed to retire State-owned coal power stations by 2030 and undertake a managed transition to renewables and storage (Ref. 589; Ref. 590). However, the Premier also states that " … WA needs a secure supply of gas as firming fuel in our system … " and that "[o]ur [Domestic Gas] policy supports affordable, reliable energy for WA households and business into the future" (Ref. 591).

The most recent WA Gas Statement of Opportunities (GSOO) forecasts gas supplies in WA's domestic gas market for the 2025–2034 period (Ref. 566). Overviews of the three forecasting scenarios used in the WA GSOO are:

- Progressive Change (low case)—explores the task of achieving Australia's Paris Agreement commitment of a 43% emissions reduction compared to 2005 levels by 2030 in a more challenging economic environment. While ongoing energy sector investments are required by national and state policies, this scenario reflects reduced consumption for commodities.
- Step Change (expected case)—is based on achieving a scale of energy transformation that supports Australia's contribution to limiting global temperature rise to below 2°C compared to pre-industrial levels. It features a high level of consumer participation and significant investments in distributed energy resources to drive the decarbonisation of Australia's economy.
- Green Energy Exports (high case)—reflects very strong decarbonisation efforts both domestically and globally to limit temperature increase to 1.5°C. This scenario features a rapid transformation of Australia's energy sectors and a strong emphasis on electrification. The strong decarbonisation assumptions drive less use of gas and more renewable sources to replace the loss of coal-fired electricity generation and meet increased energy consumption.

Key outcomes of this most recent (December 2024) WA GSOO forecast include:

- "[d]uring Australia's transition to a net zero emissions future, gas will continue to be used by Western Australian households, businesses, and industry, and support the reliability and security of the electricity sector"[115]
- there is continued "forecast risks of annual supply gaps that will require new sources of supply from 2030 onwards"[115]
- "[g]as consumption by industrial, commercial and residential consumers is forecast to increase while existing gas fields are depleting"[115]
- '[f]rom 2030, an increasing supply gap in the gas market is projected, … driven by continuous growth in industrial and minerals processing sectors, and a decline in production due to natural reserve depletion from existing gas fields"[115]
- "[g]as usage for gas-powered generation (GPG) in the South West Interconnected System (SWIS) is forecast to become peakier and more seasonal. … As a proportion of the total SWIS supply mix, GPG is projected to decline over the outlook period, but daily peak usage is forecast to increase"[115] and that "SWIS GPG is forecast to play an increasingly important role in firming renewables (both distributed photovoltaics [PV] and [variable renewable energy] VRE) and maintaining reliable and secure electricity supply"[116]

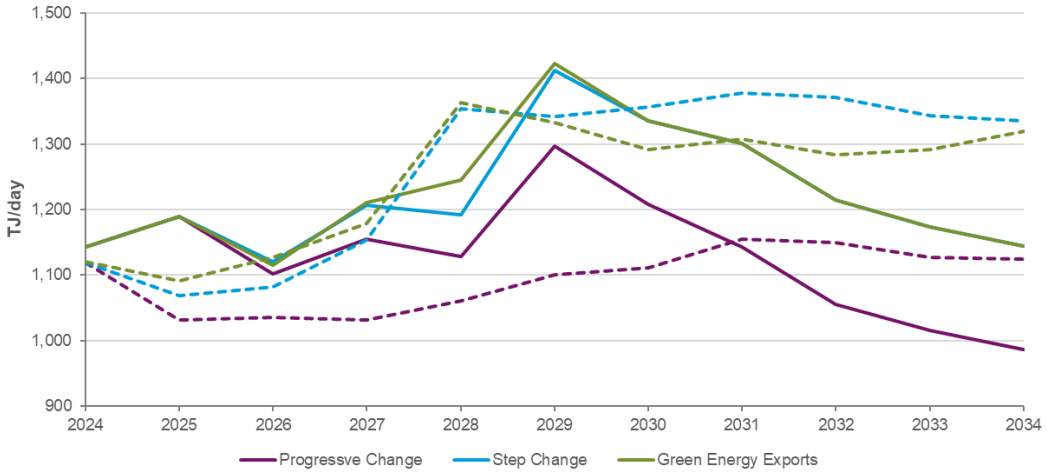
[115] Executive Summary, pp. 4 (Ref. 586).

[116] Executive Summary, pp. 7 (Ref. Ref. 586).

- "[m]ost gas production facilities are running close to, or at, capacity"[115] leading to a risk of shortages
- the uncertainty in forecasting was acknowledged, noting that "the period from 2028 is subject to the most uncertainty, with forecast supply gaps depending on evolving factors such as coal-fired generation retirements, commodity prices, project timelines and domestic gas policy"[115], however it is further stated that "[n]otwithstanding the potential uncertainty from 2028, current modelling indicates new gas supply is required from 2030 in all scenarios, consistent with the key findings of the 2023 GSOO. Significant supply gaps arise after 2029 as existing gas fields deplete. Unless new gas supply enters the market from 2030, AEMO forecasts supply deficits of up to 191 TJ/day by 2034"[117].

Figure 8-3 shows the projected domestic gas supply and domestic gas consumption for each of the three forecast scenarios over the period 2024 to 2034.

As described in Section 8.3.7.1 the Gorgon Gas Development has a commitment to reserve domestic gas under the Gorgon State Agreement.



Source: Adapted from data in Tables 16, 17 and 18 (Ref. 566)

Figure 8-3: Forecast domestic gas supply (solid lines) and domestic gas consumption (dashed lines) under three forecast scenarios, 2024 to 2034

8.3.9 projected global energy trends

The IEA uses a scenario approach within their Global Energy and Climate (GEC) Model to examine future energy trends. The scenarios are not predictions of future states; they are projections based on the assumptions underpinning each scenario and provide a way to compare possible versions of the future. The three scenarios used by the IEA are:

- STEPS—an exploratory scenario which reflects current policy settings based on a sector-by-sector and country-by-country assessment of the energy-related policies that are in place or that have been announced; however, they are incorporated in the scenario only to the extent that they are underpinned by adequate provisions for their implementation (Ref. 529; Ref. 538). The

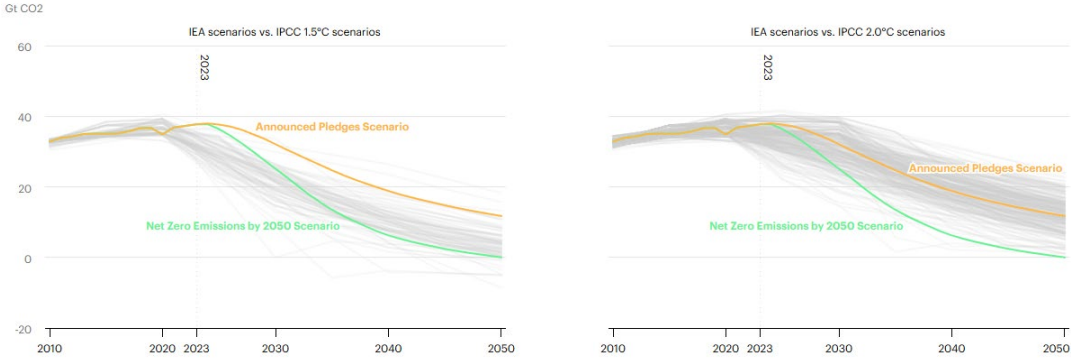
[117] Executive Summary, pp. 8 (Ref. Ref. 586).

STEPS is associated with a temperature rise of 2.4 °C in 2100 (with a 50% probability) (Ref. 529).

- Announced Pledges Scenario (APS)—an exploratory scenario which assumes that all energy and climate commitments made by governments and industries, including NDCs and longer-term net zero targets, will be met in full and on time (Ref. 529; Ref. 538). The APS is associated with a temperature rise of 1.7°C in 2100 (with a 50% probability) (Ref. 529).
- Net Zero Emissions by 2050 (NZE) Scenario—a normative scenario in that it works backwards from a defined outcome; i.e. net zero emissions from the energy sector by 2050 without offsets from other sectors, an emissions trajectory consistent with keeping the temperature rise in 2100 below 1.5 °C (with at least a 50% probability) with limited overshoot, universal access to modern energy services by 2030, and major improvements in air quality (Ref. 529; Ref. 538).

While other elements (e.g. economic and demographic context, technology costs and learning, energy prices and affordability, corporate sustainability commitments, and social and behavioural factor) are considered, the decisions made by governments are the main differentiating factor explaining the variations in outcomes across the IEA scenarios (Ref. 538).

The scenarios and GEC Model were updated as part of the IEA's World Energy Outlook (WEO) 2024 (Ref. 529). Similar to certain IPCC emissions scenarios (i.e. Category C1 and Category C3), IEA's NZE and APS scenarios are associated with at least a 50% chance of limiting the temperature rise to 1.5 °C and 2.0 °C in 2100, respectively (Figure 8-4).



Source: IEA (Ref. 538)

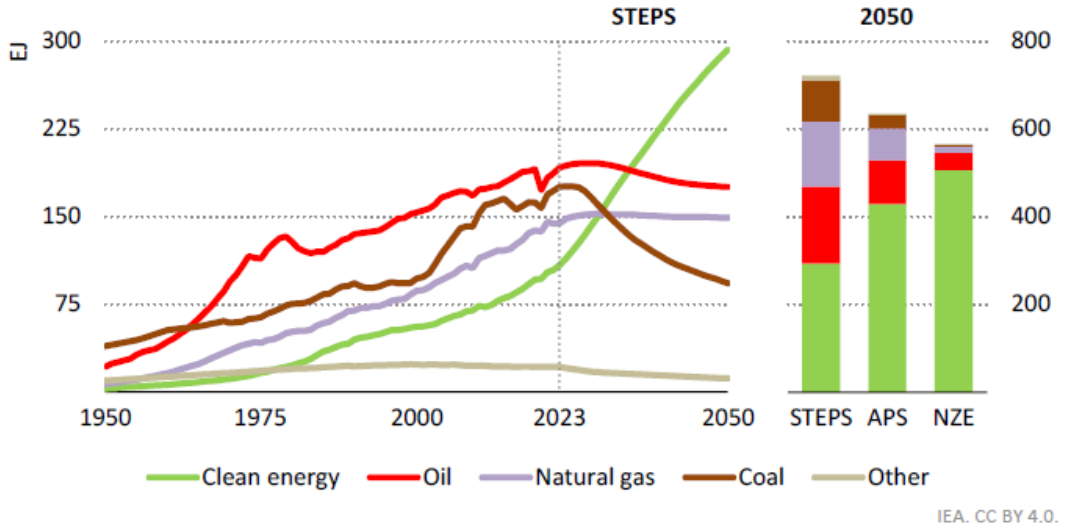
Figure 8-4: IEA's GEC Model scenarios compared to IPCC scenarios with temperature rise of 1.5 °C and 2.0 °C in 2100

8.3.9.1 global energy mix

Fossil fuels met 80% of global energy demand in 2023, decreasing slightly from providing 82% of global energy demand ten-years prior in 2013 (Ref. 529). Under STEPS the proportion of fossil fuels in global energy demand is projected to decline to 58% in 2050 (Ref. 529). Similar to the previous WEO 2023, the WEO 2024 scenarios indicate an overall peak demand for all fossil fuels (coal, oil, and gas) by 2030; however, it is noted that the trends do vary between countries at different stages of economic and energy development (Ref. 529). Fossil fuels, including natural gas, maintain a role in the global energy mix projections to 2050 under all IEA scenarios (Figure 8-5). The demand for natural gas is expected to

remain robust in emerging market and developing economies—a grouping that includes ~85% of the world's population (Ref. 529).

The WEO 2024 indicated that under all scenarios the growth in global energy demand slows due to efficiency gains, electrification, and renewables (Ref. 529). The WEO 2024 also indicated that if the rate of transition to low carbon energy sources continues, then post-2030 the increase in global energy demand could be met without additional amounts of oil, natural gas or coal; this differs from previous projections which have needed a proportion of the increase in global energy demand to be met by fossil fuels (Ref. 529). However, as discussed above, fossil fuels still maintain a role in the global energy mix projections to 2050 under all IEA scenarios (Figure 8-5).



Source: WEO 2024 (Ref. 529)

Figure 8-5: Projected global energy mix by WEO 2024 scenarios

8.3.9.2 natural gas

Natural gas is projected to play an important role as a transitional energy source as the domestic and global economy decarbonises (Ref. 569 as cited in Ref. 567). KPMG indicate that gas will remain a key component of the global energy mix because it is relatively abundant, has a lower carbon footprint compared to conventional energy options such as coal, and provides flexibility for power generation (Ref. 567).

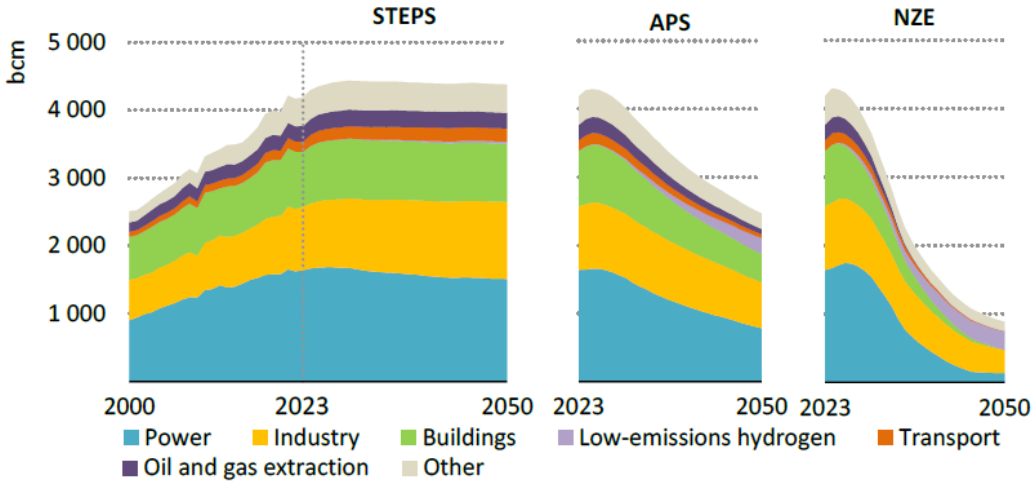
The overall global demand for natural gas increased by 0.5% in 2023—consisting of a decrease in demand in advanced economies (led by Europe) which was offset by an increase in demand from emerging market and developing economies (led by China and the Middle East) (Ref. 529). The WEO 2024 shows the projected demand for natural gas has been revised upward in all scenarios compared with the previous WEO 2023; e.g. in the STEPS the demand in 2030 has been revised up by 130 bcm compared to the WEO 2023 (Ref. 529). This increase reflects stronger anticipated demand for gas to meet growth in electricity demand in China and the Middle East (Ref. 529).

In the WEO 2024 STEPS, natural gas demand is projected to increase on average 0.5% per year over 2023–2035 to reach a maximum around 2030 (at 4,430 bcm) and then plateau, with only a slight decline through to 2050 (to 4,377 bcm) (Figure 8-6). The STEPS trajectory is largely related to the accelerated deployment of renewables, efficiency gains, and the electrification of

end-uses (Ref. 529). Sensitivity analyses indicate that natural gas demand could be higher (e.g. up 3% in 2035 if the surplus of LNG is fully absorbed) or lower (e.g. down 4% in 2035 from slower electricity demand growth and faster solar PV update) than these STEPS projections (Ref. 529). The sensitivity analysis also indicated that even based on all the high cases, the global peak for natural gas would still occur within a few years of that projected for STEPS albeit at a slightly higher absolute level (Ref. 529).

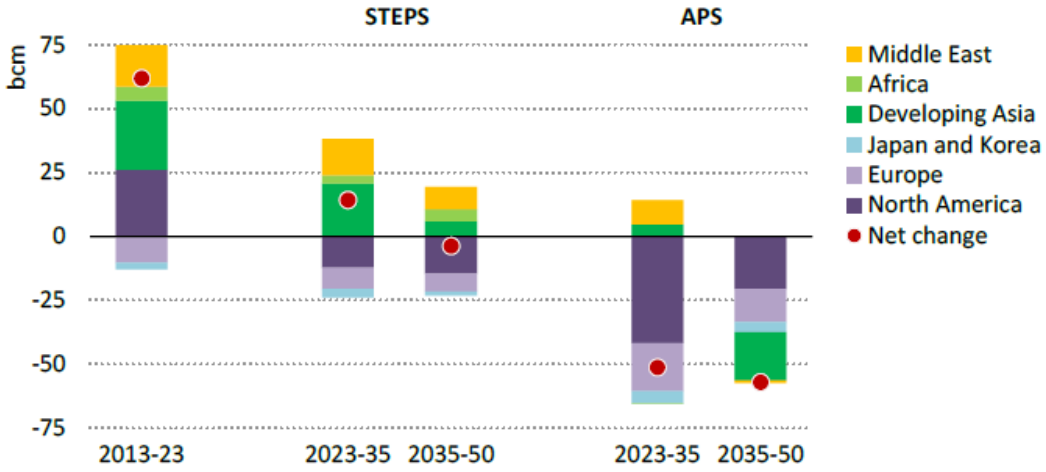
By comparison, in the APS natural gas demand is projected to start to decline in the second-half of the 2020s and is ~17% lower by 2035 and ~41% lower by 2050 than it was in 2023. Similarly for the NZE Scenario, natural gas demand is projected to be ~46% lower by 2035 and ~79% lower by 2050 than it was in 2023 (based on Table 3.2 in Ref. 529).

As described above, the trends in natural gas demand are projected to vary between advanced economies compared to emerging market and developing economies (Figure 8-7). Global natural gas trade is projected to increasingly pivot towards emerging markets in Asia (Ref. 529).



Source: WEO 2024 (Ref. 529)

Figure 8-6: Projected natural gas demand by sector and scenario (2000 to 2050)



Source: WEO 2024 (Ref. 529)

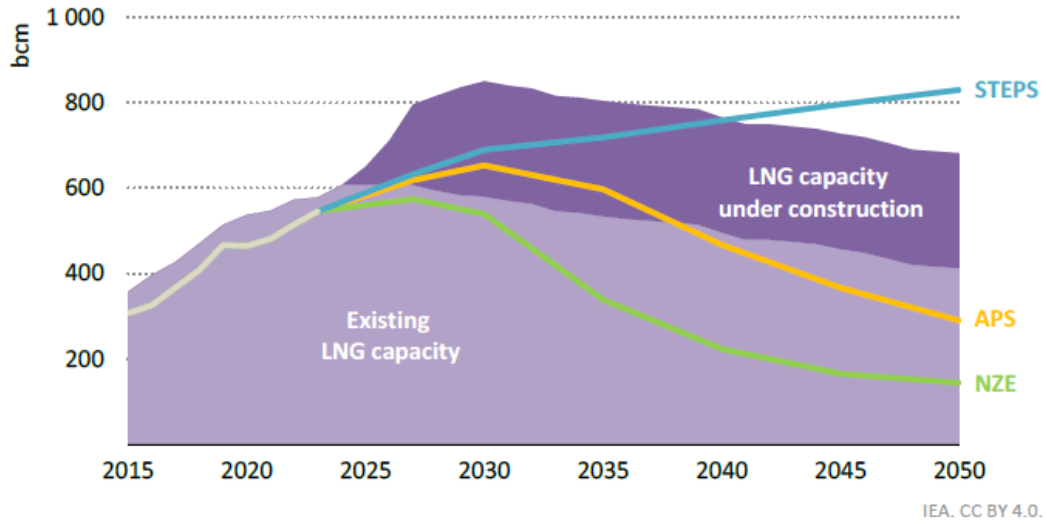
Note: Developing Asia includes China, India, Southeast Asia and Other Asia.

Figure 8-7: Projected change in average annual natural gas demand by region and scenario (2013 to 2050)

8.3.9.2.1 potential LNG oversupply

In STEPS, LNG demand is projected to increase by >2.5% per year from 2023 to 2035 (an upward revision from the previous WEO 2023), which is faster than overall natural gas demand (Ref. 529).

Around 270 bcm of annualised new LNG capacity has been approved and if delivered according to announced schedules is set to enter into operation over the period to 2030 (Ref. 529). If the announced LNG capacity eventuates, there is the potential for an LNG oversupply to the global market with capacity exceeding demand under all three scenarios (Figure 8-8). However, under STEPS, this potential oversupply does not extend post-2040 (Figure 8-8).



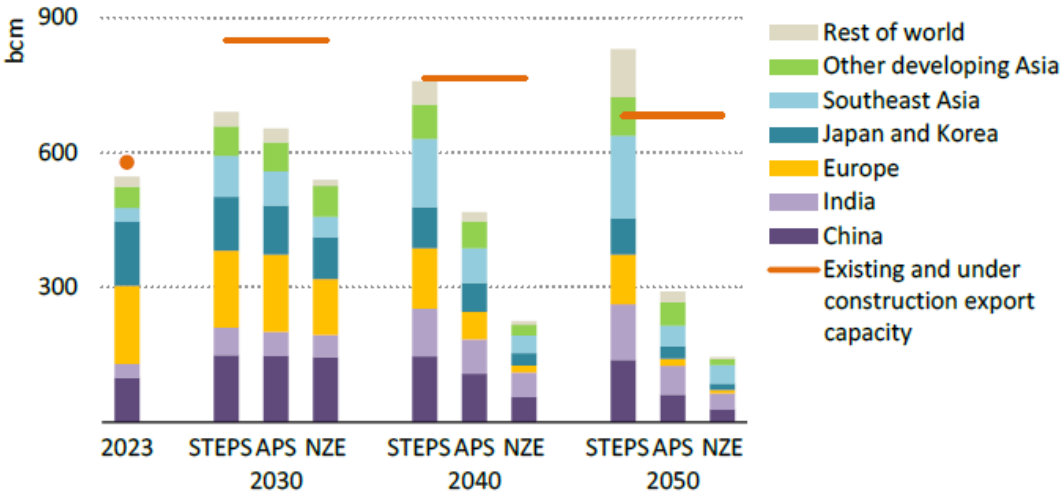
Source: WEO 2024 (Ref. 529)

Note: LNG capacity was derated to 90% of nameplate capacity.

Figure 8-8: LNG trade by scenario relative to existing and under construction export capacity

If an oversupply eventuates this could put downward pressures on natural gas prices. As of mid-2024, around one third of the export capacity under construction is un-contracted; i.e. this capacity could be made available on the spot market. There are price-sensitive markets in Asia that may increase LNG imports in response to lower prices (Ref. 529). If gas markets are to absorb the potential LNG oversupply and to continue to grow past 2030, this would require a combination of low clearing prices, higher electricity demand and slower energy transitions than projected in STEPS (Ref. 529).

However, the potential oversupply depicted in Figure 8-8 is based on nameplate capacity, which for the Gorgon Gas Development (which includes the Development) already exists. The intent of the Development is to maintain gas supply to the existing GTP on Barrow Island to sustain current production rates of LNG and domestic gas (Section 1.1). Therefore, the Gorgon Gas Development, including the Development, would be considered part of the 'existing LNG capacity' in projections. Further, as described in Section 8.3.7.2, long-term sales agreements for LNG from the Gorgon Gas Development are in place with Japan, China, Taiwan and the Republic of Korea. The demand for LNG in these regions is projected to continue to 2050 under all scenarios (Figure 8-9). The Development will also be developed in stages (Section 4.1.4), and as such if there are economic (or other) factors affecting the market, these would be considered at the time of investment and development.



Source: WEO 2024 (Ref. 529)

Figure 8-9: Projected LNG demand by region and scenario relative to existing and under construction LNG export capacity (2023 to 2050)

8.3.10 national strategies

In 2024, the Australian Government released its *Future Gas Strategy* (Ref. 509), an evidence-based framework that will underpin future government policies and actions. The strategy "establishes the role gas will play in the transition to net zero by 2050, securing affordable gas for Australia as we move to a more renewable grid, and confirming our commitment to being a reliable trading partner" (Ref. 510). The strategy identifies that Australia will need gas through to 2050 and beyond; noting that the role of gas will change, and gas-related emissions must decline, as Australia transitions to net zero (Ref. 509). Gas, however, is forecast to play an important role in firming renewable power generation and is needed in hard-to-abate sectors like manufacturing and minerals processing until such time as alternatives are viable and can be deployed at scale (Ref. 510). Sixty percent of Australia's gas reserves are in WA (Ref. 568).

Natural gas supports the standard of living and energy security (providing over a quarter of energy needs) in Australia (Ref. 509). Gas provides a "crucial role in supporting our [the Australian] economy, with the sector employing 20,000 people across the country, including remote and regional communities" (Ref. 510). Gas is also considered crucial for a Future Made in Australia as it supports manufacturing, food processing, and refining of critical minerals (Ref. 510). The Future Made in Australia plan is about maximising the economic and industrial benefits of the move to national net zero and securing Australia's place in a changing global economic and strategic landscape (Ref. 511).

The Australian Government has developed a Net Zero Plan, which sets out a roadmap for Australia's transition through to the 2035 emissions target, and the path to net zero GHG emissions by 2050 (Ref. 512). The Net Zero Plan identifies five decarbonisation priorities: clean electricity across the economy, lowering emissions by electrification and efficiency, expanding clean fuel use, accelerating new technologies, and net carbon removals scaled up (Ref. 769). The Plan states that "[n]atural gas remains an important contributor to Australia's economy and energy security throughout the transition to net zero, but its role changes and overall use declines" and that "[n]atural gas users will transition at different times due to the relative cost of natural gas and electricity, the availability and

affordability of alternative technologies and fuels, and the timing of asset turnover" (Ref. 769).

Six sectoral emissions reduction plans support the Net Zero Plan: electricity and energy, agriculture and land, the built environment, industry, resources, and transport. The Resources Sector Plan (Ref. 763) covers exploration, production, and decommissioning of gas (as well as minerals, oil and coal) resources; and is relevant to Scope 1 GHG emissions from this sector. The Electricity and Energy Sector Plan (Ref. 513) covers use of associated products (e.g. domestic gas).

8.3.11 corporate context

As outlined in Chevron Corporation's *2023 Climate Change Resilience Report* (Ref. 276), Chevron Corporation supports the global ambitions of the Paris Agreement. Chevron Corporation believes that the optimal approach for society is to drive the most efficient and cost-effective reductions economywide, paired with natural and technological emissions removal. Chevron Corporation supports a price on carbon, applied as widely and broadly as possible, as the best approach to reduce emissions. To this end, Chevron Corporation works to encourage national policies to support international linkages with the goal of ultimately establishing a liquid and integrated global carbon market.

Chevron Corporation believes the future of energy is lower carbon. Chevron Corporation is investing to grow its oil and gas business, lower the carbon intensity of its operations and grow new businesses in renewable fuels, carbon capture and offsets, hydrogen, power generation for data centres, and other emerging technologies. Chevron Corporation's strategic planning process supports an ability to operate in a lower carbon policy environment. For example, Chevron Corporation use carbon prices and derived carbon costs in business planning, investment decisions, impairment reviews, reserves calculations, and evaluation of carbon-reduction and lower carbon business opportunities.

8.3.12 australian values and sensitivities

The following provides an overview of some of the environmental values and sensitivities within the Australian jurisdiction that may be vulnerable to climate change related effects. It is acknowledged that this is not a comprehensive list as it is not practical to identify and describe all environmental values and sensitivities in Australia that may be impacted by climate change.

This overview is presented for contextual purposes only. The physical effects of climate change to Australian environmental values and sensitivities cannot reasonably be attributed to a single development's GHG emissions. Anthropogenic GHG emissions from the Development do not individually cause the physical effects of climate change, rather it is their cumulative effect, in combination with GHG emissions from all other anthropogenic and natural sources since the mid-1700's, that contribute to increased global temperature and global weather trends in the aggregate that may cause or contribute to physical effects on Australian environmental values and sensitivities. It is not reasonably practicable to measure the contribution of GHG emissions from the Development to anthropogenic impacts to climate systems and they could not be characterised as a *substantial cause* of the physical effects of climate change on environmental values and sensitivities due to their remoteness, intervening impacts and the relatively small reduction to the remaining global carbon budget from Development GHG emissions.

The following overview is distinct to that provided in Section 4, which is focused on the values and sensitivities that may be present within the DA and Hydrocarbon Ecological and Social EMBAs, and is used to inform the impact and risk assessments for other aspects associated with the Development.

8.3.12.1 matters of national environmental significance

Division 1 of Part 3 of the EPBC Act protects MNES—being a declared World Heritage property, National Heritage place, wetland of international importance (declared Ramsar wetland), listed threatened species or endangered communities, listed migratory species, Commonwealth marine area, Great Barrier Reef Marine Park, nuclear actions, and water resources (as related to unconventional gas or large coal mining developments).

Division 2 of Part 3 of the EPBC Act also protects the environment when actions are taken

- on Commonwealth land or impact upon Commonwealth land
- that impact Commonwealth Heritage places outside Australian jurisdiction
- taken by an Australian Government agency.

8.3.12.1.1 heritage values

The Convention Concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention) is the instrument used to establish a list (the World Heritage List) of properties that have outstanding universal value regarding natural or cultural significance (Ref. 599). The World Heritage List currently includes 1,248 properties—of which 972 are cultural properties, 235 are natural properties and 41 are properties that meet both cultural and natural criteria (Ref. 600). Twenty-one of these listed properties are within Australia (Table 8-14). Australia also has a further eight sites on the Tentative List for possible future World Heritage nomination (Ref. 601).

Table 8-14: Category of declared World Heritage properties in Australia

Cultural	Natural	Mixed
Australian Convict Sites Budj Bim Cultural Landscape Murujuga Cultural Landscape Royal Exhibition Building and Carlton Gardens Sydney Opera House	Australian Fossil Mammal Sites Gondwana Rainforests of Australia Great Barrier Reef Greater Blue Mountain Area Heard and McDonald Islands K'gari (Fraser Island) Lord Howe Island Group Macquarie Island Ningaloo Coast Purnululu National Park Shark Bay, Western Australia Wet Tropics of Queensland	Kakadu National Park Tasmanian Wilderness Uluru-Kata Truta National Park Willandra Lakes Region

The National Heritage List comprises places of outstanding natural, historic, and Indigenous heritage values to the Australian nation (Ref. 602). There are currently 124 places on the National Heritage List of which 19 are classed as Indigenous, 69 as historical and 36 as natural places (Ref. 603). The heritage values of each listed place are described within the Australian Heritage Database (Ref. 603) in

relation to each of the National Heritage criteria against with the values of the place were assessed.

8.3.12.1.2 wetlands

Wetlands include a variety of habitat types including swamps, marshes, billabongs, lakes, salt marshes, mudflats, mangroves, coral reefs, fens, peat bogs, or bodies of water, and may be natural or artificial, permanent or temporary (Ref. 604). Water within these areas can be static or flowing; fresh, brackish or saline; and can include inland rivers and coastal or marine waters (Ref. 604).

The Convention on Wetlands of International Importance (the Ramsar Convention) encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity. Once designated, these sites are added to the List of Wetlands of International Importance and become known as Ramsar sites (Ref. 604). There are currently over 2,500 Ramsar sites around the world; of these Australia currently has 67 Ramsar sites covering a surface area of ~8.4 ha (Ref. 605; Ref. 606). The ecological character of Australian Ramsar wetlands are described within the Australian Wetlands Database (Ref. 607).

8.3.12.1.3 listed species and ecological communities

Australia has between ~600,000–700,000 species, of which ~84% of plants, 83% of mammals, and 45% of birds are endemic to Australia (Ref. 608). Ecological communities are unique and naturally occurring groups of fauna and flora; these communities can be determined by factors such as soil type, position in the landscape, climate and water availability (Ref. 608).

The EPBC Act protects Australia's native species and ecological communities by providing for the identification and listing of species and ecological communities as threatened, and the development of management plans (conservation advices, recovery plans, threat abatement plans, etc.) for these listed species and ecological communities.

Australia currently has:

- 676 listed threatened fauna species (67 extinct, one extinct in the wild, 141 critically endangered, 240 endangered, 220 vulnerable, and seven conservation dependent) (Ref. 609)
- 1,482 listed threatened flora species (35 extinct, 285 critically endangered, 598 endangered, and 564 vulnerable) (Ref. 610)
- 104 listed threatened ecological communities (46 critically endangered, 56 endangered, and two vulnerable) (Ref. 611).

Migratory species listed under international agreements to which Australia is a party are protected under the EPBC Act. These international agreements include bilaterial migration bird agreements (JAMBA, CAMBA, ROKAMBA), Bonn Convention, Ramsar Convention and ACAP (Section 2.4). Australia currently has 154 listed migratory species (Ref. 612).

Descriptions of threatened or migratory fauna and flora, and threatened ecological communities, including listing advice and management plans (where applicable), are available in the Species Profile and Threats Database (Ref. 508).

8.3.12.1.4 commonwealth marine areas

Commonwealth marine areas are defined within section 24 of the EPBC Act. In general, these include the waters, seabed and airspace over waters between the EEZ and coastal waters. Australia has one of the largest marine jurisdictions in the world, with Australian waters covering ~14.7 million km^2 (including the waters around external territories) of which ~7.4 million km^2 are Commonwealth waters surrounding Australia (Ref. 102).

Marine bioregional plans (made under section 176 of the EPBC Act) have been developed for the south-west, north-west, north, and temperate east marine regions (Ref. 613; Ref. 102; Ref. 614; Ref. 615); these plans identify and describe conservation values within each area. Conservation values are defined as:

- KEFs
- species listed under Part 13 of the EPBC Act
- protected places, including marine reserves, heritage places, and underwater cultural heritage.

While no bioregional plan is in place, a bioregional profile has been developed for the south-east marine region and does identify and describe conservation values in the area (Ref. 616).

Australia has currently established 60 AMPs which are located within Commonwealth waters (Ref. 617). These AMPs are managed via a suite of management plans (Ref. 82; Ref. 618; Ref. 619; Ref. 620; Ref. 621;, Ref. 622; Ref. 623; Ref. 624), which identify and describe natural, cultural, heritage, and socioeconomic values associated with each of the AMPs.

8.3.12.1.5 great barrier reef marine park

The Great Barrier Reef is a network of almost 3,000 coral reefs and a diverse array of non-reef habitats stretching ~2,300 km along the east coast of Queensland (Ref. 625). The Great Barrier Reef Marine Park extends into both Commonwealth waters and State coastal waters, and is protected under the EPBC Act and the *Great Barrier Reef Marine Park Act 1975* (Cth). The park is jointly managed by Australian and Queensland Government's.

The Great Barrier Reef is listed as both a World Heritage property and National Heritage place for its outstanding natural values. There are Sea Country values for Aboriginal and Torres Strait Island peoples associated with the area, as well as ongoing social and socioeconomic values for communities and industries (Ref. 625).

8.3.12.2 ecosystems and biodiversity

Australia supports a variety of ecosystem types. Ecosystems provide habitat, promote food chains and webs, and control ecological cycles and processes (Ref. 626). Biodiversity (biological diversity) is the variety of all species—it is the different plants, animals and micro-organisms, their genes, and the terrestrial, marine and freshwater ecosystems of which they are a part (Ref. 631; Ref. 627). Biodiversity provides variety of services including ecological, cultural, and socioeconomic.

The Australian Government recognises the importance of biodiversity and is party to the United Nations Convention of Biological Diversity. The Australian Government has developed Australia's Strategy for Nature 2024–2030 (Ref. 628)

to meet the requirements of a national biodiversity strategy and action plan. Under this strategy, Australia has established national biodiversity targets which include to “protect and conserve 30% of Australia’s landmass and 30% of Australia’s marine areas by 2030” (Ref. 627; Ref. 628).

For terrestrial ecosystems, the Interim Biogeographic Regionalisation for Australia framework recognises 89 geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information (Ref. 627; Ref. 629). Types of terrestrial and aquatic ecosystems present in Australia include native vegetation (e.g. alpine, woodlands, grasses, etc.), rivers and streams, wetlands, and groundwater dependent systems (Ref. 627; Ref. 634; Ref. 635). Terrestrial protected areas cover ~22% (as of June 2022) of Australia’s landmass (Ref. 630).

For marine ecosystems, the IMCRA framework recognises 41 provincial bioregions based on a benthic bioregionalisation (biogeography of fish supplemented with a geophysical classification) (Ref. 108). These provincial bioregions are further broken down into meso-scale regions (based on biological and physical characteristics) and geomorphic units (based on common geomorphic features). Types of marine and coastal ecosystems present in Australia include mangroves, saltmarshes, dune systems, seagrasses, coral reefs, rocky reefs and kelp beds, canyons and seamounts (Ref. 632; Ref. 633). Marine protected areas cover ~48% of Australian waters (Ref. 630).

As described in Section 8.3.12.1.3 there is a high level of endemism in Australian species. Table 8-15 provides an overview of Australia’s biodiversity in a global context.

Table 8-15: Global status of Australia’s biodiversity (2009)

Species group	Global diversity
Marine fish	One of the most diverse fish faunas in the world, with more than 4,500 species.
Sharks and rays	54% of the entire chondrichthyan fauna is endemic to Australia.
Marine invertebrates	17.8% of the world’s crustaceans, 22% of bryozoans and 29.4% of sea squirts occur in Australian waters.
Terrestrial vertebrates	1,350 endemic terrestrial vertebrates, far more than the next highest country (Indonesia with 850 species).
Terrestrial mammals	305 species, of which 258 (85%) are endemic; more than 50% of the world’s marsupial taxa occur only in Australia.
Birds	17% of the world’s parrots occur in Australia – more than 50 species (second-highest level of endemism after Brazil and the same as Colombia).
Reptiles	89% endemic; some groups such as front-fanged snakes (family Elapidae), pythons and goannas are more diverse than elsewhere in the world. Australian deserts have the world’s highest lizard species diversity.
Frogs	93% endemic (highest level of endemism of any vertebrate group in Australia); 220 species.
Vascular plants	91% of flowering plants are endemic; 17,580 species of flowering plants, 16 endemic plant families (the highest in the world) and 57% of the world’s mangrove species.
Ectomycorrhizal fungi	95% endemic (22 genera and three endemic families).

Species group	Global diversity
Butterflies and moths	Many groups are unique to Australia.

Source: Biodiversity and Climate Change Expert Advisory Group (Ref. 638).

8.3.13 impact and risk evaluation

The scoping exercise (Section 7.4) identified atmospheric GHG concentrations as the receptor that may be impacted by GHG emissions.

Table 8-16 details the impact and risk evaluation and the level of consequence to receptors found to be susceptible to GHG emissions.

Table 8-16: Impact and risk evaluation for GHG emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
GHG emissions from the Development may result in: • a potential reduction to IPCC's estimated 'remaining carbon budget' to limit global warming to 1.5–2.0°C.	6	N/A	–	–	–

Impact evaluation
Potential reduction to the 'remaining carbon budget'
Remaining carbon budgets GHGs are natural and anthropogenic gaseous constituents of the atmosphere that absorb and emit radiant energy within the thermal infrared range, causing the greenhouse effect. This effect traps heat in the atmosphere. Therefore, an increase in GHG concentrations in the atmosphere increases this greenhouse effect. The Summary for Policymakers from the Working Group I contribution to the Sixth Assessment Report (WGI AR6) of the IPCC states that "[h]istorical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming" (Ref. 272). Future emissions are relevant to remaining carbon budgets, which vary based on emissions scenarios, and "indicate[] how much CO_2 could still be emitted while keeping warming below a specific temperature level" (Ref. 272). The IPCC defines the term 'carbon budget' as: "[T]he maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forces. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date. Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level." [118] AR6 WG1 outlined that the remaining carbon budgets for a 50% likelihood to limit global warming to 1.5°C, 1.7°C, and 2°C are 500 Gt CO_2-e, 850 Gt CO_2-e, and 1,350 Gt CO_2-e from the beginning of 2020, respectively[119]. The IPCC's scientific assessment reports are published every 5–7 years; the Seventh Assessment Report (AR7) cycle began in July 2023 and is expected to conclude in late-2029. As such revisions to the remaining carbon budget estimates are not expected from IPCC until the AR7 Working Group reports are ready for release.

[118] IPCC, AR6, WG1, at SPM-48 footnote 43 (Ref. 274).

[119] IPCC, AR6, WG1, at SPM-29 Table SPM.2 (Ref. 274).

Impact evaluation

The estimated total GHG emissions from the Development, including emissions associated with the transport and third-party end use of products are summarised in Table 8-13. Below are the potential reductions in the IPCC's remaining carbon budget (estimated to remain at the beginning of 2020) for a 50% likelihood to limit global warming to 1.5–2°C from these emissions:

- GHG emissions from petroleum activities within Commonwealth waters ('BFF GHG emissions'): potential ~0.0002–0.0006%
- GHG emissions from the processing of the backfill fields gas ('BFF gas processing GHG emissions'): potential ~0.01–0.02%
- GHG emissions from the transport and third-party end use of products ('BFF secondary GHG emissions'): potential ~0.04–0.12%.

The 'additional' GHG emissions from the Development not previously described and assessed under existing primary approvals (i.e. BFF GHG emissions; ~3.07 Mt CO_2-e over the life of the Development) only represent a potential ~0.0002% or ~0.0006% reduction in the remaining global carbon budget to limit global warming to 2°C or 1.5°C respectively (as estimated to remain at the beginning of 2020). This decrease is *de minimis*. Further, it is noted that this estimated potential reduction to the remaining global carbon budget is based on GHG emissions estimates (as shown in this OPP) without accounting for future mitigation (including implementation of existing emission reduction requirements for the Gorgon Gas Development and customer markets, net zero requirements, future technology or operational efficiencies, or future Australian regulatory or international policy requirements). Emissions from the Gorgon Gas Development have reduction targets on a trajectory towards net zero by 2050 under both the Commonwealth Safeguard Mechanism and State approval conditions (Sections 8.3.5.3 and 8.3.6.1), and existing customer markets (including Australia for domestic gas) have emissions reductions targets in their respective jurisdictions (Section 8.3.7). Future mitigation could result in a lower reduction to the remaining carbon budget than what is described above.

In the context of Australian GHG emissions commitments, there is both a point target and an emissions budget over the period 2021–2030 (Sections 8.3.5.1 and 8.3.5.2). To FY2024, the estimated remaining carbon budget to reach the 2030 target is 2,610 Mt CO2-e (Ref. 62). Activities for the Development are indicatively scheduled to commence from FY2027, with RFSU from FY2029 (Table 4-2). Given the indicative timing of the Development, there will be minimal reduction to Australia's remaining carbon budget to meet their 2030 target.

For comparative purposes with current Australian emission levels, the additional GHG emissions from the Development (i.e. BFF GHG emissions) are estimated to be ~3.07 Mt CO_2-e over the life of the Development (Table 8-12), which converts to an annual average of ~0.07 Mtpa CO_2-e. This is equivalent to ~0.016% of national Australian emissions (when compared to the FY2024 national inventory of 440.6 MtCO_2-e; Ref. 62). This is a *de minimis* proportion.

Role of natural gas

Note: The following evaluation is intended to be read in conjunction with the information provided in Sections 8.3.8, 8.3.9, and 8.3.10.

According to the IEA, natural gas, "which emits less carbon that most other fossil fuels", accounts for about a quarter of global electricity generation (Ref. 527). Further, IEA acknowledge that while natural gas may have a "limited role as a transition fuel from coal to renewable energy sources", it may still be needed as a back-up for variable (e.g. wind, solar) renewable power sources (Ref. 527). Within Australia, the energy market operator considers that gas has a critical role in energy supply and security during the transition to lower carbon energy sources (Ref. 528; Ref. 566); and this is supported by the Australian Governments Future Gas Strategy (Ref. 509). Further, as discussed in Section 8.3.8, a supply gap in the WA's domestic gas market is projected to occur from 2030 onwards under all modelled scenarios. The Gorgon Gas Development is one of the largest contributors to the domestic gas market in WA, having the largest indicative domestic gas reservation, and having supplied ~25% of WA's total domestic gas supply in 2024 (Section 8.3.7.1). When used as a primary energy source, LNG has several benefits over other fossil fuels, including lower emissions of sulphur dioxide, particulate matter and GHG emissions (Ref. 1).

A benchmarking assessment for the LNG processing emissions was undertaken during the Gorgon Gas Development Fourth Train Expansion Proposal Public Environmental Review / Draft Environmental Impact Statement (Ref. 6). This benchmarking assessment showed that the GFP is within the range of GHG emissions intensities compared to other Australian projects benchmarked, e.g. it has a lower emissions intensity compared to Ichthys LNG and Prelude FLNG, but a higher emissions intensity compared to Curtis Island LNG (Ref. 6). Benchmarking was more recently undertaken during the development of the GHGMP (Ref. 67), which estimated

Impact evaluation

a net GHG emissions intensity for the GFP as 0.17 t CO_2-e per t LNG. This net emissions intensity was similar or less than other comparable gas developments on the NWS (Ref. 67).

The proposed end of life for the Gorgon Gas Development, including the Development, is also considered to be consistent with the intent of the Australian Government's *Future Gas Strategy* in that the use of gas is expected to continue through to 2050 and beyond (Ref. 509).

Fossil fuels met 80% of global energy demand in 2023 (Ref. 529). While the demand for energy services is projected to continue to increase, the recent 2024 WEO indicates that demand for oil, natural gas, and coal is set to peak by 2030; however, the demand for natural gas is expected to remain robust in emerging market and developing economies (Ref. 529). The 2024 WEO also indicated that by the end of this decade the increase in global energy demand could be met without additional amounts of oil, natural gas or coal; this differs from previous projections which needed a proportion of the increase in global energy demand to be met by fossil fuels (Ref. 529). However, fossil fuels still maintain a role in the global energy mix projections to 2050 under all WEO 2024 scenarios (Section 8.3.9.1), including the APS and NZE Scenarios both of which are associated with at least a 50% chance of limiting the temperature rise to 1.5 °C and 2.0 °C in 2100. The Gorgon Gas Development is an existing development that has been producing since 2016, supplying both Australian and international markets.

Secondary GHG emissions associated with the transport and third-party end-use of LNG, condensate and domestic gas products is the largest category of emissions associated with CAPL's activities (appendix e). These secondary emissions are driven by domestic and global demand, which is in turn driven by economics, policy, regulation, and consumer behaviour on a global scale (Ref. 276). As described in Section 8.3.7, the countries with major sales agreements in place for products from the Gorgon Gas Development have submitted NDCs to the UNFCCC in alignment with the Paris Agreement (or have equivalent targets established in their country). This includes Australia for the domestic gas component of the Gorgon Gas Development (Section 8.3.7.1).

Development emissions and global anthropogenic influence on climate systems

IPCC states in the AR6 Synthesis Report: Summary for Policymakers (Ref. 756) that "[o]bserved increases in well-mixed GHG concentrations since around 1750 are unequivocally caused by GHG emissions from human activities over this period"[120]. The Synthesis Report also recognises the "interdependence of climate, ecosystems and biodiversity, and human societies"[121] and WGI AR6 of the IPCC acknowledges that "[c]limate change is a global phenomenon, but manifests differently in different regions" (Ref. 271).

Anthropogenic changes to the global climate system cannot be directly attributed to any one development or emission source or product, as they are the result of the net accumulation of global GHGs (emissions minus sinks) in the atmosphere since the industrial revolution (i.e. it is atmospheric GHG concentrations in the aggregate that contribute to global temperature or climate trends).

Based on ice core records, historical atmospheric CO_2 concentrations through glacial ice age cycles extending 650,000–800,000 years before present, ranged between ~172–300 ppm (Ref. 758). Further, measurements of air extracted from Antarctic ice cores and firn show that all three major greenhouse gases (CO_2, CH_4 and N_2O) were relatively stable for most of the past 2,000 years, before beginning to rise in the late 18th century; this timing coincided with industrialisation and the expansion of agriculture (Ref. 637). The IPCC AR6 Synthesis Report states that "[i]n 2019, atmospheric CO_2 concentrations reached 410 parts per million (ppm), CH_4 reached 1866 parts per billion (ppb) and nitrous oxide (N_2O) reached 332 ppb"[122] and that "[s]ince 1750, increases in CO_2 (47%) and CH_4 (156%) concentrations far exceed – and increases in N_2O (23%) are similar to – the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years (*very high confidence*)."[122] This is consistent with BoM and CSIRO reporting that shows the estimated increases in globally averaged atmospheric concentrations of the three major GHGs since the industrial revolution began in the mid-1700's are:

- CO_2 concentration in 2023 was ~419 ppm compared to ~277 ppm in 1750 (~51% increase)
- CH_4 concentration in 2023 was ~1,919 ppb compared to 731 ppb in 1750 (162% increase)
- N_2O concentration in 2023 was ~337 ppb compared to 273 ppb in 1750 (23% increase) (Ref. 637).

[120] IPCC AR6, Synthesis Report, SPM-4 (Ref. 784).

[121] IPCC AR6, Synthesis Report, SPM-1 (Ref. 784).

[122] IPCC AR6, Synthesis Report, 42 (Ref. 787)

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Anthropogenic sources of GHG emissions are also the results of multiple sectors and land-use practices. The IPCC indicates that in 2019, "approximately 79% of global GHG emissions came from the sectors of energy, industry, transport, and buildings together and 22% from agriculture, forestry and other land use"[123].

With respect to the energy sector, the potential accumulation of GHG emissions in the atmosphere is, in turn, influenced by global energy demand and the composition of the global energy mix. Growing populations, rising incomes, and urbanisation are the principal forces behind energy-demand growth, as they typically lead to greater use of transportation, heating, cooling, lighting, and refrigeration (Ref. 276).

Further, the changing regulatory and international initiatives on climate change (e.g. which may result in changing reduction targets and timeframes), projections in energy supply and demand, and changes in other industrial sectors or land-use practices will also influence the total global GHG emissions into the future – making a future prediction of changes to climate systems, inaccurate.

Anthropogenic GHG emissions from the Development do not individually cause the physical effects of climate change, rather it is their cumulative effect, in combination with GHG emissions from all other anthropogenic and natural sources since the mid-1700's, that contribute to increased global temperature and global weather trends in the aggregate that may cause or contribute to physical effects on Australian environmental values and sensitivities. It is not reasonably practicable to measure the contribution of GHG emissions from the Development to the cumulative anthropogenic impacts to climate systems and they could not be characterised as a *substantial cause* of the physical effects of climate change on environmental values and sensitivities, because of their remoteness to the consequence, intervening impacts and the fact GHG emissions from the Development constitute a relatively minor reduction in remaining global carbon budgets

As a contribution to the anthropogenic influence on the global climate system cannot be directly attributed to any one development, the following sections provide an overview of some of the potential impacts to climate systems and environmental values and sensitivities for contextual purposes only.

Changes to climate systems

WGI AR6 of the IPCC acknowledges, "[c]limate change is a global phenomenon, but manifests differently in different regions" (Ref. 271).

According to the IPCC AR6, the physical risks of climate change are varied and widespread. Chevron Corporation acknowledges that the company's operations are subject to disruption from natural or human causes beyond its control, including physical risks from hurricanes, severe storms, floods, heat waves, other forms of severe weather, wildfires, ambient temperature increases, sea level rise, fires, and earthquakes, some of which may be impacted by climate change and any of which could result in suspension of operations or harm to people or the natural environment (Ref. 276).

According to the IPCC, among other things, global changes to the climate system can include the following: increase in global surface temperatures, changes to frequency and intensity of precipitation, sea level rise, retreat of glaciers and artic sea ice, changes to the intensity and frequency of certain extreme weather events and droughts (Ref. 271). Specifically, the IPCC projections for the Australia include:

- **Droughts**: Additional regional changes in Australasia [. . .] include a significant decrease in April to October rainfall in southwest Western Australia, observed from 1910 to 2019 and attributable to human influence (*high confidence*[124]), which is *very likely* to continue in future. Agricultural and ecological and hydrological droughts have increased over southern Australia (*medium confidence*), and meteorological droughts have decreased over northern and central Australia (*medium confidence*). (. . .) Agricultural and ecological droughts are projected to increase in southern and eastern Australia (*medium confidence*) for a 2°C GWL."[125]

[123] IPCC AR6, Synthesis Report, SPM-4–5 (Ref. 784).

[124] "The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate." IPCC AR6, SPM-4 (Ref. 274).

[125] IPCC AR6, WG1, TS-139 (Ref. 659).

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- **Fire Weather Conditions**: "The number of evident attribution studies on compound events is limited. There is medium confidence that weather conditions that promote wildfires have become more probable in southern Europe, northern Eurasia, the USA, and Australia over the last century. In Australia a number of event attribution studies show that there is medium confidence of increase in fire weather conditions due to human influence.".[126] (. . .) Fire weather is projected to increase throughout Australia (*high confidence*) . . . .[125]
- **Precipitation**: "In the future, heavy precipitation and pluvial flooding are *very likely* to increase over northern Australia and central Australia, and they are *likely* to increase elsewhere in Australasia for global warming levels (GWLs) exceeding 2°C and with *medium confidence* for a 2°C GWL."[125]
- **Relative Sea Level Rise**: "Relative sea level has increased over the period 1993–2018 at a rate higher than GMSL around Australasia (*high confidence*). Sandy shorelines have retreated around the region, except in southern Australia, where a shoreline progradation rate of 0.1 myr–1 has been observed." [125] . . . "With the exception of a few regions with substantial land uplift, relative sea level rise is *very likely* to *virtually certain* (depending on the region) to continue during the 21st century, contributing to increased coastal flooding in low-lying areas (*high confidence*) and coastal erosion along most sandy coasts (*high confidence*) over the 21st century."[127]
- **Snowfall**: "Snowfall is expected to decrease throughout the region at high altitudes in [] Australia (*high confidence*)."[125] (. . .) "Observations in Australia show that the snow season length has decreased by 5% in the last five decades. Furthermore, the date of peak snowfall in Australia has advanced by 11 days over the last 5 decades."[128]
- **Tropical Cyclones**: "In Australia, the number of [tropical cyclones] has generally declined since 1982, and the frequency of intense TCs that make landfall in north eastern Australia has declined significantly since the 19th century (medium confidence). There is high confidence that cyclones making landfall along north eastern and north Australian coastlines will decrease in number and low confidence of an increase I their intensities for a 2°C global warming level as well as for the mid-century period with scenarios RCP4.5 and above, with the amplitude of changes increasing from RCP4.5 to RCP8.5. Decreases in frequency are projected for 'east coast lows.'"[129]

The 2024 State of the Climate report by BoM and CSIRO (Ref. 637) indicate trends similar to the IPCC projections including:

- "In the south-west of Australia there has been a decrease of around 16% in April to October rainfall since 1970. Across the same region, May to July rainfall has seen the largest reduction, by around 20% since 1970. … In the south-east of Australia, there has been a decrease of around 9% in April to October rainfall since 1994."[130]
- "There has been an increase in rainfall and streamflow across parts of northern Australia since the 1970s."[130]
- "There has been an increase in extreme fire weather, and a longer fire season, across large parts of the country since the 1950s."[130]
- "Sea levels are rising around Australia, including more frequent extreme high levels that increase the risk of inundation and damage to coastal infrastructure and communities."[130]
- "Snow depth, snow cover and number of snow days have decreased in alpine regions since the late 1950s."[130]
- "There has been a decrease in the number of tropical cyclones observed in the Australian region since at least 1982."[130]

The analyses indicated that "Australia's climate has warmed by an average of 1.51±0.23°C since national records began in 1910" and "[s]ea surface temperatures have increased by an average of 1.08°C since 1900" (Ref. 637).

Australian values and sensitivities vulnerable to climate change

The Working Group II contributions to the IPCC's Sixth Assessment Report (WGII AR6) provides a summary of the observed impacts, vulnerability and exposure, and adaptive responses

[126] IPCC AR6, WG1, TS-109 (Ref. 659).
[127] IPCC AR6, WG1, TS-134 (Ref. 659).
[128] IPCC AR6, WG1, TS-140 (Ref. 659).
[129] IPCC AR6, WG1, 12-54, 55 (Ref. 659).
[130] BoM and CSIRO, Key Points, 2 (Ref. 660).

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observed to date (Ref. 273). The WGII AR6 report notes that "[c]limate trends and extreme events have combined with exposure and vulnerabilities to cause major impacts for many natural systems, with some experiencing or at risk of irreversible change in Australia (*very high confidence*)"[131] and that "[c]limate trends and extreme events have combined with exposure and vulnerabilities to cause major impacts for some human systems (*high confidence*)"[131]. The WGII AR6 report identifies nine key climate risks for the Australasian region:

- "Loss and degradation of coral reefs and associated biodiversity and ecosystem service values in Australia due to ocean warming and marine heatwaves (*very high confidence*)
- Loss of alpine biodiversity in Australia due to less snow (*high confidence*)
- Transition or collapse of alpine ash, snowgum woodland, pencil pine and northern jarrah forests in southern Australia due to hotter and drier conditions with more fires (*high confidence*)
- Loss of kelp forests in southern Australia and southeast New Zealand due to ocean warming, marine heatwaves and overgrazing by climate-driven range extensions of herbivore fish and urchins (*high confidence*)
- Loss of natural and human systems in low-lying coastal areas due to sea-level rise (*high confidence*)
- Disruption and decline in agricultural production and increased stress in rural communities in south-western, southern and eastern mainland Australia due to hotter and drier conditions (*high confidence*)
- Increase in heat-related mortality and morbidity for people and wildlife in Australia due to heatwaves (*high confidence*)
- Cascading, compounding and aggregate impacts on cities, settlements, infrastructure, supply-chains and services due to wildfires, floods, droughts, heatwaves, storms and sea-level rise (*high confidence*)
- Inability of institutions and governance systems to manage climate risks (*high confidence*)." [131]

A previous (2009) strategic assessment by Australia's Biodiversity and Climate Change Advisory Group (Ref. 531; Ref. 638) indicates that "[b]iodiversity is one of the most vulnerable sectors to climate change". The report also notes that "Australia's biodiversity is not distributed evenly over the continent but is clustered in a small number of hotspots with exceptionally rich biodiversity", and that these "include the Great Barrier Reef, south-west Western Australia, the Australian Alps, the Queensland Wet Tropics and the Kakadu wetlands" (Ref. 531). The report identifies "a few examples of recently observed changes in Australia's biota that are consistent with the emerging climate change 'signal' ", as genetic constitution, geographic ranges, life cycles, populations, ecotonal boundaries, ecosystems, and disturbance regimes (Table 1 within Ref. 531). Further, it is noted that "many of the most important impacts of climate change on biodiversity will be the indirect ones at the community and ecosystem levels, together with the interactive effects with existing stressors (Ref. 531).

Climate change is identified as a pressure within the 2021 State of the Environment[132] (Ref. 626; Ref. 641). Observed and/or predicted impacts on terrestrial ecosystems and biodiversity include (Ref. 627):

- "Data from the Australian Long Term Ecological Research Network have been used to examine ecosystem responses to changes in climate and disturbance regimes from plots in tropical savanna, alpine systems, temperate heathlands and temperate woodlands. A range of biodiversity responses to climate were recorded, including decreases in some species and increases in others."
- "Alpine ecosystems and biodiversity in Australia are particularly vulnerable to climate change that affects snow depth and the spatial and temporal extent of snow … Long-term monitoring of alpine vegetation in Australia has shown shifts in plant species composition and diversity, changes in the timing of flowering, and declines in endangered fauna such as the mountain pygmy possum."
- The ranges of the majority of Australia's eucalypt species are predicted to shrink in size over the next 60 years … Approximately 90% of the current areas with concentrations of palaeo-endemism (i.e. places with eucalypt species that were once widespread and are now

[131] IPCC AR6, WGII, Australasia FS (Ref. 547).

[132] The EPBC Act legislates a review of the state of the Australian environment every 5 years.

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restricted to small ranges) are predicted to disappear or shift their location, and this is likely to have significant flow-on effects for ecosystem structure and function".

Observed and/or predicted impacts on aquatic ecosystems and biodiversity include (Ref. 627):

- "Aquatic ecosystems and biodiversity are recognised as being among the most vulnerable to climate change. They experience both local changes and the cumulative effects of changes in the surrounding landscape, as well as exposure to a wide range of extreme climatic events such as floods and droughts."
  - e.g. between late-2015 and early-2016 mangroves in the Gulf of Carpentaria "suffered significant mortality. This happened during an underwater heatwave (which was also responsible for bleaching on the Great Barrier Reef) in combination with a severe drought and a temporary drop in sea level due to a strong El Niño event."
- "Aquatic ecosystems in coastal areas are also affected by sea level rise and storm surge associated with intense storms. Along with structural changes and damage, these will bring changes in water salinity that can have long-term effects on wetland flora and fauna"
- "Altered water quality, as well as quantity, will be a major trigger for climate change effects on freshwater biodiversity. For example, the combination of hot conditions, low flows and significant algal blooms during the recent major drought (2018–20) resulted in mass fish kills in the Murray–Darling Basin."
- "Much of Australia has limited water resources, and there is limited scope for freshwater species to move to more favourable conditions as the climate changes. Species losses under future climates are likely to be high, particularly for inland regions of Australia."

Predicted impacts on coastal and marine ecosystems and biodiversity include (Ref. 633; Ref. 632):

- ocean warming "is associated with poleward range shifts as species move towards cooler waters" which can "cause changes in marine communities" and "can also affect the lifecycle and populations of marine species"
- "Marine heatwaves can significantly impact the supply of nutrients to the upper ocean, and change phytoplankton biomass and primary production, which can have both beneficial and detrimental effects on ecosystems."
- "Prolonged, extremely warm waters cause acute widespread ecosystem damage, with species mortality and community structure shifts, and threaten marine biodiversity and ecosystem services. Such events can have persistent impacts, with kelp forests collapsing, coral recovery taking years and important fishery species recovering slowly."
- "Climate change is affecting ocean salinity, with the effects varying across regions. … However, extreme salinity events through flooding are suggested to be a pressure to more Australian marine environments than climate change trends in salinity"
- "Ocean acidification is predicted to lead to shifts in ecosystems and biodiversity, and increase the risk to regional economies that rely on healthy and sustainable marine ecosystems, such as tourism and aquaculture."
- "One of the most significant impacts of sea level rise on Australia's coast is erosion and movement of beaches, and permanent inundation of low-lying areas."
- "Extreme rainfall events can generate local coastal flooding, either directly or via run-off from slopes or river transports. These floodwaters may carry pollution from agriculture such as soils, pesticides and fertilisers, and can cause turbid coastal plumes. This impacts marine and coastal ecosystems such as coral reefs, seagrass and kelp environments, and the species these habitats support" and conversely that "[e]xtreme dry periods can raise coastal salinity levels through evaporation, affecting marine and coastal habitats and species."
- "Extreme wind and cyclones can generate high to extreme waves, sea level and storm-surge conditions, which can cause coastal erosion and damage to coastal structures within and around coastlines and embayments."

It was also noted that Australian boundary currents (e.g. East Australian Current, Indonesian Throughflow, and Leeuwin Current) have a major influence on the marine ecosystem. While it is known that El Niño-Southern Oscillation cycles influence these boundary currents, there is a knowledge gap in predicting future state of boundary currents and an ability to assess impacts on the marine ecosystem (Ref. 633).

The National Climate Risk Assessment (delivered by the Australian Climate Service) provides an analysis of the potential risks and impacts from a changing climate. The national assessment focusses on *physical* climate risks, is domestically focussed (i.e. within Australian jurisdictional

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borders), and was completed in two stages. The first pass assessment (released in 2024; Ref. 639) identified 56 nationally significant climate risks within seven key systems. The second pass assessment (released in September 2025; Ref. 768) identified an additional seven nationally significant climate risks (i.e. 63 in total for the full National Climate Risk Assessment).

The nationally significant climate risks were identified for the natural environment (where the natural environment system refers to Australia's ecosystems and biodiversity) (Ref. 639; Ref. 768):

- **risks to aquatic and terrestrial ecosystem condition and function or landscape function** and collapse including species loss and extinction
- **risks to vulnerable environments and interconnected ecosystems**, such as mangroves, reefs and green spaces, that buffer against other disturbances and provide critical ecosystem services
- **risks to natural resources, including water security**, that increase scarcity and may result in competition and potential conflict
- **risks to species**, through loss and extinction that affect ecosystems, ecological and human communities, and intrinsic, cultural and economic values
- **risks to access, use and management of natural places** from fire season and hot days, as well as damage to roads, built infrastructure and coastal developments
- **risks to rural and Aboriginal and Torres Strait Island peoples' livelihoods** and community resilience from long-term climate-related changes and hazards
- **risks to human health, wellbeing and livelihood** from landscape change that results in disruption, migration and increased pressure on resources, especially in rural and remote communities
- **risks to iconic and unique natural places** and associated cultural, social and Aboriginal and Torres Strait Islander peoples' values from a loss of natural environments, amenity value and land and marine use.

The Australian Climate Service has rated risks[133] to Australia's key systems, both now and in the future (Ref. 768). The current risk to the natural environment system has been classified as between High and Very High; and the prediction for 2050 is for this risk to be Severe (Ref. 768).

Key findings from the second pass assessment also describe how climate hazards are projected to change:

- "Australia's climate is changing and will continue to change into the future. The country is likely to experience more intense and extreme climate hazards, and in some cases in areas where people and places haven't experienced these hazards before.
- Climate science indicates that our future extreme weather is likely to differ significantly from the past. Changes in the timing, duration, intensity and spatial patterns of hazards are likely, with many events occurring more frequently, in combination or affecting new locations.
- The change in distribution, timing and severity of extreme weather events means that historical observations on their own are not likely to be a good indicator of future risk.
- Australia currently experiences compounding and cascading hazards, and this is going to increase. Concurrent events, and reduced time between severe events will become more common" (Ref. 768).

The 'loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' has been listed as a key threatening process under the EPBC Act (Cth) (Ref. 532). The threatening process consists of reductions in the bioclimatic range within which a given species or ecological community exists due to emissions induced by human activities of GHGs (Ref. 533). The process is considered to have a continental distribution, including both terrestrial and marine areas. Ecosystems in which the process occurs includes alpine habitats, coral reefs, wetlands and coastal ecosystems, polar communities, tropical forests, temperate forests, and arid and semi-arid environments (Ref. 533).

Further, DCCEEW have identified climate change as a threat to threatened species, specifically that "[t]he changing climate is affecting Australia's biodiversity currently and will continue to threaten our species and ecological communities. Individual species may see altered distribution,

[133] The risk ratings categorise impacts into five levels (Low, Moderate, High, Very High and Severe) based on specific criteria. These ratings consider the percentage of the population affected, the extent of geographical impact, and the severity of consequences for vulnerable communities, public health, natural systems and national security (Ref. 796).

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phenology and behaviour, in turn resulting in changes to the composition and function of ecosystems and ecological communities. Climatic shifts can exacerbate the impacts of existing pressures, such as habitat fragmentation and invasive species, on threatened species and places" (Ref. 274). Actions identified within this Threatened Species Action Plan include updating conservation plans to mitigate climate change risk for susceptible species (Ref. 274). Of the 20 priority places identified within the Threatened Species Action (including the Australian Alps, Eastern Forests of Far North Queensland, and Giant Kelp Ecological Community) all identified climate change as either a major or moderate threat (Ref. 274; Ref. 640).

Climate change is identified as a threat to some protected species, including marine turtles and whales:

- The Recovery Plan for Marine Turtles in Australia (Ref. 24) states that '[c]limate change is of particular concern to marine turtles because it is likely to have impacts across their entire range and at all life stages. Climate change is expected to cause changes in dispersal patterns, food webs, species range, primary sex ratios, habitat availability, reproductive success, and survivorship'.
- The Conservation Management Plan for the Blue Whale (Ref. 20) states: '[c]limate change is expected to cause changes in migratory timing and destinations, population range, breeding schedule, reproductive success, and survival of baleen whales, including blue whale species and subspecies'.
- The Wildlife Conservation Plan for Seabirds (Ref. 38) states that "[c]onsequences to seabirds could include negative impacts from an increase in extreme weather events, reduced or changed prey abundance and distribution, and decrease in nesting habitat".
- The Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) states that '[s]uch changes have the potential to affect migratory shorebirds and their habitats by reducing the extent of coastal and inland wetlands or through a poleward shift in the range of many species".

The management plans for the Australian Marine Parks identify climate change as a pressure that may impact marine park values (Ref. 82; Ref. 618; Ref. 619; Ref. 620; Ref. 621; Ref. 622; Ref. 623; Ref. 624). The North-west Marine Parks Network Management Plan 2018 (Ref. 82) states that "[t]he impacts of climate change on the marine environment are complex and may include changes in sea temperature, sea level, ocean acidification, sea currents, increased storm frequency and intensity, species range extensions or local extinctions, all of which have the potential to impact on marine park values".

Within the Marine Bioregional Plan for the NWMR (Ref. 102), pressures related to climate change are assessed as 'of potential concern' for some species of marine turtle, inshore dolphins, sawfish, sea snakes, whale shark, dugong, and seabird and shorebird, as well as the KEFs and shipwrecks known to occur in the NWMR. Similarly within the other marine bioregional plans, pressures related to climate change were assessed as 'of concern' or 'of potential concern' to values within each bioregion (Ref. 613; Ref. 614; Ref. 615).

Evaluation summary

In summary, given that:

- natural gas emits less carbon compared to other fossil fuel alternatives
- projections in global and domestic energy trends identify natural gas as an energy source for the foreseeable future
- the Australian Government considers natural gas is part of Australia's long-term energy security and transition plans
- Gorgon Gas Development has GHG emission reduction targets on a trajectory to net zero by 2050 under both Commonwealth Safeguard Mechanism and State approval conditions
- Australia has GHG emission reduction targets that align with intent of the Paris Agreement
- customer countries adopt their own regulatory mechanisms relating to GHG emissions based on various considerations, including energy policies, GHG emissions reduction ambitions, and international commitments
- atmospheric GHG concentrations are the aggregate consequence of GHG emissions from all sectors and land-uses, and have been increasing since the mid-1700s
- climate change is a global and cumulative phenomenon, it is not reasonably practicable to measure any one development's contribution to anthropogenic impacts to climate systems

the potential impact from the Development to the reduction of IPCC's estimated remaining carbon budget for a 50% likelihood to limit global warming to 1.5–2.0°C has been evaluated as having the potential to result in an Incidental (6) consequence.

8.3.14 determination of acceptability

The acceptable level of impact is a function of the magnitude of impact and residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-17 details the determination of acceptability for GHG emissions.

Table 8-17: Determination of acceptability for GHG emissions

Determination of acceptability	
Comparison with acceptable level	Acceptable levels for the Development are defined in Section 7.6. The acceptable level (**AL-08**; see Table 8-18) is applicable to GHG emissions associated with the Development's activities in Commonwealth waters and the processing of the backfill fields gas. Australia is a party to the Paris Agreement and is currently committed to reducing GHG emissions by 43% below 2005 levels by 2030 and achieving net zero by 2050 (Ref. 516). In September 2025 Australia submitted its second NDC committing to a "[r]eduction in net national greenhouse gas emissions of 62–70% below 2005 levels by 2035, implemented as an emissions budget covering the period 2031–35" (Ref. 762). In addition, as described in Section 8.3.5 Australia also has other legislative instruments (e.g. NGER and Safeguard Mechanism schemes) to manage GHG emissions from developments in Australia. Further, the predominant amount of these emissions (BFF gas processing GHG emissions) are a proportion of the overall Gorgon Gas Development's emissions as described in existing primary and secondary environmental approvals (e.g. Ref. 3; Ref. 6; Ref. 67; Ref. 9). No change to previously approved gas processing GHG emissions is being sought under the Backfill Fields Development OPP in relation to the overall Gorgon Gas Development GHG emissions. The 'additional' GHG emissions associated with the Development (BFF GHG emissions) has been estimated at ~3.07 Mt CO_2-e over the life of the Development and within scope for approval as part of this OPP. This represents a *de minimis* potential reduction to IPCC's remaining carbon budget for a 50% likelihood to limit global warming to 1.5–2.0°C. The Gorgon Gas Development, including the Development, must comply with any State or Commonwealth environmental approvals and legislative requirements, and therefore GHG emissions will be managed to be equivalent or better than the acceptable level. As described in Sections 8.3.5.3 and 8.3.6.1 these legislative requirements have emission reduction targets in place for the Gorgon Gas Development, on a trajectory to net zero by 2050. The acceptable levels (**AL-09, AL-10** and **AL-11**; see Table 8-18) are applicable to GHG emissions associated with transport and third-party end use of the Development's products. The location of customer markets (Section 8.3.7) will determine where the BFF secondary GHG emissions are released; and these will occur both within Australia (from domestic gas use) and internationally (from LNG and condensate transport and use). As described above, GHG emissions in Australia are managed by the emitter under existing legislative requirements. For international product transport and use, GHG emissions are managed under the respective requirements of those jurisdictions. At the time of writing this OPP, all existing customer markets with long-term sales agreements have NDCs under the Paris Agreement (or equivalent GHG emission reduction targets) in place (Section 8.3.7). As described previously, anthropogenic global GHG emissions from the Development do not individually cause the physical effects of climate change, rather it is their cumulative effect, in combination with GHG emissions from all other anthropogenic and natural sources since the mid-1700's, that contribute to increased global temperature and global weather trends in the aggregate that may cause or contribute to physical effects. Therefore given that there are project, national, and international mechanisms in place to manage GHG emissions within respective jurisdictions, and that the

Determination of acceptability	
	additional GHG emissions from the Development represent a *de minimis* potential reduction to IPCC's estimated remaining carbon budget for a 50% likelihood to limit global warming to 1.5–2.0°C, the predicted level of impact is equal to or better than the acceptable levels.
Principles of ESD	**(b) 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 impact identified for GHG emissions was a potential reduction to IPCC's remaining carbon budget for a 50% likelihood to limit global warming to 1.5–2.0°C. The consequence level for this impact was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against this principle of ESD is required. Notwithstanding, CAPL acknowledges the residual uncertainty associated with evaluation of environmental impacts from GHG emissions, and presents the following consideration of the precautionary principle in relation to this aspect. Uncertainty arises from limitations in climate science, including climate modelling, revised forecasts in global energy mix, and subsequent changes in regulatory and policy requirements. These areas are expected to evolve, and new information to become available over time. CAPL has adopted **CM-12** and **CM-14** to address residual uncertainty in GHG emissions estimates and **CM-13** to address residual uncertainty in projected domestic and global energy trends and to ensure that secondary GHG emissions from the Development remain at an acceptable level in future EPs. Australia has ratified the Paris Agreement and the Doha Amendment to the Kyoto Protocol and set a target to reduce GHG emissions by 43% below 2005 levels by 2030 and reduce Australia's net GHG emissions to zero by 2050, as outlined in the *Climate Change Act 2022* (Cth). In September 2025 Australia submitted its second NDC committing to a "[r]eduction in net national greenhouse gas emissions of 62–70% below 2005 levels by 2035, implemented as an emissions budget covering the period 2031–35" (Ref. 762).The Development is not considered inconsistent with the Australian Government's efforts to achieve their NDC targets because: • the 'additional' GHG emissions associated with the Development (BFF GHG emissions) has been estimated at ~3.07 Mt CO_2-e over the life of the Development and this represents a *de minimis* reduction of IPCC's remaining global carbon budget for a 50% likelihood to limit global warming to 1.5–2.0°C. • the Gorgon Gas Development (including the Development) has a regulated net zero pathway and large proportion of emissions reduction through technical abatement (under State Ministerial conditions and Safeguard Mechanism reforms). • Chevron Corporation supports the global ambitions of the Paris Agreement (Ref. 276).
	(c) the principle of inter-generational 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
	Considering economic development that safeguards the welfare of future generations, the Development is considered to align with the core objectives of ESD by: • Providing a lower carbon intensity and reliable energy source. Chevron Corporation's purpose "is to provide the affordable, reliable, ever-cleaner energy that enables human progress" (Ref. 534). • Natural gas is projected to continue to be a part of the domestic energy mix (Section 8.3.8). The Gorgon Gas Development is one of the largest contributors to the domestic gas market in WA, having the largest

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	indicative domestic gas reservation, and having supplied ~25% of WA's total domestic gas supply in 2024 (Section 8.3.7.1). • Natural gas is projected to continue to be a part of the global energy mix to 2050 (Section 8.3.9) under all WEO 2024 scenarios (Section 8.3.9.1), including the APS and NZE Scenarios both of which are within a range of IPCC AR6 WGIII scenario projections that led to at least a 50% chance of limiting the temperature rise to 1.5°C or 2°C. • One of the UN 2030 Agenda sustainable development goals (SDGs) is "ensure access to affordable, reliable, sustainable and modern energy for all" (Ref. 535). Chevron Corporation contribute to the SDGs through their operations, partnership initiatives and social investments (Ref. 275). Chevron Corporation invest in health, education, and economic development with the goal of creating measurable and enduring value. Through membership in International Petroleum Industry Environmental Conservation Association (IPIECA), Chevron Corporation have worked with the World Business Council for Sustainable Development on the creation of an SDG Roadmap for the oil and gas sector. The Roadmap identifies how IPIECA, as an industry association, and Chevron Corporation can work toward a lower-emissions future while contributing to the 2030 Agenda. • The Australian Government acknowledges that "Australia is committed to supporting global emissions reductions to reduce the impacts of climate change and will reach net zero emissions by 2050" (Ref. 509). Moreover, by FY2023 Australia has already reduced GHG emissions by 25.9% since FY2005 (Ref. 517). Australia is "committed to remaining a reliable supplier of LNG" and "[h]onouring long-term LNG contractual obligations is essential to maintaining trusted relationships with our international partners, and to providing the energy security necessary to progress decarbonisation plans" (Ref. 509). • By providing lower emission intensity energy exports (LNG), relative to other fossil fuels, and by not materially or substantially contributing to Australia's GHG emissions, the Development is not inconsistent with the Australia Government's efforts to reach net zero by 2050. • Energy is fundamental to society, and access to reliable and affordable energy sources is interlinked with their ability to sustainably develop and maintain health, diversity, and productivity for future generations (Ref. 536). Natural gas provides both a reliable and affordable energy source and is one of the lower emission fossil fuels. The continued use of natural gas is in line with Australia's *Future Gas Strategy* (Ref. 509), the natural gas from the Gorgon Gas Development (including the Development), is produced with similar or lower emissions intensity than other comparable gas supplies on the NWS, the use of natural gas is considered to support Australia's transition to lower carbon intensive fuels, and the natural gas from the Gorgon Gas Development provides an ongoing supply of natural gas to meet continuing global energy demand. In addition, as described in Section 8.3.7, the existing customer markets with long-term sales agreements for Gorgon Gas Development products are countries that have also ratified the Paris Agreement and established their own NDCs for managing emissions (or have equivalent targets established in their country); this includes Australia for domestic gas use.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option. The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk to the environment (Section 5). Principle of ESD (d) is applied through the consideration of conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address relevant item/objective/action within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Environmental Protection Act 1986 (Cth)
The production of gas from the Greater Gorgon Area, including the gas fields associated with the Development, and its processing at the Gorgon GTP was described within primary environmental approvals (Section 8.3.6). While development of backfill fields was articulated under previous primary approvals documentation, this OPP constitutes the primary approval document for the seven backfill fields, and any additional GHG emissions resulting from this Development (i.e. BFF GHG emissions).
BFF gas processing GHG emissions associated with gas processing at the GTP on Barrow Island, and BFF secondary GHG emissions from the transport and third-party end use of products are a proportion of the overall Gorgon Gas Development emissions that have been previously described and assessed within existing primary environmental approvals (Section 8.3.6).
In October 2022, the WA Minister for Environment, pursuant to section 46 of the EP Act approved the amendment to the implementation conditions within MS 800 by way of MS 1198. This amendment included revisions to condition 26 (Reservoir Carbon Dioxide Injection System) and condition 27 (Greenhouse Gas Management Plan).</td><td>Australian legislative requirements to manage GHG emissions are addressed by adopting this EPO and control measure:
• EPO-11
• CM-10 (see Table 8-18).</td></tr>
<tr><td>National Greenhouse and Energy Reporting (NGER) Act 2007
National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015
The ‘Gorgon Operations Facility’ is registered with the CER as a facility under both the NGER and Safeguard Mechanism schemes. The scope of the Gorgon Operations Facility includes GHG emissions from both the GTP and associated facilities on Barrow Island, as well as from any activities</td><td></td></tr>
</table>

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	or facilities in Commonwealth waters. CAPL will continue to monitor and report GHG emissions, and maintain a baseline, under this legislation.	
	AMSA Marine Order 97: Marine Pollution Prevention – Air Pollution Sets out the requirements for preventing air pollution by vessels including certification requirements, reporting requirements, incineration on board a vessel, energy efficiency, servicing and record keeping.	Legislative requirements to manage GHG emissions are addressed by adopting this control measure: • **CM-09** (see Table 8-18).
	Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution) Aims at protecting the marine environment from pollution associated with vessels within Australian waters and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) Management Action A.3.1: Continue to meet Australia's international commitments to reduce GHG emissions and regulate the krill fishery in Antarctica.	As described in the above impact evaluation, the estimated additional GHG emissions associated with the Development are considered *de minimis* (~3.07 Mt CO_2-e over the life of the Development) and are not considered to be inconsistent with Australia meeting its international agreements (i.e. NDCs under the Paris Agreement). EPBC management plan requirements to manage GHG emissions are addressed by adopting this EPO and control measure: • **EPO-11** • **CM-10** (see Table 8-18).
	Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 22) Conservation action: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 21) Conservation action: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	
	National Recovery Plan for the Southern Right Whale *(Eubalaena australis)* (Ref. 23) Management Action A3.1: Continue to meet Australia's international commitments to address causes of	

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	climate change, including greenhouse gas emissions.	
	Recovery Plan for Marine Turtles in Australia (Ref. 24) Management Action A2.1: Continue to meet Australia's international commitments to address the causes of climate change.	
	Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Ref. 25)	These EPBC management plans for species that may occur within the EMBA identify climate change as a threat, but do not identify any relevant management or conservation actions.
	Recovery Plan for the Grey Nurse Shark (Carcharias taurus) *(*Ref. 32*)*	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 33)	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 34)	
	Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin) (Ref. 663)	
	Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin) (Ref. 664)	
	Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 30)	
	Conservation Advice for *Milyeringa justitia* (Barrow cave gudgeon) (Ref. 764)	
	Wildlife Conservation Plan for Seabirds *(*Ref. 38*)*	
	Wildlife Conservation Plan for Migratory Shorebirds *(*Ref. 39*)*	
	National Recovery Plan for Albatrosses and Petrels (Ref. 40)	
	Conservation Advice for the Abbott's Booby (*Papasula abbotti*) (Ref. 41)	
	Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 42)	
	National Recovery Plan for (*Sternula nereis nereis*) (Australian Fairy Tern) (Ref. 44)	
	National Recovery Plan for the Australian Painted Snipe (*Rostratula australis*) (Ref. 665)	
	Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 47)	

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	Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (Ref. 48)	
	Conservation Advice for *Numenius madagascariensis* (Far Eastern Curlew) (Ref. 49)	
	Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 50)	
	Conservation Advice (*Falco hypoleucos*) Grey Falcon (Ref. 694)	
	Conservation Advice for *Sternula albifrons* (little tern) (Ref. 666)	
	Conservation Advice *Pezoporus occidentalis* (night parrot) (Ref. 51)	
	Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 52)	
	Conservation Advice for *Erythrotriorchis radiatus* (red goshawk) (Ref. 53)	
	Conservation Advice for *Calidris canutus* (Red Knot) (Ref. 54)	
	Conservation Advice for *Phaethon rubricauda westralis* (Indian Ocean red-tailed tropicbird) (Ref. 55)	
	Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 56)	
	Conservation Advice for southern whiteface (*Aphelocephala leucopsis*) (Ref. 668)	
	Conservation Advice *Thalassarche cauta* (Shy Albatross) (Ref. 57)	
	North-west Marine Parks Network Management Plan 2018 *(*Ref. 82*)*	These management plans identify climate change as a threat, but do not identify any relevant management actions.
	Marine bioregional plan for the North-west Marine Region (Ref. 102)	
Internal Context	These environmental performance standards or procedures were deemed relevant for this aspect: • Chevron Corporation's Climate Change Resilience (Ref. 276) • Chevron Shipping's Marine Standard Non Tankers (Ref. 265).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since the inception of engagement during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation where relevant as	

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	part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. No feedback was received in relation to GHG emissions from Phase 1 stakeholder consultation. During Phase 2 consultation (i.e. formal public comment period) a submission was received regarding GHG emissions. The response to the matters and objections or claims raised in the submission is provided in appendix g.

8.3.15 environmental performance

Table 8-18 provides the EPOs defined for GHG emissions and the adopted control measures to achieve the outcome.

Table 8-18: Environment performance for GHG emissions

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-08: Greenhouse gas emissions from the Gorgon Gas Development[134,135,136] will be within limits as set by the *National Greenhouse and Energy Reporting Act 2007* (Cth) and *Environmental Protection Act 1986* (WA).	**EPO-11**: Manage GHG emissions from the 'Gorgon Operations Facility'[136] in accordance with requirements under the Commonwealth Safeguard Mechanism and from the 'Gorgon GTP'[135] in accordance with requirements under any in-force State or Commonwealth approval conditions for the Gorgon Gas Development.	**CM-10:** Chevron Australia will implement GHG emissions management, reductions, and reporting aligned with any applicable requirements under the Commonwealth Safeguard Mechanism as well as approvals under the EP Act (WA) and EPBC Act (Cth), to the extent such requirements remain in-force and as amended from time to time, including: • implementation of measures that are necessary to achieve the injection underground of at least 80% of Reservoir Carbon Dioxide[137] – offsetting the quantity of Reservoir Carbon Dioxide not injected underground • Net GHG Emissions[137] from the Gorgon GTP are within the limits set in condition 27.1 of MS 1198 • the Safeguard Mechanism baseline for the Gorgon Operations Facility declines each financial year at rates as defined within the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 – responsible emitters of facilities that exceed or expect to exceed their baselines must manage their excess emissions through various means including the surrender of ACCUs or SMCs. Note: These requirements under **CM-10** may be amended from time to time, and this control measure will be revised to reflect any contemporary requirements. **CM-09**: Vessels operating within the Development Area will comply with requirements within Marine Order 97—Marine pollution—air pollution. **CM-11:** Vessel and MODU fuel usage will be recorded during the Development.

[134] The Gorgon Gas Development includes the GFP, the Development, and potential future development of other Greater Gorgon Area fields. GHG emissions from the Gorgon Gas Development incorporates direct (Scope 1) GHG emissions from the Gorgon GTP and Gorgon Operations Facility .

[135] The 'Gorgon GTP' includes all direct (Scope 1) GHG emissions from the current operational Gorgon Gas Development facilities (as outlined in MS 800) (Section 8.3.6.1).

[136] The 'Gorgon Operations Facility' is registered with the CER as a facility under both the NGER and Safeguard Mechanism schemes (Section 8.3.5.3). The reporting boundary of the Gorgon Operations Facility includes direct (Scope 1) emissions from the 'Gorgon GTP' as well as direct (Scope 1) emissions from any activities or facilities in Commonwealth waters.

[137] Reservoir Carbon Dioxide and Net GHG Emissions are defined within MS 1198.

Acceptable levels	Environmental performance outcomes	Adopted control measures
		CM-12: Chevron Australia will develop activity-specific GHG emissions estimates for use in Environment Plans based on contemporary information (e.g. specific petroleum activity scopes, emission calculation methodologies, emission factors, etc.) as available at the time.
AL-09: Net GHG emissions associated with the transport and third-party end use of products from the Development do not represent a significant proportion of cumulative global GHG emissions. **AL-10**: The Gorgon State Agreement establishes a commitment to reserve and market domestic gas from the Gorgon Gas Development. Therefore, the acceptable level of GHG emissions from third-party end use of this domestic gas supply is inherently set by the Agreement and domestic GHG emissions are managed under relevant Australian law. **AL-11**: Acceptable levels for GHG emissions occurring outside of Australia's jurisdiction from the transport and third-party end use of Gorgon Gas Development products are managed under relevant laws of the respective customer countries.	**EPO-12**: Net GHG emissions associated with the transport and third-party end use of products from the Development do not represent a significant proportion of cumulative global GHG emissions[138] and would be managed under the laws of the respective customer countries', which reflect among other things the countries' GHG emissions reduction ambitions and international commitments.	**CM-13:** Chevron Australia will undertake routine reviews (5-yearly to align with in-force periods of Environment Plans) of the projected domestic and global energy trends, including the role of Gorgon Gas Development's product types (domestic gas, LNG, condensate) in these projections. If required, Chevron Australia will consider the application of additional control measures within Environment Plans to demonstrate that net 'secondary GHG emissions' remain at an acceptable level. **CM-14:** Chevron Australia will develop a transport and third-party end use GHG emissions estimate (e.g. 5-yearly to align with in-force periods of Environment Plans) based on contemporary information (e.g. production forecasts for the Gorgon Gas Development, emission calculation methodologies, emission factors, etc.) as available at the time. **CM-15:** Petroleum recovery will not be inconsistent with petroleum production licence obligations (i.e. approved Rate of Recovery and Field Development Plans) under the OPGGS Act and Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 and/or other relevant legislation in place at the time.

[138] Refer to Table 7-6.

8.4 light emissions

8.4.1 source

The following sources of artificial light are associated with the Development:

- navigational and operational lighting on vessels and MODU
- gas flaring from the MODU.

Table 8-19 list the activities within each phase that have the potential to generate light emissions.

Table 8-19: Phases and activities that generate Light emissions

Phase	Activity
Drilling	Well clean-up and testing
Operations	Well intervention
Support activities (all phases)	MODU operations Vessel operations

8.4.1.1 drilling

Flaring may be required as a contingency during well clean-up and flowback activities (Section 4.3.2.9). Flaring of flammable gas will generate light emissions.

A typical volume of reservoir gas flared during well flowback has been estimated at 60 MMscf per well. If flaring is required, it will be from one well at a time and may occur intermittently over ~1 day. Light emissions will be more pronounced if flaring is undertaken at night.

Unlike navigational/operational lighting, which is provided for safe access and working conditions, and which has specific light emissions defined by manufacturers, gas flares are not designed for lighting purposes and light emissions are not specified by flare manufacturers.

There is limited published information regarding light characteristics of flares. In contrast to facility lighting, most light energy emitted from natural gas flares has a wavelength >600 nanometres due to the high temperatures of natural gas combustion; this puts it in the visible and ultra-red spectra (Ref. 277; Ref. 278). Natural gas flares have been measured to have a higher peak spectral signature than facility lighting, typically within the invisible infrared range (750–900 nanometres), with lower levels of light emitted within the lower (and visible) wavelength ranges (Ref. 279; Ref. 280).

8.4.1.2 operations

Flaring may be required as part of well intervention. The rate and duration are consistent with estimates for flaring during drilling operations (Section 8.4.1.1).

8.4.1.3 support activities (all phases)

Vessels will be present in the DA supporting all phases of the Development. Their presence will be intermittent, and it is expected that the greatest numbers would occur for only a small portion (e.g. drilling, installation) of the overall duration of the Development.

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well

workovers). The MODU will move between fields but will spend most of the time at the DCs, with each well taking ~3 months to drill. The MODU is expected to have the tallest structure above sea level compared to vessels.

External lighting is used on vessels and the MODU for safe navigation and to provide safe working conditions. Vessel and facility lighting are considered standard practice. Lighting used during offshore operations is generally bright white light such as light emitting diodes, halogens, fluorescent and metal halide lights and would be similar to lighting used by other offshore mariners (e.g. shipping and fishing). The spectral signatures associated with MODU lighting are estimated as 530–620 nanometres (Ref. 284). Although MODU specifications will not be confirmed until closer to drilling and well intervention campaigns, typically the small navigation lights on the derrick are the tallest source of navigation/operational lighting.

8.4.1.4 concurrent activities

As described in Section 4.1.4, while Development will be staged so that not all fields will be developed in a single campaign; different phases of the activities may occur concurrently either within a single field (e.g. drilling and pipelay installation) or across multiple fields (e.g. drilling in one field while subsea installation is occurring in another field) The following concurrent scenarios were identified:

- concurrent activities within a single field include:
  - flaring occurring while vessel operations are undertaken. Flaring will occur intermittently over ~1 day and only from one well at a time
  - drilling (MODU) and installation (vessel) activities may be undertaken concurrently in the same field; up to ten vessels may be present over ~4 months.
- concurrent activities across multiple fields include:
  - flaring occurring in one field while drilling or vessel is taking place in another field. Flaring will occur intermittently over ~1 day and only from one well at a time
  - drilling in one field while subsea installation is taking place in another field. Up to ten vessels may be present over a period of ~4 months
  - drilling concurrently in two different fields, with a duration of up to 24 months (based on indicative drilling duration).

Activities identified as not credible included:

- the presence of two MODUs within a single field
- the presence of two flares across multiple fields (i.e. flaring occur from only one well at a time)

Consequently, further assessment of this concurrent activity has not been undertaken.

For concurrent scenarios where flaring occurs, flaring will occur intermittently over ~1 day and only from one well at a time. The overlap between flaring and MODU/vessel operations lighting would be very temporary and intermittent over the course of Development activities. In addition, given the higher light intensity of the flare, the conservative exposure area assumed for the artificial light exposure from flaring is expected to fully encompass the predicted artificial light exposure areas for MODU/vessels. Therefore, the risk assessment for flaring is considered

a conservative assessment of potential impacts to receptors under concurrent scenarios involving flaring, and no further assessment of this concurrent activity has been undertaken.

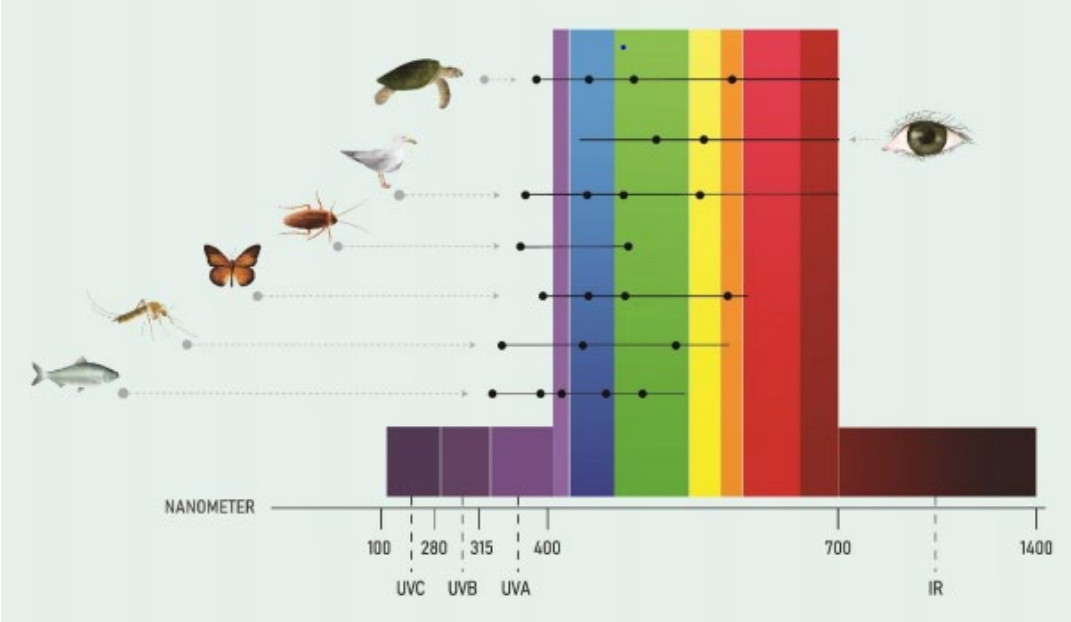
8.4.2 modelling and exposure assessment

8.4.2.1 describing light

Light is a form of energy that is emitted over a particular band of frequencies and wavelengths of the electromagnetic spectrum. Fauna perceive light differently to humans. Depending on the species, the visible spectrum for fauna can vary between the ultraviolet and infrared spectra (i.e. wavelengths between ~300 and >700 nanometres) (Ref. 37). For fauna, being sensitive to light within a specific range of wavelengths means that they can perceive light at that wavelength, and it is likely they will respond to that light source (Ref. 37).

Factors affecting how wildlife perceive light include the type of cells used to detect light (photopic versus scotopic vision); whether the light is viewed directly from the source or as reflected light; how the light interacts with the environment; and the distance from the light source (Ref. 37).

Figure 8-10 shows the sensitivity of different species to different wavelengths, with most species sensitive to short wavelength light (i.e. in the ultraviolet / violet / blue spectra).



Source: Ref. 37. Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivities

Figure 8-10: Ability to perceive light and peak sensitivities to light for humans and fauna

8.4.2.2 light modelling (flaring)

MODU types that may be used during the Development include a semisubmersible, drill ship or well intervention vessel or jack-up (Section 4.3.6.1). The exact MODU specifications will not be known until closer to drilling or well intervention campaigns being undertaken. Consequently, the height of the flare tip and flame height are also not yet known and are expected to vary between fields. However, for the risk assessment, the flare height for this Development was

identified based on the MODUs previously used by CAPL within the Gorgon Gas Development area. Relevant analogues were used to evaluate the most suitable spatial extent for flaring light emissions during the Development.

scenarios

Table 8-20 summarises the scope scenarios for flaring light emissions on other projects which included permanent facilities (i.e. FPSO, MOPU [Mobile Offshore Production Unit] or platforms) above the sea surface. In contrast, the Development concept for this OPP is subsea tiebacks with no permanent above-surface facilities.

Table 8-20: Scope scenarios for flaring light emissions

Project	Facility	Flaring rate	Flaring height (above sea level)	Duration
Gorgon Gas Development Backfill Fields (This Development)	MODU	~60 MMscf per well	16 m (based on previous MODUs)	Occur intermittently over ~1 day
Dorado Development (Ref. 282)	FPSO	~125 MMscfd per annum	110 m	Up to 48 hours
Corowa Development (Ref. 283)	MOPU	Peak flaring rate of ~17 MMscfd	105 m	Continuous

exposure criteria

The visibility of an artificial light does not necessarily imply a measurable change in ambient light, and therefore a potential impact (Ref. 283).

There are currently no published or accepted thresholds at which artificial light may impact fauna. Therefore, light modelling for Dorado and Corowa Developments were used to identify the potential spatial extent for light visibility. The modelling for these projects used different methodologies. Dorado Development used line of sight visibility based on the proportion of the full moon (Ref. 282), while Corowa was based on available photometric light measurements (Ref. 283; Ref. 654).

In addition, CAPL conducted a line-of-sight analysis using the methodology outlined by Young (Ref. 677), as illustrated below, to verify the spatial exposure. As identified in Table 8-20, based on previous MODUs used by CAPL within the Gorgon Gas Development area, a flare height of ~16 m above operating sea level is expected. However, a flare height of 40 m was used to ensure further conservatism in estimating the radius of the area of effect.

$$dl = \sqrt{2Rh}$$

Where:

dl = total line of sight

R = radius of earth

h = height of object

modelling outputs

Table 8-21 details the modelling results.

Table 8-21: Comparison of flaring lighting emission between the Development and analogue modelling results

Potential analogue	Distance (km)	Description
Gorgon Gas Development: Backfill Fields (This Development)	22.6	This is the distance when the flare would drop below the horizon.
Dorado Development (Ref. 282)	42.4	This is the distance 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, though it becomes more likely within 20.7 km.
Corowa Development (Ref. 283)	31.3	Based on a line of sight analysis (Ref. 283), the maximum distance light that may be visible extends up to ~36.5 km. However, beyond 31.3 km there was no measurable change to the ambient light intensity levels (i.e. <0.001 lux).

Given the difference in the modelling outputs, the methodology between the projects, and the uncertainties regarding flaring specifications for the Development (e.g. exact height of the flare tip and flame height), a conservative approach based on the line-of-sight visibility (i.e. distance the flare falls below the horizon) has been chosen to determine the spatial extent of flaring light emissions.

As the flare height expected for the Development's is less than half the flare height of Dorado and the volume of flaring for the Development is approximately half of the volume to be flared at Dorado, the 42.4 km line of sight distance has been used as a conservative spatial extent to assess the environmental impacts from flaring.

The 42.4 km distance to where the flare drops below the horizon was applied as a buffer around the proposed DCs to determine the predicted artificial light exposure areas for use in the impact assessment. The distances in relation to the BIAs and HCTS of light sensitive species are shown in Figure 8-11 to Figure 8-21. In addition, the maximum light extent from flaring activities in relation to AMPs (i.e. the Montebello Marine Park) is shown in Figure 8-22.

8.4.2.3 light modelling (MODU)

As mentioned in Section 8.4.2.2, MODU specifications will not be known until closer to the drilling or well intervention campaigns. To support the risk assessment, a conservative, worst-case scenario approach has been adopted. The modelling scenarios used a floating liquefied natural gas (FLNG) facility (used in Torosa modelling; [Ref. 284]) and a semi-submersible MODU (used in VIC/P79 Otway modelling; [Ref. 654]). Lighting from these facilities was considered comparable to MODUs previously used by CAPL within the Gorgon Gas Development area or those likely to be selected for the Development. The MODU will be equipped with external lighting to ensure a safe working environment and compliance with maritime navigation requirements. These analogues are considered representative due to comparable operational lighting intensity, structural height above sea level, and similar offshore operational contexts. Consequently, the Torosa and VIC/P79 Otway analogues provide a robust basis

for predicting the spatial extent of MODU operational light emissions during the Development.

scenario

Both scenarios, the Torosa and VIC/P79 Otway, used a drill rig / MODU as the basis for the modelling. The scenarios included operational lighting on the MODU during drilling activities.

exposure criteria

Typical illuminance (light intensity) values from natural light sources are described in Table 8-22. The minimum threshold used to describe a change in ambient light conditions within this artificial light assessment is an illuminance equivalent to a new moon (moonless clear night sky; 0.001 lux). Beyond this threshold, no impact to light-sensitive fauna is assumed (Ref. 284; Ref. 654). This threshold (0.001 lux) was selected because fauna undertake nocturnal activities under the natural range of full moon (0.1 lux) to new moon (0.001 lux) without known adverse impacts.

Photometric measurements (illuminance) are biased towards the human eye; therefore, the use of this threshold is considered conservative because a quarter moon radiance (a radiometric measurement) is the biologically relevant threshold in the modelling below.

Table 8-22: Natural light illuminance

Natural light source description	Illuminance (lux)
Direct sunlight	100,00–130,000
Full daylight, indirect sunlight	10,00–20,000
Overcast day	1,000
Very dark day	100
Twilight	10
Deep twilight	1
Full moon	0.1
Quarter moon	0.01
Moonless clear night sky (new moon)	0.001
Moonless overcast night sky	0.0001

modelling output

Table 8-23 details the modelling results for the analogues. The more conservative spatial extent (i.e. 12.6 km) was adopted as the spatial extent to assess the environmental impacts from operational light emissions from the MODU.

Table 8-23: Modelling results of artificial light emissions from the MODU

Illuminance	Analogue	
	Torosa - drill rig (Ref. 284)	VIC/P79 Otway Drilling – MODU (Ref. 654)
<0.001 lux at distances (i.e. no measurable change to the ambient illuminance levels)	>12.6 km	>9 km
0.01–0.001 lux (comparable to ambient illuminance levels between a moonless clear night sky and a quarter moon)	1.2-12.6 km	3-9 km

Illuminance	Analogue	
	Torosa - drill rig (Ref. 284)	VIC/P79 Otway Drilling – MODU (Ref. 654)
0.01–0.1 lux (comparable to ambient light levels during a quarter moon to full moon night sky)	0.8-1.2 km	1-3 km
>0.1 lux (comparable to ambient light levels during full moon to twilight)	Up to 0.8 km	Up to 1 km

The 12.6 km distance to no measurable change from ambient conditions was applied as a buffer around the proposed DCs to determine the predicted artificial light exposure areas for use in the impact assessment. The distances in relation to the BIAs and HCTS of light sensitive species are shown in Figure 8-11 to Figure 8-21. In addition, the maximum light extent from MODU operations in relation to AMPs (i.e. the Montebello Marine Park) is shown in Figure 8-22.

8.4.2.4 light modelling (vessels)

As the specific vessels to be used for the Development activities will be confirmed closer to each Development phase, a conservative, worst-case approach has been adopted for the risk assessment. Analogue light modellings for construction and pipelay vessels with operational profiles and structural dimensions comparable to, or larger than, those previously used by CAPL or anticipated for the Development were used. The relevant analogues which predicted the extent of biologically relevant light spill (Ref. 655; Ref. 656; Ref. 657), were used to evaluate the spatial extent of vessel operational light emissions during the Development. Given similar or larger operational profiles, and structural dimensions of the vessels, the modelling results from these analogues are considered appropriate to support the impact assessment for artificial light emissions from vessels.

scenario

Specifics of the vessels' light inventories were input into the ILLUMINA model. The ILLUMINA model is a three-dimensional model that accounts for both line of sight and atmospheric scattering, allowing light attenuation over distance and light glow extent to be modelled.

exposure criteria

In the absence of any published or generally accepted units of measurement, or scale, for measuring the impact of artificial light on marine fauna, moonlight was selected as a proxy and the light model output (radiance, in units of $W/m^2/sr$) was converted to units of full moon equivalents (Ref. 655; Ref. 656; Ref. 657). Table 8-24 lists the potential impact criteria for marine turtles based on radiance thresholds relative to moon radiance.

Table 8-24: Potential impact criteria for marine turtles to artificial light emissions

Proportion of radiance of a full moon[1]	Description
1 to 10	Light or light glow visible and impact likely. Represents a bright light, equivalence of up to ten times the radiance of one moon. This light radiance will override the moderating influence of the ambient full moon at the time of exposure.
0.1 to 1	Light or light glow visible and behavioural impact possible, depending on ambient moon phase at the time of exposure, which will influence the

Proportion of radiance of a full moon[1]	Description
	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 to 0.1	Light or light glow visible but behavioural impact unlikely; as in, 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 the light output from a new moon

1. Where 10 equals the radiance of ten full moons and 0.01 equals a 100th the radiance of one full moon

modelling outputs

Table 8-25 details the modelling results for the analogues. The largest spatial exposure was identified for one of the construction vessel scenarios (Table 8-25; Ref. 656). The result shows that >16.2 km from the construction vessel radiance has reduced to ambient conditions. At distances ~5.2 – 16.2 km from the vessel, light may be visible at 0.01 to 0.1 light radiance (Table 8-25). However, as identified in Table 8-24, light radiance at these levels is not expected to be biologically relevant and result in behavioural impacts. At distances of <5.2 km from the vessel, the level of radiance is considered biologically important, and behaviour impacts may occur (Ref. 656).

Table 8-25: Modelling results of artificial light emissions from vessels

Proportion of radiance of a full moon[1]	Analogue			
	Pipelay vessel (Ref. 655)	Construction vessel (Ref. 656)	Pipelay vessel (Ref. 657)	Construction vessel (Ref. 657)
1 to 10	0.2 km	0.5 km	0.2 km	0.1 km
0.1 to 1	0.6 km	1.7 km	0.7 km	0.6 km
0.01 to 0.1	1.8 km	5.2 km	3.3 km	2.5 km
<0.01	5.7 km	>16.2 km	>14.8 km	>10.9 km

1. Where 10 equals the radiance of ten full moons and 0.01 equals a 100th the radiance of one full moon

The 5.2 km distance was applied as a buffer around the DA to determine the predicted artificial light exposure areas for use in the impact assessment. The distances in relation to the BIAs and HCTS of light sensitive species are shown in Figure 8-11 to Figure 8-21. In addition, the maximum light extent from vessel activities in relation to AMPs (i.e. the Montebello Marine Park) is shown in in Figure 8-22.

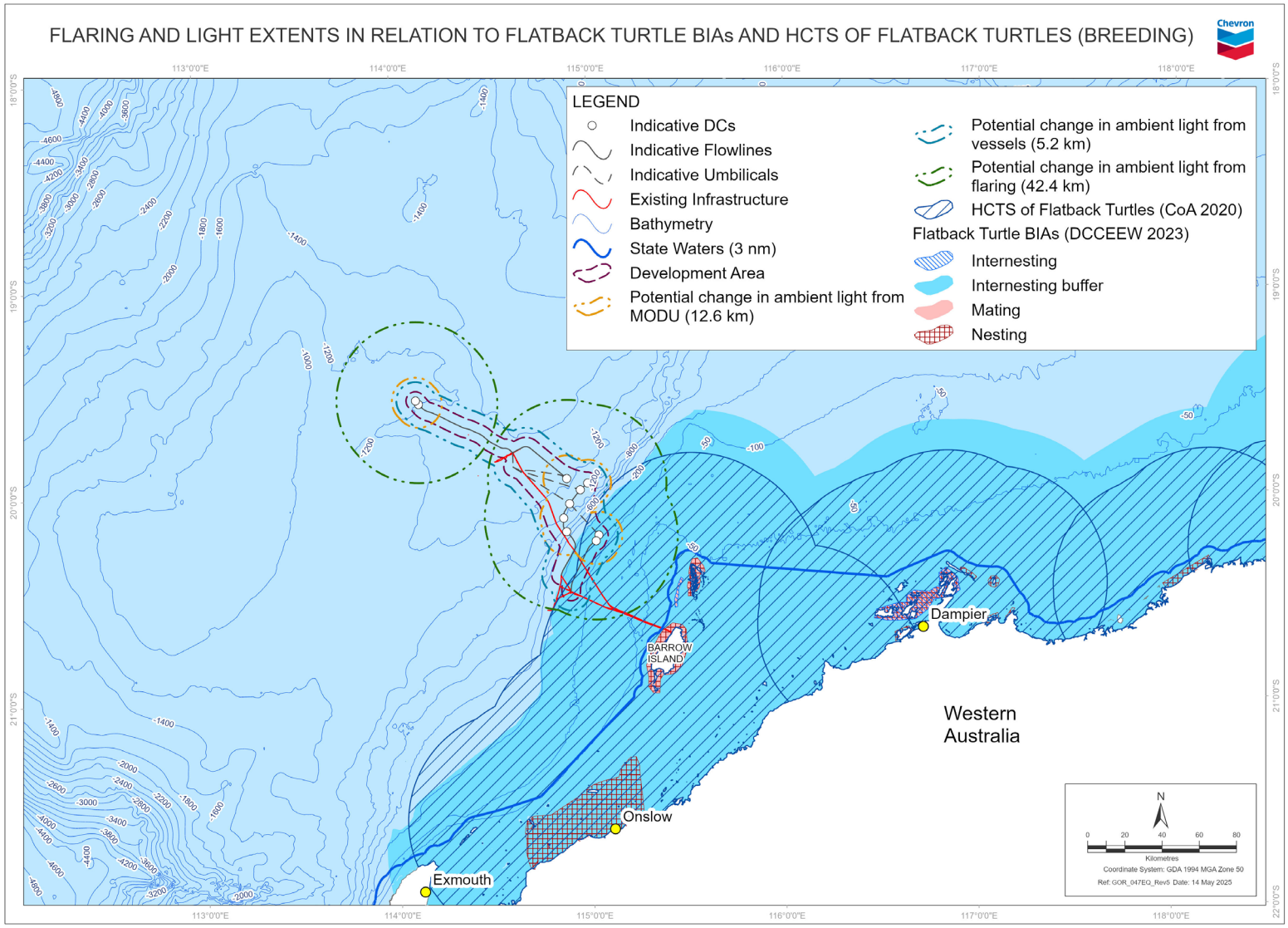


Figure 8-11: Flaring and light extents in relation to flatback turtle BIAs and HCTS areas (breeding)

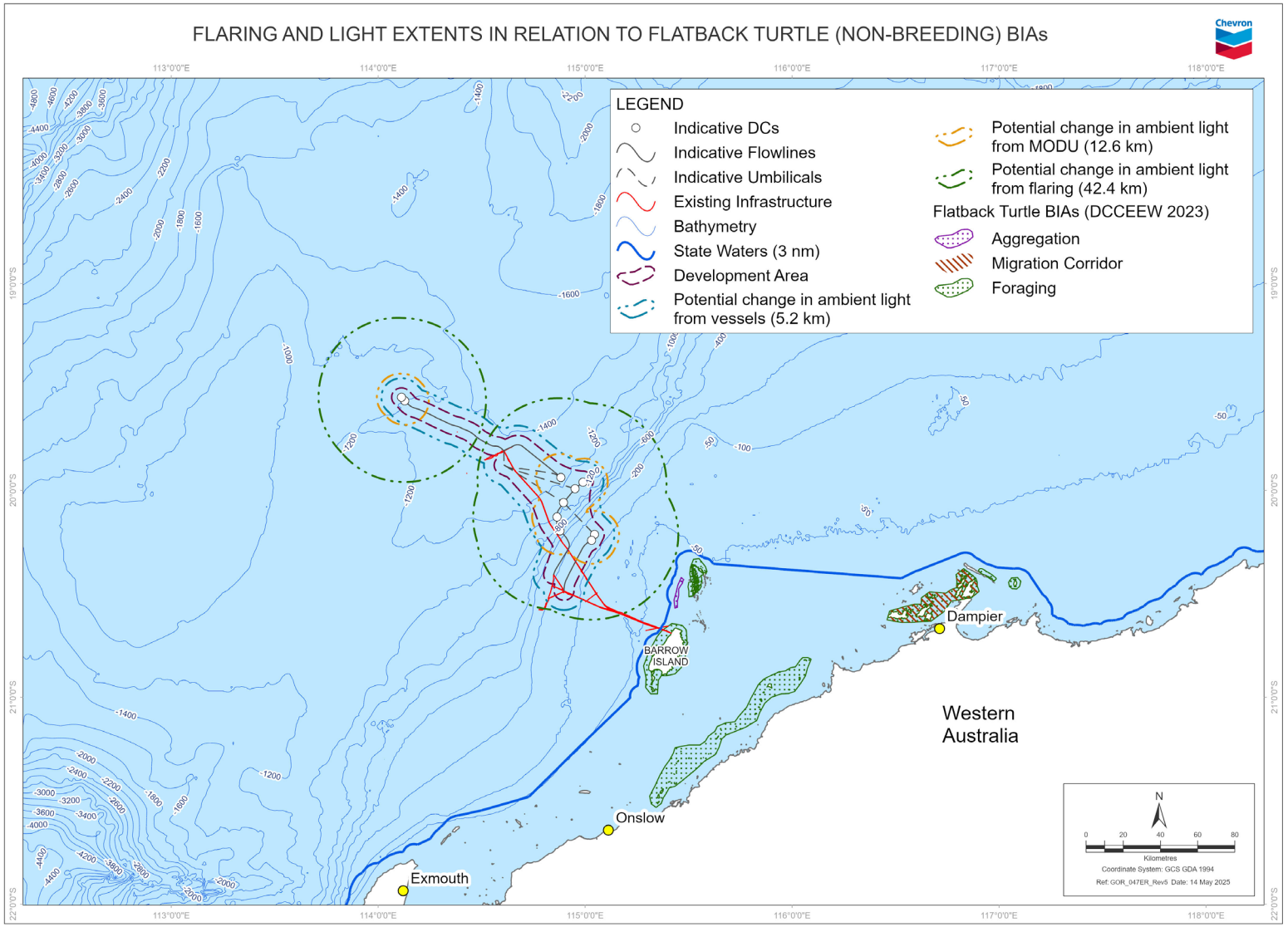


Figure 8-12: Flaring and light extents in relation to flatback turtle BIAs (non-breeding)

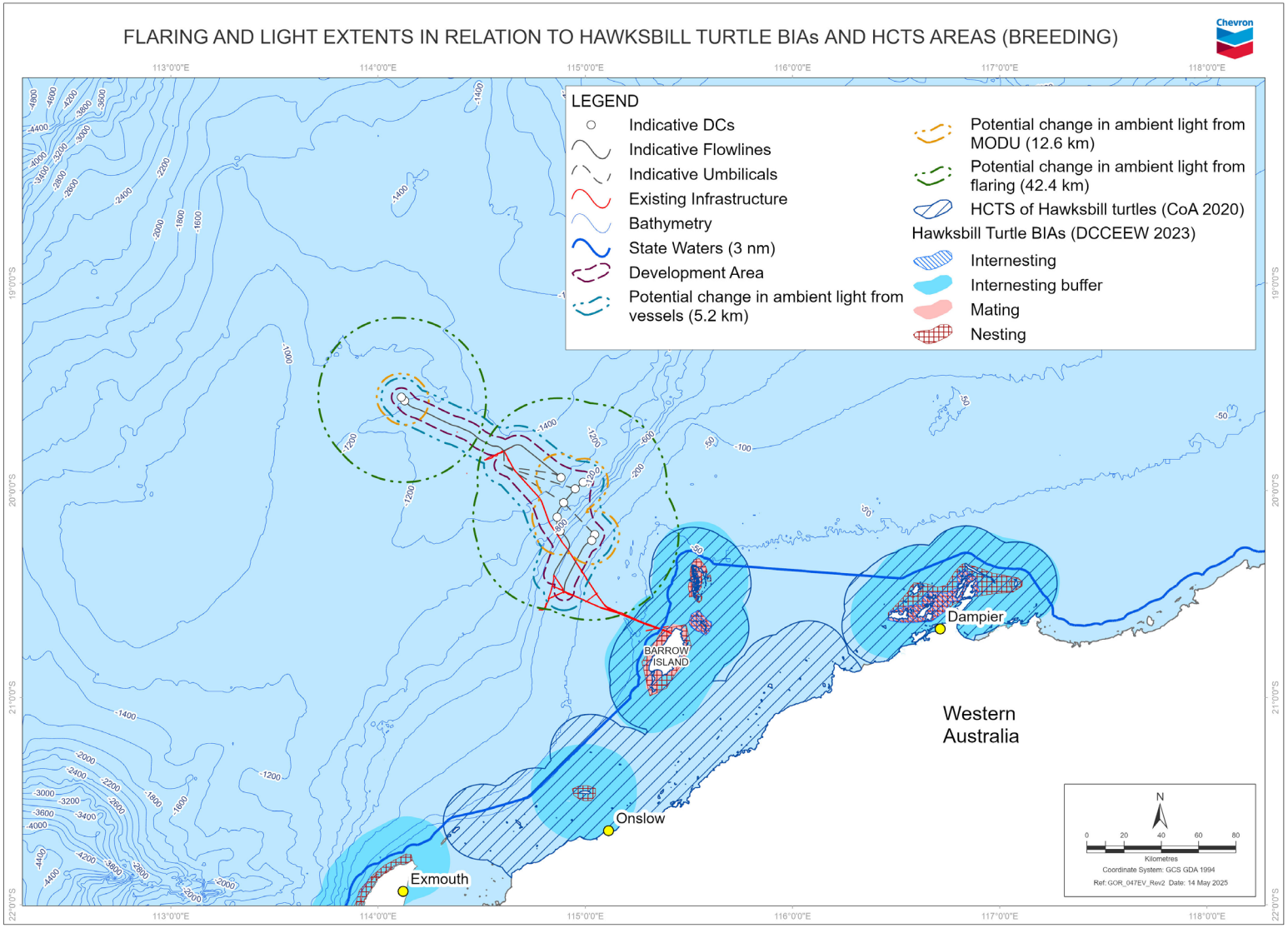


Figure 8-13: Flaring and light extents in relation to hawksbill turtle BIAs and HCTS areas (breeding)

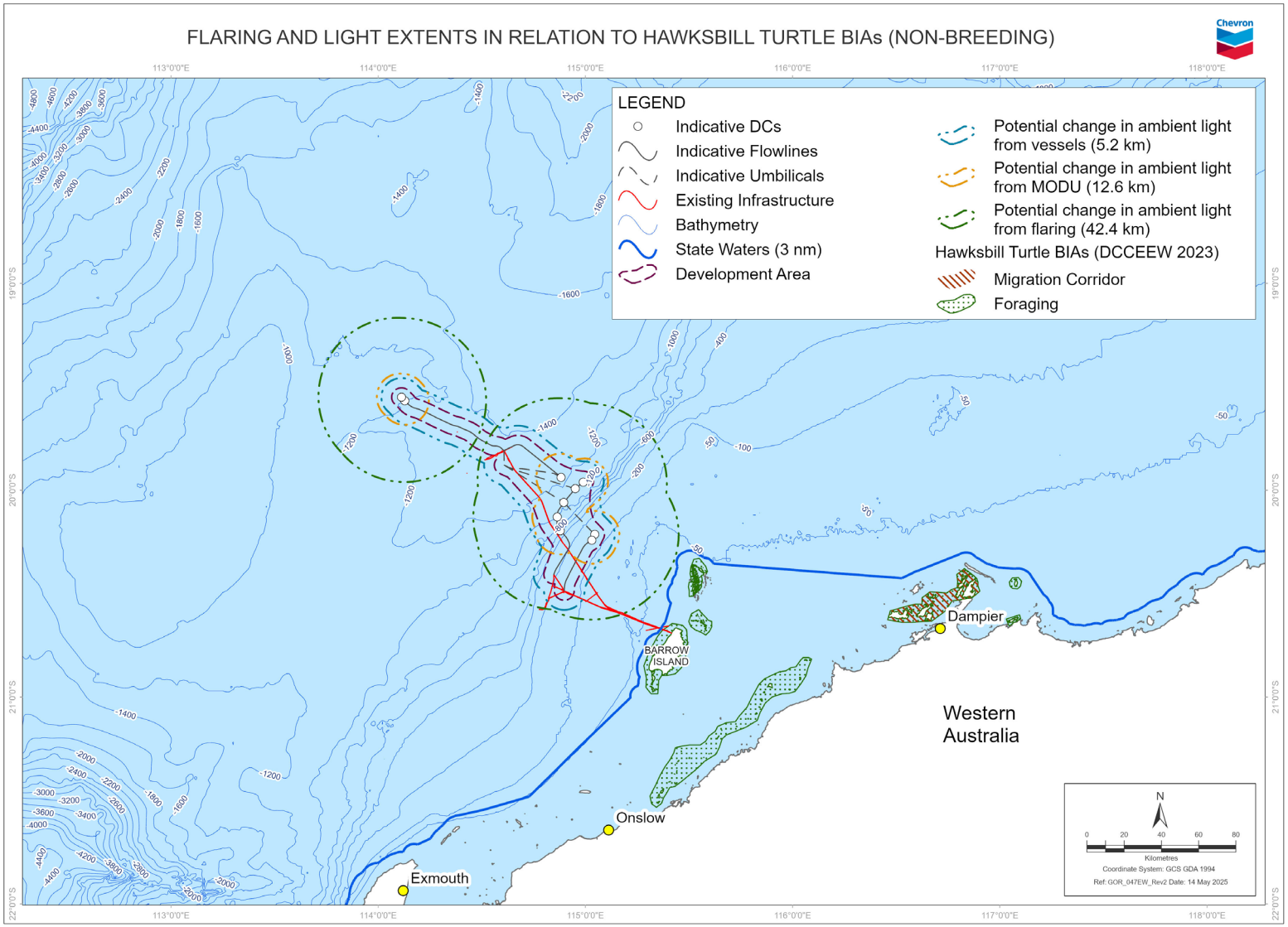


Figure 8-14: Flaring and light extents in relation to hawksbill turtle BIAs (non-breeding)

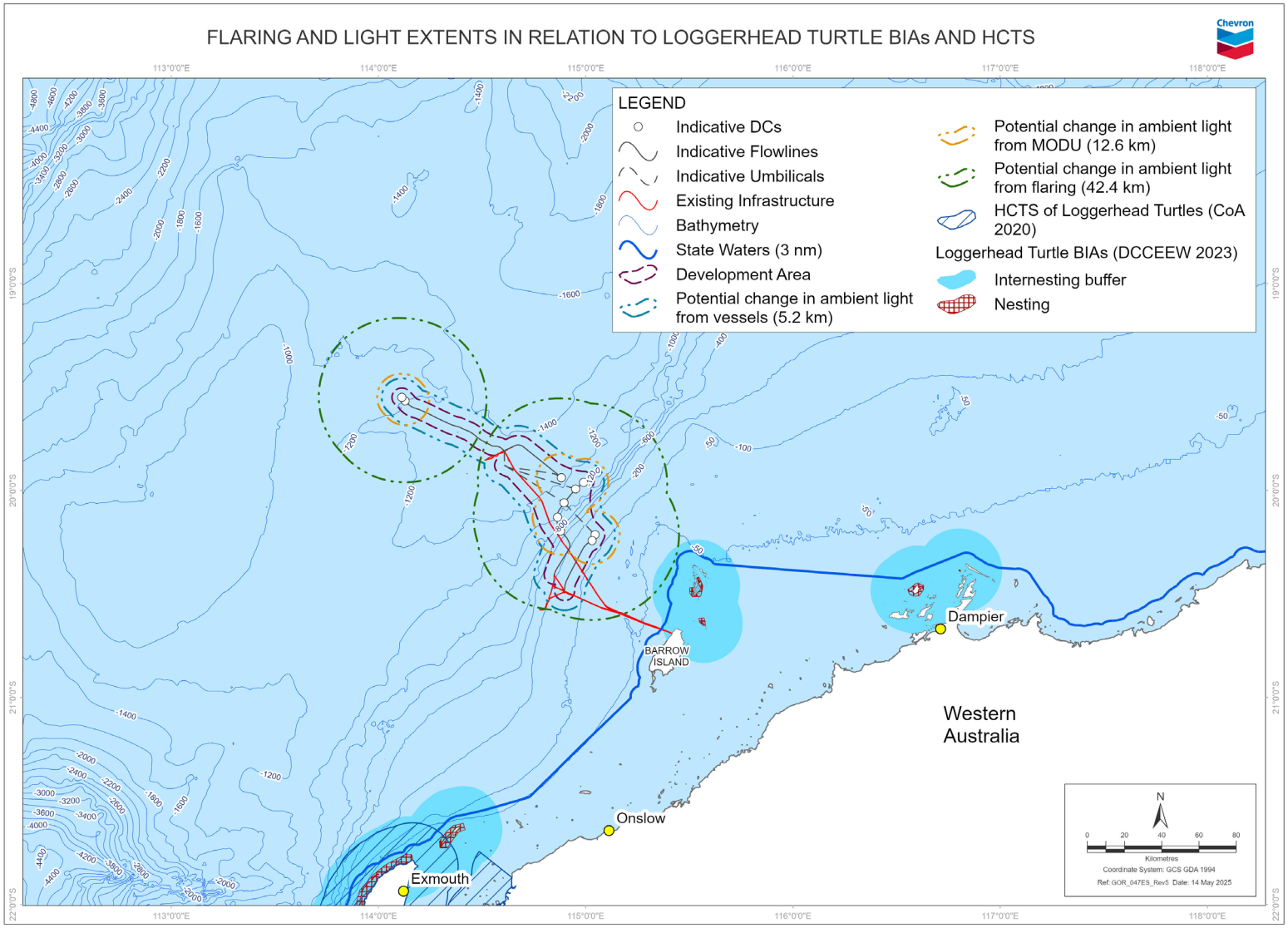


Figure 8-15: Flaring and light extents in relation to loggerhead turtle BIAs and HCTS areas

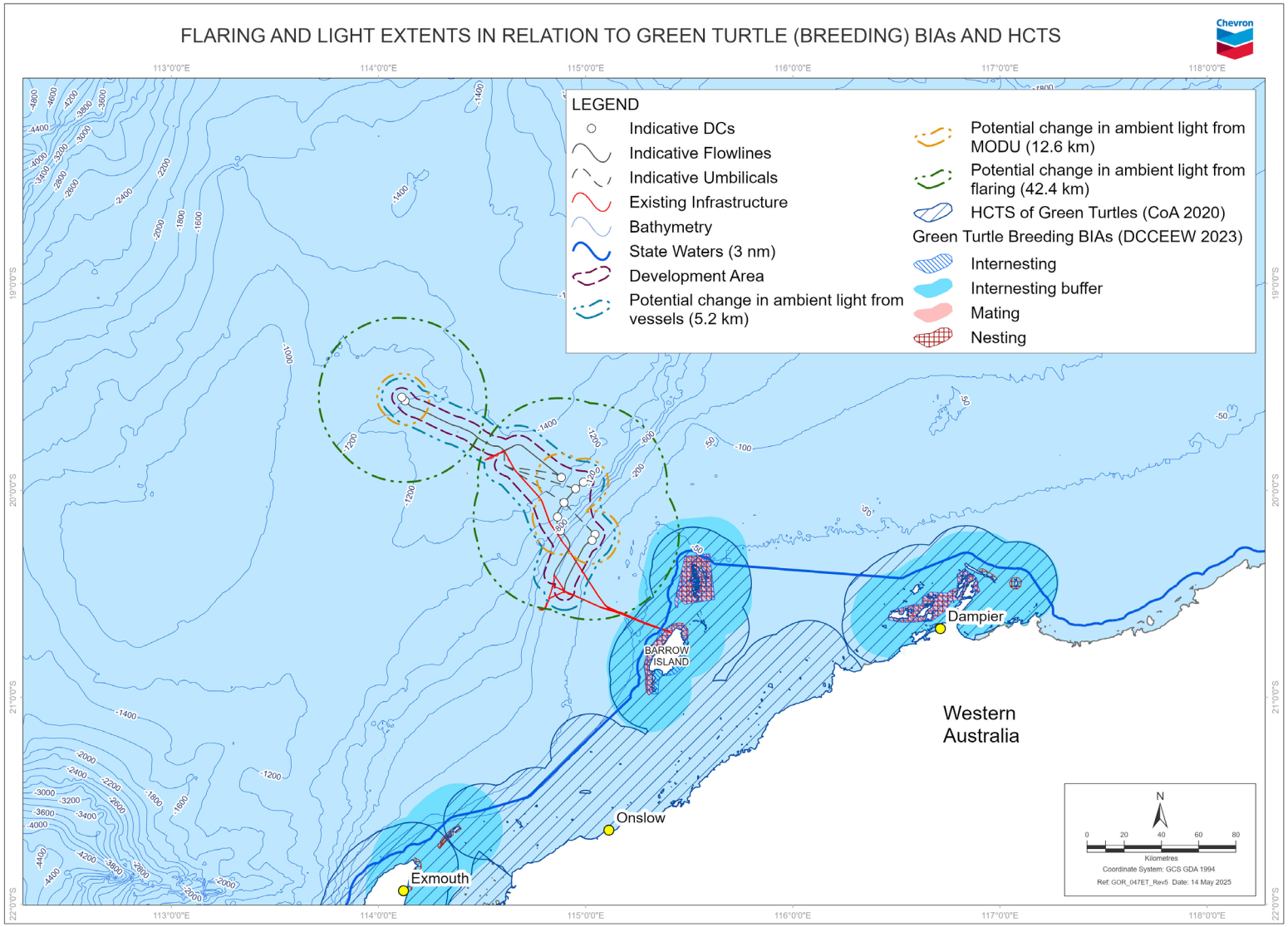


Figure 8-16: Flaring and light extents in relation to green turtle (breeding) BIAs and HCTS areas

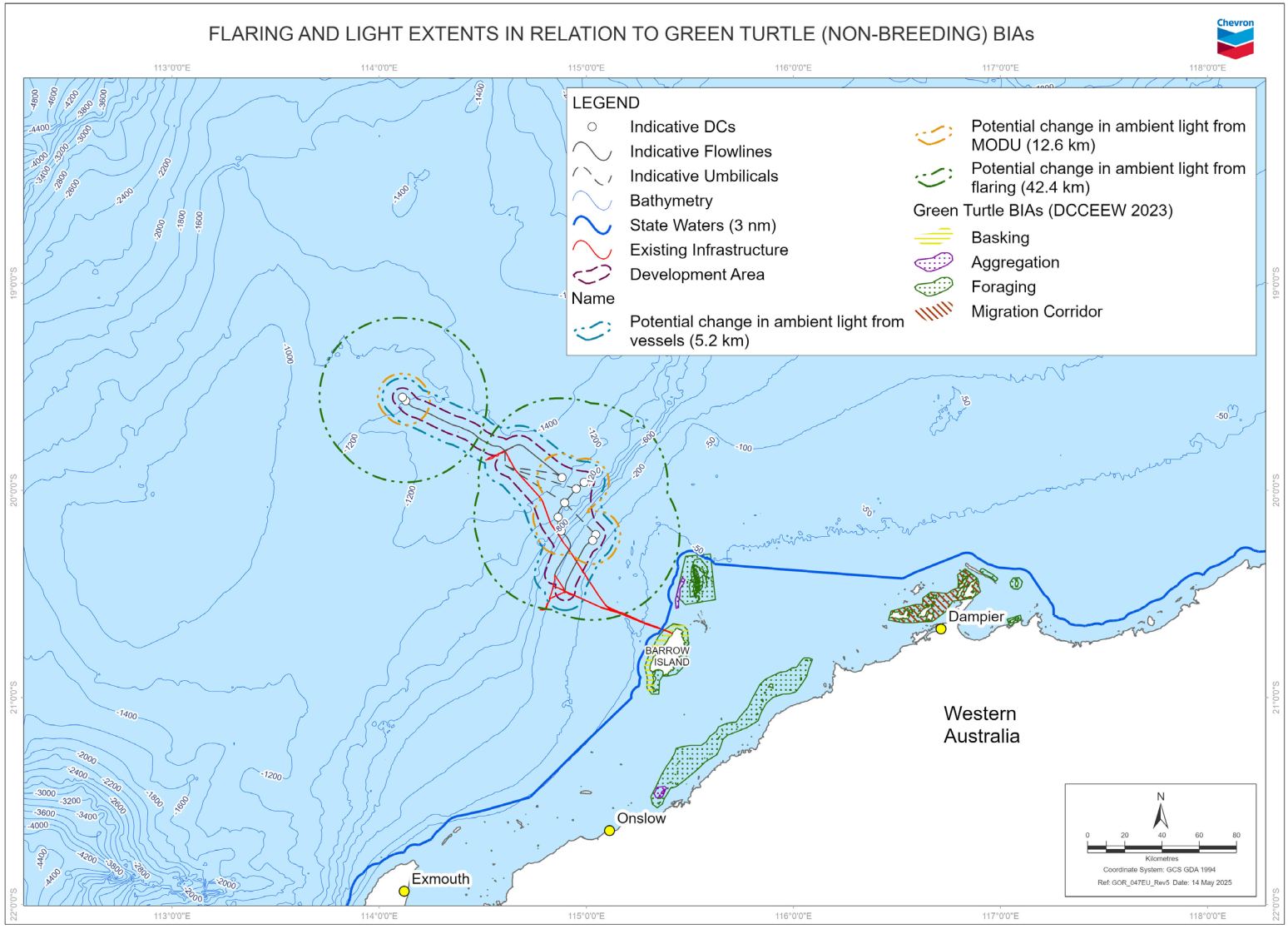


Figure 8-17: Flaring and light extents in relation to green turtle (non-breeding) BIAs

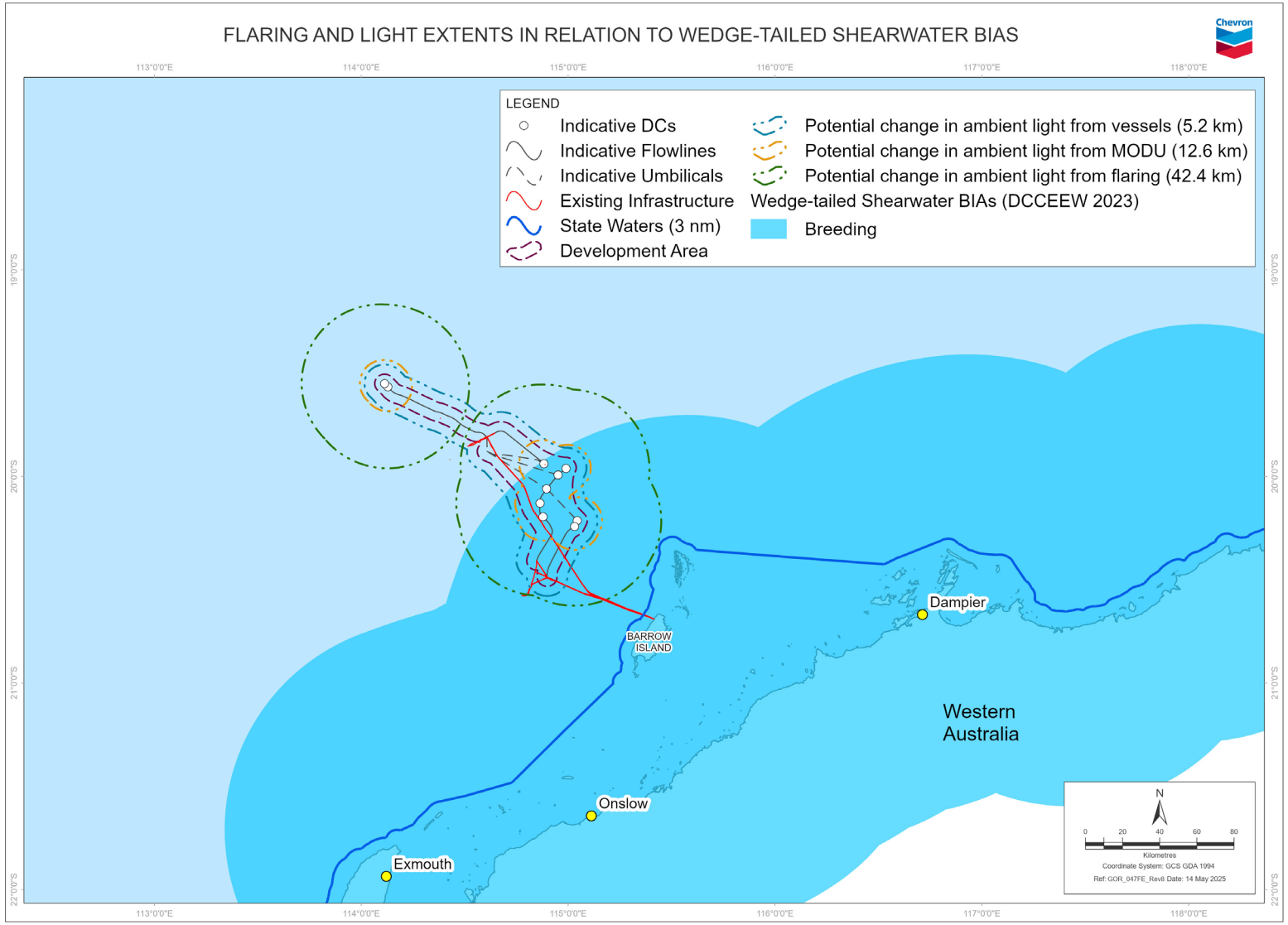


Figure 8-18: Flaring and light extents in relation to wedge-tailed shearwater BIAs

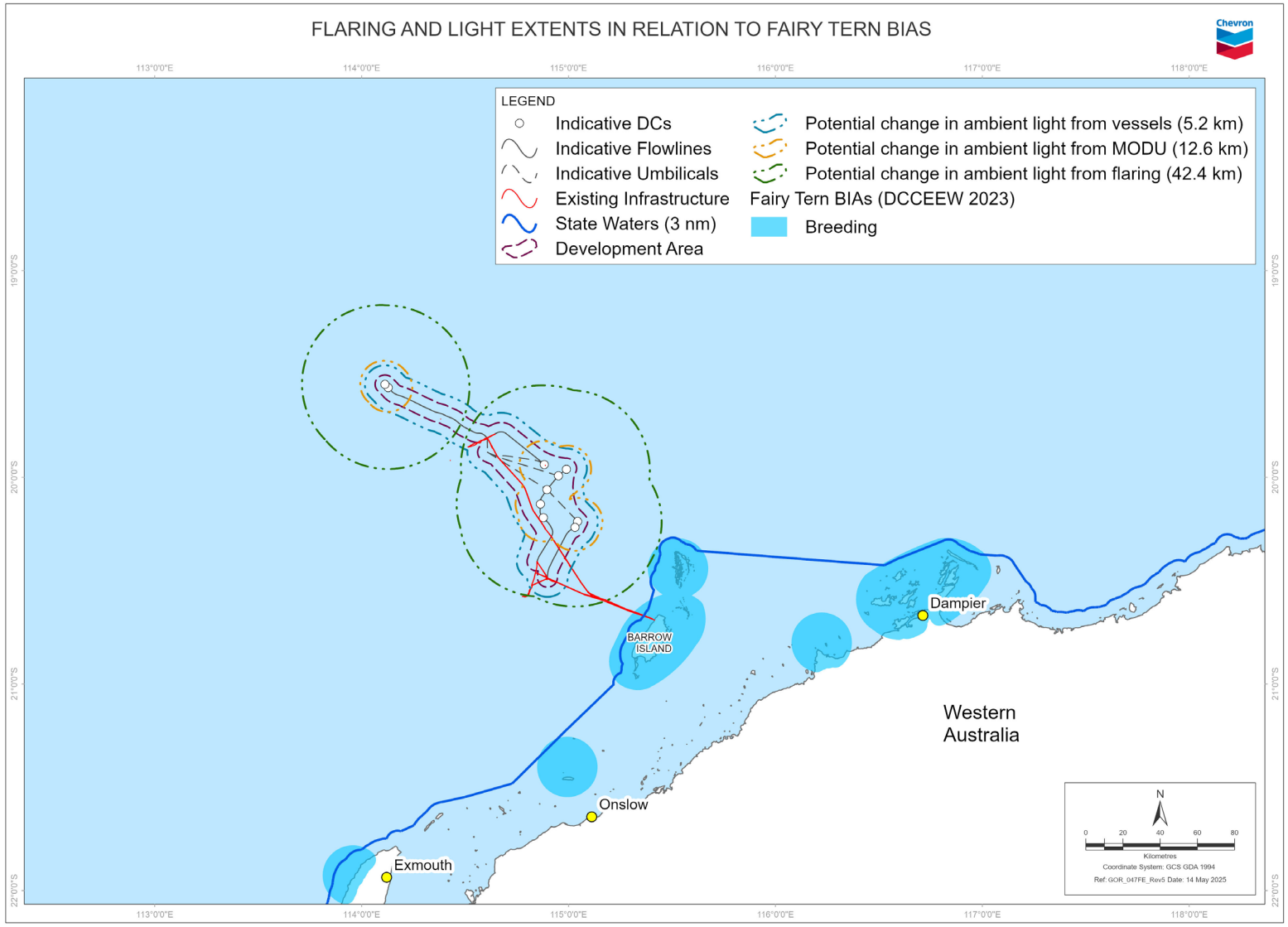


Figure 8-19: Flaring and light extents in relation to fairy tern BIAs

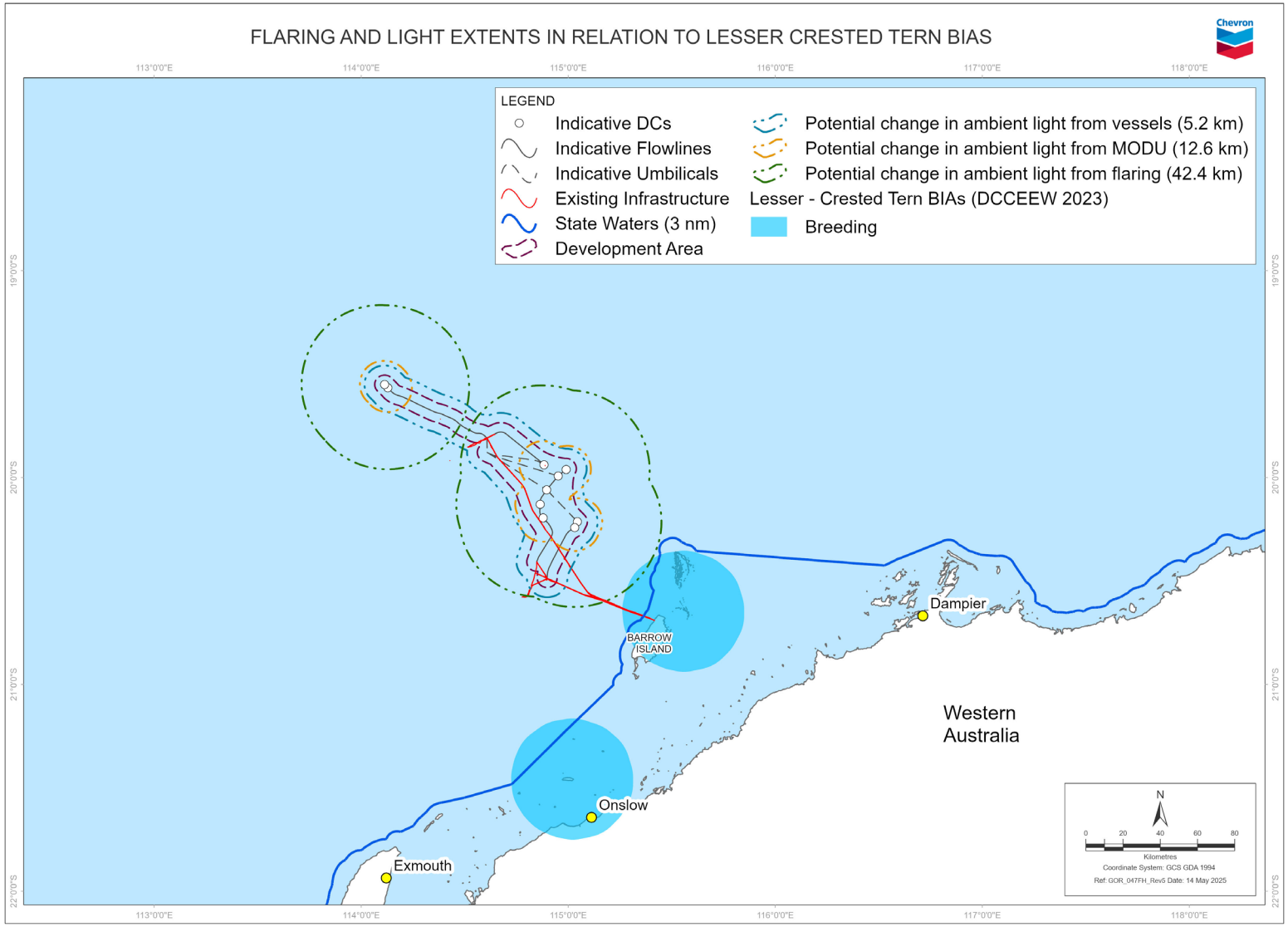


Figure 8-20: Flaring and light extents in relation to lesser crested tern BIAs

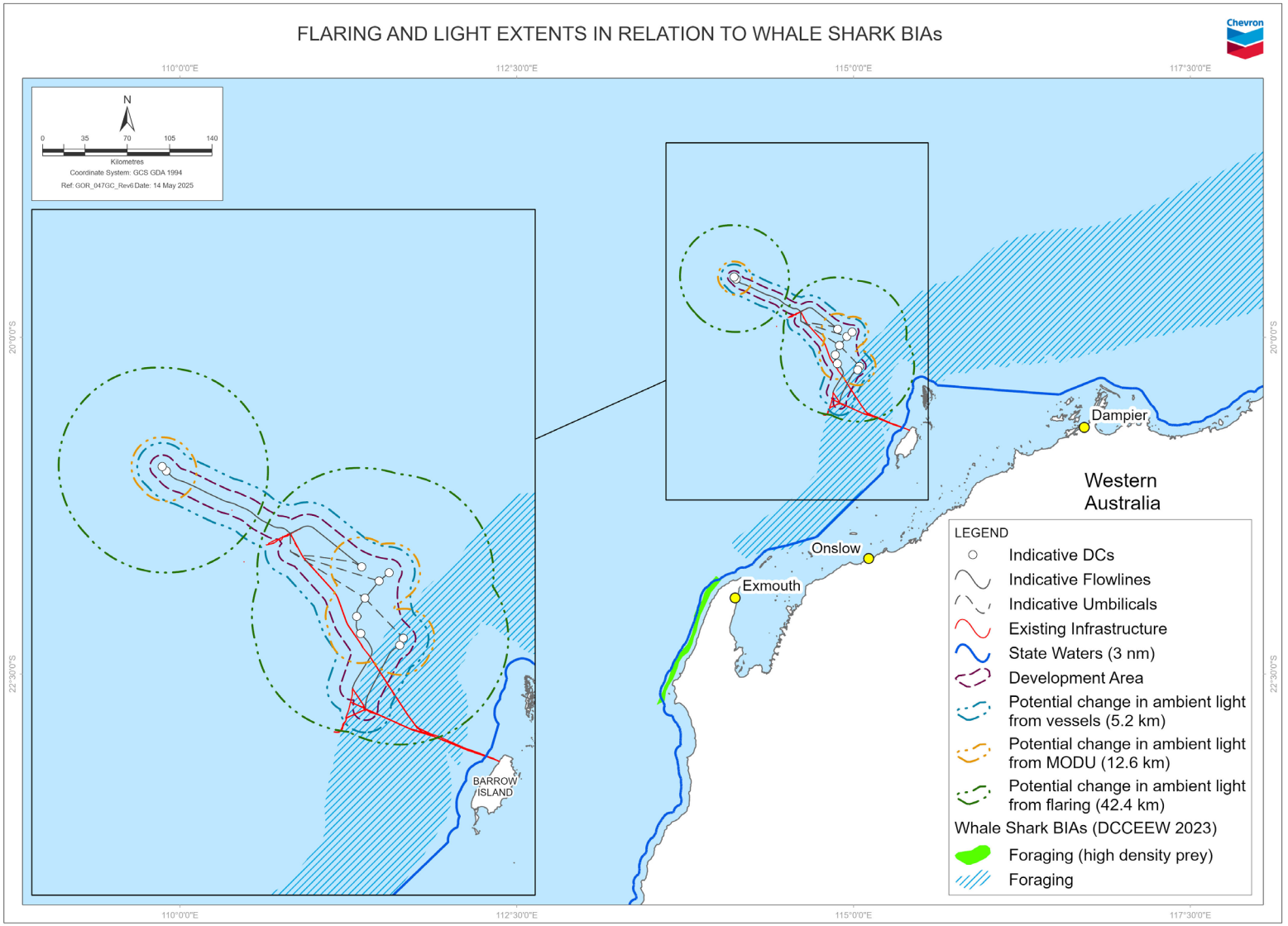


Figure 8-21: Flaring and light extents in relation to whale shark BIAs

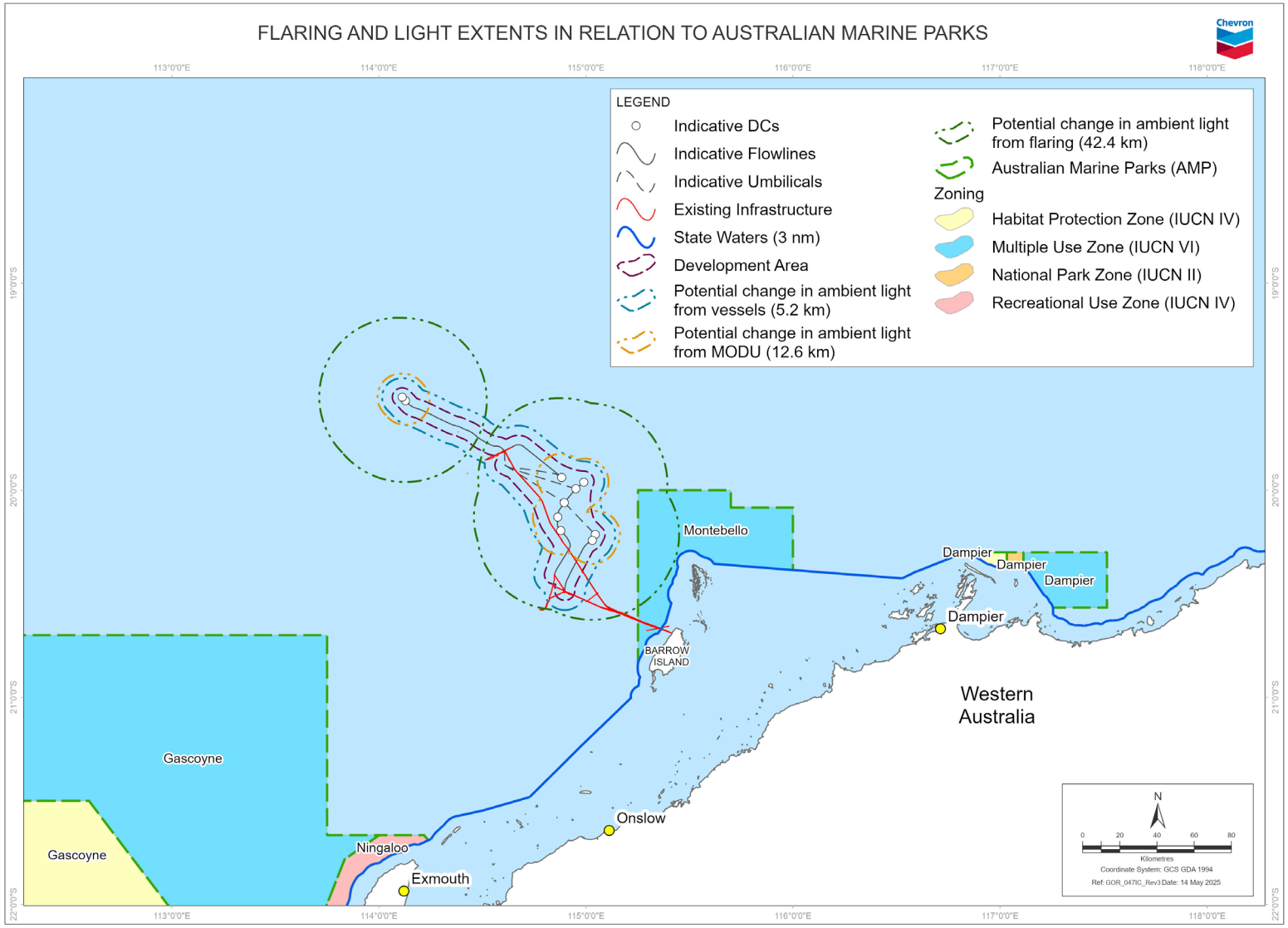


Figure 8-22: Flaring and light extents in relation to AMPs

8.4.2.5 concurrent scenarios

The potential effects of concurrent lighting sources and their impacts on receptors are not simply additive, but are complex, dependent on a range of factors such as the frequency, intensity, directionality and distance between light sources, physical environmental factors that affect light such as humidity and level of cloud cover, as well as various aspects of receptors, including their distance from the light sources, how they view and perceive the light sources and the subsequent influence of this light on behaviour (Ref. 750). Therefore, a conservative, worst-case approach was taken for the Development in determining the potential exposure areas to concurrent artificial light sources under various scenarios, as detailed below.

concurrent activities within a single field

For scenarios where a MODU and installation vessels (Section 8.4.1.4) are operating in close proximity, artificial light exposure areas may overlap, in which case, a conservative approach has been adopted in determining the concurrent artificial light exposure area for the purposes of the risk assessment. For example, if a single installation vessel has a predicted light exposure area with a diameter of ~10.4 km (~5.2 km radius), and a MODU has a predicted light exposure area of 25.2 km (~12.6 km radius), then concurrent operations could result in a combined exposure area extending up to~36 km diameter. In addition, since the area of overlap is at the edges of the light field from each source, receptors are likely to see these as two separate light sources (concurrent but not overlapping), rather than a cumulative light source, except in rare scenarios where vessels are in very close proximity and/or cloud cover results in a combined skyglow, perceived as a single light source by distant receptors (Ref. 37; Ref. 749).

concurrent activities across multiple fields

To support the risk assessment of concurrent scenarios across multiple fields (Section 8.4.1.4), a conservative worst-case scenario approach has been adopted. Given that the predicted light exposure from MODU operations exceeds that of vessel activities —and considering the potential for longer concurrent durations—simultaneous drilling activities in two different fields have been selected for assessment.

Based on the predicted light exposure from MODU operations (12.6 km, Section 8.4.2.3), overlapping light exposure areas may occur between:

- C&D DCs and G&E DC
- C&D DCs and Semele DCs
- C&D DCs and WTR DCs
- G&E DC and Semele DCs

No other overlapping light exposure areas across multiple fields have been identified.

Concurrent activities may result in predicted light exposure areas ranging from ~34.5 km diameter (i.e. maximum credible overlap [i.e. Semele DC-2 and G&E DC-1]; Figure 8-23A) to ~49.7 km diameter (i.e. minimum credible overlap [i.e. C&D DC-1 and WTR DC-1]; Figure 8-23B). It is noted that any potential exposure area resulting from concurrent activities is located further offshore, with WTR predicted light exposure area being the closest extend to nearshore habitat (as shown in Figure 8-23).

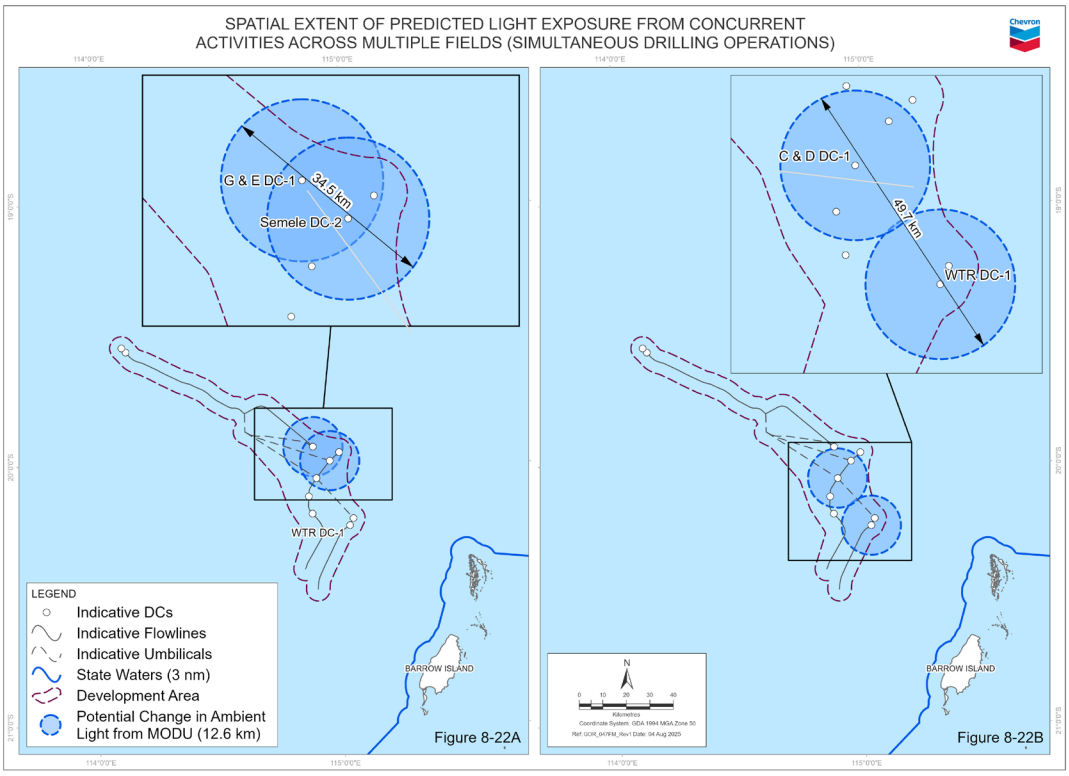


Figure 8-23: Spatial extent of predicted light exposure from concurrent activities across multiple fields (simultaneous drilling operations)

8.4.3 impact and risk evaluation

The scoping exercise (Section 7.4) identified receptors that are susceptible to light emissions; these are:

- ambient light
- marine reptiles
- seabirds and shorebirds
- fishes, including sharks and rays
- AMPs
- cultural heritage values: Traditional Owners.

The National Light Pollution Guidelines for Wildlife (Ref. 37) recommend species-specific impacts should be assessed where there is important habitat for listed species that are known to be affected by artificial light within 20 km of a project. The 20 km threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings (demonstrated to occur at 15–18 km) and fledgling seabirds grounded in response to artificial light 15 km away (Ref. 37).

Table 8-26 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to light emissions in the relevant spatial extent.

The National Light Pollution Guidelines (Ref. 37) do not provide specific guidance for assessing impacts to plankton, marine invertebrates, or marine mammals. Cetaceans, for example, predominantly use acoustic senses rather than visual sources to monitor their environment (Ref. 642). As such, light is not considered to be a significant factor in cetacean behaviour or survival. Consequently, it is

considered that impacts to these species are not likely to be of a level that requires assessment.

Exposure to people and communities (from impacts such as reduced visual amenity) will not credibly occur. The closest residential area is ~130 km away (i.e. Onslow) from the DA, and the largest spatial exposure from light emissions was identified as 42.4 km. Consequently, light emissions will not be visible from any residential areas on the mainland.

Although fish may potentially be impacted by light emissions, they are not considered particularly sensitive to light. Furthermore, light is likely restricted to localised areas of direct light spill on the sea surface, and there is no specific guidance in the National Light Pollution Guidelines (Ref. 37). Therefore, light emissions are not expected to result in a change in the viability of the population of commercially important fish species, or a change in values and sensitivities of the fish assemblage values of the continental slope demersal fish communities KEF.

Therefore, impacts from light emissions to commercial fisheries, people, and communities, KEFs and marine mammals are not expected, and are not evaluated further.

Table 8-26: Impact and risk evaluation for light emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Light emissions may result in: • localised and temporary change in ambient light	6	A localised and temporary change in ambient light may result in: • change to behaviour in marine reptiles	6	5	Very Low (10)
		A localised and temporary change in ambient light may result in: • change to behaviour in birds	5	5	Very Low (9)
		A localised and temporary change in ambient light may result in: • change to behaviour in fish	6	5	Very Low (10)
		A localised and temporary change in ambient light may result in: • change to values and sensitivities of Australian Marine Parks	5	5	Very Low (9)
		A localised and temporary change in ambient light may result in: • change to cultural heritage values: Traditional Owners	5	5	Very Low (9)

Impact evaluation
Ambient light
Change in ambient light The MODU, vessels and flaring activities associated with the Development will generate light emissions, resulting in a change to ambient light. As identified in Section 8.4.2, changes to ambient light are expected at distances of up to 42.4 km, 12.6 km and 5.2 km from flaring activities, MODU and vessels operations, respectively.

Impact evaluation

MODU and Vessels

Navigational and operational lighting from the MODU and vessel operations are temporary sources of light, as the Development has no permanent above-surface facilities, unlike a platform or FPSO. The MODU is expected to be present for ~3 months to drill each well. Vessels will be used throughout all phases of the Development, with their presence varying from ~3 months per drilling activity to up to ~12 months during installation and commissioning. Activities may be undertaken 24 hours a day, as such, lighting is required at night for navigation and to ensure safe operations when working on the vessels and MODU. Given the expected distances for changes to ambient light, light emissions from vessels and MODU operations are localised and are not predicted to impact ambient light conditions on the mainland, Montebello Islands or Barrow Island (~130 km, ~50 km and ~60 km from the DA, respectively).

Flaring

Flaring may be required as a contingency during well flowback activities. If required, it will be an infrequent, short-term occurrence (may intermittently occur over ~1 day) and will be undertaken from one well at a time.

Given the expected distances for changes to ambient light, light emissions from flaring activities are not predicted to impact ambient light conditions on the mainland, Montebello Islands or Barrow Island (~153 km, ~52 km and ~63 km from the closest DC [i.e. WTR DC-1], respectively).

Given the temporary and/or limited extent of the predicted artificial light exposure areas, CAPL determined the impacts associated with a change in ambient light levels to have an Incidental (6) consequence level.

Concurrent activities

For concurrent activities within a single field, MODU and vessel operations are estimated for ~4 months with a potential exposure area extending up to~36 km diameter, while for concurrent activities across multiple fields, operations are estimated for up to 24 months with a potential exposure area ranging from ~34.5 km to ~49.7 km diameter (Figure 8-23). Areas exposed to overlapping light extents may not necessarily be exposed to greater light intensity, since the effect is not simply additive, and the overlapping areas are towards the edges of the individual light fields, where light is getting closer to ambient levels (noting that light intensity is inversely proportional to the distance from the source). Also, any potential exposure area resulting from concurrent activities is within areas of the DA located further offshore, with WTR predicted light exposure area being the closest extent to nearshore habitat (e.g. Figure 8-23B).

Given the offshore location of the DA (~50 km from the closest coast), no spatial overlap extend to the nearest coasts and the temporary extent (i.e. no permanent above-surface facilities) of the artificial light exposure areas, CAPL determined that the impacts associated with a direct change in ambient light levels from concurrent activities are not expected to exceed those already assessed for MODU and vessels above.

Risk evaluation

Marine reptiles

Change to behaviour

Activities that result in changes to ambient light conditions, may lead to a subsequent change in the behaviour of light-sensitive fauna. Light emissions have the potential to change behaviour of marine reptiles, such as inhibiting nesting by adult females and disrupting the orientation and sea-finding behaviour of hatchlings (Ref. 37; Ref. 24; Ref. 286).

As outlined in Section 8.4.2, changes to ambient light are predicted to extend up to 12.6 km from the MODU and 5.2 km from the vessels operations. If flaring is required during well flowback activities, light exposure may temporarily (~1 day) extend up to 42.4 km.

Section 6.3.3.2 has identified several marine reptile species listed as threatened and/or migratory under the EPBC Act, including the EPBC threatened short-nosed sea snake, leaf-scaled sea snake and salt-water crocodile. These sea snakes prefer shallow water and reef habitat to depths of 10 m. In addition, light has not been identified as a threat for either species (Ref. 27; Ref. 26). Similarly, the salt-water crocodile inhabits coastal waters, estuaries, lakes, inland swamps, and marshes (Ref. 537). As the predicted artificial light exposure areas are not expected to impact islands and nearshore habitats, and consequently, potential sea snakes or salt-water crocodile habitats, these species are not expected to be impacted by these light exposure areas. Therefore, they have not been evaluated further.

In addition, as identified in Figure 8-11 to Figure 8-17, overlap with marine turtle BIAs and HCTS (internesting buffer) may also occur. The predicted artificial light exposure areas for the MODU and vessels overlap the flatback turtle internesting buffer BIA and HCTS (internesting buffer). This overlap is limited to the southern section of the DA only (i.e. close to or within indicative WTR, C&D and Semele DCs and infrastructure). No other BIAs or HCTS were identified in relation to MODU and vessel lighting.

For flaring activities, the predicted artificial light exposure area overlaps with the following BIAs and HCTS:

- flatback turtle BIA (internesting buffer) and HCTS (internesting buffer) (Figure 8-11 and Figure 8-12)
- hawksbill turtle BIA (internesting buffer) and HCTS (internesting buffer) (Figure 8-13 and Figure 8-14)
- loggerhead turtle BIA (internesting buffer) (Figure 8-15)
- green turtle BIA (internesting buffer) and HCTS (internesting buffer) (Figure 8-16,Figure 8-17).

Overlap with these identified BIAs and HCTS is limited to the WTR, C&D, and Semele DCs. The flatback turtle BIA and HCTS also overlap with G&E DC exposure areas. No other BIAs or HCTS were identified.

The *National Light Pollution Guidelines* (Ref. 37) indicate that a 20 km buffer or exposure area can provide a general precautionary light impact limit based on observed effects of sky glow on marine turtle hatchlings (i.e. onshore emerging from nests and sea finding up to 15–18 km away from artificial light (Ref. 141; Ref. 658). The *Recovery Plan for Marine Turtles in Australia* (Ref. 24) identifies light emissions as a key threat because they can disrupt critical behaviours, such as nesting, hatchling orientation, sea finding, and dispersal. The plan also defines the HCTS of a species for nesting for each species at a stock level. Light pollution is classified as “of less concern” to turtles during offshore-based activities in open waters (Ref. 287).

The general guidance is that turtles require naturally illuminated beaches for successful nesting and sea-finding behaviour (Ref. 24; Ref. 288; Ref. 289). The closest nesting habitats critical to the survival of a species to the DA include Barrow, Montebello and Lowendal islands, which have been identified as nesting habitat for flatback, green, and hawksbill turtles (Ref. 24).

At its closest, the DA is located ~50 km and ~60 km from the Montebello and Barrow Islands respectively. Because artificial light exposure is predicted to alter ambient conditions up to 42.4 km, 5.2 km and 12.6 km from the flaring, vessels and MODU, respectively, no direct light spill onto coastal areas is expected. Consequently, adult nesting turtles, or turtle hatchlings within nesting habitats are not expected to be exposed to light emissions from these activities.

Once hatchlings emerge from their nest, they orient towards the sea (Section 6.3.3.2.1) using topographic and brightness cues orienting to the low elevation light horizon (Ref. 697). While artificial light can attract hatchlings during their nearshore transit (Ref. 706; Ref. 719), this is typically associated with land-based light pollution, which can cause hatchlings to become misoriented, return to the beach, fail or delay their movement toward the ocean (Ref. 287; Ref. 706, Ref. 707). Offshore light sources may also cause misorientation in coastal waters; however, given the absence of direct light spill onto coastal areas, such effects are not anticipated and have therefore not been further evaluated.

Upon entering to the water, during the frenzy (Section 6.3.3.2.1), hatchlings primarily use wave direction as an orientation cue to reach deeper water (Ref. 24). In the absence of wave cues, swimming hatchlings may orient towards light (Ref. 708, Ref. 709) and in some cases, over short distances (50-150 m), light cues may override wave cues (Ref. 710). As previously identified, flatback, green and hawksbill turtles nest on the Montebello and Barrow islands (~50 km and ~60 km from the DA). Flatback turtles do not have a known oceanic development phase; instead, hatchlings are considered to develop in shallow coastal waters without leaving the Australian continental shelf (Ref. 698; Ref. 699 in Ref. 290). In contrast, green and hawksbill hatchlings disperse into oceanic currents and gyres. A study simulating particle dispersal from various coastal locations in WA found that particles released from wide continental shelves, such as those along the NWS, tended to remain on the shelf (Ref. 701). This suggests that green and hawksbill turtle hatchlings in WA may also be retained on the shelf during early dispersal.

Given the offshore location of the DA, the predicted artificial light exposure from the vessels (5.2 km) and MODU (12.6 km), and the shelf-bounded dispersal behaviour of hatchlings, it is not expected that dispersing hatchlings would be attracted to light sources from these activities. Therefore, they have not been evaluated further. For flaring activities, given the very short-term (intermittent over ~1 day per well) and infrequent nature (required as a contingency during well clean-up and flowback activities) of the activity, as well as the fact that light exposure from potential flaring is limited (to drilling and well intervention activities only), if hatchlings were

present in the predicted exposure area (i.e. when they reach deeper waters), they would be passively drifting with ocean currents (Section 6.3.3.2.1), as their active-swimming phase (i.e. the frenzy period) would have concluded prior to entering this area. Therefore, they have not been evaluated further.

HCTS for internesting is defined as a distance seaward from nesting habitat critical for the survival of a species —60 km for flatbacks and 20 km for hawksbill and green turtles (Ref. 24). Studies have indicated that the internesting behaviour of flatback turtles on the NWS appears more spatially restricted (Ref. 24) than those suggested by the Recovery Plan for Marine Turtles in Australia. Whittock et. al. (Ref. 146) reported that flatback turtles prefer habitats nearer the coast and at relatively shallow depths during internesting periods. Unsuitable flatback turtle internesting habitat was defined by Whittock (Ref. 146) as waters >25 m deep and >27 km from the coast.

Although the predicted artificial light exposure areas from the vessels and MODU overlap parts of the internesting buffer for the habitat critical for the survival of the species, these areas are considered unsuitable for flatback internesting habitat. This is due to their offshore location (at its closest, the artificial light exposure areas are ~42 km and ~39 km from the coast, respectively), and water depths (>50 m for both). Therefore, it is very unlikely that internesting flatback turtles would aggregate within the vessel and MODU lighting spatial extent. As a result, any presence of marine turtles within the predicted light exposure would be of a transitory nature.

Short-term and infrequent flaring from WTR, C&D and Semele DCs may generate light emissions that may overlap suitable offshore flatback turtle internesting habitat on the west coast of Montebello Islands. Flatback turtle nesting is more common on the east coast beaches of Barrow Island (i.e. opposite side of the island to the DA and 10 km further); thus, the area of overlap may not represent preferred internesting habitat for this species. CAPL has undertaken a marine turtle monitoring program and an annual light monitoring program, under the Gorgon Gas Development: Long-term Marine Turtle Management Plan (Ref. 290). The monitoring program has been carried out since operation of the Gorgon Gas Development marine facilities adjacent to the east coast of Barrow Island began in 2005. No adverse impacts have been reported to flatback turtle populations for nesting and hatching due to night-time light emissions (Ref. 198). Consequently, exposure of internesting flatback turtles to light emissions from flaring is not expected to result in adverse impacts to flatback turtle populations. As a result, any presence of flatback turtles within the predicted light exposure would be of a transitory nature.

Green, loggerhead and hawksbill turtles have also demonstrated spatially restricted behaviour during internesting (Ref. 24) and have been recorded as staying with within 5 km of Barrow Island and within shallow coastal waters (Ref. 142). As previously identified, no BIAs or HCTS of these species were identified within the MODU or vessels' predicted artificial light exposure areas. As a result, internesting behaviour is not expected within the predicted light exposure areas and any presence of these species would be of a transitory nature. For flaring activities, given observed behaviours and internesting habitat preferences, if present, these marine turtles would be expected within the southern section of the predicted artificial light exposure area. Given the very short-term (intermittent over ~1 day per well) and infrequent nature (required as a contingency during well clean-up and flowback activities) of the activity, as well as the fact that light exposure from potential flaring is limited (to drilling and well intervention activities only), any disruption is expected to be temporally and spatially limited.

Given the previous details, any impact to marine turtles would be limited to temporary disturbance. As such, the consequence associated with this impact has been evaluated as Incidental (6).

The spatial extent of predicted light emissions from the Development does not overlap mainland nor other island marine turtle nesting habitat and the majority of the artificial light exposure areas is limited to deeper offshore waters that are unsuitable for internesting behaviour. In addition, the activities associated with light emission are relatively short and discrete campaigns. Therefore, the likelihood was evaluated as Remote (5).

The risk ranking of the potential to change to behaviours for marine reptiles from light emissions is Very Low (10).

Concurrent activities

For concurrent activities within a single field (Section 8.4.2.5), MODU and vessel operations are estimated for ~4 months with a potential exposure area extending up to~36 km diameter, while for concurrent activities across multiple fields (Section 8.4.2.5), operations are conservative estimated with a maximum of 24 months with a potential exposure area ranging from ~34.5 km to ~49.7 km diameter (Figure 8-23). It is noted that any potential exposure area from these concurrent activities is located further offshore, with WTR predicted light exposure area being the closest extent to nearshore habitat (e.g. Figure 8-23B).

In most scenarios, light exposure areas from concurrent activities will be perceived as distinct light sources, especially when marine reptiles are in close proximity given the distance between sources. However, under cloud cover conditions, increased skyglow from multiple sources may occur and be viewed by distant receptors (Ref. 749). Given the conservatism built into assessments, the offshore location of the DA (~50 km of the Montebello Islands and 60 km of Barrow Island) relative to habitats more frequently used by turtles, and the seasonal and transitory nature of the marine turtles within the DA, the concurrent impact of multiple light exposure areas is not expected to affect the biological behaviours of marine turtles within the DA to an extent greater than that already conservatively assessed for individual sources above.

Although the predicted artificial light exposure areas for the MODU and vessels overlap the flatback turtle internesting buffer BIA and HCTS (internesting buffer) (Figure 8-11 to Figure 8-17), as previously identified, the DA and predicted artificial light exposure areas from vessels and MODU are not considered to be suitable for internesting habitat; consequently, only a small number of transient marine turtles are expected to be present. Similarly, it is not expected that dispersing hatchlings would be attracted to light sources from these activities (i.e. frenzy period would have concluded prior to entering this area). Light pollution is classified as “of less concern” to turtles during offshore-based activities in open waters (Ref. 287).

Given the offshore location of the DA (~50 km from the closest coast), no spatial overlap from concurrent activities is expected to extend to nearest coasts, the transitory nature of the marine turtle presence and the temporary extent (i.e. no permanent above-surface facilities) of the artificial light exposure areas, the impact of increased light intensity or potentially larger exposure area resulting from concurrent activities is not expected to adversely affect the biological behaviours of marine turtles to an extent greater than that already assessed above for individual MODU and vessels activities.

Seabirds and Shorebirds

Change to behaviour

Activities that result in a change in ambient light conditions, may lead to potential changes in the behaviour of seabirds and shorebirds such as disruption to foraging, breeding or migration behaviours.

As outlined in Section 8.4.2, changes to ambient light are predicted to extend up to 12.6 km from the MODU and 5.2 km from vessels operations. If flaring is required during well flowback activities, light exposure may extend up to 42.4 km.

Anthropogenic disturbance (including artificial lighting) is identified as a threat within the *Wildlife Conservation Plan for Migratory Shorebirds* (Ref. 39). Similarly, light pollution is identified as a threat within the *Wildlife Conservation Plan for Seabirds* (Ref. 38).

Young birds (fledglings) are more likely to become disorientated by artificial light sources. The *National Light Pollution Guidelines* (Ref. 37) consider fledglings vulnerable to artificial lighting within ~20 km of their nests. This distance is a precautionary limit based on observed sky glow effects causing fledgling seabirds to ground in response to artificial light 15 km away (Ref. 37). No emergent land suitable for roosting or nesting habitat was identified within the DA. The nearest potential nesting habitats — the mainland, and closest coasts, Montebello Islands or Barrow Island, are ~130 km, ~50 km and ~60 km from the DA, respectively; therefore, exposure of nesting adult birds or fledglings to artificial light emissions from the activity is not expected.

Section 6.3.3.4 has identified several migratory shorebirds and seabirds listed as threatened and/or migratory under the EPBC Act. In addition, as identified in Figure 8-18 to Figure 8-20, only the wedge-tailed shearwater breeding BIA, was identified overlapping the MODU and vessel predicted artificial light exposure areas. For flaring, the predicted artificial light exposure area overlaps wedge-tailed shearwater, the fairy tern and lesser crested tern breeding BIAs (Figure 8-18 to Figure 8-20), The BIAs for these species are buffers around islands that the species is known to nest on as they may forage in the waters surrounding the islands during nesting seasons (Section 6.3.3.4).

It is possible that nocturnally active seabirds and/or migratory shorebirds may be affected by light-spill and alter their normal behaviours. Light emissions can confuse nocturnal foraging behaviours of shearwater, petrel and albatross species (order: Procellariiformes) since they are instinctively attracted to light due to their exploitation of bioluminescent prey (Ref. 291; Ref. 292). Foraging opportunities for shearwaters outside of bright moonlit nights may be increased due to the temporal presence of artificial light (Ref. 751). Light emissions can also displace migratory shorebirds from suitable nocturnal roosts and foraging sites which adversely increases energy costs to migratory travel, and again may result in some individuals becoming grounded on vessel decks (Ref. 37). The mechanism of birds being attracted to light is not fully understood, but it is proposed that the artificial lighting may override the internal magnetic compass of migratory shorebirds or nocturnal seabirds (Ref. 501).

In all seabirds, their photopic vision (light-adapted) is most sensitive in the long wavelength range (590–740 nm, orange to red) while their scotopic (dark-adapted) vision is more sensitive to short wavelengths (380–485 nm, violet to blue) (Ref. 37). Peak spectral emissions from MODU, vessels and flares are not expected to occur within these lower and more sensitive wavelength bands of blue, violet and ultraviolet light (i.e. not within the sensitive ranges for scotopic vision). However, the intensity of light may be a more important cue than colour for seabirds; very bright light will attract them, regardless of colour (Ref. 37).

The presence of the wedge-tailed shearwater in the Pilbara is seasonal, typically occurring between mid-August to April. These birds are known to forage relatively close to breeding islands or over a large area, depending on prey availability. The main fledgling period for shearwaters in Australia is during April/May (Ref. 37). They are known to breed on islands off Barrow Island (Double and Boodie islands), and the Lowendal and Montebello Islands and to forage relatively close to breeding islands or over a large area, depending on prey availability (Ref. 172).Potential changes in the behaviour may occur from the Development activities.

Artificial light at night, may also attract birds to the light source and disorient them during migration, especially during nights with low visibility, such as periods of fog, cloud cover, bad weather (Ref. 742). Marquenie et al. (Ref. 293) estimated that a change in migratory behaviour of birds would be limited to <5 km from the source. Consequently, potential impacts are expected to be spatially restricted to the DA affecting only individuals.

The subspecies of fairy and lesser crested terns identified within the DA are likely sedentary. The subpopulation of fairy tern is based along the Pilbara and upper Gascoyne coasts from Exmouth Gulf to the Dampier Archipelago, including Barrow, Montebello, and Lowendal islands (Section 6.3.3.4.3). The Australian fairy tern nest from late-July to late-September. They feed in near-shore waters adjacent to nesting colonies and around island archipelagos (Ref. 44). Similarly, the lesser crested tern is identified to nest in the Pilbara region, including the Lowendal Islands and potentially the Montebello Islands (Ref. 170). Their breeding season is between March and June and forage in the surf of the ocean.

Given the distance from the DA to the closest coasts, Montebello and Barrow Islands (~50 km and ~60 km, respectively), the predicted changes to ambient light form the MODU and vessels operations (up to 12.6 km and 5.2 km, respectively) and the foraging behaviours identified in offshore waters near to nesting colonies, potential impacts to seabirds and migratory shorebirds are expected to be limited to negligible affecting only individuals. For flaring activities, potential impacts may also occur; however, due to the infrequent (contingency activity during well flowback activities) and short-term occurrence activity (may occur intermittently over ~1 day) they are also expected to be limited affecting only individuals.

Because light emissions have the potential to cause localised short-term impact to a small number of seabird or shorebirds species over the course of the Development, the consequence associated with this impact has been evaluated as Minor (5).

The spatial extent of light emissions from the Development does not overlap any known nesting habitat for seabirds or shorebirds and thus changes to nesting and fledgling emergence are not expected. In addition, the Development activities are relatively short and discrete campaigns. Therefore, the likelihood of exposing seabirds and shorebirds was evaluated as Remote (5).

The risk ranking of the potential to change to behaviours for seabirds and shorebirds from light emissions is Very Low (9).

Concurrent activities

For concurrent activities within a single field (Section 8.4.2.5), MODU and vessel operations are estimated for ~4 months with a potential exposure area extending up to ~36 km diameter, while for concurrent activities across multiple fields (Section 8.4.2.5), operations are conservative estimated with a maximum of 24 months with a potential exposure area ranging from ~34.5 km to ~49.7 km diameter (Figure 8-23). It is noted that any potential exposure area from these concurrent activities is located further offshore, with WTR predicted light exposure area being the closest extend to nearshore habitat (e.g. Figure 8-23B).

In most scenarios, light exposure areas from concurrent activities will be perceived as distinct light sources, especially by birds in close proximity. Given the conservatism built into assessments, the offshore location of the DA (~50 km of the Montebello Islands and 60 km of Barrow Island), and the seasonal presence of seabirds and migratory birds within the DA, the concurrent impact of multiple light exposure areas is not expected to affect the behaviour of nesting adult birds or fledglings to an extent greater than that already conservatively assessed for individual sources above.

As previously identified, the potential changes to foraging behaviour are expected to be limited. While foraging opportunities outside of bright moonlit nights may be increased due to the temporal presence of artificial light (Ref. 751), the concurrent impact of multiple light exposure areas is not

expected to affect foraging behaviour than that already conservatively assessed for individual sources above. For migratory birds, nocturnal migratory behaviour may be influenced by artificial light, particularly during low-visibility conditions such as fog, cloud cover, bad weather (Ref. 742). However, foggy conditions are rarely encountered on the NWS. As previously mentioned, although light intensity (i.e. very bright light) from MODUs and vessels may attract birds, the peak spectral emissions are not expected to fall within the range most sensitive to seabird night vision (scotopic vision). As a result, any attraction is unlikely to contribute additional impacts beyond those already assessed. Furthermore, Marquenie et al. (Ref. 293) estimated that a change in migratory behaviour of birds would be limited to <5 km from the source. Consequently, potential impacts are expected to be spatially restricted to the DA affecting only individuals.

Consequently, the impact of artificial lighting from concurrent activities are not expected to adversely affect migratory behaviours of seabirds and shorebirds to an extent greater than already assessed above for individual sources above.

Construction for different stages of the Development may occur over a period of years (either sequentially or with gaps between development stages depending on gas supply strategy requirements at the time). However, as described above changes in migratory behaviour are expected to be spatially restricted to the DA affecting only individuals. The predicted exposure areas are also not static; i.e. depending on what activities are occurring each year, different parts of the DA and adjacent areas may be exposed to artificial light. Similarly, migratory behaviour is known to be dynamic given their seasonal occurrence. Consequently, potential impacts over a period of years are expected to be spatially restricted to the DA affecting only individuals.

Fishes, including sharks and rays

Change to behaviour

Light emissions are not known to change behaviour in adult offshore pelagic fishes, including sharks and rays. The *National Light Pollution Guidelines* do not specifically address light impacts to fish species, although it is recognised that light can cause changes in fish assemblages (Ref. 37). Light-sensitive fishes may instinctively be attracted to and move towards light emission sources or prey on other species that aggregate at the edges of artificial light halos, while some species are known to avoid light (Ref. 294).

As outlined in Section 8.4.2, changes to ambient light are predicted to extend up to 12.6 km from the MODU and 5.2 km from the vessels operations. If flaring is required during well flowback activities, light exposure may extend up to 42.4 km. These potential light exposures may cause temporary and minor changes to adult fish behaviours such as attraction, avoidance, and opportunistic feeding at night.

Light emissions may also change migratory behaviours of zooplankton. Zooplankton are negatively phototactic, such that when exposed to light zooplankton will swim away from the light source (Ref. 294; Ref. 295). Light emissions at night are known to potentially limit the initiation and magnitude of the Diel Vertical Migration (DVM) i.e. vertical migration of zooplankton to surface waters (Ref. 294).

Section 6.3.3.3 has identified listed threatened and/or migratory fish species under the EPBC Act have the potential to occur. In addition, the predicted artificial light exposure from MODU, vessels and flaring overlap the whale shark foraging BIA (Figure 8-21). This BIA is associated with foraging behaviours during northward migration from Ningaloo Reef / North West Cape along the 200 m isobath during July to November (Ref. 33). Consequently, whale sharks are expected to be transient within the area. No other BIAs were identified.

Nocturnal surface feeding behaviours by whale sharks have been reported when the vertical migration of zooplankton attracts whale sharks to the surface (Ref. 296). Light emissions from the Development may limit the initiation and magnitude of DVM, which may in-turn, temporarily reduce the opportunity of foraging whale sharks to feed on zooplankton in areas immediately surrounding vessels or MODU during the Development. However, light has not been identified as a key threat for the whale shark (Ref. 33). The area of impact of limiting the initiation and magnitude of DVM is likely to be restricted to areas where light is directly visible to fishes including fish larvae/zooplankton. Light spill on the ocean surface is only visible to fishes immediately surrounding the light source. This area of light spill is considered highly localised and temporary based on the presence of MODU/vessels in the DA at night during the Development. As a result, the potential to limit the initiation and magnitude of DVM is also considered highly localised and temporary. Therefore, changes to fish species composition or abundance are expected not to occur.

Given the limited light spill exposure, the transient nature of the fish and sharks and no known aggregations areas are identified, the consequence associated this impact has been evaluated as Incidental (6).

Although sections of the spatial extents for MODU, vessel and flaring overlap the whale shark foraging BIA, this species is not identified as sensitive to light. In addition, as the Development activities are relatively short and discrete campaigns, and only transient individuals could be exposed the likelihood of the consequence occurring has been evaluated as Remote (5).

The risk ranking of behavioural disruption to fishes, including sharks and rays from light emissions is Very Low (10).

Concurrent activities

For concurrent activities within a single field (Section 8.4.2.5), MODU and vessel operations are estimated for ~4 months with a potential exposure area extending up to~36 km diameter, while for concurrent activities across multiple fields (Section 8.4.2.5), operations are estimated for up to 24 months with a potential exposure area ranging from ~34.5 km to ~49.7 km diameter (Figure 8-23).

Concurrent activities occurring either within a single field or across multiple fields, may result in multiple or overlapping light exposure areas. Light penetration in water is inherently limited due to absorption and scattering. Even in clear offshore waters, light typically penetrates only to the photic zone, beyond which light levels drop off sharply (Ref. 752). Similar to light from individual sources, this may result in temporary changes in behaviour, such as increased foraging opportunities. However, given the transient nature of the fish and sharks and that no known aggregations areas have been identified, these effects are likely to be temporary and restricted to within the field of any given light source, rather than additive. Any combined effect on behaviour from cumulative impact of multiple light exposure areas is not expected to adversely affect the biological behaviours of fishes and sharks within the DA to an extent greater than already assessed above.

The spatial extent of concurrent light spill from the Development are expected to be limited and restricted to the water surface. As previously identified, the potential impacts to fish and sharks are expected to be limited. Light has not been identified as a key threat for the whale shark (Ref. 33).

Given the limited light exposure (i.e. surface waters), the transitory nature of the fish and sharks and the temporary extent (i.e. no permanent above-surface facilities) of the artificial light exposure areas, the cumulative impact of increased light intensity or potentially larger exposure area is not expected to adversely affect fish and shark species to an extent greater than already assessed above.

Construction for different stages of the Development may occur over a period of years (either sequentially or with gaps between development stages depending on gas supply strategy requirements at the time). However, as described above changes in biological behaviours of fishes and sharks, including foraging, are expected to be spatially restricted to the DA affecting only individuals. The predicted exposure areas are also not static; i.e. depending on what activities are occurring each year, different parts of the DA and adjacent areas may be exposed to artificial light. Similarly, given the transient nature of the fish and sharks and that no known aggregations areas have been identified, these effects are likely to be temporary and restricted to the DA affecting only individuals.

AMPs

Change to values and sensitivities

The predicted artificial light exposure from vessels and MODUs does not extend into any AMP (Figure 8-22). Consequently, changes to values and sensitivities from light emission of vessels or MODUs are not expected. Therefore, it is not discussed further.

The predicted artificial light exposure from flaring from all DCs, except Chandon DCs, extents into the boundaries of the Australian Montebello Marine Park (Figure 8-22). No other AMPs overlap the predicted flaring light exposure .

The Montebello Marine Park is zoned as a Multiple Use Zone (IUCN VI), which is a zone “managed to allow ecologically sustainable use while conserving ecosystems, habitats and native species. The zone allows for a range of sustainable uses, including commercial fishing and mining where they are consistent with park values” (Ref. 82). The natural values of this AMP include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for regionally significant marine fauna.

Potential impacts to the values of the Montebello Marine Park may occur due to indirect consequences of an impact to marine fauna. However, as previously described, the consequence rank was assessed as Minor (5), expected to occur at a local scale or affects a minor part of a species (i.e. not having lasting effect to marine fauna population), with a residual risk of Very Low (9).

CAPL consider that the Development can be undertaken in a manner that is not inconsistent with the objectives of the North-west Marine Parks Network Management Plan (Ref. 82). As such, CAPL has ranked the risk for AMPs consistent with that for marine fauna; i.e. consequence as Minor (5), likelihood as Remote (5), and residual risk as Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from light emissions includes indirect impacts to intangible Traditional Owner heritage from the change in behaviour of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential change in behaviour of marine fauna from light emissions. Consequence evaluations of light emissions resulting in the change in behaviour of marine reptiles, birds and fish are provided above. The highest consequence level was Minor (5), as such, the consequence of changes to cultural heritage values from light emissions is also evaluated as Minor (5). Light emissions from vessels, MODUs and flaring are temporary, non-routine, infrequent and of short duration. Because of the limited spatial extent and temporary nature of the change arising from light emissions, significant adverse changes to cultural heritage values from light emissions is not predicted to occur. Therefore, the likelihood of the consequence occurring is evaluated as consistent with that of the highest consequence ranking – i.e. the likelihood is assessed as Remote (5). The risk of light emissions to Traditional Owner cultural heritage values is Very Low (9).

8.4.4 determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of impact and/or residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-27 details the determination of acceptability for light emissions.

Table 8-27: Determination of acceptability for light emissions

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-07, AL-12**, **AL-13**, **AL-14, AL-15** and **AL-16** as defined in Table 7-6 and shown below in Section 8.4.5. As described in the impact and risk evaluation (Section 8.4.2.5), changes to ambient light are predicted to be temporary and limited in extent. Impacts to marine fauna are predicted to range from incidental impacts with temporary disturbance to individuals to localised, short-term disturbance to a small number of individuals. The predicted impacts would not decrease the availability or quality of important habitat or result in impacts at population level that would prevent long-term recovery or survival. As such, the predicted level of impact for these receptors is better than **AL-12**, **AL-13**, **AL-14** and **AL-15**. Given the predicted impacts to marine fauna, no lasting effects are expected on the values of the Montebello Marine Park that would prevent the conservation of biodiversity within the North-west Marine Parks Network. Therefore, the predicted level of impact to AMPs is better than **AL-16**. Because of the limited spatial extent and temporary nature of light emissions no lasting impact to traditional owner cultural values attributed is predicted. As such, the predicted level of impact is equal to **AL-07**.
Principles of ESD	**(b) 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 highest consequence level for light emissions to marine reptiles, birds and fish was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">damage, and therefore, no further evaluation against principle of ESD (b) is required.
Notwithstanding, CAPL also notes that:
• The literature reviews on predicted light exposure areas (Section 8.4.2) provides scientific certainty to inform the impact and risk evaluation for light emissions.
• To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td></td><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the impact and risk from light emissions based on relevant environmental legislation and other requirements as listed below.
• The regulation and management of light emissions in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for light emissions to marine reptiles, birds and fish was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to light emissions has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>Navigation Act 2012 (Cth)
Requires navigational and safety lighting for vessels.</td><td>Legislative requirements to manage light emissions are addressed by adopting this control measure:
• CM-16.</td></tr>
</table>

Determination of acceptability		
	National Light Pollution Guidelines for Wildlife (Ref. 37) Recommends: • best-practice lighting design to reduce light pollution and minimise the effect on wildlife • undertaking an environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship, or reproduction.	Exposure areas from light emissions from the Development activities (including any potential cumulative effects from concurrent activities), and any associated impacts or risks, have been described in the above impact and risk evaluation. EPBC management plan requirements to manage light emissions are addressed by adopting these EPOs and control measures: • **EPO-14** • **EPO-15** • **EPO-16** • **CM-17**. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Recovery Plan for Marine Turtles in Australia 2017–2027 (Ref. 24) *Action A8.1*: Artificial light within or adjacent to HCTS of marine turtles will be managed such that marine turtles are not displaced from these habitats (as per section 3.3 Table 6 of Ref. 24). Note: This is also a specific action identified for the G-NWS individual stock. *Action A8.3*: Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution. In addition to the above actions, the following specific actions have been identified for individual turtle stocks: • F-Pil: Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue • H-WA: Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and dispersing hatchlings can continue.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) Action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	
	Wildlife Conservation Plan for Seabirds (Ref. 38) Action 2d: Ensure all areas of important habitat for seabirds are considered appropriately and consistently in the development assessment process.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 40) **Conservation Advice Rhincodon typus Whale Shark** (Ref. 33)	These EPBC management plan for this species that may occur within the light exposure areas identifies light pollution as a threat but does not identify any relevant actions.

Determination of acceptability		
	North-west Marine Parks Network Management Plan 2018 The class approval for mining operations within a multiple use zone requires a NOPSEMA-accepted EP to be in place before activities commence.	As described in Section 2.1.1.1, EPs associated with the Development will be submitted after the OPP has been accepted by NOPSEMA.
Internal context	These procedures were identified as relevant for this aspect: • Gorgon Gas Development and Jansz Feed Gas Pipeline: Long-term Marine Turtle Management Plan (Ref. 290) • Chevron Shipping's Marine Standard Non Tankers (Ref. 265)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to light emissions from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.4.5 environmental performance

Table 8-28 lists the EPO defined for light emissions and the adopted control measures to achieve the outcome.

Table 8-28: Environmental performance for Light emissions

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-12: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species. **AL-13**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act.	**EPO-13**: Artificial light emissions from planned Development activities do not prevent light sensitive marine fauna[141] from undertaking biological important behaviours[142]. **EPO-14**: Artificial light within or adjacent to habitat critical to the survival of marine turtles[143] will be managed such that marine turtles are	**CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-17**: Where there is a risk of behavioural effects on marine fauna from artificial light emissions, CAPL will adopt an adaptive management approach which identifies activity-specific preventative mitigation

[141] Where light sensitive marine fauna includes marine turtles, seabirds and migratory shorebirds.

[142] Where biologically important behaviours are defined as behaviour associated with critical life functions (e.g. reproduction, foraging, migration, and resting) (Ref. 719).

[143] Where habitat critical to the survival of marine turtle species is defined in Table 6 of the Recovery Plan for Marine Turtles in Australia (Ref. 24).

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-14: Impacts from the Development will not decrease the availability or quality of marine fauna habitat to the extent that it interferes with the recovery of the population of an EPBC Act listed threatened species. **AL-15**: Impacts from the Development will not decrease the availability or quality of important habitat[139] to the extent that it interferes with the survival of the population of an EPBC Act listed migratory species. **AL-16**: No impact on the natural values of the Montebello Marine Park[140] from the Development that would prevent the conservation of biodiversity within the North-west Marine Parks Network.	not displaced from these habitats. **EPO-15**: Manage artificial light from offshore sources to ensure biologically important behaviours of: • nesting adults and emerging/dispersing hatchlings of the flatback turtle Pilbara stock (F-Pil) can continue • nesting adults and dispersing hatchlings of the hawksbill turtle WA (H-WA) can continue. **EPO-16**: Implement an adaptive management approach (**CM-17**) for artificial light emissions from the Development such that it can be demonstrated that risks have been reduced to as low as reasonably practicable and can be managed to meet acceptable levels. The outcomes of this adaptive management approach will be incorporated into Environment Plans for the petroleum activities associated with this Development.	measures such that the potential risks from artificial light emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will in: • lighting requirements for safe navigation and operations • seasonal presence and behaviour of marine fauna within indicative activity windows • location(s) of the petroleum activity in relation to sensitive fauna receptors • type, location, and duration of any concurrent activities • existing (e.g. Recovery Plan for Marine Turtles in Australia 2017–2027 [Ref. 24]) or contemporary regulatory requirements as available at the time. Mitigation options may include those as described within existing (e.g. National Light Pollution Guidelines [Ref. 37]) or contemporary guidance as available at the time.
AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

[139] Where important habitat for migratory species are defined within the MNES Significant Impact Guidelines (Ref. 72).

[140] Where the natural values of the Montebello Mark Park are described in the North-west Marine Parks Network Management Plan (Ref. 82).

8.5 underwater sound emissions

8.5.1 terminology

Within this OPP the following terms have been adopted to describe underwater sound sources and received levels:

- **impulsive**—sounds that are typically transient, brief (less than one second), broadband, and consist of high peak sound pressure with rapid rise and rapid decay times (Ref. 350; Ref. 678)
- **non-impulsive**—sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically do not have a high peak sound pressure with rapid rise or decay times (Ref. 350; Ref. 678)
  - **continuous non-impulsive**—sounds where the sound pressure level remains above ambient (Ref. 678) and has a repetition rate of ≥10 Hz (Ref. 550)
  - **intermittent non-impulsive**—sounds that have interrupted levels of low or no sound, or bursts of sounds separated by silent periods (Ref. 678) and has a repetition rate of <10 Hz (Ref. 550)
- **temporary threshold shift** (TTS)—reversible loss of hearing sensitivity (e.g. as the result of receptor hair cells in the cochlea becoming fatigued) (Ref. 297)
- **permanent threshold shift** (PTS)—an irreversible loss of hearing sensitivity (e.g.as a result of physical injury to hearing organs); considered auditory injury (Ref. 297)
- **sound pressure level** (SPL)—the level of the time-mean-square sound pressure in a stated frequency band and time window; typically expressed in terms of root-mean-square (rms) (Ref. 297)
- **sound exposure level** (SEL)—the level of the sound exposure in a stated frequency band and time window (Ref. 297).

8.5.2 source

Underwater sound emissions generated by the Development include both impulsive and non-impulsive sound sources.

The Development will generate these impulsive underwater sounds from VSP operations during well evaluation, and from some types of geophysical survey (e.g. SBP) equipment (Table 8-29).

The Development will generate non-impulsive underwater sounds from vessel and MODU operations (associated with propeller cavitation, thrusters, hydrodynamic flow around the hull), operation and decommissioning of subsea infrastructure, drilling, the operation of machinery and equipment, use of acoustic positioning equipment, and from some types of geophysical survey (e.g. MBES, SSS) equipment (Table 8-29).

Underwater sound emissions from the Development will add to the existing ambient sound in the region. Ambient sound includes natural physical (e.g. wind, waves, rain), biological (e.g. echolocation, communication) and pre-existing anthropogenic (e.g. shipping) sources.

The largest changes in ambient sound as a result of the Development are associated with the use of vessels and/or MODUs, and as such will be temporary.

The ongoing sound emissions from the operation of the hydrocarbon system only result in small ensonified areas within the immediate vicinity of subsea infrastructure.

Table 8-29 identifies activities within each phase that have the potential to generate impulsive and non-impulsive underwater sound within the DA.

Table 8-29: Phases and activities that generate underwater sound emissions

Phase	Activity	Type of Sound
Surveys	Geophysical survey (SBP)	Impulsive
	Geophysical survey (SSS, MBES)	Non-impulsive
Drilling	Acoustic positioning (transponders)	Non-impulsive
	Drilling	Non-impulsive
	Well evaluation (VSP)	Impulsive
Installation and commissioning	Acoustic positioning (transponders)	Non-impulsive
	Excavation and trenching	Non-impulsive
Operations	Operation of the hydrocarbon system	Non-impulsive
	Maintenance and repairs (excavation)	Non-impulsive
	Well intervention (drilling)	Non-impulsive
Decommissioning	Acoustic positioning (transponders)	Non-impulsive
	Flowline and MEG pipeline decommissioning (excavation)	Non-impulsive
	Umbilical decommissioning (excavation)	Non-impulsive
	Other subsea infrastructure decommissioning (excavation)	Non-impulsive
	Well plug and abandonment (cutting)	Non-impulsive
Support activities	MODU operations	Non-impulsive
	Vessel operations	Non-impulsive
	Helicopter operations	Non-impulsive
	ROV operations	Non-impulsive

8.5.2.1 surveys

Geophysical surveys of the activity locations may be required at various times during the life of the Development (Section 4.3.1.1).

Surveys are undertaken from a support vessel and may be supported by ROVs or AUVs.

Geophysical survey techniques proposed for the Development and example operating frequency and sound source levels are shown in Table 8-30.

Table 8-30: Example source levels and operating frequencies for different geophysical survey equipment

Equipment	Source level[144] (db re 1 µPa @ 1 m)	Operating frequency (kHz)	Data source
SSS	*rms:* 201–205 *PK*: 206–210	100–400	Ref. 550
	rms: 200–234	9–900	Ref. 299
MBES	*rms:* 218–224 *PK*: 225–228	100–300	Ref. 550
	rms: 210–245	10–455	Ref. 299
SBP (chirp)	*rms:* 178–209 *PK*: 184–214	3–12	Ref. 550
	rms: 161–230	2–23	Ref. 299
SBP (boomer)	*rms:* 205 *PK*: 211	0.2–6	Ref. 550
	rms: 205–225	0.3–6	Ref. 299

8.5.2.2 drilling

The drilling activities listed in Table 8-29 will generate underwater sound from the use of the MODU's DP (described in Section 8.5.2.6); the action of the drill whilst drilling, the use of acoustic positioning (if required), and the use of VSP (if required during well evaluation).

As described in Section 4.3.2.1, the type of MODU has not yet been finalised and may be a semisubmersible, drill ship, or jack-up. Where a DP MODU is selected for use, the thrusters will generate continuous non-impulsive underwater sound for the duration of the activity (Section 8.5.2.6). Indicative source levels for MODUs during drilling for jack-ups, semi-submersibles, and drill ships are ~142–145 dB re 1 µPa @ 1 m, ~132–193 dB re 1 µPa @ 1 m, and ~145–193 dB re 1 µPa @ 1 m respectively (Ref. 299). Drill ships are typically noisier than semi-submersibles and jack-ups under similar operating conditions as the hull is in direct contact with the water (Ref. 299). A drill ship under DP has been evaluated for the purposes of impact and risk assessment (Section 8.5.3.1.1).

Transponders may be used to accurately position the MODU over the proposed well locations and emit short pulses of medium to high frequency sound. Transmissions are not continuous but consist of short 'chirps' when active and do not emit any sound when on standby. Indicative source levels for acoustic positioning equipment are ~184–206 dB re 1 µPa @ 1 m with operating frequencies of ~19–50 Hz (Ref. 299).

VSP (a source of impulsive sound) may be used for well evaluations during drilling. A typical source level for a VSP consisting of 3 x 250 cui airguns is ~239 dB re 1 µPa @ 1 m (Ref. 299). VSP operations (excluding downtime) may take up to 24 hours per well to complete (Section 4.3.2.10).

8.5.2.3 installation and commissioning

Sounds generated by installation activities are typically dominated by the vessels themselves (Section 8.5.2.6) rather than specific activities (e.g. pipelay). Example

[144] Where RMS = root mean square; PK = peak.

source levels during pipelay and trenching activities have been estimated at ~183–184 dB re 1 µPa @ 1 m and ~178–179 dB re 1 µPa @ 1 m respectively (Ref. 299).

Positioning transponders may be used to accurately position subsea equipment; indicative source levels and frequences are described above in Section 8.5.2.2.

8.5.2.4 operations

Operations will generate non-impulsive sound emissions from wellheads and subsea infrastructure, as well as during maintenance and repair (including well intervention) activities.

Kent et al. (Ref. 300) summarises underwater sound studies from different types of petroleum activities, including one study undertaken by McCauley (Ref. 679) that measured sound produced by an operational wellhead and associated pipework. The broadband sound level of the wellhead was 113 dB re 1 µPa rms (Ref. 300). Sound emissions from the pipeline were a weaker signal and difficult to differentiate from the sound emissions of a nearby FPSO (Ref. 300).

Sound emissions measured by JASCO from operating choke valves for Woodside's Angel facility (Ref. 680 cited in Ref. 301) indicated choke valves produce non-impulsive sound, and the frequency and intensity of sound emitted depends on the rate of production from the well. Sound intensity at low production rates (16% and 30% choke positions) was ~154–155 dB re 1 µPa @ 1 m, with higher production rates (85% and 74% choke positions) resulting in lower sound levels (141–144 dB re 1 µPa @ 1 m). Sound from operating choke valves was broadband in nature, with most acoustic energy concentrated above 1 kHz.

Sound emissions from excavation during maintenance and repairs and from well intervention activities are not different from those mentioned in Section 8.5.2.3 and 8.5.2.2 respectively.

8.5.2.5 decommissioning

During decommissioning non-impulsive underwater sound is generated from excavation and cutting of infrastructure such as flowlines, pipelines, and umbilicals, and from abrasive cutting while well plug and abandonment occurs. Sound emissions from excavation during decommissioning are comparable to those mentioned in Section 8.5.2.3.

Sound emissions generated by jet cutting of a wellhead below the seabed, in water depths of 80 m, produced broadband sound from approximately 10 Hz to more than 10 kHz and had a broad peak centred around 1 kHz, with an estimated broadband source level was 189 dB re 1 µPa rms @ 1 m. (Ref. 681 cited in Ref. 300). JASCO modelling of a diamond saw cutter predicted that sound levels would be below 120 dB re 1 µPa within ~300 m of the source; the study also indicated that the sound of subsea cutting would not substantially increase the sound field being produced from general vessel operations (Ref. 682 as cited in Ref. 683).

8.5.2.6 support activities

Support activities vary for each phase and source levels are described below.

8.5.2.6.1 vessel operations

During drilling there may be multiple support vessels with the MODU (e.g. for position, resupply, general standby, etc.).

The installation and commissioning phase for each field will take ~12–15 months. Within the ~12–15 month timeframe, non-impulsive underwater sound will be generated by vessels during the installation of flowlines, MEG pipelines, and subsea structures, and pre-commissioning, commissioning and start-up activities (Table 8-29).

During the operations phase, inspections will be undertaken with a frequency determined based on risk (Section 4.3.4.2). Inspections are generally conducted using a vessel and AUV or ROV.

The frequency of maintenance and repair activities depends on the results of inspections (Section 4.3.4.3). If minor maintenance or repair is required, vessels may remain on site for an estimated ~6 months. If major maintenance or repair is required – including for contingency power supply – vessels may be on site for an estimated ~12 months.

Decommissioning of flowlines, umbilicals and other subsea structures may be carried out using pipelay, construction and support vessels similar to that used for installation and commissioning phase described above.

8.5.2.6.2 MODU operations

Drilling activities are required to establish multiple wells in each field and may take an estimated 24 months per field (~3 months to drill each well). The maximum number of wells per field is 8.

As described in Section 4.3.2.1, the type of MODU has not yet been finalised and may be a semisubmersible, drill ship, or jack-up. If a mooring system is used, generation of non-impulsive underwater sound from the thrusters will be limited to assist the MODU to get to location and will not be used for the entire duration of the activity. A jack-up MODU may be used in shallower water only and would likely be towed into position by support vessels, then the hull ‘jacked-up’. If the DP option is used, the thrusters will generate continuous non-impulsive underwater sound for the entire duration of the activity. The DP option is considered to be the worst-case for non-impulsive sound emissions and will be evaluated for the purposes of impact and risk assessment (Section 8.5.3.1.1).

Well suspension and P&A may be carried out using a MODU or a well intervention vessel, and support vessels similar to that used for drilling. Underwater sound emissions from these activities are estimated to be the same as those predicted for the drilling phase (refer to Section 8.5.2.2).

8.5.2.6.3 helicopter operations

Routine helicopter operations are generally limited to the drilling, installation, and decommissioning phases of the Development where installation vessels (e.g. pipelay and construction vessels) and the MODU will be serviced by helicopters[145]. Helicopter flight frequency may be ~15 to16 times per week for an installation vessel, whereas the MODU may be serviced by ~5 flights per week.

Helicopter operations will generate underwater sound emissions during take-off and landing on the installation vessels and MODU. During take-off and landing, the helicopter will ascend/descend to the helideck where air borne engine sound emissions may ensonify the water column.

Underwater sound frequencies from helicopter operations are expected to be below 500 Hz (Ref. 304). Based on a study by Richardson et al. (Ref. 304),

[145] Helicopters may also be used during longer IMR campaigns during the operational phase of the Development.

audible underwater sound emissions from helicopter operations are limited to a very short time period (~38 seconds) during take-off or landing, resulting in a broadband source level of up to 162 dB re 1 µPa @ 1 m (Ref. 304; Ref. 299).

8.5.2.6.4 ROV operations

ROVs/AUVs typically have few moving parts and use low propulsion power, and as such have a very low underwater sound signature (Ref. 684). Measurements of an AUV indicated a broadband (100–5,000 Hz) source level of 124 dB re 1 µPa @ 1 m (Ref. 684).

8.5.3 underwater sound modelling—non-impulsive

JASCO Applied Sciences (JASCO) undertook a series of modelling studies (Ref. 297; Ref. 685; Ref. 686; Ref. 687; Ref. 550) to inform the impact and risk assessment associated with non-impulsive underwater sound emissions from the Development.

8.5.3.1 scenarios

The acoustic modelling studies considered 38 individual vessel/MODU based activity scenarios (scenarios 1 to 36; 17A, 18A) across five representative areas within the DA, and eight concurrent activities scenarios (scenarios 37 to 40; 41A, 41B, 42A, 42B) (Table 8-31; Table 8-32). The five representative areas capture the variability of the marine environment (e.g. depth, bathymetry, sediment type) across the DA and consider how sound attenuates in each area.

The individual activity scenarios were modelled to encompass all Development phases and a range of indicative vessel configurations.

As described in Section 4.1.4, the Development will be staged so that not all fields will be developed in a single campaign, however different phases of the activities may occur concurrently either within a single field (e.g. drilling and pipelay installation) or across multiple fields (e.g. drilling in one field while subsea installation is occurring in another field). The eight concurrent activity scenarios consider the potential for concurrent activities during the Development.

In addition to acoustic propagation modelling, a more realistic prediction of non-impulsive underwater water sound exposures for migrating pygmy blue whales was undertaken using animal movement modelling (‘animat modelling’) for six of the 38 individual activity scenarios and three of the eight combined scenarios (Table 8-31).

The acoustic propagation and animat modelling studies predicted horizontal distances from activities at which underwater sound levels reached effect criteria (Section 8.5.3.2) corresponding to levels of potential impact to marine fauna. Geophysical survey techniques such as SSS and MBES also generate non-impulsive sound emissions, however these are high frequency emissions which attenuate rapidly in water. As such, a spherical modelling has approach has been applied to these sources (as described in Section 8.5.3.5).

Table 8-31: Non-impulsive model scenarios with relevant Development fields and phases

Model area (and relevant fields)	Model scenario[146]	Scenario description	Approximate water depth	Development phase
Individual activities				
1 (Chandon)	1, 2	Drilling (with and without resupply vessel)	1,149–1,292 m	Drilling Operations Decommissioning
	3, 4, 5	Pipelay (with and without support vessel/s)		Installation and commissioning Decommissioning
	6	IMR		Installation and commissioning Operations
	7, 8*	Subsea installation (with and without support vessel/s)		Installation and commissioning Decommissioning
2 (G&E; Semele)	9, 10	Drilling (with and without resupply vessel)	1,208–1,328 m	Drilling Operations Decommissioning
	11, 12, 13	Pipelay (with and without support vessel/s)		Installation and commissioning Decommissioning
	14*	IMR		Installation and commissioning Operations
	15, 16	Subsea installation (with and without support vessel/s)		Installation and commissioning Decommissioning
3 (C&D)	17, 18*	Drilling (with and without resupply vessel)	918–974 m	Drilling Operations Decommissioning
	17A, 18A	Drilling (with and without resupply and support vessels)		
	19, 20, 21*	Pipelay (with and without support vessel/s)		Installation and commissioning Decommissioning
	22	IMR		Installation and commissioning Operations
	23, 24	Subsea installation (with and without support vessel/s)		Installation and commissioning Decommissioning
4 (C&D)	25, 26, 27	Pipelay (with and without support vessel/s)	389–400 m	Installation and commissioning Decommissioning

[146] Model scenarios marked with an asterisk were also used for animat modelling.

Model area (and relevant fields)	Model scenario[146]	Scenario description	Approximate water depth	Development phase
	28	IMR		Installation and commissioning Operations
5 (WTR)	29, 30*	Drilling (with and without resupply vessel)	141–145 m	Drilling Operations Decommissioning
	31, 32, 33*	Pipelay (with and without support vessel/s)		Installation and commissioning Decommissioning
	34	IMR		Installation and commissioning Operations
	35, 36	Subsea installation (with and without support vessel/s)		Installation and commissioning Decommissioning
Concurrent activities				
1 and 3	37	Pipelay with support vessels (Area 1) + drilling with resupply vessel (Area 3)	As above for relevant model areas	Drilling Installation and commissioning Decommissioning
1, 2, and 3	38	Subsea installation with support vessels (Area 1) + IMR (Area 2) + drilling with resupply vessel (Area 3)		Drilling Installation and commissioning Operations Decommissioning
3 and 5	39	Drilling with resupply vessel (Area 3) + pipelay with support vessels (Area 5)		Drilling Installation and commissioning Decommissioning
5	40	Drilling with resupply vessel + pipelay with support vessels		
2	41A	Drilling with resupply and support vessels + subsea installation with support vessels		
3	42B			
2	42A	Drilling with resupply and support vessels + subsea installation with support vessels + pipelay with support vessels		
3	42B			

Table 8-32: Model scenario and associated indicative vessel fleets and Development activity durations

Model scenario	Indicative vessel fleet	Indicative duration for model scenario
Individual activities		
1, 9, 17, 29	MODU under DP	~3 months of drilling per well

Model scenario	Indicative vessel fleet	Indicative duration for model scenario
17A	MODU with 2 OSVs, all under DP	Up to ~24 months per field or co-developed field
2, 10, 18, 30	MODU with resupply offshore support vessel (OSV) alongside for 8 hrs, both under DP	Intermittent activity (<24 hours/event)
18A	MODU with 2 OSVs, and a resupply OSV alongside for 8 hrs, all under DP	Intermittent activity (<24 hours/event)
3, 11, 19, 25, 31	Pipelay vessel under DP	~6 months pipelay per field or co-developed field
4, 12, 20, 26, 32	Pipelay vessel with OSV, both under DP	Intermittent activity
5, 13, 21, 27, 33	Pipelay vessel with 2 OSVs, all under DP	Intermittent activity
6, 14, 22, 28, 34	IMR vessel under DP	~2 months of pre-commissioning, and ~3 months of commissioning and start-up per field or co-developed field ~6 months (minor maintenance or repair) ~12 months (major maintenance or repair)
7, 15, 23, 35	Offshore construction vessel (OCV) under DP	~4 months subsea installation per field or co-developed field
8, 16, 24, 36	OCV with 2 OSVs and 1 tug, all under DP	Intermittent activity
Concurrent activities		
37 (combined scenarios 5 and 18)	Pipelay vessel with 2 OSVs, all under DP MODU with resupply OSV alongside for 8 hrs, both under DP	~6 months (based on indicative pipelay duration)
38 (combined scenarios 8, 14 and 18)	OCV with 2 OSVs and 1 tug, all under DP IMR vessel under DP MODU with resupply OSV alongside for 8 hrs, both under DP	~4 months (based on indicative subsea installation duration)
39 (combined scenarios 18 and 33)	MODU with resupply OSV alongside for 8 hrs, both under DP Pipelay vessel with 2 OSVs, all under DP	~6 months (based on indicative pipelay duration)
40 (combined scenarios 30 and 33)	MODU with resupply OSV alongside for 8 hrs, both under DP Pipelay vessel with 2 OSVs, all under DP	~6 months (based on indicative pipelay duration)
41A, 41B	MODU with 2 OSVs, and a resupply OSV alongside for 8 hrs, all under DP OCV with 2 OSVs and 1 tug, all under DP	~4 months (based on indicative subsea installation duration)

Model scenario	Indicative vessel fleet	Indicative duration for model scenario
42A, 42B	MODU with 2 OSVs, and a resupply OSV alongside for 8 hrs, all under DP Pipelay vessel with 2 OSVs, all under DP OCV with 2 OSVs and 1 tug, all under DP	~4 months (based on indicative subsea installation duration)

8.5.3.1.1 source levels

The MODU and vessels used in the modelling are indicative of the general vessel types that may be used for the activities covered by the OPP. A vessel's sound depends on the vessel's size, power, propulsion system and the design characteristics of the given system (Ref. 297).

The indicative sound source level used to represent a drill ship under DP and associated drilling sound is the broadband (10 Hz to 31 kHz) source level of 188.0 dB re 1 μPa^2m^2s (Ref. 297). The source level adopted for the purposes of this risk evaluation is considered conservative (over estimation of expected source level) for a DP MODU; as this source value is based on conservatively measured levels in offshore deepwater Novia Scotia of the *Stena IceMAX* concurrently with four OSVs, all operating in DP mode (Ref. 298). The broadband source level for the drilling OSV has been modelled at 181.2 dB re 1 μPa^2m^2s (Ref. 297).

The indicative source levels (and associated considerations) used to represent vessels operating under DP during installation, commissioning and operation activities are the following broadband (10 Hz to 31 kHz) source levels of:

- pipelay vessel—188.0 dB re 1 μPa^2m^2 s (derived from measured values of the world's largest pipelay vessel the *Allseas Solitaire* and several pipelay support vessels during the Nord stream construction in the Swedish Baltic Sea (Ref. 302)
- construction vessel—194.0 dB re 1 μPa^2m^2 s (derived from measure values of the *Siem Saphire* on DP in the Otway basin; no context provided on the measurement window statistical variability, sea state, thruster utilization or concurrent vessel activity within the measured report (Ref. 303)
- pipelay resupply vessel (OSV)—182.7 dB re 1 μPa^2m^2 s
- support tug—184.4 dB re 1 μPa^2m^2 s
- OSVs—181.2 dB re 1 μPa^2m^2 s (Ref. 297)
- IMR vessel—181.0 dB re 1 μPa^2m^2s (Ref. 297).

Similar to the DP MODU, the source levels assigned to the individual pipelay vessel are based on measured values that also included 3–4 offshore support vessels on DP during the measurement window and typically in locations attributable to significant sea states (Novia Scotia and Swedish Baltic Sea), therefore the modelled scenarios generated for the purposes of this risk evaluation are considered an overestimation of the actual sound generated in many of these scenarios.

8.5.3.2 effect criteria

Different species groups perceive and respond to sound differently, and so different effect criteria have been established. The modelling studies used the following effect criteria which was based on the best available science at the time of the modelling:

- sound exposure guidelines for fish, fish eggs and fish larvae, and marine turtles, from Popper et al. (Ref. 305)[147]
- frequency-weighted accumulated SEL_{24h} from Finneran et al. (Ref. 314) for the onset of PTS and TTS in marine turtles
- frequency-weighted accumulated SEL_{24h} from the United States National Marine Fisheries Service (NMFS) (Ref. 307) and Southall et al. (Ref. 306) for the onset of PTS and TTS in marine mammals
- un-weighted SPL for behavioural effects in marine mammals based on the current interim United States National Oceanic and Atmospheric Administration (NOAA) criterion (Ref. 308).

These effect criteria are shown in Table 8-33.

Note: For the purpose of interpreting and applying Action Area A.2 of the Conservation Management Plan for the Blue Whale (Ref. 20), published guidance from the Australian Government has defined 'injury to blue whales' as "both permanent and temporary hearing impairment [PTS and TTS] and any other form of physical harm arising from anthropogenic sources of underwater noise" (Ref. 353).

8.5.3.2.1 revised effect criteria

marine mammals (TTS and AUD INJ)

Since the acoustic modelling studies for this OPP were completed, the United States NMFS released updated technical guidance for assessing the effects of anthropogenic sound on marine mammals (Ref. 350). The changes to the previous 2018 guidance include:

- revised generalised hearing ranges for marine mammal functional hearing groups
- revised auditory weighting functions
- inclusion of the term 'auditory injury' (AUD INJ), which includes, but is not limited to, PTS
- revised effect criteria for the onset of TTS and AUD INJ.

A comparison between hearing ranges and effect criteria used in the OPP modelling studies versus the revised guidance is shown in Table 8-34. The revised generalised hearing ranges do not change the hearing group categorisation of any cetaceans (i.e. low frequency, high frequency, very high frequency) that may potentially be present within the DA or broader Hydrocarbon EMBAs (Section 6.3.3.1). The greatest change in auditory weighting functions was for high frequency cetaceans with the revised function showing increased sensitivity to lower frequency (<10 kHz) sounds for this functional hearing group. For low frequency cetaceans the effect criteria decreased by 2 dB, while for high

[147] Only quantitative effect criteria were modelled; qualitative effect criteria were applied directly in the impact and risk assessment.

and very high frequency cetaceans they increased by 3 dB and 8 dB respectively. It is the combined effect of both the revised auditory weighting functions and revised effect criteria, together with the sound characteristics of the source (e.g. the vessels) that will determine the magnitude and direction of any change in predicted ensonified range due to the updated NMFS 2024 technical guidance.

On behalf of CAPL, the Centre for Marine Science and Technology (CMST) undertook an assessment to estimate how previously modelled ensonified ranges under the NMFS 2018 guidance may change under the updated NMFS 2024 guidance (Ref. 688). CMST undertook this assessment by:

- digitised the source spectra for the seven MODU/vessel types used in the JASCO (Ref. 297) numerical modelling
- applied the 2018 and 2024 NMFS auditory weighting functions to these source spectra to estimate source levels relevant to the three functional hearing groups (low, high, and very high frequency cetaceans)
- applied a spherical spreading approach to the weighted sound source levels to estimate the distance to reach both the 2018 and 2024 NMFS effect criteria
- determined a ratio of change between the distances to reach the two effect criteria.

CMST consider the use of spherical spreading to provide a reasonable approximation as the horizontal distances to effect criteria predicted in the JASCO numerical modelling were relatively short (i.e. less than the water depth) (Ref. 688). It is acknowledged that results from spherical spreading will not exactly match the numerical modelling undertaken by JASCO (e.g. there are environmental characteristics and sound pattern constructive/destructive interferences that are incorporated into acoustic propagation models that are not accounted for in the simpler spherical spreading). However, spherical spreading is considered to provide reasonable results over short ranges, and therefore the CMST assessment provides an indication of the order of magnitude and direction of change in ensonified ranges from the updated effect criteria.

The ratios of change for the different vessel types determined by the CMST assessment are shown in Table 8-35.

These ratios have been used as ‘scaling factors’ to provide an indication of the potential magnitude and direction of change the updated criteria would have to the existing predicted maximum horizontal distances (R_{max}) from the JASCO numerical modelling:

- for single vessel scenarios the estimated ratio for that source and functional hearing group was applied
- for multi-vessel scenarios the estimated ratio for the strongest (highest) source level was applied
  - this approach is considered appropriate where the other sources are several dB quieter as they do not significantly contribute to the cumulative sound field (Ref. 688)
  - this is the case for JASCO modelling ‘individual activity’ scenarios described in Table 8-31 and Table 8-32 as the main vessel (e.g. drillship, pipelay or OCV has higher source levels (~5–10 dB) compared to the support vessels)

- for ‘concurrent activity’ scenarios (as described in Table 8-31, Table 8-32, and Table 8-46)
  - where the concurrent activities are separated (e.g. in different fields, or within a single field but without overlapping ensonified areas) the factors are applied as above
  - where the concurrent activities are occurring in close proximity to each other such that the ensonified areas would overlap
    - the estimated ratio for the strongest (highest) source level was applied where the other sources are several dB quieter (e.g. subsea installation and drilling or subsea installation and pipelay, as the source level for the OCV is ~6 dB higher than the drillship or pipelay vessel).

The adopted factors are also shown in Table 8-35, and the resulting indicative ranges are shown in Table 8-40, Table 8-41, and Table 8-42 for low, high, and very high frequency cetaceans respectively, and in Table 8-43 for animat modelling. Given the existing (i.e. under previous guidelines) predicted maximum horizontal distances to TTS and PTS are typically relatively short, the indicative magnitude of change resulting from the updated guidelines to TTS and AUD-INJ do not introduce a substantial change to these distances, or subsequently to the outcomes of the risk assessment or proposed environmental management (control measures, EPOs) as presented in this OPP.

No revised numerical modelling is intended to be undertaken for this OPP; however, an EPO (**EPO-22**; Table 8-57) has been included to ensure that any new acoustic modelling undertaken for subsequent EPs incorporate contemporary effect criteria available at the time of the modelling.

marine turtles (TTS and AUD INJ)

Since the acoustic modelling studies for this OPP were completed, the United States Navy released updated effect criteria for assessing the effects of sound on marine turtles (Ref. 703). Changes between the previous 2017 (Phase 3; Finneran et al. [Ref. 314]) and the revised 2025 (Phase 4; Accomando et al. [Ref. 703]) guidance include:

- revised audiogram and exposure function
- inclusion of the term AUD INJ (which includes, but is not limited to, PTS)
- revised effect criteria for the onset of TTS and AUD INJ.

No studies have measured TTS in marine (sea) turtles. The previous Phase 3 TTS onset effect criteria for non-impulsive sound for marine turtles was based on data from fish; whereas the revised Phase 4 effect criteria is extrapolated from TTS data on freshwater turtles. Both the previous and revised effect criteria apply a 20 dB difference between TTS and AUD INJ (previously PTS) for non-impulsive sounds (Ref. 703; Ref. 314). A comparison between effect criteria used in the OPP numerical modelling studies versus the updated guidance is shown in Table 8-36.

CMST undertook an assessment to estimate how previously modelled ensonified ranges under the Phase 3 guidance may change under the updated Phase 4 guidance. This assessment was undertaken following the same method as described above for the marine mammal effect criteria.

The ratios of change for the different vessel types determined by the CMST assessment are shown in Table 8-37. These ratios have been used as ‘scaling

factors' to provide an indication of the potential magnitude and direction of change the updated criteria would have to the existing predicted maximum horizontal distances from the JASCO numerical modelling. The adopted factors are also shown in Table 8-37, and the resulting indicative ranges are shown in Table 8-39.

Table 8-33: Effect criteria for non-impulsive sound for different types of impacts and species groups

Receptor	Mortality[148] and potential mortal injury	Recoverable injury[149]	PTS onset	TTS onset	Masking[150]	Behaviour[151]
Low frequency cetaceans	N/A	N/A	SEL_{24h}: 199 dB re 1 μPa^2s	SEL_{24h}: 179 dB re 1 μPa^2s	N/A	SPL: 120 dB re 1 µPa
High frequency cetaceans	N/A	N/A	SEL_{24h}: 198 dB re 1 μPa^2s	SEL_{24h}: 178 dB re 1 μPa^2s	N/A	
Very high frequency cetaceans	N/A	N/A	SEL_{24h}: 173 dB re 1 μPa^2s	SEL_{24h}: 153 dB re 1 μPa^2s	N/A	
Marine turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	SEL_{24h}: 220 dB re 1 μPa^2s	SEL_{24h}: 200 dB re 1 μPa^2s	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish (no swim bladder)[152]	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	N/A	(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)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	N/A	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish (swim bladder involved in hearing)	(N) Low (I) Low (F) Low	170 dB re 1 µPa SPL for 48 hours	N/A	158 dB re 1 µPa SPL for 12 hours	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low

[148] Mortality and mortal injury refers to immediate or delayed death (Ref. 311).

[149] Recoverable injury includes injuries unlikely to result in mortality, such as hair cell damage and minor haematoma (Ref. 303; Ref. 311).

[150] Masking refers to impairment of hearing sensitivity in the presence of noise (Ref. 311).

[151] For fish and turtles: behavioural effects refer to a substantial change (i.e. does not include small changes such as startle responses) in behaviour (Ref. 311). For cetaceans: behavioural effects can range in severity from no observable response to more substantial changes (Ref. 315).

[152] Also appropriate for sharks (Ref. 303).

Receptor	Mortality[148] and potential mortal injury	Recoverable injury[149]	PTS onset	TTS onset	Masking[150]	Behaviour[151]
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	N/A	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low

Relative risk (high, moderate, low) is given for fauna at three distances from the source (near [N], intermediate [I] and far [F]). Where 'near' is considered to be in the order of tens of meters from the source, 'intermediate' is hundreds of meters, and 'far' in the thousands of meters (Ref. 305).

Table 8-34: Comparison between NMFS guidance for TTS, PTS and AUD INJ onset effect criteria for cetacean hearing groups

Functional hearing group	NMFS 2018 Technical Guidance			NMFS 2024 Technical Guidance		
	Generalised hearing range	TTS onset	PTS onset	Generalised hearing range	TTS onset	AUD INJ onset
Low frequency cetaceans	7 Hz to 35 kHz	SEL_{24h}: 179 dB re 1 μPa^2s	SEL_{24h}: 199 dB re 1 μPa^2s	7 Hz to 36 kHz	SEL_{24h}: 177 dB re 1 μPa^2s	SEL_{24h}: 197 dB re 1 μPa^2s
High frequency cetaceans	150 Hz to 160 kHz	SEL_{24h}: 178 dB re 1 μPa^2s	SEL_{24h}: 198 dB re 1 μPa^2s	150 Hz to 160 kHz	SEL_{24h}: 181 dB re 1 μPa^2s	SEL_{24h}: 201 dB re 1 μPa^2s
Very high frequency cetaceans	275 Hz to 160 kHz	SEL_{24h}: 153 dB re 1 μPa^2s	SEL_{24h}: 173 dB re 1 μPa^2s	200 Hz to 165 kHz	SEL_{24h}: 161 dB re 1 μPa^2s	SEL_{24h}: 181 dB re 1 μPa^2s

Table 8-35: Estimated ratio of change between estimated distances to reach NMFS 2018 and NMFS 2024 effect criteria based on a spherical spreading approach

Activity	Vessel type	Ratio of estimated ranges to effect criteria (2018:2024)	'Scaling factor' adopted to provide indicative magnitude and direction of change for numerical modelling scenarios
Low frequency cetaceans			
Drilling	Drillship	1.33	1.33
	OSV	1.30	
Pipelay	Pipelay vessel	1.33	1.33
	Pipelay resupply vessel	1.30	
	OSV	1.30	

Activity	Vessel type	Ratio of estimated ranges to effect criteria (2018:2024)	'Scaling factor' adopted to provide indicative magnitude and direction of change for numerical modelling scenarios
Subsea installation	OCV	1.30	1.30
	Support tug	1.37	
	OSV	1.30	
IMR	IMR vessel	1.36	1.36
High frequency cetaceans			
Drilling	Drillship	1.24	1.24
	OSV	2.43	
Pipelay	Pipelay vessel	2.93	2.93
	Pipelay resupply vessel	2.40	
	OSV	2.43	
Subsea installation	OCV	2.42	2.42
	Support tug	5.58	
	OSV	2.43	
IMR	IMR vessel	2.31	2.31
Very high frequency cetaceans			
Drilling	Drillship	0.55	0.55
	OSV	0.57	
Pipelay	Pipelay vessel	0.65	0.65
	Pipelay resupply vessel	0.57	
	OSV	0.57	
Subsea installation	OCV	0.57	0.57
	Support tug	0.71	
	OSV	0.57	
IMR	IMR vessel	0.59	0.59

Table 8-36: Comparison between United States Navy Phase 3 and Phase 4 TTS, PTS, and AUD INJ effect criteria for marine turtles

Functional hearing group	United States Navy Phase 3 (2017)		United States Navy Phase 4 (2025)	
	TTS onset	PTS onset	TTS onset	AUD INJ onset
Marine turtles	SEL_{24h}: 200 dB re 1 μPa^2s	SEL_{24h}: 220 dB re 1 μPa^2s	SEL_{24h}: 178 dB re 1 μPa^2s	SEL_{24h}: 198 dB re 1 μPa^2s

Table 8-37: Estimated ratio of change between estimated distances to reach United States Navy Phase 3 (2017) and Phase 4 (2025) effect criteria for marine turtle based on a spherical spreading approach

Activity	Vessel type	Ratio of estimated ranges to effect criteria (2017:2025)	'Scaling factor' adopted to provide indicative magnitude and direction of change for numerical modelling scenarios
Drilling	Drillship	8	8
	OSV	10	
Pipelay	Pipelay vessel	8	8
	Pipelay resupply vessel	10	
	OSV	10	
Subsea installation	OCV	10	10
	Support tug	7	
	OSV	10	
IMR	IMR vessel	7	7

8.5.3.3 modelling results

For all data presented in this section the source levels used to determine maximum over depth horizontal distances are based on indicative source levels associated with the specific activity and/or vessel type (Section 8.5.3.1.1).

Where several modelled scenarios are representative of a single activity type (e.g. drilling), such as where type and number of vessels has been varied in the scenarios, the furthest distance from the source that fauna may be exposed to sound levels above the effect criteria has been selected for evaluation of potential risks.

Maximum distances relevant to the sound source can be presented in two formats:

- R_{max}, where this is the maximum range to the given effect criteria sound level
- $R_{95\%}$, where this is the range to given effect criteria sound level after the 5% of farthest points were excluded.

In cases where a sound level contour is irregular in shape (e.g. small protrusions or anomalous fringes) or there is separated contours (e.g. isolated smaller ensonified area/s separate to the main area) the R_{max} parameter may be misrepresentative of the maximum distance. However, the R_{max} distance parameter has been used as a conservative approach to inform the impact and risk assessment in this OPP.

8.5.3.3.1 fishes

Table 8-38 summarises the maximum horizontal distances (R_{max}) to non-impulsive sound effect criteria for fishes with swim bladders involved in hearing for the different activity types in different areas (fields) of the DA. All maximum distances to TTS onset effect criteria were ≤90 m for all activity types and fields. Maximum distances to recoverable injury effect criteria for pipelay and subsea installation were ≤50 m; with this criterion not reached for drilling or IMR activities. No substantial variation in maximum distances for either effect criteria was observed across fields.

The largest of the maximum distances from all activities and areas to non-impulsive effect criteria for fishes with swim bladder involved in hearing has been applied as a buffer around the entire DA and shown in Figure 8-24. This spatial extent provides an indicative worst-case EMBA to inform impact and risk assessments (i.e. it assumes a vessel could operate anywhere in the DA) for fishes with swim bladder involved in hearing. It is not indicative of the realistic extent of ensonified areas around vessel activities, which would be the distances as presented in Table 8-38.

Table 8-38: Maximum horizontal distance (R_{max}) to non-impulsive sound effect criteria for fishes (with swim bladder involved in hearing)

Area and activity	R_{max} (km) to recoverable injury	R_{max} (km) to TTS onset
Effect criteria	*170 dB re 1 µPa SPL for 48 hours*	*158 dB re 1 µPa SPL for 12 hours*
Area 1 (Chandon)		
Drilling	–	0.08
Pipelay	0.05	0.06
Subsea installation	0.04	0.09

Area and activity	R_{max} (km) to recoverable injury	R_{max} (km) to TTS onset
IMR	–	–
Area 2 (G&E; Semele)		
Drilling	–	0.07
Pipelay	0.03	0.07
Subsea installation	0.04	0.09
IMR	–	0.02
Area 3 (C&D)		
Drilling	–	0.08
Pipelay	0.04	0.06
Subsea installation	0.04	0.09
IMR	–	–
Area 4 (C&D)		
Pipelay	0.05	0.09
IMR	–	0.02
Area 5 (WTR)		
Drilling	–	0.07
Pipelay	0.05	0.06
Subsea installation	0.03	0.09
IMR	–	–

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m).

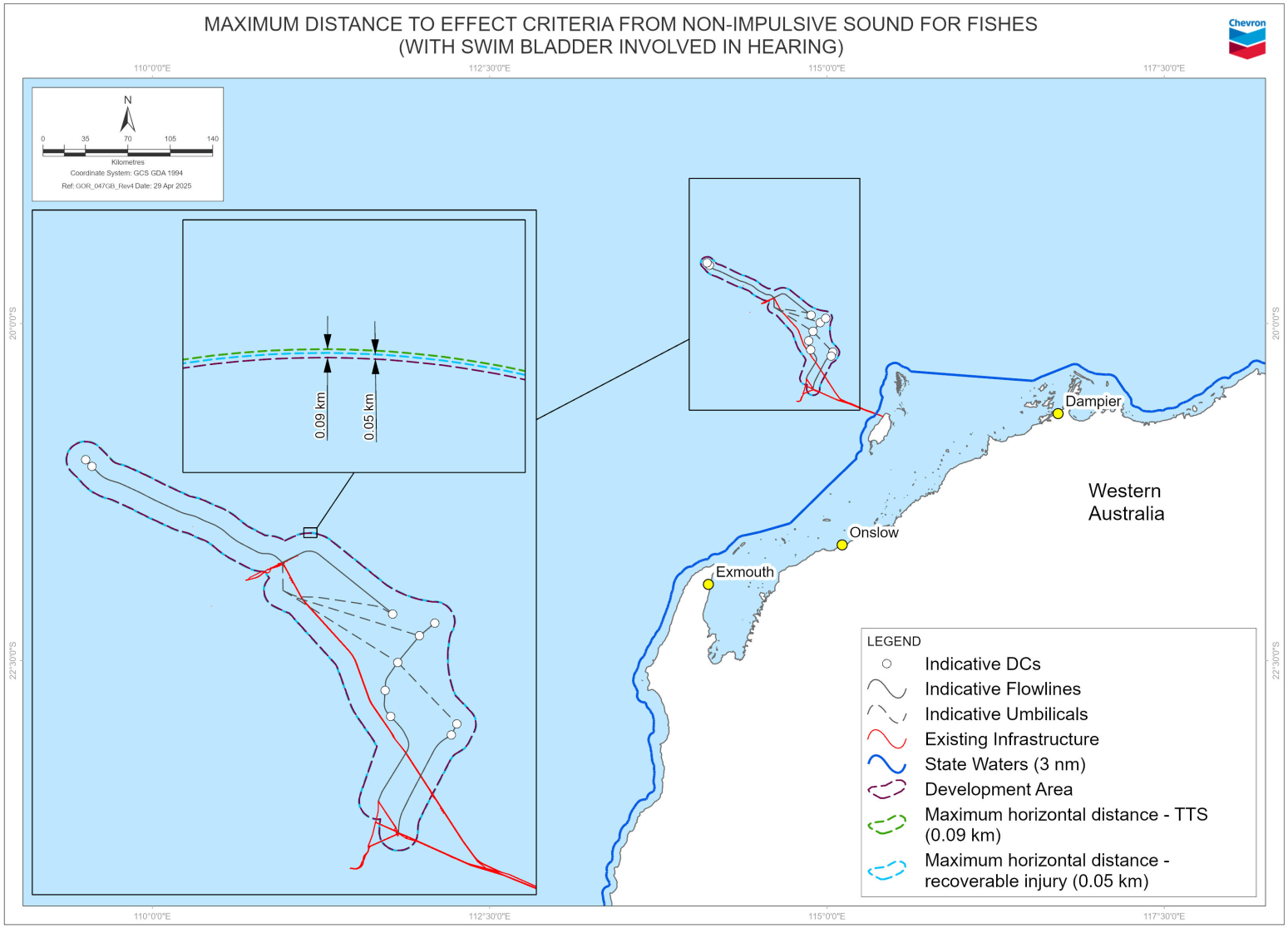


Figure 8-24: Maximum distance to effect criteria from non-impulsive sound for fishes (with swim bladder involved in hearing)

8.5.3.3.2 marine reptiles

Table 8-39 summarises the maximum horizontal distances (R_{max}) to marine turtle effect criteria from non-impulsive sound sources for the different activity types in different areas (fields) of the DA.

Predicted maximum distances to Phase 3 (2017) PTS and TTS onset effect criteria were ≤140 m and ≤180 m respectively for all activity types and fields. No substantial variation in maximum distances for either effect criteria was observed across fields. Indicative ranges to Phase 4 (2025) AUD-INJ onset effect criteria were generally ≤400 m, with one scenario at ~1.4 km; and for TTS onset effect criteria the indicative ranges are ≤1.8 km. The highest indicative ranges were associated with subsea installation activities (Table 8-39).

The largest of the maximum distances from all activities and areas to non-impulsive effect criteria for marine turtles has been applied as a buffer around the entire DA and shown in Figure 8-25 and Figure 8-26. This spatial extent provides an indicative worst-case EMBA to inform impact and risk assessments (i.e. it assumes a vessel could operate anywhere in the DA). It is not indicative of the realistic extent of ensonified areas around vessel activities, which would be the distances as presented in Table 8-39.

Table 8-39: Maximum horizontal distance(R_{max}) to non-impulsive effect criteria for marine turtles

Area and activity	R_{max} (km) to TTS onset	Indicative range[153] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[153] (km) to AUD INJ onset
Effect criteria	*SEL_{24h}: 200 dB re 1 µPa²s*	*SEL_{24h}: 178 dB re 1 µPa²s*	*SEL_{24h}: 220 dB re 1 µPa²s*	*SEL_{24h}: 198 dB re 1 µPa²s*
Area 1 (Chandon)				
Drilling	0.12	0.96	0.02	0.16
Pipelay	0.11	0.88	0.05	0.40
Subsea installation	0.18	1.80	0.04	0.40
IMR	0.05	0.35	–	0.07[154]
Area 2 (G&E; Semele)				
Drilling	0.11	0.88	–	0.08[154]
Pipelay	0.12	0.96	0.05	0.40
Subsea installation	0.17	1.70	0.04	0.40
IMR	0.05	0.35	–	0.07[154]
Area 3 (C&D)				
Drilling	0.12	0.96	0.02	0.16
Pipelay	0.12	0.96	0.04	0.32
Subsea installation	0.18	1.80	0.14	1.40
IMR	0.05	0.35	0.02	0.14

[153] Indicative ranges to United States Navy Phase 4 (2025) effect criteria are based on applying 'scaling factors' from spherical spreading comparisons (see Section 8.5.3.2.1). These ranges are unlikely to represent an exact distance based on numerical modelling, but provide an indication of the magnitude of change from the R_{max} values from numerical modelling under the previous United States Navy Phase 3 (2017) effect criteria to an estimated range under the Phase 4 effect criteria. These indicative ranges are considered appropriate to inform the risk assessment within this OPP.

[154] Note: For the scenarios where no R_{max} value under the Phase 3 effect criteria was not defined (i.e. when the effect criteria was not reached within the limits of the modelling resolution [20 m]), it was conservatively assumed that this distance was 10 m (i.e. half the model resolution) to allow the appropriate scaling factor to be applied to provide an indicative range under the Phase 4 effect criteria.

Area and activity	R_{max} (km) to TTS onset	Indicative range[153] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[153] (km) to AUD INJ onset
Area 4 (C&D)				
Pipelay	0.05	0.40	0.02	0.16
IMR	0.12	0.84	0.05	0.35
Area 5 (WTR)				
Drilling	0.12	0.96	0.02	0.16
Pipelay	0.12	0.96	0.05	0.40
Subsea installation	0.17	1.70	0.03	0.30
IMR	0.05	0.35	0.02	0.14

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m).

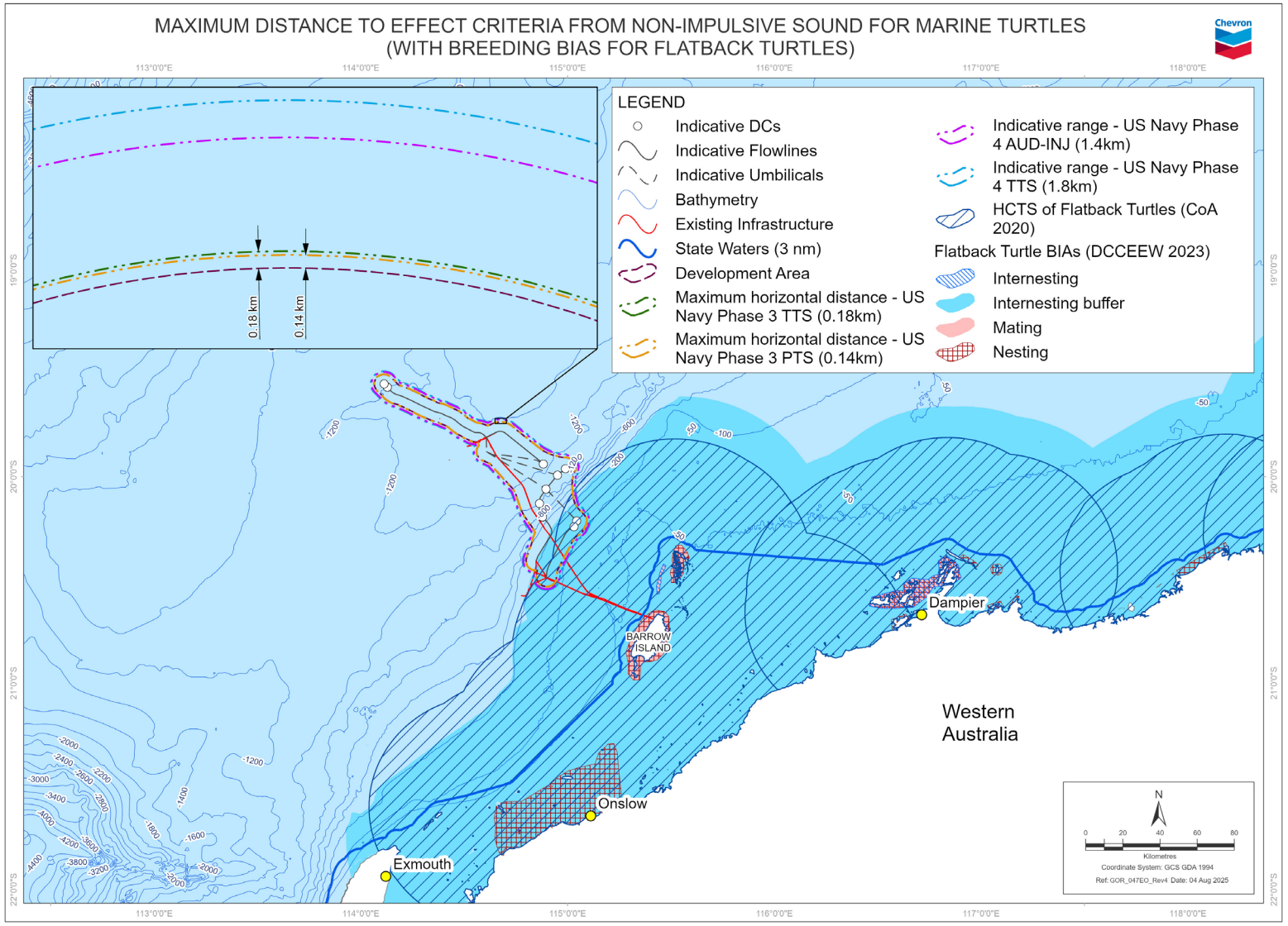


Figure 8-25: Maximum distance to effect criteria from non-impulsive sound for marine turtles (with breeding BIAs for flatback turtles)

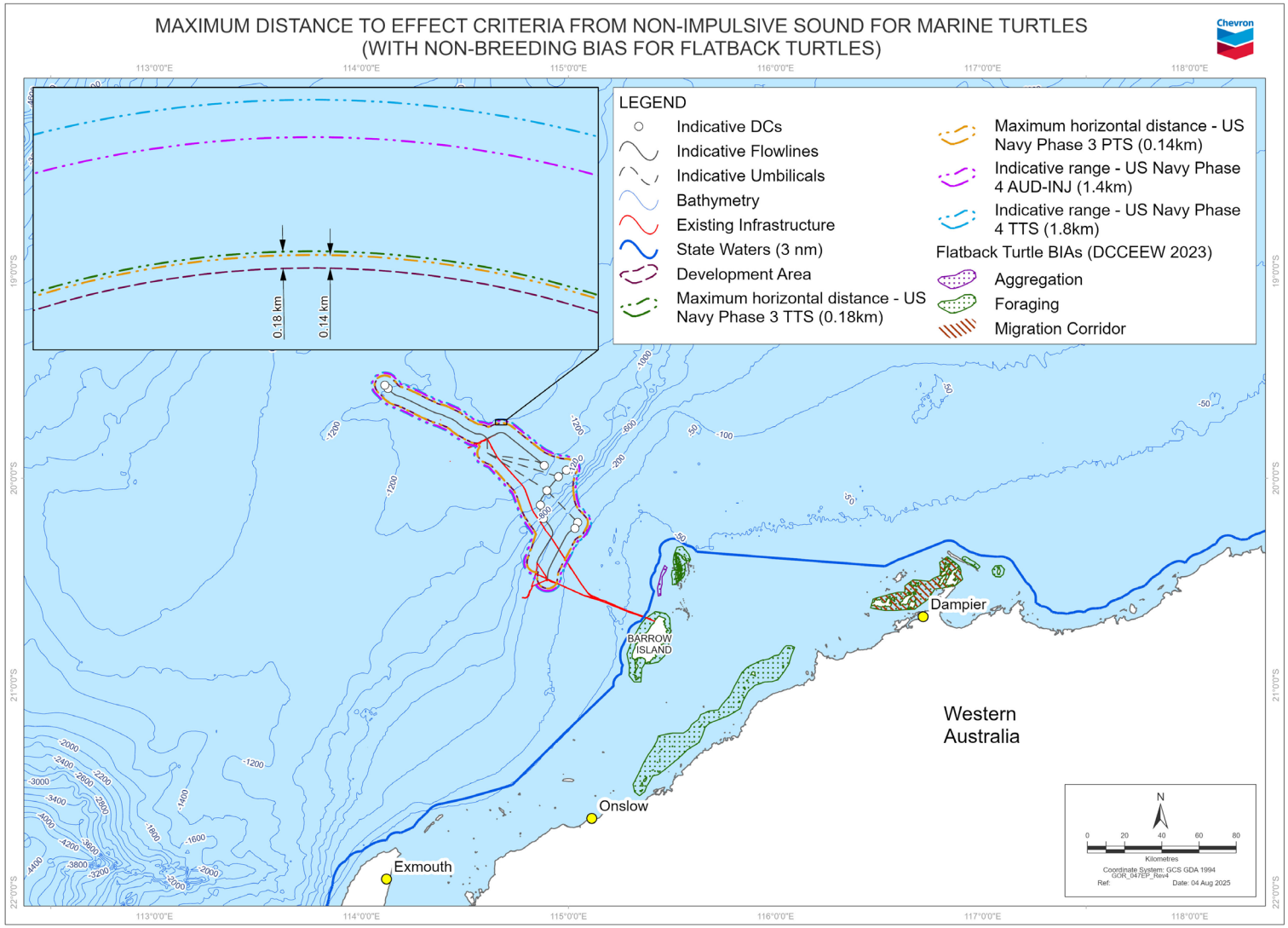


Figure 8-26: Maximum distance to effect criteria from non-impulsive sound for marine turtles (with non-breeding BIAs for flatback turtles)

8.5.3.3.3 marine mammals

Table 8-40, Table 8-41 and Table 8-42 summarise the maximum horizontal distances (R_{max}) to cetacean effect criteria from non-impulsive sound sources for the different activity types in different areas (fields) of the DA.

Maximum distances to behavioural effect criteria for all cetacean hearing groups were 1.74–18.3 km; the smaller ensonified areas are associated with the single IMR vessel scenario, while the largest ensonified areas are associated with construction vessels (either pipelay or subsea installation). Some variation in predicted ensonified areas was also evident across fields, likely reflective of the different water depths and seafloor geomorphology (e.g. continental shelf or slope).

For comparative purposes the R_{max} and $R_{95\%}$ ranges have also been presented in the tables for the behavioural effect criteria. For most scenarios substantial differences in the measurements were not observed; however, for some modelled scenarios (e.g. Area 3 and Area 5) differences do occur. For example, the large difference between the R_{max} and $R_{95\%}$ for drilling and pipelay in Area 3 is due to the model predicting small isolated contours above the effect criteria away from the main ensonified area (see Figures 36, 38 and 39 in appendix d). As described in Section 8.5.3.3, the use of R_{max} in these situations may be misrepresentative and over conservative.

Predicted maximum distances to NMFS 2018 PTS onset effect criteria were ≤210 m, ≤160 m, and ≤210 m for low, high, and very high frequency cetacean hearing groups respectively for activity types and fields. Indicative ranges to NMFS 2024 AUD-INJ onset effect criteria were ≤270 m, ≤390 m, and ≤120 m for low, high, and very high frequency cetacean hearing groups respectively.

Maximum distances to NMFS 2018 TTS onset effect criteria were 0.36–4.58 km, 0.02–0.19 km, and 0.27–3.33 km for low frequency, high frequency, and very high frequency cetacean hearing groups respectively. Indicative ranges to NMFS 2024 TTS onset effect criteria were 0.49–5.95 km, 0.05–0.46 km, and 0.16–1.83 km for low, high, and very high frequency cetacean hearing groups respectively. Variations in maximum distances are evident between activity types and areas. For example, for low frequency cetaceans, the smaller ensonified areas are associated with the single IMR vessel scenario, while the largest ensonified areas are associated with subsea installation. There are also differences between areas (fields), with the larger ensonified areas predicted for Area 5 (WTR) which is located on the continental shelf in comparison to the offshore deeper areas. For the very high frequency cetaceans, the smaller ensonified areas are again associated with the single IMR vessel scenario, but the largest ensonified areas are associated with drilling, and no substantial variation was predicted across fields.

The largest of the maximum distances from all activities and areas to non-impulsive effect criteria for cetaceans has been applied as a buffer around the entire DA and shown in Figure 8-27. This spatial extent provides an indicative worst-case EMBA to inform impact and risk assessments (i.e. it assumes a vessel could operate anywhere in the DA) for all marine mammals behavioural effects, and for low frequency cetaceans for TTS and PTS. It is not indicative of the realistic extent of ensonified areas around vessel activities, which would be the distances as presented in the below tables.

In addition, the maximum distance to behavioural effect criteria for cetaceans from non-impulsive sound in relation to AMPs (specifically the Montebello Marine Park) is shown in Figure 8-28.

Table 8-40: Maximum horizontal distance (R_{max}) to non-impulsive effect criteria for low frequency cetaceans

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Effect criteria	*SEL_{24h}: 179 dB re 1 µPa²s*	*SEL_{24h}: 177 dB re 1 µPa²s*	*SEL_{24h}: 199 dB re 1 µPa²s*	*SEL_{24h}: 197 dB re 1 µPa²s*	*SPL: 120 dB re 1 µPa*
Area 1 (Chandon)					
Drilling	0.83	1.10	0.10	0.13	5.87 (5.61)
Pipelay	1.07	1.42	0.12	0.16	6.72 (6.39)
Subsea installation	1.82	2.37	0.21	0.27	15.7 (13.9)
IMR	0.36	0.49	0.04	0.05	1.99 (1.91)
Area 2 (G&E; Semele)					
Drilling	0.84	1.12	0.11	0.15	5.85 (5.56)
Pipelay	1.08	1.44	0.12	0.16	6.88 (6.46)
Subsea installation	1.81	2.35	0.21	0.27	15.4 (11.5)
IMR	0.36	0.49	0.04	0.05	1.74 (1.68)
Area 3 (C&D)					
Drilling	0.84	1.12	0.11	0.15	12.1 (5.23)
Pipelay	1.08	1.44	0.12	0.16	13.0 (6.12)
Subsea installation	2.10	2.73	0.21	0.27	14.0 (12.9)
IMR	0.36	0.49	0.04	0.05	2.64 (2.46)
Area 4 (C&D)					
Pipelay	1.47	1.96	0.12	0.16	18.3 (16.6)
IMR	0.37	0.50	0.04	0.05	2.24 (2.04)

[155] Indicative ranges to NMFS (2024) effect criteria are based on applying 'scaling factors' from spherical spreading comparisons (see Section 8.5.3.2.1). These ranges are unlikely to represent an exact distance based on numerical modelling, but provide an indication of the magnitude of change from the R_{max} values from numerical modelling under the previous NMFS 2018 effect criteria to an estimated range under the NMFS 2024 effect criteria. These indicative ranges are considered appropriate to inform the risk assessment within this OPP.

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Area 5 (WTR)					
Drilling	1.66	2.21	0.11	0.15	10.4 (9.10)
Pipelay	2.18	2.90	0.12	0.16	12.9 (10.9)
Subsea installation	4.58	5.95	0.21	0.27	17.3 (14.5)
IMR	0.63	0.86	0.04	0.05	3.76 (3.43)

Table 8-41: Maximum horizontal distance (R_{max}) to non-impulsive effect criteria for high frequency cetaceans

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Effect criteria	*SEL_{24h}: 178 dB re 1 μPa^2s*	*SEL_{24h}: 181 dB re 1 μPa^2s*	*SEL_{24h}: 198 dB re 1 μPa^2s*	*SEL_{24h}: 201 dB re 1 μPa^2s*	*SPL: 120 dB re 1 µPa*
Area 1 (Chandon)					
Drilling	0.16	0.20	0.04	0.05	5.87 (5.61)
Pipelay	0.09	0.26	0.04	0.12	6.72 (6.39)
Subsea installation	0.19	0.46	0.15	0.36	15.7 (13.9)
IMR	0.02	0.05	–	0.02[156]	1.99 (1.91)
Area 2 (G&E; Semele)					
Drilling	0.17	0.21	0.05	0.06	5.85 (5.56)
Pipelay	0.09	0.26	–	0.03[156]	6.88 (6.46)
Subsea installation	0.19	0.46	0.04	0.10	15.4 (11.5)
IMR	–	0.02[156]	–	0.02[156]	1.74 (1.68)

[156] Note: For the scenarios where R_{max} value under the NMFS 2018 effect criteria was not defined (i.e. when the effect criteria was not reached within the limits of the modelling resolution [20 m]), it was conservatively assumed that this distance was 10 m (i.e. half the model resolution) to allow the appropriate scaling factor to be applied to provide an indicative range under the NMFS 2024 effect criteria.

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Area 3 (C&D)					
Drilling	0.16	0.20	0.04	0.05	12.1 (5.23)
Pipelay	0.09	0.26	–	0.03[156]	13.0 (6.12)
Subsea installation	0.18	0.44	0.16	0.39	14.0 (12.9)
IMR	0.02	0.05	–	0.02[156]	2.64 (2.46)
Area 4 (C&D)					
Pipelay	0.09	0.26	0.04	0.12	18.3 (16.6)
IMR	0.02	0.05	–	0.02[156]	2.24 (2.04)
Area 5 (WTR)					
Drilling	0.16	0.20	0.05	0.06	10.4 (9.10)
Pipelay	0.09	0.26	0.05	0.15	12.9 (10.9)
Subsea installation	0.19	0.46	–	0.02[156]	17.3 (14.5)
IMR	0.02	0.05	–	0.02[156]	3.76 (3.43)

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m).

Table 8-42: Maximum horizontal distance (R_{max}) to non-impulsive effect criteria for very high frequency cetaceans

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Effect criteria	*SEL_{24h}: 153 dB re 1 μPa^2s*	*SEL_{24h}: 161 dB re 1 μPa^2s*	*SEL_{24h}: 173 dB re 1 μPa^2s*	*SEL_{24h}: 181 dB re 1 μPa^2s*	*SPL: 120 dB re 1 µPa*
Area 1 (Chandon)					
Drilling	3.31	1.82	0.21	0.12	5.87 (5.61)
Pipelay	1.02	0.66	0.11	0.07	6.72 (6.39)
Subsea installation	2.61	1.49	0.21	0.12	15.7 (13.9)
IMR	0.27	0.16	0.03	0.02	1.99 (1.91)

Area and activity	R_{max} (km) to TTS onset	Indicative range[155] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[155] (km) to AUD INJ onset	R_{max} ($R_{95\%}$) (km) to behavioural effects
Area 2 (G&E; Semele)					
Drilling	3.31	1.82	0.21	0.12	5.85 (5.56)
Pipelay	1.02	0.66	0.11	0.07	6.88 (6.46)
Subsea installation	2.61	1.49	0.21	0.12	15.4 (11.5)
IMR	0.27	0.16	0.03	0.02	1.74 (1.68)
Area 3 (C&D)					
Drilling	3.31	1.82	0.21	0.12	12.1 (5.23)
Pipelay	1.02	0.66	0.10	0.07	13.0 (6.12)
Subsea installation	2.62	1.49	0.21	0.12	14.0 (12.9)
IMR	0.27	0.16	0.03	0.02	2.64 (2.46)
Area 4 (C&D)					
Pipelay	1.06	0.69	0.10	0.07	18.3 (16.6)
IMR	0.27	0.16	0.03	0.02	2.24 (2.04)
Area 5 (WTR)					
Drilling	3.33	1.83	0.21	0.12	10.4 (9.10)
Pipelay	1.12	0.73	0.12	0.08	12.9 (10.9)
Subsea installation	2.80	1.60	0.21	0.12	17.3 (14.5)
IMR	0.28	0.17	0.03	0.02	3.76 (3.43)

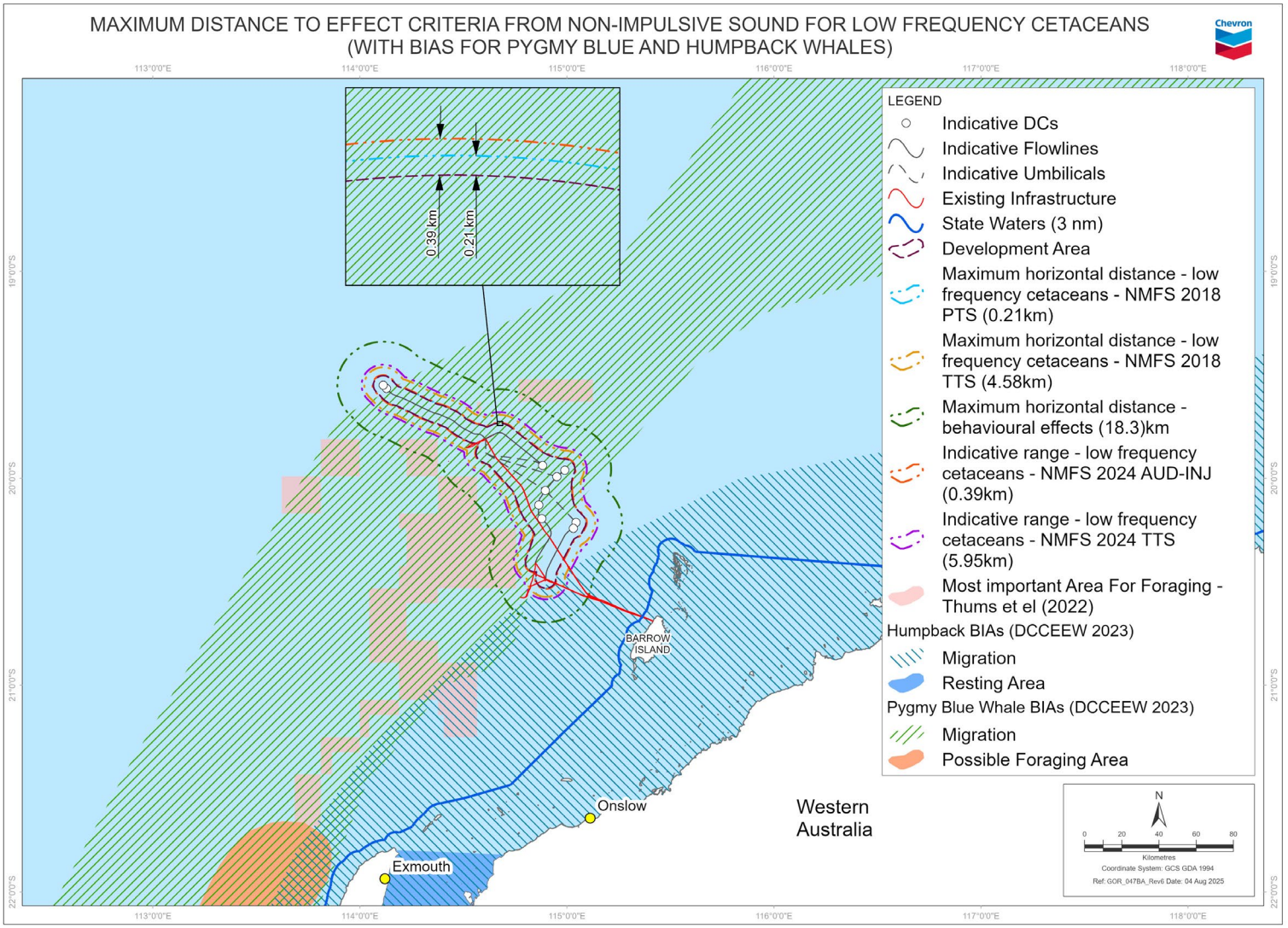


Figure 8-27: Maximum distance to effect criteria from non-impulsive sound for low frequency cetaceans (with BIAs for pygmy blue and humpback whales)

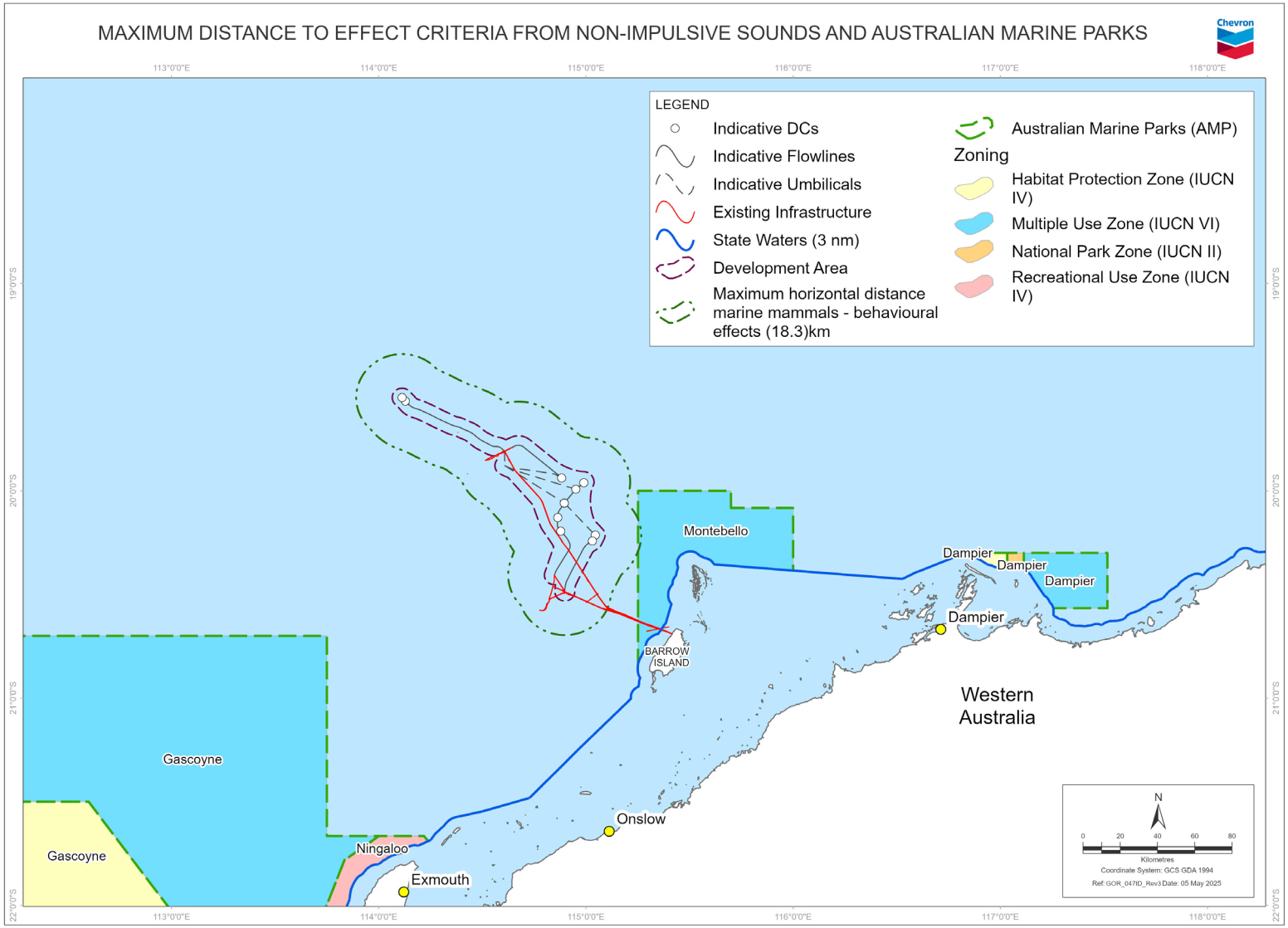


Figure 8-28: Maximum distance to behavioural effect criteria from non-impulsive sound for marine mammals (with AMPs)

8.5.3.3.4 animat modelling

In addition to the acoustic propagation modelling study, JASCO undertook an acoustic exposure analysis for migrating pygmy blue whales (Ref. 297), which describes the modelled predictions of sound levels that individual pygmy blue whales may receive during the Development activities.

Sound exposure distribution estimates are determined by moving large numbers of simulated animals ('animats') through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models (Ref. 297). This approach provides the most realistic prediction of the maximum expected SPL, and the temporal accumulation of sound exposure level (SEL_{24h}) for comparison against the relevant effect criteria (Ref. 297).

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to model the movement of pygmy blue whales through the predicted sound field. Biologically meaningful movement rules were applied to each animat in the model to represent whale behaviours. This included swim speeds, direction, diving and ascent rates, dive depths (for both migratory dives near the surface and deeper exploratory or feeding dives), and time spent at or near the surface before diving again. The animats, were set to simulate the real-world movements of migrating pygmy blue whales within their migratory BIA.

JASMINE predicts the accumulated exposure of the animats to sound in the modelled ensonified areas. It should be noted that JASMINE model does not implement potential avoidance behaviour, in which case the animat moving through the ensonified area would potentially dive to water depths or horizontal planes where it is quieter (i.e. outside of the ensonified area). Accordingly results of the animat modelling are still conservative by design as potential avoidance behaviour would result in less sound accumulation and exposure ranges that are significantly shorter than the acoustic ranges to effect criteria for pygmy blue whales. Furthermore, the scenarios and source levels applied within the modelling do not consider the fact non-impulsive acoustic sources such as DP thrusters are highly dynamic over time in response to changing metocean conditions; therefore, in most cases actual source levels will be significantly lower than the source levels adopted within the model for the purposes of this risk evaluation.

The modelled 95th percentile exposure ranges ($ER_{95\%}$) from the sound source for the individual activity scenarios to the relevant effect criteria for low frequency cetaceans are shown in Table 8-43. Within the $ER_{95\%,}$ there is generally some proportion of animats that do not exceed the threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which the animats are exposed to the sound field over time, both vertically and horizontally. The probability that an animat within the $ER_{95\%}$ was exposed above threshold was also computed and is shown in Table 8-43. Indicative ranges to NMFS 2024 TTS and AUD-INJ onset effect criteria for the animat modelling results are also shown in Table 8-43.

For comparison the R_{max} (or $R_{95\%}$) predicted from acoustic propagation modelling for the same scenarios is also shown in Table 8-43. As expected, the maximum distances from animat modelling are smaller than those predicted from the propagation modelling which does not take into account any movement of the animal. Under animat modelling, the maximum exposure ranges for TTS onset substantially reduced and were not reached for PTS onset (Table 8-43) such that the risk of accumulated exposure of an extended 24 hour period at these received sound level is not considered credible for low frequency cetaceans. The maximum

exposure range to reach the behavioural effect criteria for marine mammals also reduced (~21–77%) compared to acoustic modelling (Table 8-43).

Table 8-43: Animat modelling maximum exposure range ($ER_{95\%}$) to non-impulsive effect criteria for low frequency cetaceans

Modelling	Parameter	TTS onset	PTS onset	Behavioural effects
Effect criteria		*SEL_{24h}: 179 dB re 1 µPa²s*	*SEL_{24h}: 199 dB re 1 µPa²s*	*SPL: 120 dB re 1 µPa*
Scenario 8 (Area 1, Subsea installation)				
Acoustic modelling	R_{max} ($R_{95\%}$)[157]	1.82 km	0.21 km	15.7 km (13.9 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.04 km (67%)	–	12.4 km (99%)
Indicative animat range[158] (km)		0.05	0.01[159]	N/A
Scenario 14 (Area 2, IMR)				
Acoustic modelling	R_{max} ($R_{95\%}$)	0.36 km	0.04 km	1.74 km (1.68 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.02 km (87%)	–	0.73 km (88%)
Indicative animat range[158] (km)		0.03	0.01[159]	N/A
Scenario 17A (Area 3; Drilling)				
Acoustic modelling	R_{max} ($R_{95\%}$)	0.98 km	0.08 km	12.6 km (11.5 km)
Animat modelling (unrestricted)	$ER_{95\%}$	0.02 km (87%)	–	4.08 km (75%)
Indicative animat range[158] (km)		0.03	0.01[159]	N/A
Scenario 18 (Area 3; Drilling)				
Acoustic modelling	R_{max} ($R_{95\%}$)	0.84 km	0.11 km	12.1 km (5.23 km)
Animat modelling (unrestricted)	$ER_{95\%}$	0.02 km (76%)	–	2.76 km (77%)
Indicative animat range[158] (km)		0.03	0.01[159]	N/A
Scenario 18A (Area 3; Drilling)				
Acoustic modelling	R_{max} ($R_{95\%}$)	1.01 km	0.11 km	12.8 km (11.8 km)
Animat modelling (unrestricted)	$ER_{95\%}$	0.02 km (88%)	–	4.20 km (76%)

[157] Where $R_{95\%}$ distances were available for acoustic modelling, these have also been provided for comparative purposes.

[158] Indicative ranges to NMFS (2024) effect criteria are on based applying 'scaling factors' from spherical spreading comparisons (see Section 8.5.3.2.1). These ranges are unlikely to represent an exact distance based on numerical modelling, but provide an indication of the magnitude of change from the $ER_{95\%}$ values from numerical modelling under the previous NMFS 2018 effect criteria to an estimated range under the NMFS 2024 effect criteria. These indicative ranges are considered appropriate to inform the risk assessment within this OPP.

[159] Note: For the scenarios where no $ER_{95\%}$ value under the NMFS 2018 effect criteria was not defined (i.e. when the effect criteria was not reached within the limits of the modelling resolution [20 m]), it was conservatively assumed that this distance was 10 m (i.e. half the model resolution) to allow the appropriate scaling factor to be applied to provide an indicative range under the NMFS 2024 effect criteria.

Modelling	Parameter	TTS onset	PTS onset	Behavioural effects
Indicative animat range[158] (km)		0.03	0.03[159]	N/A
Scenario 21 (Area 3; Pipelay)				
Acoustic modelling	R_{max} ($R_{95\%}$)	1.08 km	0.12 km	13.0 km (6.12 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.02 km (91%)	–	5.03 km (73%)
Indicative animat range[158] (km)		0.03	0.03[159]	N/A
Scenario 30 (Area 5; Drilling)				
Acoustic modelling	R_{max} ($R_{95\%}$)	1.66 km	0.11 km	10.4 km (9.10 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.02 km (80%)	–	8.03 km (>99%)
Indicative animat range[158] (km)		0.03	0.03[159]	N/A
Scenario 33 (Area 5: Pipelay)				
Acoustic modelling	R_{max} ($R_{95\%}$)	2.18 km	0.12 km	12.9 km (10.9 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.02 km (77%)	–	9.56 km (>99%)
Indicative animat range[158] (km)		0.03	0.03[159]	N/A

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m)

8.5.3.3.5 concurrent activities

The model scenarios that involved concurrent activities across two or three areas (i.e. scenarios 37, 38, 39) resulted in multiple (separate) ensonified areas (see Figures 55, 56 and 57 in appendix d). For comparative purposes the percentage increase in total ensonified area above the behavioural effect criteria for marine mammals of the concurrent activity scenario compared to the sum of individual scenarios was 0.37–4.03% (Ref. 297). This percentage increase in total ensonified area is dependent on the distance between activities/areas and the type of activity.

The modelled scenario that involved concurrent activities within a single field (i.e. scenario 40) resulted in single merged ensonified area (see Figure 58 in appendix d). Using the same comparison as above, the difference between the sum of individual scenarios and the total ensonified area for the concurrent activities was 12.9% (Ref. 297). This percentage increase in total ensonified area is dependent on the distance between activities (in this case pipelay activities were ~16 km from drilling and subsea installation activities).

Scenarios 41A, 41B, 42A, and 42B were also based on concurrent activities within a single field. While not the same scenario, 42A and 42B also included pipelay operations, however the pipelay activity was ~6 km from the DCs, compared to ~16 km away in scenario 40. Consequently, the relative increase in distance (R_{max}) or area parameters are lower.

Animat modelling was also undertaken for scenarios 41A, 41B, 42A, and 42B (Ref. 686; Ref. 687). Similar to animat modelling for individual activity scenarios (described in Section 8.5.3.3.4) the maximum distances to TTS and PTS onset criteria for low frequency cetaceans are substantially reduced (Table 8-44) such

that the risk of accumulated exposure over an extended 24 hour period at these sound levels is not considered credible for low frequency cetaceans. The maximum exposure range to reach the behavioural effect criteria for marine mammals also reduced (~18–54%) compared to acoustic modelling (Table 8-44).

Table 8-44: Concurrent activities animat modelling maximum exposure range ($ER_{95\%}$) to non-impulsive effect criteria for low frequency cetaceans

Modelling	Parameter	TTS onset	PTS onset	Behavioural effects
Effect criteria		*SEL_{24h}: 179 dB re 1 µPa²s*	*SEL_{24h}: 199 dB re 1 µPa²s*	*SPL: 120 dB re 1 µPa*
Scenario 41A (Area 2, Drilling and subsea installation)				
Acoustic modelling	R_{max} ($R_{95\%}$)[160]	2.23 km	0.23 km	15.8 km (14.0 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.03 km (60%)	<0.01 (8%)	13.0 km (90%)
Indicative animat range[158] (km)		0.04	0.01[159]	N/A
Scenario 41B (Area 2, Drilling and subsea installation)				
Acoustic modelling	R_{max} ($R_{95\%}$)	3.24 km	0.24 km	14.6 km (13.5 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.04 km (70%)	–	11.7 km (82%)
Indicative animat range[158] (km)		0.05	0.01[159]	N/A
Scenario 42A (Area 2; Drilling, subsea installation, and pipelay)				
Acoustic modelling	R_{max} ($R_{95\%}$)	2.68 km	0.23 km	17.0 km (15.1 km)
Animat modelling (unrestricted)	$ER_{95\%}$	0.03 km (65%)	<0.01 (7%)	10.8 km (>99%)
Indicative animat range[158] (km)		0.04	0.01[159]	N/A
Scenario 42B (Area 3; Drilling, subsea installation, and pipelay)				
Acoustic modelling	R_{max} ($R_{95\%}$)	4.14 km	0.25 km	25.5 km (16.6 km)
Animat modelling (unrestricted)	$ER_{95\%}$ (P_{exp})	0.03 km (75%)	–	11.7 km (73%)
Indicative animat range[158] (km)		0.04	0.01[159]	N/A

8.5.3.4 concurrent activities (additional qualitative analysis)

For the purposes of the impact and risk assessment in this OPP, further qualitative analysis was undertaken to describe the potential variety of concurrent activities and associated ensonified areas for the Development.

The sequencing of different field developments is unknown and will be scheduled based on contemporary gas supply strategy for the Gorgon GTP at the time development decisions are made (Section 4.1.4).

Table 8-45 presents a series of indicative scenarios that have been used to investigate the potential risks associated with concurrent activities for both within a

[160] Where $R_{95\%}$ distances were available for acoustic modelling, these have also been provided for comparative purposes.

single field and across multiple fields. The predicted ensonified areas associated with each set of concurrent activities has also been presented as an approximate proportion of the width of the pygmy blue migration BIA[161]. Depending on the combination and location of activities, these may ensonify ~23–52% (or ~19–59% based on the narrower and broader sections) of the width of the pygmy blue whale migration BIA at any one time. Note: As per the description in Section 6.3.3.1.2, pygmy blues whales have been observed to migrate through areas broader than just the BIA, particularly during their southern migration.

Based on a similar approach, an indicative worst-case length of the pygmy blue whale BIA ensonified above the TTS onset criterion has been presented in Table 8-46 to investigate the potential risks associated with concurrent activities and potential accumulated exposure above this accumulated SEL_{24h} effect criteria. Travel speed for pygmy blue whales during migration was estimated by Thums et al (Ref. 135), as ~2.4 km/h during northern migration, and ~4.0–5.0 km/h during southern migration. Using these travel speeds, the accumulated duration of exposure within areas ensonified above the TTS onset effect criteria was estimated at up to ~6 hours during northern migration or up to ~3 hours during southern migration (noting that these estimates assume no behavioural effect [e.g. avoidance] occurs to reduce exposure duration). By scaling modelling R_{max} to indicative ranges for the NMFS 2024 TTS onset effect criteria, estimated a potential accumulated exposure duration of ~7 hours during northern migration and up to ~4 hours during southern migration.

[161] Note: As the width of the BIA changes, these are presented based on a width through the DA (i.e. as most representative), but also as a range based on the narrow BIA width to the north, and broader BIA width to south of the DA (see widths as marked on Figure 8-31 to Figure 8-32.

Table 8-45: Potential concurrent activity scenarios and estimated width of the pygmy blue whale migration BIA exposed to sound above the behavioural effect criteria for marine mammals

Concurrent activity scenario description	Relevant model areas and scenarios	Indicative duration of concurrent activities	Estimated width of ensonified areas within the pygmy blue whale BIA above behavioural effect criteria for marine mammals	Potential duration of exposure of pygmy blue whales above behavioural effect criteria for marine mammals
Notes for interpretating values presented in this table:	*1. The 'indicative duration of concurrent activities' refers to a schedule duration (i.e. not a duration that an individual pygmy blue whale would be exposed to these activities given that their presence is seasonal and transitory).* *2. The proportion of the width of the pygmy blue whale migration BIA[162] ensonified above the behavioural effect criteria is presented; however, as described in Section 6.3.3.1.2 migration occurs over a broader area than just the BIA.* *3. The behavioural effect criteria is not a cumulative exposure criteria. The estimate of exposure duration based on migrating swim speeds[163] is presented to give a more realistic 'duration' of concurrent activities applicable to a migrating pygmy blue whale compared to the 'schedule duration'.*			
Single field, concurrent drilling, subsea installation and pipelay	Area 2 (G&E) Scenario 41A + Scenario 13	~3.5 months (based on indicative subsea installation at in-field location)	R_{max} for scenarios 41A and 13 were 15.8 km and 6.88 km respectively. Therefore, potential total width of ensonified area(s) may be up to ~45.4 km (Figure 8-29). This represents ~42% (34–48%) of the width of the migration BIA. Note: The closer the pipelay vessels move towards the location of the drilling and subsea installation activities the ensonified areas will start to overlap. Based on scenario 42A (where pipelay is ~6 km away from drilling and subsea installation activities) the modelled R_{max} is ~17 km. Therefore, while the separate areas presented above represent a greater spatial extent, this extent is expected to vary over the indicative duration of concurrent activities.	The largest length of ensonified area is ~31.6 km; this is based on the scenario 41A as the larger of the ensonified areas (Figure 8-29). During northern and southern migrations this may result in ~13 hours and ~6–8 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).
	Area 2 (G&E)	~0.5 months (based on indicative subsea installation	R_{max} for scenarios 10, 13, and 16 were 5.85 km, 6.88 km, and 15.4 km respectively. Therefore, potential total width of ensonified	The largest length of ensonified area is ~30.8 km; this is based on the scenario 16 as the larger of the ensonified areas.

[162] Note: The width of the pygmy blue whale migration BIA varies; as such these proportions are presented based on the distance through the centre of the DA, and then the narrow width to the north of the DA and broader width to the south the BIA (refer to marked distances in Figure 8-29).

[163] Assumed northern migration swim speed is ~2.4 km/hr, and southern migration is ~4-5 km/hr (see Section 6.3.3.1.2).

Concurrent activity scenario description	Relevant model areas and scenarios	Indicative duration of concurrent activities	Estimated width of ensonified areas within the pygmy blue whale BIA above behavioural effect criteria for marine mammals	Potential duration of exposure of pygmy blue whales above behavioural effect criteria for marine mammals
	Scenario 10 + Scenario 13 + Scenario 16	duration at tie-in location)	area(s) is ~56.3 km. This represents ~52% (42–59%) of the width of the migration BIA. As above, depending on the location of the pipelay vessels the ensonified areas may overlap; however separate areas have been presented as representative of greater total ensonified area.	During northern and southern migrations this may result in ~13 hours and ~6–8 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).
Single field, concurrent drilling and subsea installation	Area 2 (G&E) Scenario 41A	~3.5 months (based on indicative subsea installation at field location)	R_{max} for scenario 41A was 15.8 km. Therefore, potential total width of ensonified area(s) is ~31.6 km. This represents ~29% (23–33%) of the width of the migration BIA.	The largest length of ensonified area is ~31.6 km. During northern and southern migrations this may result in ~13 hours and ~6–8 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).
Single field, concurrent drilling and pipelay	Area 2 (G&E) Scenario 10 + Scenario 13	~3–6 months (based on indicative duration of pipelay activities)	R_{max} for scenarios 10 and 13 were 5.85 km and 6.88 km respectively. Therefore, potential total width of ensonified area(s) is ~25.5 km. This represents ~23% (19–27%) of the width of the migration BIA. Depending on the location of the pipelay vessels the ensonified areas may overlap; however separate areas have been presented as representative of greater total width of ensonified areas.	The largest length of ensonified area is ~13.8 km; this is based on the scenario 13 as the larger of the ensonified areas. During northern and southern migrations this may result in ~6 hours and ~38 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).
Two fields, concurrent drilling, subsea installation and pipelay	Area 2 (G&E) + Area 3 (C&D) Scenario 41A + Scenario 13 + Scenario 41B + Scenario 21	~3.5 months (based on indicative subsea installation at field location)	R_{max} for scenarios 41A, 13, 41B, and 21 were 15.8 km, 6.88 km, 14.6 km, and 13.0 km respectively. To describe a potential worst-case spatial extent, pipelay for G&E has been applied at the Jansz tie-in while drilling and subsea operations both occur at the DC. For C&D, drilling and subsea operations have both been applied at DC-3 while pipelay occurs at the Gorgon tie-in (Figure 8-30).	The largest length of ensonified area is ~68 km (Figure 8-30). During northern and southern migrations this may result in ~28 hours and ~14–17 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).

Concurrent activity scenario description	Relevant model areas and scenarios	Indicative duration of concurrent activities	Estimated width of ensonified areas within the pygmy blue whale BIA above behavioural effect criteria for marine mammals	Potential duration of exposure of pygmy blue whales above behavioural effect criteria for marine mammals
			The estimate of total width of ensonified areas extending into the BIA is ~56 km. This represents ~52% (41–59%) of the width of the migration BIA.	
	Area 1 (Chandon) + Area 5 (WTR) Scenario 2 + Scenario 5 + Scenario 8 Scenario 30 + Scenario 33 + Scenario 36	~3.5 months (based on indicative subsea installation at field location)	R_{max} for scenarios 2, 5, 8, 30, 33, 36 were 5.87 km, 6.72 km, 15.7 km, 10.4 km, 12.9 km, and 17.3 km respectively. To describe a potential worst-case spatial extent for the Chandon field an adjusted R_{max} distance was applied at DC-1 for both drilling and subsea installation, and modelled R_{max} for pipelay at the Jansz tie-in. For WTR, an adjusted R_{max} distance was applied at DC-2 for both drilling and subsea installation, and modelled R_{max} for pipelay at the Gorgon tie-in (Figure 8-31). The estimate of total width of ensonified areas extending into the BIA is ~41 km. This represents ~37% (30–42%) of the width of the migration BIA.	The largest length of ensonified area is ~58 km (Figure 8-30). During northern and southern migrations this may result in ~24 hours and ~12–15 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).
Single activity (drilling, subsea installation, or pipelay) across three fields	Area 2 (G&E) subsea installation (Scenario 16) + Area 3 (C&D) drilling (Scenario 18A) + Area 5 (Chandon) pipelay (Scenario 5)	~4 months (based on indicative duration of subsea installation activities)	R_{max} for scenarios 16, 18A, and 5 were 15.4 km, 12.8 km, and 6.72 km respectively. To describe a potential worst-case spatial extent, pipelay for Chandon occurs at a nominal location along the Chandon to Jansz pipeline (such that ensonified area is wholly within the BIA), drilling is at DC-3 for C&D, and subsea installation is in the G&E field. The estimate of total width of ensonified areas extending into the BIA is ~55 km. This represents ~51% (41–58%) of the width of the migration BIA.	The largest length of ensonified area is ~49 km (Figure 8-30). During northern and southern migrations this may result in ~20 hours and ~10–12 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).

Concurrent activity scenario description	Relevant model areas and scenarios	Indicative duration of concurrent activities	Estimated width of ensonified areas within the pygmy blue whale BIA above behavioural effect criteria for marine mammals	Potential duration of exposure of pygmy blue whales above behavioural effect criteria for marine mammals
Single activity (drilling) across two fields	Area 2 (G&E) + Area 3 (C&D) Scenario 10 + Scenario 18A	up to ~24 months (based on indicative drilling duration)	R_{max} for scenarios 10 and 18A were 5.85 km and 12.8 km respectively. Therefore, potential total width of ensonified area(s) is ~37.3 km. This represents ~34% (28–39%) of the width of the migration BIA.	The largest length of ensonified area is ~37.3 km. During northern and southern migrations this may result in ~16 hours and ~7–9 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours).

Table 8-46: Potential concurrent activity scenarios and estimated length of the pygmy blue whale migration BIA exposed to sound above the TTS onset effect criteria for marine mammals

Scenario description	Relevant model areas scenarios	Indicative duration of concurrent activities	Estimated length of ensonified areas above TTS onset effect criteria for pygmy blue whales	Potential duration of exposure of pygmy blue whales above R_{max} to NMFS 2018 TTS onset effect criteria	Potential duration of exposure of pygmy blue whales above indicative ranges to NMFS 2024 TTS onset
Notes for interpretating values presented in this table:	*1. The 'indicative duration of concurrent activities' refers to a schedule duration (i.e. not a duration that an individual pygmy blue whale would be exposed to these activities given that their presence is seasonal and transitory).* *2. The TTS onset effect criteria is a cumulative exposure criteria. The estimate of exposure duration based on migrating swim speeds[163] is presented to give a more realistic 'duration' of concurrent activities applicable to a migrating pygmy blue whale compared to the 'schedule duration'.*				
Single field, concurrent subsea installation and pipelay	Area 5 (WTR) Scenario 36 + Scenario 33	~4 months (based on indicative subsea installation duration)	R_{max} for scenarios 33 and 36 were 2.18 km and 4.58 km respectively. Therefore, potential total length of ensonified area(s) is ~13.5 km. Note: These ensonified areas from WTR activities do not actually extend into the pygmy blue whale migration BIA, but is presented as a worst-case distance for risk assessment purposes. These ensonified areas would also only partially extend into the humpback whale migration BIA when works occur at the Gorgon tie-in (but not from the WTR field itself).	During northern and southern migrations this may result in an accumulated duration of exposure of above the SEL_{24h} effect criteria of ~6 hours and ~3 hours respectively.	Based on scaled indicative ranges to the NMFS TTS onset criteria, during northern and southern migrations this may result in an accumulated duration of exposure above the SEL_{24h} effect criteria of ~7 hours and ~4 hours respectively.

Scenario description	Relevant model areas scenarios	Indicative duration of concurrent activities	Estimated length of ensonified areas above TTS onset effect criteria for pygmy blue whales	Potential duration of exposure of pygmy blue whales above R_{max} to NMFS 2018 TTS onset effect criteria	Potential duration of exposure of pygmy blue whales above indicative ranges to NMFS 2024 TTS onset
Two fields, concurrent subsea installation and pipelay	Area 2 (Semele) + Area 3 (C&D) Scenario 16 + Scenario 13 + Scenario 24 + Scenario 21		R_{max} for scenarios 13, 16, 21, and 24 were 1.08 km, 1.81 km, 1.08 km, and 2.1 km respectively. Therefore, potential total length of ensonified area(s) is ~12.1 km. Note: These are likely to exist as separate ensonified areas, but represent a potential total maximum length above the effect criteria.	During northern and southern migrations this may result in an accumulated duration of exposure above the SEL_{24h} effect criteria of ~5 hours and ~2–3 hours respectively.	Based on scaled indicative ranges to the NMFS TTS onset criteria, during northern and southern migrations this may result in an accumulated duration of exposure above the SEL_{24h} effect criteria of ~7 hours and ~3–4 hours respectively.

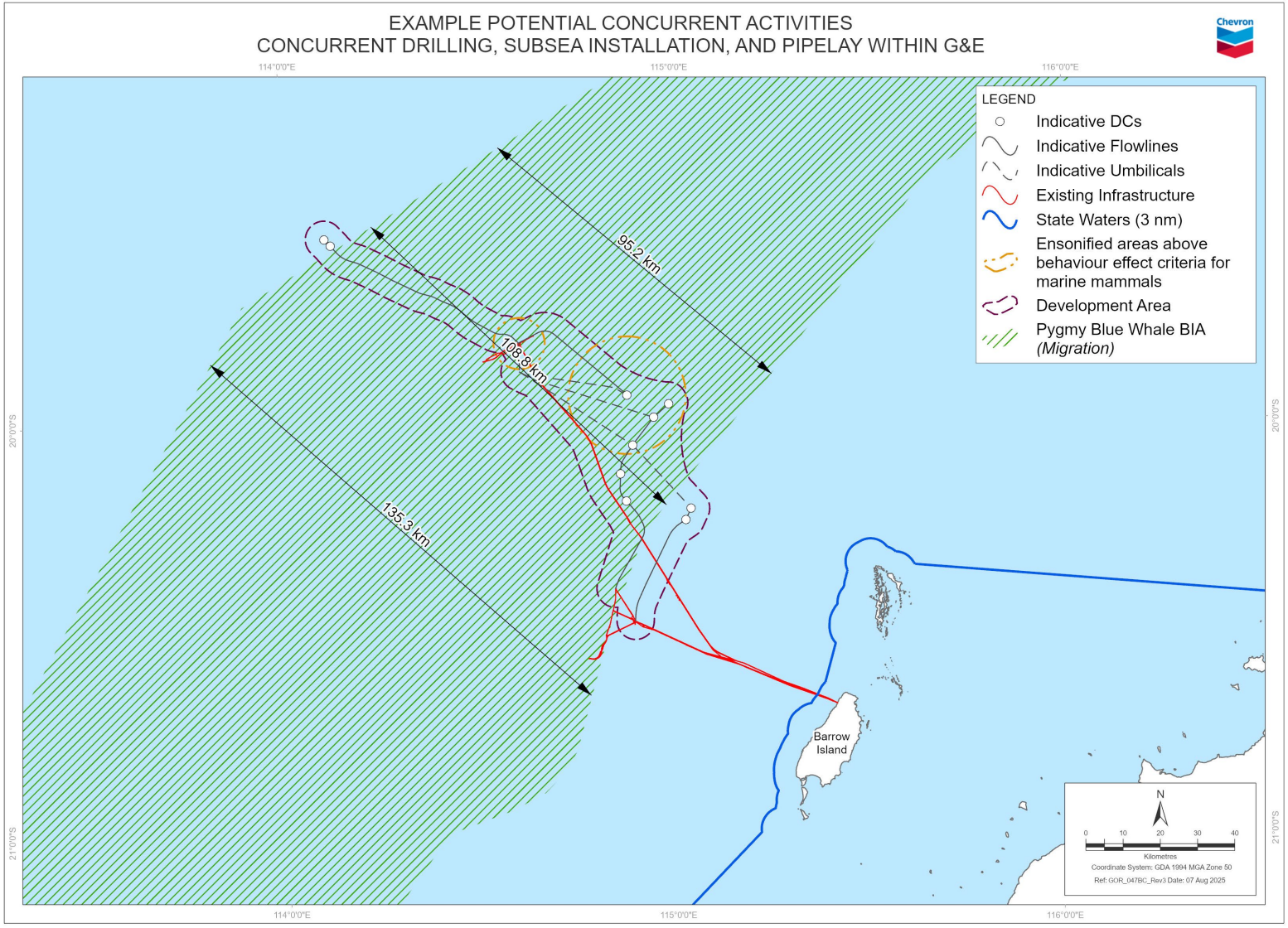


Figure 8-29: Example potential concurrent activities—concurrent drilling, subsea installation, and pipelay within G&E

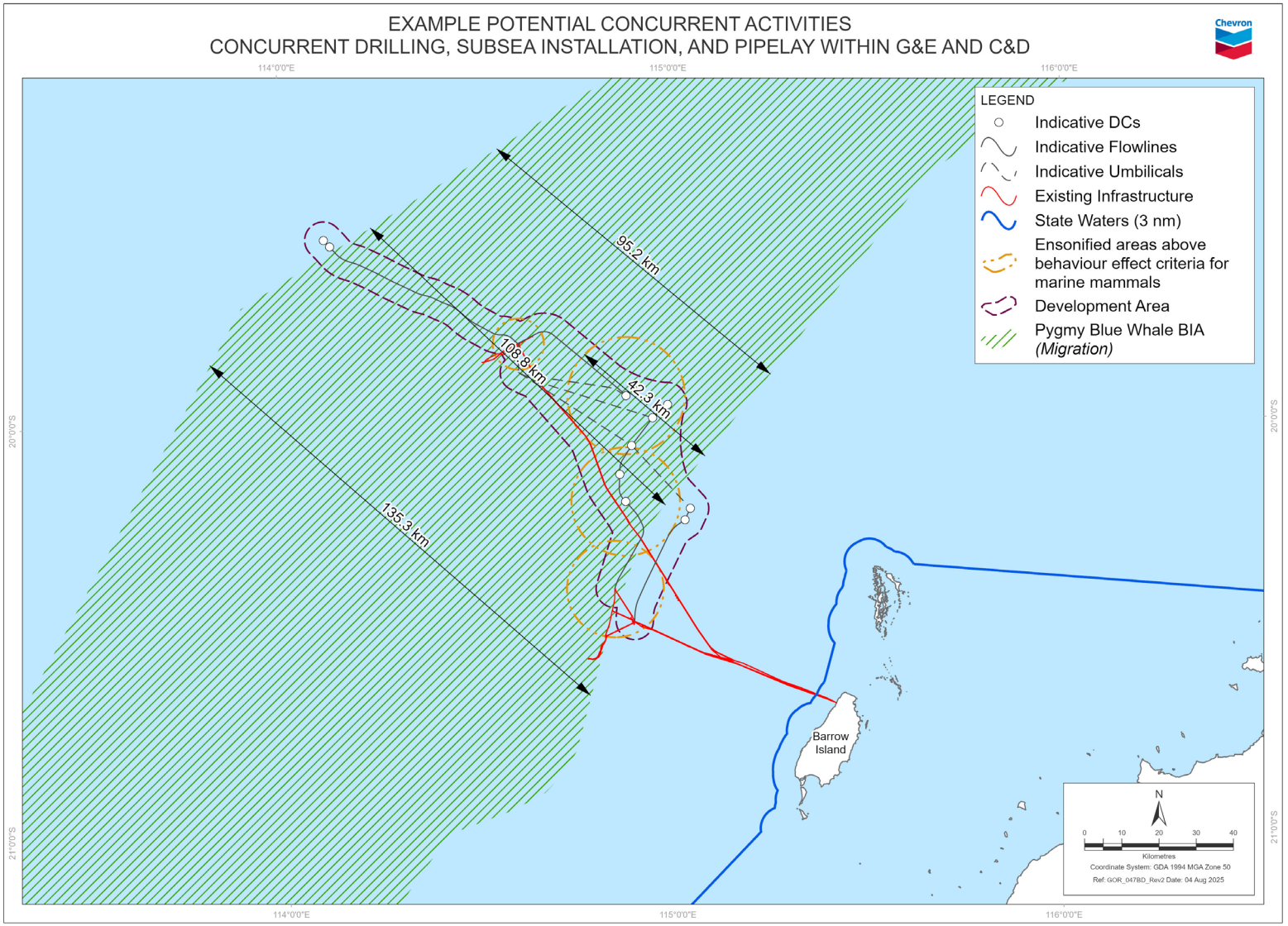


Figure 8-30: Example potential concurrent activities—concurrent drilling, subsea installation, and pipelay within G&E and C&D

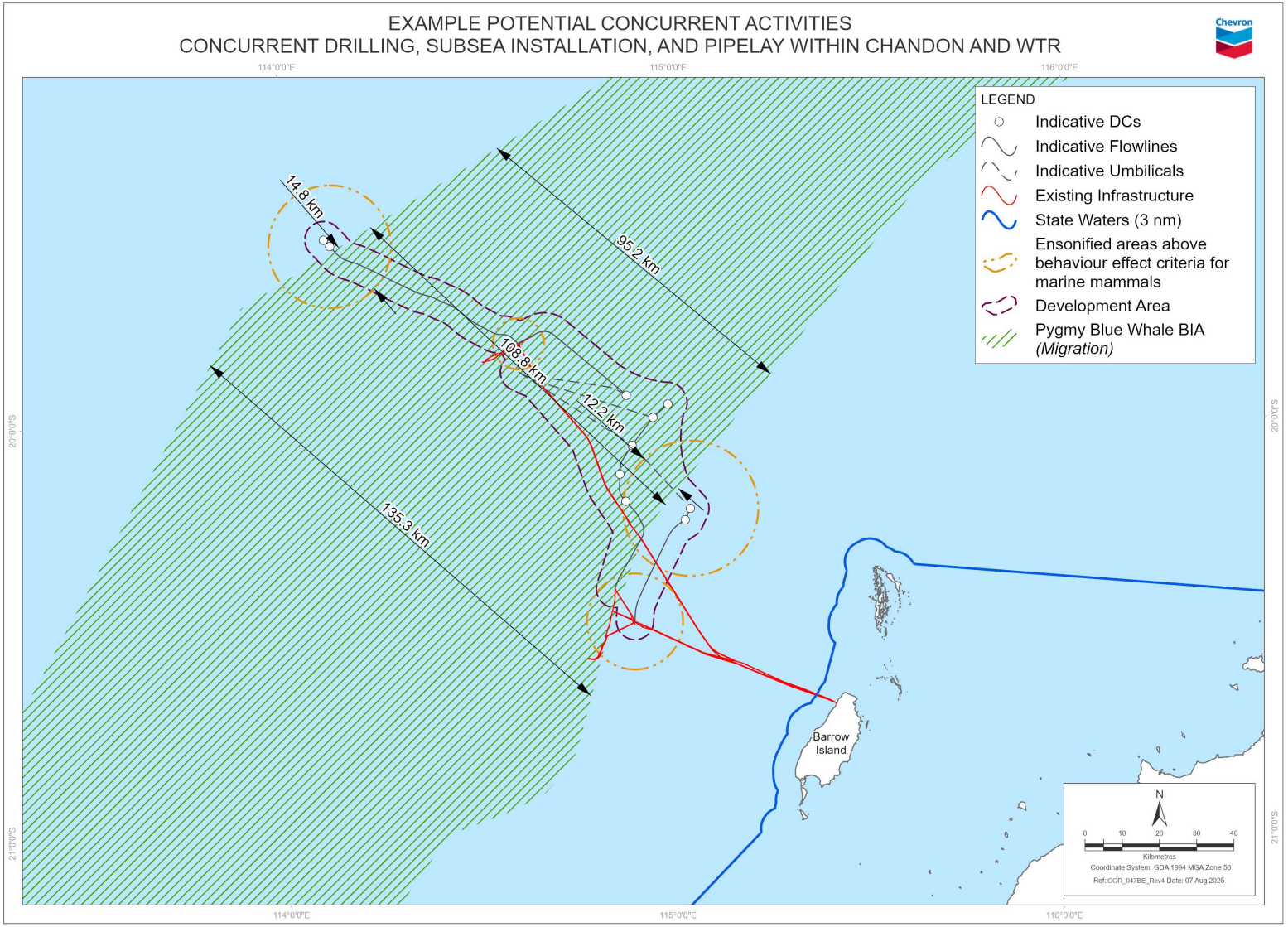


Figure 8-31: Example potential concurrent activities—concurrent drilling, subsea installation, and pipelay within Chandon and WTR

8.5.3.5 geophysical surveys (SSS, MBES)

Geophysical survey techniques such as SSS and MBES also generate non-impulsive sound emissions, however these are high frequency sound emissions which attenuate rapidly in water. To estimate the distances at which effect criteria may be exceeded by SSS and MBES systems, JASCO utilised a simple spreading loss model to calculate estimates of sound propagation (Ref. 550). A spreading loss model was considered an appropriate modelling approach given the high frequency (and corresponding small wavelength) of the source sound.

An SSS at two different operating frequencies and two different MBES systems were modelled. Both the SSS (operating frequencies of 100 kHz and 400 kHz) and MBES (operating frequencies of 100 kHz and 300 kHz) equipment modelled would not be heard by low frequency cetaceans, fish, and turtles; and therefore no effects were predicted. The spreading loss modelling indicated the following for high and very high frequency cetaceans:

- SSS
  - maximum horizontal distance ~340–705 m for the behavioural response criterion
  - maximum distance to reach SEL_{24h} effect criteria for PTS onset was ~29 m for very high frequency cetaceans; the effect criteria for high frequence cetaceans was not reached
  - maximum distance to reach SEL_{24h} effect criteria for TTS onset was ~9 m and ~23–264 m for high and very high frequency cetaceans respectively.
- MBES
  - maximum horizontal distance ~565–1,212 m for the behavioural response criterion
  - maximum distance to reach SEL_{24h} effect criteria for PTS onset was ~10 m and ~79–277 m for high and very high frequency cetaceans respectively
  - maximum distance to reach SEL_{24h} effect criteria for TTS onset was ~31–166 m and ~251–700 m for high and very high frequency cetaceans respectively.

Note: The above assessment by JASCO is based on comparisons to the effect criteria that were in place at the time the OPP modelling was completed (i.e. NMFS 2018 for cetaceans, and Phase 3 for marine turtles). However, the above assessment of SSS and MBES is considered appropriate to inform the risk evaluation in this OPP given that:

- the geophysical sources are high frequency sounds, that would not be heard by turtles or low frequency cetaceans
- the updated auditory weighting function for high frequency cetaceans shows increased sensitivity to lower frequency sounds (and the geophysical frequencies are above this)
- the updated effect criteria for high and very high frequency cetaceans increased by 3 dB and 8 dB respectively, and therefore given the source characteristics, the distances to updated effect criteria are likely to be similar or decrease compared to those described above for NMFS 2018.

An EPO (**EPO-22**; Table 8-57) has been included to ensure that any acoustic assessments undertaken for subsequent EPs incorporate contemporary effect criteria available at the time.

8.5.4 underwater sound modelling—impulsive

JASCO undertook modelling studies (Ref. 297; Ref. 550) to inform the impact and risk assessment associated with impulsive underwater sound emissions from the Development.

Geophysical survey techniques such as SBP generate impulsive sound emissions, however these are moderate to high frequency emissions which attenuate rapidly in water and the area of exposure is within the immediate vicinity of the activity. As such, a spherical modelling has approach has been applied to these sources (as described in Section 8.5.4.3).

VSP, which is a higher intensity low frequency impulsive sound source, has been modelled to conservatively represent the loudest impulsive sound source associated with the Development. The acoustic modelling study considered three VSP scenarios (scenarios A, B, and C) across three representative areas within the DA (Table 8-47).

A 750 in^3 VSP source suspended at a depth of 5 m was modelled with JASCO's Airgun Array Source Model (AASM, Ref. 297). The AASM indicates most energy will be produced at frequencies below 300 Hz, with a peak source level of ~239 dB re 1 µPa m (Ref. 297).

Table 8-47: Impulsive sound modelling scenarios with relevant Development fields and phases

Model area (and relevant fields)	Model scenario	Scenario description	Approximate water depth	Development phase
1 (Chandon)	C	VSP	1,153 m	Drilling
3 (C&D)	B	VSP	924 m	Drilling
5 (WTR)	A	VSP	143 m	Drilling

8.5.4.1 effect criteria

The modelling studies used the following effect criteria which was based on the best available science at the time of the modelling:

- sound exposure guidelines for fish, fish eggs, and larvae from Popper et al. (Ref. 305)[164, 165]
- peak pressure levels (PK) and frequency-weighted accumulated SEL_{24h} from Finneran et al (Ref. 314) for the onset of PTS and TTS in marine turtles

[164] Only quantitative effect criteria were modelled; qualitative effect criteria were applied directly in the impact and risk assessment.

[165] Popper et al. (Ref. 311) cites varying accumulation periods for a number of sound events at particular time intervals. For this assessment 24 h was used based on the independent expert peer review by Popper (Ref. 319) that concluded that a 24-hour period to assess SEL and any associated effects is likely to be conservative for assessing the potential effects to fish.

- marine turtle behavioural response threshold of 166 dB re 1 µPa (SPL) along with a sound level associated with behavioural disturbance of 175 dB re 1 µPa from McCauley et al (Ref. 313)
- PK and frequency-weighted accumulated SEL_{24h} from the United States NMFS (Ref. 307) and Southall et al. (Ref. 306) for the onset of PTS and TTS in marine mammals
- un-weighted SPL for behavioural effects in marine mammals based on the current interim United States NOAA criterion (Ref. 308)

These effect criteria are shown in Table 8-48.

Research is ongoing into the relationship between sound and its effects on benthic invertebrates, including the relevant metrics for both effect and impact (Ref. 297). Marine invertebrates lack a gas-filled bladder and are unable to detect the pressure component of sound waves (Ref. 321; Ref. 322) or “hear” sound in the way that mammals and fish can. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing (Ref. 297). I. Peak-peak pressure levels (PK-PK) and particle acceleration (ms^{-2}) at the seafloor were used to help assess effects of sound on benthic invertebrates. A PK-PK of 202 dB re 1 µPa is considered a no effect sound level (Ref. 309), and PK-PK of 209–213 dB re 1 µPa (Ref. 310; Ref. 311; Ref. 689; Ref. 690) for sound levels related to different levels of potential impairment.

8.5.4.1.1 revised effect criteria

As described in Section 8.5.3.2.1, since the acoustic modelling studies for this OPP were completed, the United States NMFS and United States Navy have released updated guidance and effect criteria for cetaceans and marine turtles.

CMST undertook an assessment to estimate how previously modelled ensonified ranges for a VSP sound source may change. This assessment was undertaken following the same method as described previously for the non-impulsive sound sources (except based on the VSP source spectra).

Where dual criteria exist (for cetaceans only), the CMST assessment focused on the cumulative SEL effect criteria rather than peak SPL. There are complexities in the prediction of peak SPL that cannot be resolved within a spherical spreading. However, based on the existing numerical modelling, peak SPL criterion were only reached for very high frequency cetaceans and the distances were either the same as the cumulative SEL metric (TTS onset) or slightly higher (PTS onset) (Table 8-53). As such, a comparison based on the cumulative SEL effect criteria is considered to appropriate to the nature and scale of the potential risk, and appropriate to provide a reasonable indication of the order of magnitude and direction of change in ensonified ranges from the updated effect criteria.

A comparison between effect criteria used in the OPP modelling studies versus the updated guidance is shown in Table 8-49. The ratio of change determined by the CMST assessment are also shown in Table 8-49. These ratios have been used as ‘scaling factors’ to provide an indication of the potential magnitude and direction of change the updated criteria would have to the existing predicted maximum horizontal distances from the JASCO numerical modelling. The resulting indicative ranges are shown in Table 8-53 (marine turtles) and Table 8-53 (cetaceans).

Table 8-48: Effect criteria for impulsive sound for different types of impacts and species groups

Receptor	Mortality and potential mortal injury	Recoverable injury	PTS onset	TTS onset	Masking	Behaviour
Low frequency cetaceans	N/A	N/A	SEL_{24h}: 183 dB re 1 μPa^2s PK: 219 dB re 1 µPa	SEL_{24h}: 168 dB re 1 μPa^2s PK: 213 dB re 1 µPa	N/A	SPL: 160 dB re 1 µPa
High frequency cetaceans	N/A	N/A	SEL_{24h}: 185 dB re 1 μPa^2s PK: 230 dB re 1 µPa	SEL_{24h}: 170 dB re 1 μPa^2s PK: 224 dB re 1 µPa	N/A	
Very high frequency cetaceans	N/A	N/A	SEL_{24h}: 155 dB re 1 μPa^2s PK: 202 dB re 1 µPa	SEL_{24h}: 140 dB re 1 μPa^2s PK: 196 dB re 1 µPa	N/A	
Marine turtles	N/A	N/A	SEL_{24h}: 204 dB re 1 μPa^2s PK: 232 dB re 1 µPa	SEL_{24h}: 189 dB re 1 μPa^2s PK: 226 dB re 1 µPa	N/A	SPL: 166 dB re 1 µPa SPL: 175 dB re 1 µPa
Fish (no swim bladder)[166]	SEL_{24h}: >219 dB re 1 μPa^2s PK: >213 dB re 1 µPa	SEL_{24h}: >216 dB re 1 μPa^2s PK: >213 dB re 1 µPa	N/A	SEL_{24h}: >>186 dB re 1 μPa^2 s	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish (swim bladder not involved in hearing)	SEL_{24h}: 210 dB re 1 μPa^2s PK: >207 dB re 1 µPa	SEL_{24h}: 203 dB re 1 μPa^2s PK: >207 dB re 1 µPa	N/A	SEL_{24h}: >>186 dB re 1 μPa^2 s	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish (swim bladder involved in hearing)	SEL_{24h}: 207 dB re 1 μPa^2s PK: >207 dB re 1 µPa	SEL_{24h}: 203 dB re 1 μPa^2s PK: >207 dB re 1 µPa	N/A	SEL_{24h}: 186 dB re 1 μPa^2s	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate

[166] Also appropriate for sharks (Ref. 303).

Receptor	Mortality and potential mortal injury	Recoverable injury	PTS onset	TTS onset	Masking	Behaviour
Fish eggs and fish larvae	SEL_{24h}: >210 dB re 1 μPa^2s PK: >207 dB re 1 µPa	(N) Moderate (I) Low (F) Low	N/A	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Relative risk (high, moderate, low) is given for fauna at three distances from the source (near [N], intermediate [I] and far [F]). Where 'near' is considered to be in the order of tens of meters from the source, 'intermediate' is hundreds of meters, and 'far' in the thousands of meters (Ref. 305).

Table 8-49: Comparison between TTS, PTS, and AUD INJ onset effect criteria for cetacean and marine turtles and estimated ratio of change between distances to reach effect criteria based on a spherical spreading approach

Functional hearing group	NMFS 2018 Technical Guidance (cetaceans) United States Navy Phase 3 (marine turtles)		NMFS 2024 Technical Guidance(cetaceans) United States Navy Phase 4 (marine turtles)		Ratio of estimated ranges to effect criteria
	TTS onset	PTS onset	TTS onset	AUD INJ onset	
Low frequency cetaceans	SEL_{24h}: 168 dB re 1 μPa^2s	SEL_{24h}: 183 dB re 1 μPa^2s	SEL_{24h}: 168 dB re 1 μPa^2s	SEL_{24h}: 183 dB re 1 μPa^2s	1.12
High frequency cetaceans	SEL_{24h}: 170 dB re 1 μPa^2s	SEL_{24h}: 185 dB re 1 μPa^2s	SEL_{24h}: 178 dB re 1 μPa^2s	SEL_{24h}: 193 dB re 1 μPa^2s	4.98
Very high frequency cetaceans	SEL_{24h}: 140 dB re 1 μPa^2s	SEL_{24h}: 155 dB re 1 μPa^2s	SEL_{24h}: 144 dB re 1 μPa^2s	SEL_{24h}: 159 dB re 1 μPa^2s	0.72
Marine turtles	SEL_{24h}: 189 dB re 1 μPa^2s	SEL_{24h}: 204 dB re 1 μPa^2s	SEL_{24h}: 169 dB re 1 μPa^2s	SEL_{24h}: 184 dB re 1 μPa^2s	5.77

8.5.4.2 modelling results

The R_{max} distance parameter has been used as a conservative approach to inform the impact and risk assessment in this OPP.

For the per-pulse sound fields metrics for maximum-over-depth SPL, SEL, and PK and seafloor PK and PK-PK are provided. The use of seafloor metrics are relevant so sound levels for assessing effects on benthic invertebrates or demersal fish, fish eggs, and fish larvae (Ref. 297).

8.5.4.2.1 benthic invertebrates

Table 8-50 summarises the maximum horizontal distances to modelled seafloor PK-PK benthic invertebrate effect criteria from impulsive sound sources. The modelling indicated that the only criterion reached was the no effect criterion within Area 5 (WTR). The maximum distance to effect criteria from the VSP sound source would apply as buffers around the indicative WTR DCs only.

Table 8-50: Maximum horizontal distance (R_{max}) to impulsive effect criteria at the seafloor for benthic invertebrates

Area	R_{max} (km) to no effect	R_{max} (km) to impairment
Effect criteria	*$PK\text{-}PK_{seafloor}$: 202 dB re 1 µPa*	*$PK\text{-}PK_{seafloor}$: 209–213 dB re 1 µPa*
Area 1	*	*
Area 3	*	*
Area 5	0.06	*

An asterisk indicates the sound level was not reached.

8.5.4.2.2 fishes

Maximum-over-depth PK effect criteria for fish were not reached within the modelling resolution (20 m; Ref. 297). Sound levels for $PK_{seafloor}$ effect criteria for fish were also not reached (Ref. 297). Therefore, Table 8-51 summarises the maximum horizontal distances (R_{max}) to fishes accumulated SEL_{24h} effect criteria from the VSP source. Where the accumulated SEL_{24h} effect criteria were reached, the number of impulses (shots) per 24-hour period that needed to be release were ≥150 impulses for mortality and potential mortal injury, ≥50 impulses for recoverable injury, and ≥5 impulses for TTS onset (Ref. 297). No substantial variation in maximum distances for either effect criteria was observed across fields.

The maximum distance to effect criteria from the VSP sound source would apply as buffers around the indicative DCs only; VSP would not be used elsewhere in the DA.

Table 8-51: Maximum horizontal distance (Rmax) to impulsive effect criteria for fishes

Area	R_{max} (km) to mortality and potential mortal injury	R_{max} (km) to recoverable injury	R_{max} (km) to TTS onset
Fish (no swim bladder)			
Effect criteria	*SEL_{24h}: >219 dB re 1 µPa^2s*	*SEL_{24h}: >216 dB re 1 µPa^2s*	*SEL_{24h}: >>186 dB re 1 µPa^2s*
Area 1	–	–	0.37

Area	R_{max} (km) to mortality and potential mortal injury	R_{max} (km) to recoverable injury	R_{max} (km) to TTS onset
Area 3	–	–	0.37
Area 5	–	–	0.57
Fish (swim bladder not involved in hearing)			
Effect criteria	*SEL_{24h}: 210 dB re 1 µPa²s*	*SEL_{24h}: 203 dB re 1 µPa²s*	*SEL_{24h}: >>186 dB re 1 µPa²s*
Area 1	0.02	0.05	0.37
Area 3	0.02	0.05	0.37
Area 5	0.02	0.05	0.57
Fish (swim bladder involved in hearing)			
Effect criteria	*SEL_{24h}: 207 dB re 1 µPa²s*	*SEL_{24h}: 203 dB re 1 µPa²s*	*SEL_{24h}: 186 dB re 1 µPa²s*
Area 1	0.03	0.05	0.37
Area 3	0.03	0.05	0.37
Area 5	0.03	0.05	0.57
Fish eggs and fish larvae			
Effect criteria	*SEL_{24h}: >210 dB re 1 µPa²s*		
Area 1	0.02		
Area 3	0.02		
Area 5	0.02		

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m).

8.5.4.2.3 marine reptiles

Maximum-over-depth PK effect criteria for marine turtles were not reached within the modelling resolution (20 m; Ref. 297). Therefore, Table 8-53 summarises the maximum horizontal distances (R_{max}) to marine turtle SPL and accumulated SEL_{24h} effect criteria from the VSP sound source. Where the accumulated SEL_{24h} effect criteria were reached, the number of impulses (shots) per 24-hour period that needed to be release were ≥100 impulses for PTS onset, and ≥5 impulses for TTS onset (Ref. 297). Indicative ranges to Phase 4 (2025) TTS and AUD-INJ onset effect criteria are also shown in Table 8-52. No substantial variation in maximum distances for PTS, TTS or behavioural disruption effect criteria was observed across fields; a higher distance to behavioural response was predicted for the shallow waters in Area 5 compared to the deeper offshore sites.

The maximum distances to impulsive effect criteria for marine reptiles from the VSP sound source would apply as buffers around the indicative DCs only; VSP would not be used elsewhere in the DA.

Table 8-52: Maximum horizontal distance (R_{max}) to impulsive effect criteria for marine turtles

Area	R_{max} (km) to TTS onset	Indicative range[167] (km) to TTS onset	R_{max} (km) to PTS onset	Indicative range[167] (km) to AUD INJ onset	R_{max} (km) to behavioural response	R_{max} (km) to behavioural disturbance
Effect criteria	*SEL_{24h}: 189 dB re 1 µPa²s*	*SEL_{24h}: 169 dB re 1 µPa²s*	*SEL_{24h}: 204 dB re 1 µPa²s*	*SEL_{24h}: 184 dB re 1 µPa²s*	*SPL: 166 dB re 1 µPa*	*SPL: 175 dB re 1 µPa*
Area 1	0.21	1.21	0.03	0.17	0.59	0.21
Area 3	0.21	1.21	0.03	0.17	0.59	0.21
Area 5	0.24	1.38	0.03	0.17	1.03	0.27

[167] Indicative ranges to United States Navy Phase 4 (2025) effect criteria are based on applying 'scaling factors' from spherical spreading comparisons (see Section 8.5.4.1.1). These ranges are unlikely to represent an exact distance based on numerical modelling, but provide an indication of the magnitude of change from the R_{max} values from numerical modelling under the previous United States Navy Phase 3 (2017) effect criteria to an estimated range under the Phase 4 effect criteria. These indicative ranges are considered appropriate to inform the risk assessment within this OPP.

8.5.4.2.4 marine mammals

Table 8-53 summarises the maximum horizontal distances (R_{max}) to marine mammal effect criteria from the VSP sound source. Where the accumulated SEL_{24h} effect criteria were reached, the number of impulses (shots) per 24-hour period that needed to be released were ≥5 impulses and ≥300 impulses for PTS onset in low frequency and very high frequence cetaceans respectively; and ≥5 impulses and ≥10 impulses for TTS onset in low frequency and very high frequence cetaceans respectively (Ref. 297). Indicative ranges to NMFS 2024 TTS and AUD-INJ onset effect criteria are also shown in Table 8-53. No substantial variation in maximum distances for PTS or TTS onset in very high frequency cetaceans was observed across fields. Some variation is present for behavioural response effect criteria with higher distances predicted for the shallow waters in Area 5 compared to the deeper offshore sites; and similarly for TTS onset criteria for low frequency cetaceans.

The maximum distances to effect criteria from the VSP sound source would apply as buffers around the indicative DCs only; VSP would not be used elsewhere in the DA. For visualisation an example of this has been shown in the inset of Figure 8-32.

Table 8-53: Maximum horizontal distance (Rmax) to impulsive effect criteria for marine mammals

Area	R_{max} (km) to PTS onset		Indicative range[168] (km) to AUD INJ onset	R_{max} (km) to TTS onset		Indicative range[168] (km) to TTS onset	R_{max} (km) to behavioural response
Low frequency cetaceans							
Effect criteria	*SEL_{24h}: 183 dB re 1 μPa^2s*	*PK: 219 dB re 1 µPa*	*SEL_{24h}: 183 dB re 1 μPa^2s*	*SEL_{24h}: 168 dB re 1 μPa^2s*	*PK: 213 dB re 1 µPa*	*SEL_{24h}: 168 dB re 1 μPa^2s*	*SPL: 160 dB re 1 µPa*
Area 1	0.26	–	0.29	1.47	–	1.65	1.35
Area 3	0.26	–	0.29	1.68	–	1.88	1.33
Area 5	0.48	–	0.54	3.20	–	3.58	2.37
High frequency cetaceans							
Effect criteria	*SEL_{24h}: 185 dB re 1 μPa^2s*	*PK: 230 dB re 1 µPa*	*SEL_{24h}: 193 dB re 1 μPa^2s*	*SEL_{24h}: 170 dB re 1 μPa^2s*	*PK: 224 dB re 1 µPa*	*SEL_{24h}: 178 dB re 1 μPa^2s*	*SPL: 160 dB re 1 µPa*
Area 1	–	–	0.05[169]	–	–	0.05[169]	1.35
Area 3	–	–	0.05[169]	–	–	0.05[169]	1.33
Area 5	–	–	0.05[169]	–	–	0.05[169]	2.37
Very high frequency cetaceans							
Effect criteria	*SEL_{24h}: 155 dB re 1 μPa^2s*	*PK: 202 dB re 1 µPa*	*SEL_{24h}: 159 dB re 1 μPa^2s*	*SEL_{24h}: 140 dB re 1 μPa^2s*	*PK: 196 dB re 1 µPa*	*SEL_{24h}: 144 dB re 1 μPa^2s*	*SPL: 160 dB re 1 µPa*
Area 1	0.02	0.06	0.01	0.13	0.13	0.09	1.35
Area 3	0.02	0.06	0.01	0.13	0.13	0.09	1.33
Area 5	0.02	0.06	0.01	0.13	0.13	0.09	2.37

A dash indicates the effect criteria was not reached within the limits of the modelling resolution (20 m).

[168] Indicative ranges to NMFS 2024 effect criteria are based on applying 'scaling factors' from spherical spreading comparisons (see Section 8.5.4.1.1). These ranges are unlikely to represent an exact distance based on numerical modelling, but provide an indication of the magnitude of change from the R_{max} values from numerical modelling under the previous NMFS 2018 effect criteria to an estimated range under the NMFS 2024 effect criteria. These indicative ranges are considered appropriate to inform the risk assessment within this OPP.

[169] Note: For the scenarios where no R_{max} value under the NMFS 2018 effect criteria was defined (i.e. when the effect criteria was not reached within the limits of the modelling resolution [20 m]), it was conservatively assumed that this distance was 10 m (i.e. half the model resolution) to allow the appropriate scaling factor to be applied to provide an indicative range under the NMFS 2024 effect criteria.

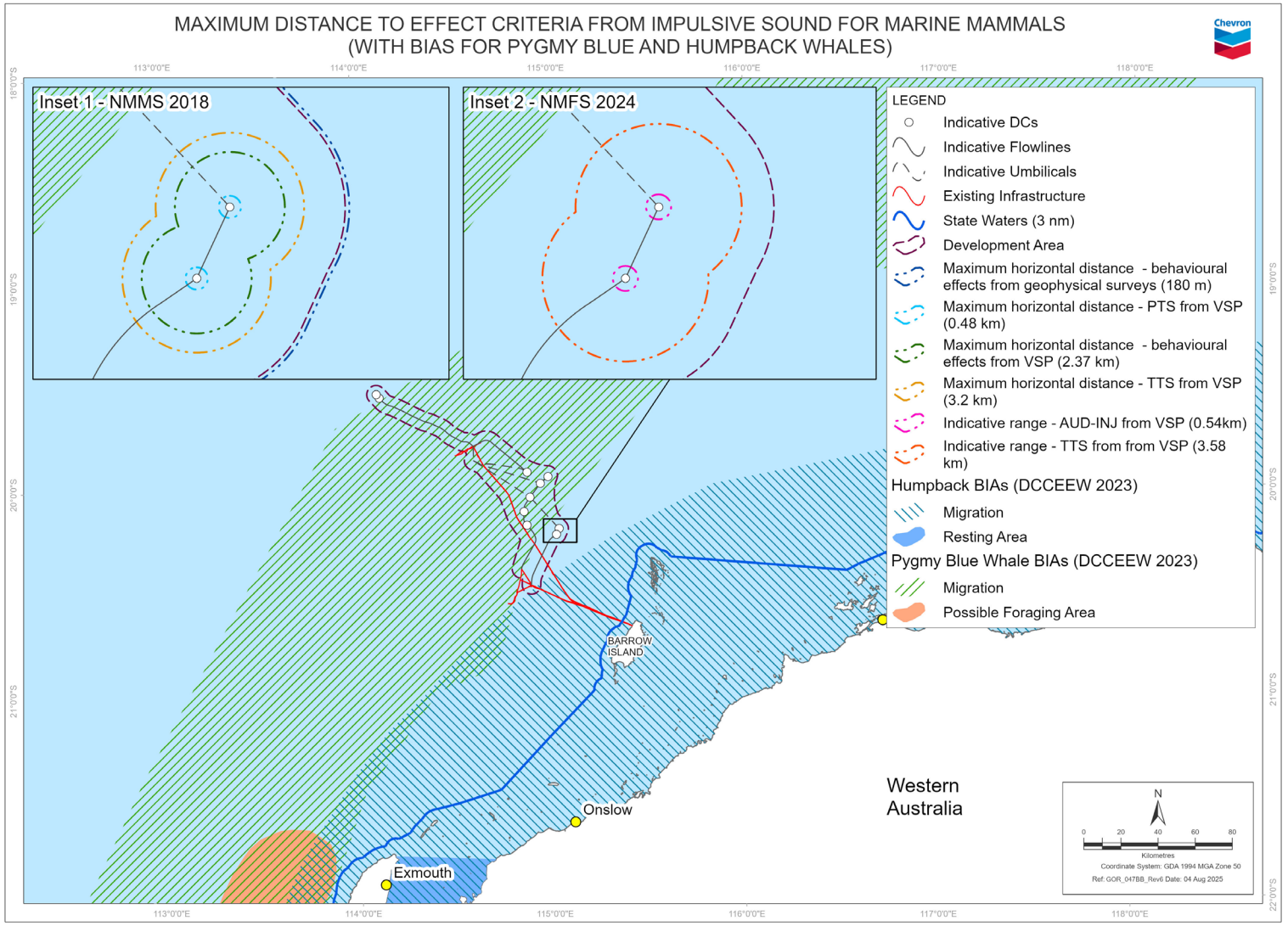


Figure 8-32: Maximum distance to effect criteria from impulsive sound for low frequency cetaceans (with BIAs for pygmy blue and humpback whales)

8.5.4.3 geophysical surveys (SBP)

Geophysical survey techniques such as SBP also generate non-impulsive sound emissions, however these are moderate to high frequency sound emissions which attenuate rapidly in water. To estimate the distances at which effect criteria may be exceeded by SBP systems, JASCO utilised a simple spreading loss model to calculate estimates of sound propagation (Ref. 550).

Three types of chirp SBPs and one boomer SBP were modelled. The spreading loss modelling indicated the following for marine mammals:

- chirp SBP
  - maximum horizontal distance ~4–180 m for the marine mammal behavioural response criterion
  - PK effect criteria for all marine mammal hearing groups may be exceeded at very short horizontal distances from the SPB sources, ~2 m and ~5 m for PTS onset and TTS onset, respectively
  - for the lower-powered systems (source levels 178–179 db re 1 µPa @ 1 m) SEL_{24h} effect criteria for PTS or TTS onset were not reached, except for TTS onset for very high frequency cetaceans with a maximum distance of ≤20 m
  - for the higher-powered system (source level 209 db re 1 µPa @ 1 m) SEL_{24h} effect criteria PTS onset were ~28 m, 3 m and ~604 m for low, high, and very high frequency cetaceans respectively; and for TTS onset were ~808 m, ~66 m, and ~5,493 m for low, high, and very high frequency cetaceans respectively
- boomer SBP
  - maximum horizontal distance ~90 m for the marine mammal behavioural response criterion
  - PK effect criteria for all marine mammal hearing groups may be exceeded at very short horizontal distances from the SPB source, ~1 m and ~3 m for PTS onset and TTS onset, respectively
  - SEL_{24h} effect criteria for PTS onset were not reached for low or high frequency cetaceans; and for very high frequency cetaceans the maximum distance was ~3 m
  - SEL_{24h} effect criteria for TTS onset were not reached for high frequency cetaceans; for low and very high frequency cetaceans the maximum distance was ~7 m and ~88 m respectively.

JASCO's assessment also noted that the geophysical survey equipment considered could result in physiological impacts to fish located within metres of the sources, but would not result in physiological impacts to marine turtles located within metres of the sources (Ref. 550). PK-PK effect criteria as relevant to benthic invertebrates may be exceeded but only within very close proximity to the geophysical survey sources; and given the general positioning of equipment (e.g. hull mounted from vessel, or several tens of metres from the seafloor on ROV/AUVs) it is unlikely that PK-PK effect criteria would be exceeded at the seafloor (Ref. 550).

Note: The above assessment by JASCO is based on comparisons to the effect criteria that were in place at the time the OPP modelling was completed (i.e. NMFS 2018 for cetaceans, and Phase 3 for marine turtles). However, the

above assessment of SBP is considered appropriate to inform the risk evaluation in this OPP given that:

- the geophysical sources are moderate to high frequency sounds
- the updated auditory weighting function for high frequency cetaceans shows increased sensitivity to lower frequency sounds (and the geophysical frequencies are above this)
- the SEL_{24h} effect criteria for low frequency cetaceans did not change
- the updated SEL_{24h} effect criteria for high and very high frequency cetaceans increased by 8 dB and 4 dB respectively, and therefore given the source characteristics, the distances to updated effect criteria are likely to be similar or decrease compared to those described above for NMFS 2018
- the updated SEL_{24h} effect criteria for turtles decreased by 20 dB; however most of the source energy is above the hearing frequencies of turtles.

An EPO (**EPO-22**; Table 8-57) has been included to ensure that any acoustic assessments undertaken for subsequent EPs incorporate contemporary effect criteria available at the time.

8.5.5 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the area that may be impacted by underwater sound emissions:

- ambient sound
- benthic invertebrates
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- AMPs
- cultural heritage values: Traditional Owners.

Although fish may potentially be impacted by underwater sound, the area of influence is localised and is not expected to result in a change in the viability of the population of commercially important species or the fish assemblages associated with KEFs Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values from underwater sound are not expected; and are not evaluated further.

8.5.5.1 non-impulsive sound

Table 8-54 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to non-impulsive underwater sound.

Table 8-54: Impact and risk evaluation for non-impulsive underwater sound

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Underwater sound emissions may result in: • localised and temporary change in ambient underwater sound	5	A localised and temporary change in ambient underwater sound may result in: • change to behaviour in fishes, including sharks and rays	6	2	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine reptiles	6	2	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine mammals	5	2	Moderate (6)
		A localised and temporary change in ambient underwater sound may result in: • mortality or auditory impairment to marine fauna	5	3	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to values and sensitivities of Australian Marine Parks	5	3	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to cultural heritage values: Traditional Owners	5	3	Low (7)

Impact evaluation

Ambient sound

Localised and temporary change in ambient underwater sound

Non-impulsive underwater sound emissions from the Development will locally increase underwater sound levels from ambient levels.

Underwater acoustic recordings between 2006 and 2017 from the NWS found natural physical processes (e.g. wind), anthropogenic (e.g. ships) and biological noise (e.g. whale song) contributed to the soundscape for the region (Ref. 315).

Underwater broadband ambient sound spectrum levels range from 45–60 dB re 1 µPa in quiet regions (light shipping and calm seas) to 80–100 dB re 1 µPa for more typical conditions, and >120 dB re 1 µPa during periods of high winds, rain or 'biological choruses' (many individuals of the same species vocalising near simultaneously in reasonably close proximity to each other) (Ref. 316). Low frequency ambient sound levels (20–500 Hz) are frequently dominated by distant shipping plus some great whale species. Above the 300–400 Hz range weather-related sounds exceed shipping sounds, and wind wave conditions and nearby rainfall dominate the 500–50,000 Hz range (Ref. 316). Soundscape monitoring in the Jansz area undertaken during 2021–2023 (Ref. 659) identified that the dominant sources of sound at low frequencies (<100 Hz) were shipping and baleen whales, and in the mid-frequencies (0.1–1 kHz) was wind.

Impact evaluation

A NWS shipping fairway crosses the proposed G&E to Jansz pipeline and the indicative routes for the G&E, C&D, and Semele umbilicals, and is expected to significantly influence ambient sound levels in this section of the DA (Figure 6-45). A review of ships using the shipping fairway during January 2023 found up to 13 container ships a day passed through the DA (Ref. 317). A study measuring underwater radiated noise from modern commercial ships including container ships, bulk carriers and tanker ships found a 54 kGT container ship had the highest broadband source level at 188 dB re 1 µPa @ 1 m (Ref. 318).

Non-impulsive underwater sound will be generated from multiple sources (Table 8-29) associated with the Development. With the exception of the operation of the subsea hydrocarbon system (wellheads, pipelines, etc.) which remain in situ for the duration of field life, the other non-impulsive sound sources from the Development are only present within the DA for shorter periods (e.g. days to months).

Acoustic modelling of underwater sound levels associated with vessel-based activities for the Development found the largest radii to effect criteria (marine mammal behavioural effect) was ~18.3 km (associated with a pipelay vessel with 2 OSVs) near the continental slope; pipelay activities are estimated to take 3–6 months per field or co-developed field.

Concurrent activities in a single field or across multiple fields may result in the overlapping of ensonified areas to create one larger merged ensonified area (e.g. as predicted for combined scenarios 40, 41A/B, 42 A/B; Section 8.5.3.3.5) or multiple separate ensonified areas (e.g. scenarios 37, 38, 39; Section 8.5.3.3.5). If the distance between concurrent activities are smaller than the sum of the effect radii of the individual activities, then a merged ensonified area would be expected. The type of activity, and distance between the activities, will determine if concurrent activities produce a greater ensonified area (whether merged or separate) compared to individual activities (Section 8.5.3.3.5).

Changes in underwater sound levels from all vessel/MODU-based activities from the Development, whether occurring separately or concurrently will be temporary and the underwater soundscape will return to ambient levels upon completion of activities.

Sound emitted from helicopter operations is typically below 500 Hz (Ref. 319). The peak-received level diminishes with increasing helicopter altitude, but the duration of audibility often increases with increasing altitude. Estimates of SPL for helicopters range 149–162 dB re 1 µPa (Ref. 304; Ref. 320). Richardson et al. (Ref. 304) report that helicopter sound was audible in air for four minutes before it passed over underwater hydrophones, but detectable under water for only 38 seconds at 3 m depth, and 11 seconds at 18 m depth.

Underwater sound emissions associated with ROV use, operation of subsea infrastructure and cutting of subsea infrastructure during decommissioning are minimal compared to other sound sources (Section 8.5.2) and are not considered further.

Taking the above into consideration, the consequence of a localised and temporary change in ambient underwater sound has been assessed as Minor (5).

Risk evaluation

Fishes, including sharks and rays

Sounds that fishes may detect are mostly confined to low frequencies (often no more than 800–1,000 Hz) (Ref. 323). A review of non-impulsive sound sources generated by the Development found the installation, operation, and decommissioning of subsea infrastructure, the operation of MODUs (including drilling), vessels, helicopters, and ROVs, and use of acoustic positioning equipment, will generate sounds within fish hearing frequencies. The loudest non-impulsive sources for the Development will be generated by vessel/MODU based activities, and as such this forms the basis of the following evaluation.

Several fish species have the potential to occur within the DA, including listed threatened and/or migratory species (Section 6.3.3.3). The DA overlaps the following BIAs for fishes, including sharks and rays:

- whale shark BIA (foraging).

The BIA overlap occurs with the part of the DA associated with activities for WTR; the BIA is also adjacent to the C&D to Gorgon pipeline as it traverses the continental shelf (Figure 6-30). Sharks are assessed against the effect criteria for fish with no swim bladder (Table 8-33).

The fish assemblages observed during surveys (Ref. 104; appendix a) indicated that shallower sites were generally characterised by sharks and Carangidae, whereas the deeper sites were

characterised by Carangidae, Macrouridae, Halosauridae and unidentified anguilliform (eel-like) fishes (Section 6.3.3.3). That is, there are fish with and without swim bladders present within the DA. Pelagic fishes accounted for 99% of individuals observed (n = 33,594) (Ref. 104; appendix a). Pelagic fishes are generally considered mobile and/or transient in nature (Ref. 743). Demersal fishes present throughout soft sediment habitats in the DA (Ref. 104; appendix a) are also generally mobile taxa without any site attachment (Ref. 743).

Change to behaviour

A range of behavioural responses have been observed in fishes in the presence of anthropogenic sounds; e.g. changes in swimming behaviour and orientation (including startle reactions), changes in schooling patters and distributions, avoidance of the sound source (Ref. 305). It is also noted that the responses may habituate with repeated presentations of the same sounds (Ref. 305).

Currently, quantitative effect criteria for behavioural responses of fishes from non-impulsive sound do not exist (Ref. 305). Based on qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a moderate to high risk of a behavioural effect in fish (with and without swim bladders), fish eggs, and fish larvae, within the tens to hundreds of metres from the source; this risk reduces to low at thousands of metres from the source.

The southern extent of the DA overlaps with the whale shark foraging BIA. Based on satellite tagging data (2005–2008) whale sharks generally transited south before heading on trajectories towards the north-west (Indian Ocean), north (Indonesia), or north-east (along continental shelf break) after the seasonal aggregation period at Ningaloo. Recent habitat use analysis (based on satellite tagging 2005–2019) demonstrated that the most common movement pathway from away from Ningaloo Reef was north towards pinnacle features and south to Shark Bay (Ref. 695; Section 6.3.3.3.1). These pinnacle features occur to the north-east and north of Montebello Islands and are outside of the DA (see inset of Figure 6-30). The are no geomorphic features within the DA itself that were identified as having an affect on habitat use for whale sharks (Section 6.3.3.3.1). Whale shark migration along the ~200 m bathymetry contour in northern WA occurs mainly between July and November; this migration route is also associated with a foraging BIA (Section 6.3.3.3.1; Figure 6-30).

The part of the DA that intersects with this BIA is associated with the WTR development, and as such a MODU may be present at the WTR DC's for up to ~24 months and vessels undertaking installation and commissioning activities may be in the area for ~12 months. Part of the pipelay activities for the C&D to Gorgon pipeline will also occur adjacent to the whale shark foraging BIA. As described above, the risk of behavioural effects in sharks (i.e. fish with no swim bladder) are limited to within tens to hundreds of metres from the sound source. Therefore, based on the location of the BIA and the spatial extent of Development activities, the presence of whale sharks within this portion of the BIA are not at risk of potential exposure during construction activities for the entire Development. While there is also the potential for presence within the broader DA, given described behaviours and habitat use (Section 6.3.3.3.1), any whale shark presence is expected to be transitory. In addition, given the spatial extent of exposure (i.e. tens to hundreds of metres) the areas of higher use by whale sharks (e.g. outside of the DA over pinnacle features) are not at risk of potential exposure during activities from Development.

The Conservation Advice for whale sharks (Ref. 33) does not identify sound emissions as a threat. Elasmobranchs are known to use electroreception for orientation and navigation, detection of prey, detection of conspecifics, and potential predators (Ref. 784 cited in Ref. 785). It is expected that the potential effects to whale sharks associated with underwater sound will be the same as for other pelagic fish species.

As such, the Development has the potential to cause localised change to behaviour in transient fishes, including sharks and rays, therefore resulting in an Incidental (6) consequence.

The likelihood of the consequence occurring is assessed as Occasional (2).

Overall, the risk of non-impulsive underwater sound resulting in temporary change to behaviour in fishes, including sharks and rays is Low (7).

Note: This risk evaluation is based on the potential for any behavioural response to occur. If it were to focus on a behavioural effect disrupting a particular biologically important behaviour (e.g. foraging), then the likelihood (and resulting risk level) would be lower given the alignment of multiple circumstances (e.g. shark would need to be present and close enough to a vessel to be within the ensonified area, and a food source supply would have to be present, etc.) needed for the risk to eventuate.

Change to behaviour (concurrent activities)

While the Development will be staged so that not all fields will be developed in a single campaign, different phases of the activities may occur concurrently. Concurrent activities introduce the

potential for the occurrence of multiple ensonified areas or larger merged ensonified areas at a single time (Sections 8.5.3.3.5 and 8.5.3.4).

Given the predicted distances for behavioural responses in transient fish to occur (i.e. tens to hundreds of metres from a source), the potential for merged ensonified areas is low except if vessels are in very close proximity; i.e. part of the same activity scope (e.g. a resupply vessel for a MODU or installation vessel) rather than most concurrent activity scenarios (e.g. drilling and pipelay within a single field). As such, this risk has not been evaluated further

The potential for multiple ensonified areas across the DA is considered credible, however given the small effect radii (tens to hundreds of metres from a sources), the existence of multiple small ensonified areas within the DA at any one time is not expected to change the predicted residual risk level as evaluated for individual activities.

Mortality and impairment

Underwater sound can cause mortality or auditory impairment (recoverable injury, TTS, masking) of fishes. PTS does not occur in fish due to hair cells within the ear constantly being added and replaced when damaged (Ref. 305).

Currently, quantitative effect criteria for mortality or auditory impairment to most fishes do not exist (Ref. 305).

Based on the qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a low risk of mortality or potential mortal injury in fish (with and without swim bladders), fish eggs, and fish larvae, within the tens of metres from the source. As such mortality or potential mortal injury to fishes (including sharks) is not considered credible and have not been considered further.

Based on the qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a low risk of recoverable injury to fish with no swim bladder, fish with a swim bladder not involved in hearing, fish eggs, or fish larvae within the tens of metres from the source. As such recoverable injury to these fishes (including sharks) is not considered credible and have not been considered further. For fish with a swim bladder involved in hearing, acoustic modelling against the quantitative effect criteria for recoverable injury indicated that fish within ~30–50 m of the sound source for an extended (48 hour) period may be at risk (Table 8-38).

Based on the qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a moderate risk of TTS onset in fish with no swim bladder (including sharks) and fish with a swim bladder not involved in hearing within tens of metres from the source; this risk reduces to low within hundreds of metres of the source. The risk of TTS in fish eggs and fish larvae is low at all distances (Table 8-33; Ref. 305). For fish with a swim bladder involved in hearing, acoustic modelling against the quantitative effect criteria for TTS onset indicated that fish within ~20–90 m of the sound source for an extended (12 hour) period may be at risk (Table 8-38). While experiencing TTS, fishes may have decreased fitness through impaired communication, prey and predator detection (Ref. 305). However, Popper and Hawkins (Ref. 327) report that fish that showed TTS recovered to normal hearing levels within hours to several days.

Based on the qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a moderate to high risk of masking to fish (with and without swim bladders) at all relative distances from the source; this differs to fish eggs and fish larvae which are considered at high risk within tens of metres, but the risk reduces to low at thousands of metres (Table 8-33; Ref. 305). Continuous sound of any level that is detectable by fish can mask signal detection, and thus may have a pervasive effect on fish behaviour; however, the consequences of this masking and any attendant behavioural changes for the survival of fishes are unknown (Ref. 305).

It is important to note that the modelled non-impulsive vessel sound sources assume the radiating vessel sound is emanating from a single point source, whereas in reality the sound will be emanating from each individual thruster, some of which have significant spatial separation beyond the predicted range of recoverable injury and TTS onset, reflective of the length of the vessels. Accordingly in real world conditions it is considered not credible that the quantitative effect criteria associated with recoverable injury or TTS onset for fishes with swim bladders involved in hearing would be reached.

As described above, transient whale sharks may be present in the DA. Based on the qualitative effect criteria for fish with no swim bladder, there is a low risk of mortality or potential mortal injury or recoverable injury within all relative distances from a sound source; however there is a moderate risk of TTS onset within tens of metres, reducing to a low risk within hundreds of metres of a sound source (Table 8-33; Ref. 305). Given the transient nature of whale sharks, TTS onset from accumulated sound exposure at these close distances is considered unlikely. Given the spatial extent of exposure (i.e. tens of metres) the areas of higher use by whale sharks (e.g. outside of the DA over pinnacle features) are not at risk of potential exposure during activities from Development. As such, only whale sharks transiting through the DA may be exposed to sound emissions from Development activities.

As such, the Development has the potential to cause localised auditory impairments in transient fishes, including sharks and rays, therefore resulting in a Minor (5) consequence.

The likelihood of the consequence occurring is assessed as Seldom (3).

Overall, the risk of non-impulsive underwater sound resulting in an auditory impairments in transient fishes, including sharks and rays is Low (7).

Auditory impairment (concurrent activities)

As described previously, while the Development will be staged so that not all fields will be developed in a single campaign, different phases of the activities may occur concurrently. Concurrent activities introduce the potential for the occurrence of multiple ensonified areas or larger merged ensonified areas occurring at the same time (Sections 8.5.3.3.5 and 8.5.3.4).

Given the predicted distances for masking in transient fish to occur (i.e. tens to thousands of metres from a source), the occurrence of merged or multiple ensonified areas within the DA at any one time is not expected to change the predicted residual risk level as evaluated for individual activities.

Marine reptiles

Sounds that marine reptiles hear are mostly confined to low frequencies (between 50 and 1,500 Hz in water) (Ref. 305). A review of sound sources generated by the Development found that the installation, operation and decommissioning of subsea infrastructure, the operation of MODUs (including drilling), vessels, helicopters and ROVs, and the use of acoustic positioning equipment, will generate sounds at frequencies within marine reptile hearing frequencies. The loudest non-impulsive sources for the Development will be generated by vessel/MODU based activities, and as such this forms the basis of the following evaluation.

Several marine reptile species have the potential to occur within the DA, including listed threatened and/or migratory species (Section 6.3.3.2). Maximum horizontal distances to effect criteria for reptiles for non-impulsive sources (Figure 8-25; Figure 8-26) overlaps the following BIAs and HCTS for marine reptiles:

- flatback turtle BIA (internesting buffer)
- flatback turtle HCTS (internesting buffer).

Whittock et al. (Ref. 146) reported that flatback turtles prefer habitats in proximity to the coast and at relatively shallow depths during internesting periods. The study found the maximum distance from the nearest coast and maximum water depth of 27.8 km and <44 m, respectively, was recorded for an internesting flatback turtle. The mean maximum distance away from the coast and mean water depth observed during the study was less than 6.1 km and <10 m, respectively (Ref. 146). This suggests that although the DA overlaps the extent of both the internesting BIA and HCTS of flatback turtles, due to the distance offshore (at the closest ~50 km from Barrow Island, and ~45 km from Montebello Islands) and water depths within the DA (~100–1,400 m) it would be unlikely that flatback turtles would be undertaking internesting behaviours within the DA. Therefore, based on these observed habitat preferences, any presence of marine turtles within the DA is expected to be transitory in nature only.

As described in Section 6.3.3.2, any presence of marine turtle hatchlings within the DA is also expected to be of a transitory nature due to dispersal via ocean currents. The DA is in water depths of ~100–1,400 m and >45 km from the closest coast, and therefore the active-swimming phase (i.e. during frenzy and early-dispersal) of hatchlings would be over before reaching the DA (and if they reach they DA).

The DA does not overlap any other BIAs or HCTS for marine reptiles (Table 6-12; Table 6-13).

While the threatened short-nosed sea snake was identified within the PMST as potentially being present within the DA, this species is not expected to be present given known habitat preferences for shallow water and reef habitat (Table 6-11; Section 6.3.3.2); underwater sound has also not been identified as a threat for this species (Ref. 27). Other EPBC marine listed sea snake species may occur in broader habitats within the NWMR; however, noise pollution has not been identified as a pressure for sea snake species (Ref. 287). As such, underwater sound is not considered to be a significant factor in sea snake behaviour or survival and therefore risks to these reptiles have not been considered further.

Change to behaviour

The Recovery Plane for Marine Turtles states that marine turtles do not have external ears, but potentially use sound for navigation, locating prey and avoiding predators (Ref. 24). However, at this time there is no evidence that marine turtles have the anatomical structures needed for echolocation (Ref. 737); whereas their use geomagnetic, water movement (including wave direction), or light cues to navigate has been observed (e.g. Ref. 737; Ref. 738; Ref. 719). The Recovery Plan for Marine Turtles in Australia (Ref. 24) identifies noise interference as a key

threat; however also acknowledges that it is not known how marine turtles are affected by sound. Some field evidence suggests that marine turtles avoid impulsive sound, however the source of agitation could not be identified and the avoidance could have been to the vessel and towed equipment themselves (Ref. 305).

Currently, quantitative effect criteria for behavioural responses of marine turtles from non-impulsive sound do not exist (Ref. 305). Based on qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a high risk of a behavioural effect in marine turtles within the tens of metres from the source; this risk reduces to moderate at hundreds of metres, and low at thousands of metres from the source.

Despite overlapping internesting buffer HCTS and BIAs for flatback turtles, the DA does not overlap preferred shallow coastal habitats for internesting adult flatback turtles, and therefore risks of behavioural effects from non-impulsive underwater sound is limited to transient individual marine turtles. Similarly, if hatchlings were present in the DA, they would be moving with ocean currents are not remaining stationary in the vicinity of sound sources.

As such, the Development has the potential to cause localised short-term change to behaviour in transient marine turtles, therefore resulting in an Incidental (6) consequence.

The likelihood of the consequence occurring is assessed as Occasional (2).

Overall, the risk of non-impulsive underwater sound resulting in behavioural effects in marine reptiles is Low (7).

Change to behaviour (concurrent activities)

Concurrent activities introduce the potential for the occurrence of multiple ensonified areas or larger merged ensonified areas occurring at the same time Sections 8.5.3.3.5 and 8.5.3.4).

Given the predicted distances for behavioural responses in transient marine turtles to occur (i.e. tens to hundreds of metres from a source), the potential for merged ensonified areas is low except if vessels are in very close proximity; i.e. part of the same activity scope (e.g. a resupply vessel for a MODU or installation vessel) rather than most concurrent activity scenarios (e.g. drilling and pipelay within a single field). As such, this risk has not been evaluated further.

The potential for multiple ensonified areas across the DA is considered credible, however given the small effect radii (tens to hundreds of metres from a sources), the existence of multiple small ensonified areas within the DA at any one time is not expected to change the predicted residual risk level as evaluated for individual activities.

Mortality and impairment

Underwater sound can cause mortality or auditory impairment (recoverable injury, TTS, PTS, masking) of marine reptiles. Little is known about hearing and the role of sound for marine turtles due to a lack of studies being conducted that examine these physiological effects, and as such establishing guidelines is difficult (Ref. 305). The effect criteria developed for TTS and PTS onset have been developed from audiograms and are theoretical effects (Ref. 314).

Based on the qualitative guidelines from Popper et al. (Table 8-33; Ref. 305) there is a low risk of mortality and potential mortal injury or recoverable injury to marine turtles at all relative distances from the source. As such mortality or potential mortal injury, and recoverable injury to marine turtles is not considered credible and have not been considered further.

Based on the qualitative guidelines, there is a high risk of masking within tens to hundreds of metres from the sound source (Table 8-33; Ref. 305). Continuous sound of any level that is detectable by a marine turtle can mask signal detection, and thus may have a pervasive effect on behaviour; however, the consequences of this masking and any attendant behavioural changes for the survival of marine turtles are unknown (Ref. 305).

Results from acoustic modelling against the quantitative NMFS 2018 effect criteria for TTS and PTS onset indicated that the maximum distance to effect criteria for marine turtles was ~50–180 m and <20–140 m respectively (Table 8-39). Based on application of a scaling factor (see discussion in Section 8.5.3.2.1), the estimated indicative range to NMFS 2024 effect criteria for TTS and AUD-INJ onset effect criteria are ~0.35–1.8 km and ~0.07–1.4 km respectively. The increase in distance to reach the revised effect criteria primarily result from the ~22 dB decrease between NMFS 2018 and NMFS 2024 effect criteria.

Note that the SEL_{24h} effect criteria is a cumulative metric that requires a receptor to be consistently exposed to sound at the relevant effect criteria for a 24-hour period before the associated auditory impairment (TTS or PTS) may occur. However, the onset of these TTS and PTS (or AUD-INJ) effects may also be reached by shorter durations of exposure at higher sound levels. If marine turtles are present within or adjacent to the DA, based on habitat preferences they are expected to be transiting through the area. Further, adult marine turtles would likely exhibit a behavioural response (e.g. avoidance) within tens to hundreds of metres of the sound source (Ref. 305), and any hatchlings would be continually moving with ocean currents, therefore

reducing the risk of auditory effects from cumulative exposure at small distances from the sound source.

The consequence associated with localised masking effects, or the potential for accumulated exposure causing auditory impairment (TTS) or injury (AUD-INJ including PTS), as a result of non-impulsive underwater sound has been determined to be Minor (5).

The likelihood of the consequence occurring is assessed as Seldom (3).

Overall, the risk of non-impulsive underwater sound resulting in auditory impairment or injury effects in transient marine turtles is Low (7).

Auditory impairment (concurrent activities)

As described previously, concurrent activities introduce the potential for the occurrence of multiple ensonified areas or larger merged ensonified areas occurring at the same time (Sections 8.5.3.3.5 and 8.5.3.4).

Given the predicted distances for auditory impairment or injury in marine turtles to occur (i.e. tens to thousands of metres from a source), and if they are present the transient behaviour of turtles within the vicinity of the DA, the occurrence of merged or multiple small ensonified areas within the DA at any one time is not expected to change the predicted residual risk level as evaluated for individual activities.

Marine mammals

Review of sound sources generated by the Development found all non-impulsive sound sources (Table 8-29) will generate sounds at frequencies within marine mammal hearing frequencies. The loudest non-impulsive sources for the Development will be generated by vessel/MODU based activities, and as such this forms the basis of the following evaluation.

Several marine mammal species have the potential to occur within the DA, including listed threatened and/or migratory species (Section 6.3.3.1). Maximum horizontal distances to effect criteria for marine mammals for non-impulsive sources (Figure 8-27) intersect with the following BIAs for marine mammals:

- humpback whale BIA (migration [north and south])
- pygmy blue whale BIA (migration).

Sound emissions associated with the Development that has the potential to extend into the humpback whale migration BIA would primarily occur from activities associated with WTR and the C&D to Gorgon pipeline as it traverses the continental shelf. Whereas sound emissions from activities associated with all fields has the potential to extend into the pygmy blue whale BIA.

Humpback and pygmy blue whales are known to be present within the general region of the DA during their respective migration periods:

- humpback whales—presence within the Jansz region has been recorded from July to October (Ref. 123; Ref. 659; Table 6-18) encompassing both their northern and southern migrations
- pygmy blue whales—presence within the Jansz region has been recorded from late-March to mid-September (peak late-May to June) during northern migration, and during early-October to late-January (peak late-November and early-December) for the southern migration (Ref. 644; Table 6-18).

‘Possible Foraging Areas’ as defined within the Conservation Management Plan for the Blue Whale (Ref. 20), and characterised as foraging BIAs, occur ~172 km south-west and ~877 km north-east of the DA. Thums et al. (Ref. 135) identified ‘most important areas’ for foraging for the pygmy blue whale based on proxy indicators. The DA does not intersect with any of these ‘most important areas’ for foraging (Figure 6-17), however there is some overlap between these areas and the maximum horizontal distance to behavioural effect criteria (when conservatively applied as a buffer around the DA) (Figure 8-27).

Based on PMST searches (appendix b), no biologically important areas or associated behaviours were identified for high or very high frequency cetaceans within DA (Table 6-8; Table 6-10). Therefore, if present in the DA, high and very high frequency cetaceans are expected to be transiting through the area.

Change to behaviour

Behavioural changes to marine mammals from underwater sound may include alterations of dive patterns, swim speeds, swim orientation, group cohesiveness, and changes in acoustic behaviour (Ref. 330). In some contexts (e.g. to loud sounds), behavioural responses represent avoidance strategies and an increase in energy expenditure for humpback whales (Ref. 330). Goldbogen et al. (Ref. 333) found blue whales changed orientation and horizontal displacement when exposed to mid-frequency sonar sound. Southall et al. (Ref. 334) also found baleen whales showed

directional avoidance of a stationary sonar sound source and were more likely to do this if there was not a concentrated food source present. Minke whales (a low frequency cetacean) are expected to display avoidance behaviours such as changing swimming direction and speed away from acoustic deterrent sources (Ref. 348).

The acoustic modelling predictions found the maximum horizontal distance (R_{max}) to behavioural effect criteria for all cetacean functional hearing groups was 1.74–18.3 km (Table 8-40); the smaller ensonified areas are associated with the single IMR vessel scenario, while the largest ensonified areas are associated with construction vessels (either pipelay or subsea installation). Some variation in predicted ensonified areas was also evident across fields, likely reflective of the different water depths and seafloor geomorphology (e.g. continental slope and shelf) (Section 8.5.3.3.3).

Humpback whales

To determine the largest intersect between a single predicted ensonified area and the humpback whale migration BIA, the largest R_{max} to behavioural effect criteria from Area 5 (17.3 km) was applied to the Gorgon field indicative tie-in location (i.e. closest activity location to the BIA). This ensonified area extends ~15 km into the humpback whale migration BIA. The width of the BIA at this location is ~117 km, and so this ensonified area represents ~13% of the BIA width.

However, the energetic cost of avoiding a sound source associated with the Development (e.g. tens of kilometres) is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) of humpback whales migrating between Antarctic and Kimberley waters (Section 6.3.3.1.1). Therefore, this level of behavioural avoidance within the humpback whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales.

Pygmy blue whales (migration)

To determine the largest intersect between a single predicted ensonified area and the pygmy blue whale migration BIA, the largest R_{max} to behavioural effect criteria from Area 4 (18.3 km) was applied, and assumed to wholly be within the BIA. Therefore, the ensonified area would intersect ~36.6 km of the pygmy blue whale migration BIA. The width of the pygmy blue whale BIA varies; based on a width range of ~95.2–135.3 km, this ensonified area represents ~27–38% of the BIA width. The energetic cost of avoiding the source associated with the Development (e.g. tens of kilometres) is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) of pygmy blue whales migrating between Southern Ocean and Indonesian waters (Section 6.3.3.1.2). Therefore, this level of behavioural avoidance within the pygmy blue whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales.

A more realistic prediction of non-impulsive underwater water sound exposures for migrating pygmy blue whales was undertaken using 'animat modelling' for selected model scenarios (Section 8.5.3.3.4; Ref. 297). For the modelled scenarios, the maximum exposure range ($ER_{95\%}$) to reach the behavioural effect criteria for marine mammals reduced by ~21–77% compared to R_{max} distances from acoustic modelling (Table 8-44). Using the same example as above for comparison, by reducing the largest R_{max} (18.3 km) by ~21–77% (i.e. down to ~8–29 km), this would then represent ~7–26% of the width of the migration BIA. This reduced deviation further supports that behavioural avoidance within the pygmy blue whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales.

However, as described in Section 6.3.3.1.2 studies based on tagged or passive acoustic monitoring (e.g. Ref. 128; Ref. 129; Ref. 644) have observed that the migratory corridor for pygmy blue whales is broader than the defined BIA. This particularly occurs for the southern migration where pygmy blue whales have been detected in further offshore waters (e.g. ~260–400 km; Ref. 129; Ref. 644) and appear to utilise more than the BIA. In the Jansz region, McCauley et al. (Ref. 644) have demonstrated two distinct focal routes during the northern migration, one just west of the continental shelf edge and one ~260 km from the mainland; i.e. through the shallower parts of the DA and then further offshore of the DA (Figure 6-16). The focal route to the west of the Jansz is similar to that previously described by Double et al. (Ref. 128) for pygmy blue whales migrating northward from North West Cape. The presence of migratory whales has also been observed to vary temporally and spatially each year (Ref. 644; Ref. 659). Therefore, while predicted ensonified areas may take up a proportion of the designated migration BIA, the actual migration routes used by pygmy blue whales occur over a broader area and thus any proportion of a migration corridor would actually be lower.

Pygmy blue whales (foraging during migrations)

As described in Conservation Management Plan (Ref. 20), Foraging Areas for blue whales are generally associated with areas of high primary productivity that can support sufficient densities of krill, such as oceanographic upwelling or frontal systems. There are no defined 'Foraging Areas' or 'Known Foraging Areas' within north-west WA. The closest of these types of areas to the DA

are described as 'Possible Foraging Areas' (Ref. 20) and are ~172 km south-west (around Ningaloo/North West Cape) and ~877 km north-east (around Scott Reef) of the DA.

Pygmy blue whales have been observed to exhibit traits of a mixed capital-income breeding strategy, utilising both known foraging areas and intermittent/opportunistic foraging (Ref. 643). Habitat suitability analyses describes the north-west of WA (extending offshore from the continental shelf) as suitable foraging habitat; however notes that the suitability of habitat is related to dynamic and localised oceanic processes that may occur at different temporal scales (Ref. 505; Section 6.3.3.1.2). Further, Thums et al. (Ref. 135) identified 'most important areas' for foraging for the pygmy blue whale based on proxy indicators. There is some overlap between these 'most important areas' for foraging and the maximum horizontal distance (as conservatively applied as a buffer to the entire DA) to behavioural effects (Figure 8-27). The use of these 'most important areas' is not expected to be continual throughout the year but associated with pygmy blue whale presence during migration periods. . Furthermore, opportunistic foraging areas are known to be dynamic given their dependence on presence of prey (Ref. 135; Ref. 349). Tagging studies suggest a reliance on more ephemeral prey in north-west Australia compared to south-west Australia where whales have high residency (Ref. 643).

A review by UWA demonstrated that there were no oceanographic features (including bathymetry, currents and eddies, chlorophyll concentrations) within the Jansz area that may lead to higher primary productivity and/or an increased likelihood of pygmy blue whale foraging in the area (Ref. 651; Section 6.3.3.1.2). Sonar surveys to determine the presence of sufficient biomass of prey to support foraging pygmy blue whales were undertaken by CMST (Ref. 653). This study indicated that the Jansz area may be able to support opportunistic feeding in surface waters (<100 m water depth) for short durations (hours); however, in comparison to known prey aggregations observed at Perth Canyon, the biomass observed at the Jansz area is unlikely to represent a consistent and reliable feeding area (Ref. 653). Therefore, the DA and surrounding area is not considered to represent a Foraging Area, but may provide opportunistic foraging if the environmental conditions provide for the aggregation of prey at sufficient quantities at the time a pygmy blue migrates through the area. This is consistent with studies of tagged pygmy blue whales that demonstrated more opportunistic foraging in north-west Australia, compared to southern areas (e.g. Perth Canyon, Ningaloo) (Ref. 643).

While decreases in body condition have been observed in pygmy blue whales between one northern and southern migration season based on image analysis from Perth Canyon (northern migration 2021, 2022) and Geographe Bay (southern migration 2022), it is unknown if this represents natural variability (e.g. within-season variation in body condition as seen in other baleen whale species) or was due to environmental or anthropogenic stresses at breeding/feeding grounds or along their migratory route (Ref. 755).

Therefore, while areas of the migration BIA may be ensonified above behavioural effect criteria by Development activities, for this to interrupt opportunistic foraging also requires the presence of prey to coincide with the transit of a migrating whale. The energetic cost of disturbing an opportunistic feeding event for a pygmy blue whale within or adjacent to the DA is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) and therefore the scale of potential opportunistic foraging between Southern Ocean and Indonesian waters.

Other cetaceans

No BIAs for migration (or other biologically important behaviours) have been identified for other cetaceans within the vicinity of the DA, and as such it is expected that if they transit through the area they would also be able to avoid non-impulsive sound sources at comparatively little energetic cost to greater migratory or transit movements relevant to respective species.

Risk level evaluation

As outlined above, the DA intersects the pygmy blue whale and humpback whale migration BIAs. However, the presence of these and other cetaceans are expected to seasonal and transitory in nature. The Development has the potential to cause a change to behaviour in marine mammals within ~1.74–18.3 km of non-impulsive vessel/MODU based sound sources. The energetic cost of avoiding non-impulsive source is likely to be small in the context of the greater migratory movements of all cetacean species.

There are no geomorphic or oceanographic features within or adjacent to the DA that are generally associated with the areas of high primary productivity that can support the prey biomass requirements of blue whales. However, like most open ocean areas, the DA may present opportunities for foraging should ephemeral prey be present in sufficient quantities. However, the energetic cost of disturbing an opportunistic feeding event for a pygmy blue whale within or adjacent to the DA is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) and therefore the scale of potential opportunistic foraging between Southern Ocean and Indonesian waters.

The consequence associated with localised behavioural change as a result of non-impulsive underwater sound has been determined to be Minor (5).

The likelihood of the consequence occurring is assessed as Occasional (2).

Overall, the risk of a change to behaviour in marine mammals from non-impulsive underwater sound is Moderate (6).

However, it is noted that this risk evaluation is based on the potential for any behavioural response to occur. If it were to focus on a behavioural effect causing a reduction in fitness, or a behavioural effect disrupting foraging, then the likelihood (and resulting risk level) would be lower given the alignment of multiple circumstances (e.g. cetacean would need to be present and close enough to a vessel to be within the ensonified area, and a food source supply would have to be present, etc.) needed for the risk to eventuate.

Change to behaviour (concurrent activities)

While the Development will be staged so that not all fields will be developed in a single campaign, different phases of the activities may occur concurrently (Section 4.1.4). The acoustic modelling considered the aggregate contribution of sound emissions from combined concurrent activity scenarios during the Development (Sections 8.5.3.3.5 and 8.5.3.4). Results of the combined scenarios found ensonified areas will not merge if distances between concurrent activities are larger than the sum of the effect radii of the individual activities; and conversely, if activities are within close proximity of each other than a larger merged ensonified area may occur.

Concurrent Development activities will ensonify a greater area of the pygmy blue whale BIA than the humpback whale BIA, and as such this forms the basis of the following evaluation.

As the sequencing of the field developments is not known, a range of potential scenarios were described in Section 8.5.3.4 and these showed that the resulting ensonified area above the marine mammal behavioural effect criteria may vary from ~23–50% (or ~19–59% based on the narrower and broader sections) of the width of the migration BIA for the pygmy blue whale (Table 8-45). However, as described above, the actual migration corridor utilised by pygmy blue whales is broader that the designated BIA (during both northern and southern migrations) and as such the proportion of migratory corridor exposed to sound above the effect criteria would be lower. For the same range of potential scenarios, the estimated duration a pygmy blue whale may be exposed to sounds above the behavioural effect criteria ranged ~6–28 hours during northern migration, or ~3–17 hours during southern migration (Table 8-45). Therefore, underwater sound associated with the Development may result in migrating pygmy blue whales to make some spatial deviations within the migration BIA, however the energetic cost of these deviations (e.g. tens of kilometres) is likely small in the context of the greater migratory movements (e.g. thousands of kilometres). Further, there is no evidence to indicate that sound levels below the behavioural effect criteria would elicit a behavioural response from marine mammals. As such, for the case of multiple ensonified areas, it would be expected that a marine mammal would be able to travel between these areas without disturbance.

Depending on the particular combination of activities, there may be some overlap between the ‘most important areas’ for foraging and the predicted ensonified area above behavioural effect criteria. However, as described above, the use of these areas is not expected to be continual throughout the year but associated with pygmy blue whale migration. Foraging in the vicinity of the Jansz area is opportunistic and dependent on the presence of prey in sufficient quantities. There are no geomorphic or oceanographic features present in the Jansz area that would provide for a consistent and reliable food source. Therefore, the energetic cost of disturbing an opportunistic feeding event for a pygmy blue whale within or adjacent to the DA is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) and therefore the scale of potential opportunistic foraging events between Southern Ocean and Indonesian waters.

Construction for different stages of the Development may occur over a period of years (either sequentially or with gaps between development stages depending on gas supply strategy requirements at the time). However, as described above the potential deviations required around ensonified areas and/or the potential disturbance of an opportunistic feed event, are unlikely to have high energetic costs to pygmy blue whales. The ensonified areas are also not static; i.e. depending on what activities are occurring each year, different parts of the DA and adjacent areas may be exposed to sound. Similarly, opportunistic foraging areas are known to be dynamic given their dependence on presence of prey.

The occurrence of multiple temporary ensonified areas or single merged ensonified areas at any one time from concurrent Development activities is not expected to change the predicted residual risk level as evaluated for individual activities.

Auditory impairment

Underwater sound can cause auditory impairment (TTS, PTS, masking) of marine mammals. TTS is completely recoverable, with 24 hours thought to be sufficient for recovery to occur (Ref. 307; Ref. 306). However, for pygmy blue whales guidance from the Australian Government has defined TTS and PTS as an injury (Ref. 353).

The term auditory injury (AUD INJ) has been incorporated into the updated effect criteria (see Section 8.5.3.2.1). AUD INJ is considered damage to the inner ear that can result in destruction of tissue, such as the loss of cochlear neuron synapses or auditory neuropathy (Ref. 350; Ref. 351; Ref. 352). AUD INJ may or may not result in PTS. Refer to Section 8.5.3.2.1 for a discussion on the potential effect of the changes in effect criteria.

Auditory masking may occur when there is a reduction in audibility for one sound (signal) caused by the presence of another sound (noise), impeding the ability of an animal to perceive a signal (Ref. 335, Ref. 336). For this to occur, the noise must be loud enough and have a similar frequency to the signal, and both signal and noise must occur at the same time. 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 (Ref. 337, Ref. 338, Ref. 339, Ref. 340). Currently, there are no specific received level thresholds for reliably assessing or regulating masking responses to underwater sound (Ref. 341). A study undertaken by Clark et al (Ref. 342), considers the potential for masking and communication impacts is classified as high near the vessel (within tens of metres), moderate within hundreds of metres, and low within thousands of metres (Ref. 342). Some cetaceans might respond acoustically to underwater sound in a range of ways, including by increasing the amplitude of their calls (Lombard effect), changing their spectral (frequency content) or temporal vocalisation properties, and in some cases, cease vocalising (Ref. 343, Ref. 344, Ref. 345, Ref. 346, Ref. 347). Given the relatively small predicted ensonified area for masking effects (i.e. tens to hundreds of metres from a source), and the mobile nature of cetacean species, it is considered highly unlikely underwater sound associated with the Development will result in auditory masking.

Acoustic modelling predicted that the maximum horizontal distance (R_{max}) to the PTS onset effect criteria for low, high, and very high frequence cetaceans was up to ~0.21 km, ~0.15 km, and ~0.21 km respectively (Table 8-40; Table 8-41; Table 8-42). Indicative ranges to NMFS 2024 AUD-INJ onset effect criteria were up to ~0.27 km, ~0.39 km, and ~0.12 m for low, high, and very high frequency cetacean hearing groups respectively. Note that the SEL_{24h} effect criteria is a cumulative metric that requires a receptor to be consistently exposed to sound at the relevant effect criteria for a 24-hour period before the auditory impairment may occur. However, the onset of PTS (or AUD-INJ) effects may also be reached by shorter durations of exposure at higher sound levels. Given that cetaceans (if present) are expected to be transitory through the area the risk of accumulated sound exposure at those close distances for PTS onset to occur is considered unlikely. Further, for the modelled scenarios where animat modelling was undertaken (Section 8.5.3.3.4), these showed that the effect criteria for PTS onset in low frequency cetaceans was not reached.

Acoustic modelling predicted that the maximum horizontal distance (R_{max}) to the TTS onset effect criteria for low, high, and very high frequency cetaceans was up to ~4.58 km, ~0.19 km, and ~3.33 km respectively (Table 8-40; Table 8-41; Table 8-42). Indicative ranges to NMFS 2024 TTS onset effect criteria were up to ~5.95 km, ~0.46 km, and ~1.83 km for low, high, and very high frequency cetacean hearing groups respectively. For the modelled scenarios where animat modelling was undertaken (Section 8.5.3.3.4), these showed that the predicted maximum exposure ranges for TTS onset in low frequency cetaceans substantially reduced (predicted maximum horizontal distances up to ~0.04 km (or indicative range of up to ~0.05 km).

However, for risk assessment purposes, an estimate of potential exposure time to a migrating pygmy blue whale (i.e. a low frequency whale) to an ensonified area based on acoustic modelling is presented. Travel speed for pygmy blue whales during migration was estimated by Thums et al (Ref. 135), as ~2.4 km/h during northern migration, and ~4.0–5.0 km/h during southern migration. Based on a R_{max} of ~4.58 km (i.e. total diameter of ensonification at ~9.2 km), the duration a migrating pygmy blue whale is expected to remain in the ensonified area would be ~1.8–3.8 hours, i.e. substantially less than the 24 hours exposure at this received sound level required for TTS onset to occur. However, the onset of TTS effects may also be reached by shorter durations of exposure at higher received sound levels. As all cetaceans are expected to be transient within the vicinity of the DA, the accumulated sound exposure required for TTS onset to occur is considered unlikely.

The maximum horizontal distance also assumes that the non-impulsive sound sources (typically vessel or MODU DP thrusters) will be operating consistently at the source levels described within Section 8.5.3.1.1. In reality DP thrusters are highly dynamic in response to varying metocean conditions; accordingly, it is highly unlikely the source levels will be constant at the specific source

levels modelled over a 24 hour period. Further, the source levels adopted within this risk evaluation are considered highly conservative (particularly for the drillship and pipelay vessel; Section 8.5.3.1.1). It is also important to note that the modelled source values assume the radiating vessel/MODU sound is emanating from a single point source, whereas in reality the sound will be emanating from each individual thruster, some of which have significant spatial separation beyond most of the ranges of PTS or TTS predicted, reflective of the length of the vessels. In addition, given that behavioural responses for cetaceans are predicted at distances much larger than those for auditory impairments or injury, and that it is unlikely that cetaceans will remain within the immediate proximity of a non-impulsive sound source for extended durations, the risk of TTS or PTS onset is further reduced.

The consequence associated with localised masking effects, or the potential for accumulated sound exposure causing auditory impairment (TTS) or injury (AUD-INJ including PTS), as a result of non-impulsive underwater sound has been determined to be Minor (5).

The likelihood of the consequence occurring is assessed as Seldom (3).

Overall, the risk of non-impulsive underwater sound resulting in auditory impairment or injury effects in transient marine mammals is Low (7).

Auditory impairment (concurrent activities)

As described previously, while the Development will be staged so that not all fields will be developed in a single campaign, different phases of the activities may occur concurrently. Concurrent activities introduce the potential for the occurrence of multiple ensonified areas or larger merged ensonified areas occurring at the same time (Sections 8.5.3.3.5 and 8.5.3.4).

Based on a similar assessment of travel speed for pygmy blue whales and accumulated sound exposure above the TTS onset criterion, estimates of potential duration of exposure for indicative concurrent activities were determined as ~2–7 hours (Table 8-46); i.e. all substantially less than the 24 hours exposure required for TTS onset to occur at that SEL_{24h} received sound level. Like pygmy blue whales, other low, high and very high frequency cetaceans are expected to be transient within the vicinity of the DA, and therefore the accumulated exposure time for all hearing groups above TTS effect criteria is expected to be below the 24 hours.

Given the predicted distances for TTS onset in cetaceans to occur, and the mobile and transient nature of presence within the vicinity of the DA, the occurrence of merged or multiple ensonified areas at any one time is not expected to change the predicted residual risk level as evaluated for individual activities.

AMPs

Change to values and sensitivities

The potential ensonified area at or above the behavioural effect criterion for marine mammals from the Development extends into the boundaries of the Commonwealth Montebello Marine Park (Figure 8-28). No other AMPs are within the predicted potential extents of ensonified areas for marine fauna and their respective noise effect criteria.

The Montebello Marine Park is zoned as a Multiple Use Zone (IUCN VI), which is a zone “managed to allow ecologically sustainable use while conserving ecosystems, habitats and native species. The zone allows for a range of sustainable uses, including commercial fishing and mining where they are consistent with park values” (Ref. 82). The natural values of this AMP include the presence of species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for protected marine fauna.

Potential impacts to the values of the Montebello Marine Park may occur due to potential impacts on marine mammals. The risk evaluations to these receptors are provided above, and the consequence of behavioural response of marine mammals was assessed as Minor (5). It is therefore expected that there would also be no long-term or significant impacts to the values of the Montebello Marine Park.

CAPL consider that the Development can be undertaken in a manner that is not inconsistent with the objectives of the North-west Marine Parks Network Management Plan (Ref. 82).

As such, CAPL has ranked the risk for AMPs: consequence as Minor (5), likelihood as Seldom (3), and residual risk as Low (7).

Cultural heritage value: Traditional Owners

Change to cultural heritage values

Potential changes to cultural heritage values from underwater sound includes indirect impacts to intangible Traditional Owner cultural heritage from a change to behaviour in marine fauna.

Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1).

Intangible cultural heritage refers to the "practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage" (Ref. 354). Specific intangible values of Sea Country identified through consultation on other CAPL activities included Dreamtime stories and songlines. In particular, stakeholders have previously identified the existence of songlines that go through Barrow Island and offshore.

No impact pathway to a change in access to Country from the emission of non-impulsive underwater sound is anticipated. The consequence evaluations for marine fauna are provided above and were assessed as having a localised and minor environmental impact and is not expected to affect the overall population of the species. Further, as described in the above evaluations, most sources of non-impulsive underwater sound emissions within the DA are temporary and are not expected to affect the long-term underwater soundscape of the marine environment. The longer-term source of sound from the operation of the subsea hydrocarbon system is expected to be limited to within the immediate vicinity (e.g. tens to hundreds of metres) of the subsea infrastructure. As such, it is anticipated that intangible heritage values such as songlines and connection to Country would not be significantly adversely affected from non-impulsive underwater sound emissions from within the DA. Given the offshore location of the DA and predominantly temporary nature of the activities, a significant adverse change to cultural heritage values attributed to the offshore marine area from non-impulsive underwater sound emissions is not predicted to occur.

The highest consequence level was Minor (5) for a change in behaviour in marine mammals, as such, the consequence of changes to cultural heritage values from underwater sound is also evaluated as Minor (5).

As such, CAPL has ranked the risk to intangible Traditional Owner cultural heritage values: consequence as Minor (5), likelihood as Seldom (3), and residual risk as Low (7)

8.5.5.2 impulsive sound

Table 8-55 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to underwater sound in the sound area.

Table 8-55: Impact and risk evaluation for impulsive underwater sound

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Underwater sound emissions may result in: • localised and temporary change in ambient underwater sound	6	A localised and temporary change in ambient underwater sound may result in: • change to behaviour in benthic invertebrates	6	5	Very Low (10)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in fishes, including sharks and rays	6	4	Very Low (9)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine reptiles	6	4	Very Low (9)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine mammals	6	4	Very Low (9)

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
		A localised and temporary change in ambient underwater sound may result in: • mortality or auditory impairment to marine fauna	6	5	Very Low (10)
		A localised and temporary change in ambient underwater sound may result in: • change to cultural heritage values: Traditional Owners	6	4	Very Low (9)

Impact evaluation

Ambient sound

Localised and temporary change in ambient underwater sound

Impulsive underwater sound emissions from the Development will locally and temporarily increase underwater sound levels from ambient levels. Impulsive sound sources from the Development includes VSP (up to 24 hours per well, where VSP is selected for well evaluation purposes) and use of SBP during geophysical surveys (may take ~3–4 weeks per survey).

VSP is a low frequency impulsive sound source and the most intensive impulsive sound source associated with the Development. Acoustic modelling of VSP determined that distances to most effect criteria were small (e.g. metres to hundreds of metres); however, the largest radii to effect criteria (marine mammal behavioural effect criteria) was 1.33–2.37 km from the source (Section 8.5.4.2).

SBPs are a moderate to high frequency impulsive sound source. These frequency sounds typically attenuate more rapidly in water than low frequency sounds. Acoustic modelling determined that the distances to most effect criteria were small (e.g. metres to hundreds of metres); however, depending on the equipment type and power the exposure above effect criteria for very high frequency cetaceans may extend kilometres from the source (Section 8.5.4.3).

The consequence of causing a change in ambient underwater sound from impulsive sound sources has been assessed as Incidental (6) as it will result in localised and short-term (days to weeks) impacts and will return to ambient levels upon completion of work.

Risk evaluation

Benthic invertebrates

Change to behaviour

At the seafloor interface, benthic invertebrates (crustaceans and bivalves) 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 (Ref. 550).

A review of sound sources generated by the Development found VSP and geophysical SBP has the potential to acoustically induce particle motion stimuli for benthic invertebrates.

A spreading loss model was used to calculate estimates of sound propagation from geophysical SBP equipment. The model indicated PK-PK noise effect criteria for benthic invertebrates may be exceeded but only within very close proximity to the sound source; given the general positioning of equipment (e.g. hull mounted from vessel, or several tens of metres from the seafloor on ROV/AUVs) it is unlikely that PK-PK effect criteria would be exceeded at the seafloor (Ref. 550).

Acoustic modelling indicated that PK-$PK_{seafloor}$ level of 202 dB re 1 µPa PK-PK, which is associated with no effect to benthic invertebrates (crustaceans), was reached at ~60.8 m from the VSP array only at Site A (shallow waters) (Ref. 297). The no-effect criteria was not reached at either of the two deeper water sites that were modelled.

Based on searches of the EPBC Act protected matters database (Ref. 122; appendix b) no EPBC listed benthic invertebrate or any TECs was identified within the DA. As described in

Risk evaluation
Section 6.3.1.1, the benthic habitat surveys indicate the DA is predominantly characterised by bare sediment with no biota (Ref. 104; appendix a). The only site with very low (1% total cover) biota (cnidarians) presence was at Gorgon M1, an indicative tie-in location (Ref. 104; appendix a). This site is >20 km from the nearest indicative DCs and as such is not at risk of ensonification from VSP activities. Given the lack of biotic coverage within the DA, and the limited spatial and temporal exposures impulsive sound sources, the consequence associated with this aspect has been determined to be Incidental (6). The likelihood of the consequence occurring is assessed as Remote (5) noting benthic invertebrates were generally not observed within the DA during benthic habitat surveys. Overall, the risk of impulsive underwater sound resulting in a change to behaviour in benthic invertebrates is Very Low (10). **Auditory impairment** Acoustic modelling indicated that PK-PK$_{seafloor}$ levels of 209–212 dB re 1 µPa and 213 dB re 1 µPa, which are associated with impairment in benthic invertebrates (crustaceans and molluscs), were not reached at any of the modelled site (Ref. 297). As such, the risk of impairment in benthic invertebrates from the VSP array is not considered credible, and no further evaluation has been undertaken.
Fishes, including sharks and rays
Impulsive underwater sound sources associated with the Development that are audible to fishes include VSP and SPB geophysical survey techniques. Both impulsive sound sources are of short durations: VSP (up to 24 hours each well) and SBP (moving source over ~3–4 weeks per survey). Several fish species have the potential to occur within the DA, including listed threatened and/or migratory species (Section 6.3.3.3). A foraging BIA for whale sharks was also identified to intersect with the DA. The fish assemblages observed during surveys (Ref. 104; appendix a) indicated that shallower sites were generally characterised by sharks and Carangidae, whereas the deeper sites were characterised by Carangidae, Macrouridae, Halosauridae and unidentified anguilliform (eel-like) fishes (Section 6.3.3.3). That is, there are fish with and without swim bladders present within the DA. Pelagic fishes accounted for 99% of individuals observed (n = 33,594) (Ref. 104; appendix a). Pelagic fishes are generally considered mobile and/or transient in nature (Ref. 743). Demersal fishes present throughout soft sediment habitats in the DA (Ref. 104; appendix a) are also generally mobile taxa without any site attachment (Ref. 743). **Change to behaviour** Currently, quantitative threshold criteria for behavioural responses of fishes (and fish larvae) from impulsive sound do not exist (Ref. 305). Based on qualitative guidelines for seismic sources from Popper et al. (Table 8-48; Ref. 305) there is a high risk of a behavioural effect in fish (with and without swim bladders) within tens of metres of a VSP source, and moderate risk for fish eggs and fish larvae. Similarly, the assessment of indicative SBP geophysical equipment determined that these types of sound sources could result in physiological impacts to fish located within metres of the sources (Section 8.5.4.3; Ref. 550). Whale shark migration along the ~200 m bathymetry contour in northern WA occurs mainly between July and November; this migration route is associated with a foraging BIA (Section 6.3.3.3.1). The intersect with the BIA occurs within the shallower water depths of the DA associated with activities for WTR; the BIA is also adjacent to the C&D to Gorgon pipeline as it traverses the continental shelf (Figure 6-30). However, as described in Section 6.3.3.3.1, the most common movement pathway from away from Ningaloo Reef was north towards pinnacle features and south to Shark Bay (Ref. 695; Section 6.3.3.3.1). These pinnacle features occur to the north-east and north of Montebello Islands and are outside of the DA (see inset of Figure 6-30). The are no geomorphic features within the DA itself that were identified as having an effect on habitat use for whale sharks (Section 6.3.3.3.1). The Conservation Advice for whale sharks (Ref. 33) does not identify sound emissions as a threat. Elasmobranchs are known to use electroreception for orientation and navigation, detection of prey, detection of conspecifics, and potential predators (Ref. 753 cited in Ref. 754). As such, it is expected that the potential effects to whale sharks associated with underwater sound will be the same as for other pelagic fish species. If transient pelagic or demersal fish species are within the DA, and within tens of metres of an impulsive sound source, it is expected that any impacts would be limited to temporary behavioural responses such as startle response or avoidance behaviour (Ref. 323; Ref. 324; Ref. 322).

Risk evaluation
Larval fishes behavioural responses are expected to be limited to minor changes in swimming patterns or have little or no effect (Ref. 325; Ref. 326). Applying the effect criteria for fish eggs and fish larvae, more broadly to plankton in general, would expect similar limited behavioural effects within the near (tens of metres) of an impulsive sound source. Any effects to plankton have to be assessed in the context of natural mortality rates, which are generally considered high and variable. Plankton also have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (Ref. 102). Short (e.g. up to 24 hours for VSP, or a moving geophysical source for up to ~3–4 weeks) and temporary impulsive sound emissions on plankton populations are unlikely to cause a significant change in behaviour at a measurable level. As such, the Development has the potential to cause temporary change to behaviour in transient fishes, including whale sharks, and more broadly to plankton within tens of metres of an impulsive sound source, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Unlikely (4). Overall, the risk of impulsive sound resulting in a change to behaviour in fishes, including sharks and rays, is Very Low (9).
Mortality and auditory impairment
Acoustic modelling indicated that maximum-over-depth PK effect criteria for fish were not reached within the modelling resolution (20 m; Ref. 297). Sound levels for $PK_{seafloor}$ effect criteria for fish were also not reached (Ref. 297). As such the discussion below is based on accumulated SEL_{24h} effect criteria only. Acoustic modelling indicated that the effect criteria for mortality and potential mortal injury, and recoverable injury, were not reached for fish with no swim bladders (Table 8-51; Ref. 297). These criteria are also applicable to whale sharks (i.e. no risk of mortality or recoverable injury is predicted for whale sharks). Acoustic modelling indicated that the R_{max} from VSP to mortality and potential mortal injury effect criteria for fish with swim bladders, and fish eggs and fish larvae was up to 0.03 km (Table 8-51; Ref. 297). The R_{max} from the VSP to recoverable injury effect criteria was up to 0.05 km for fish with swim bladders (Table 8-51; Ref. 297). Seismic sound sources have been identified as moderate risk causing recoverable injury within the near vicinity (tens of metres) of a sound source and low risk beyond this distance for fish eggs and fish larvae (Table 8-48; Ref. 297). Fish species are expected to be transient through the DA. Given their transient nature, these fish are not expected to remain within close proximity (within ~30–50 m) of a sound source for extended periods (e.g. 24 hours) such that an auditory injury due to accumulated sound exposure would occur. Furthermore, VSP activities are expected to last <24 hours each well and a geophysical survey sound source is not from a static position. On this basis, recoverable injury to fish is not considered credible and has therefore not been considered further. Acoustic modelling indicated that the R_{max} from the VSP to TTS onset effect criteria was up to 0.57 km for fish (both with and without a swim bladder; i.e. including whale sharks) (Table 8-51; Ref. 297). Seismic sound sources have been identified as moderate risk causing TTS onset within the near vicinity (tens of metres) of a sound source and low risk beyond this distance for fish eggs and fish larvae (Table 8-48; Ref. 297). Fish species are expected to be transient through the DA. Given their transient nature, these fish are not expected to remain within close proximity (<570 m) of a sound source for extended periods such that auditory impairment due to accumulated sound exposure would occur. Furthermore, VSP activities are expected to last up to 24 hours each well and a geophysical survey sound source is not from a static position. On this basis, TTS onset to fish is not considered credible and has therefore not been considered further.
Marine reptiles
Impulsive sources audible to marine reptiles include VSP (up to 24 hours each well). The medium to high frequency of SBPs used in geophysical surveys are typically outside the hearing frequency range of turtles (Ref. 550). Several listed threatened and/or migratory marine turtle species have the potential to occur within the DA. One internesting buffer BIA and HCTS of the flatback turtle overlaps the southern section of the DA. The Development does not overlap any other marine turtle BIAs or HCTS. Whittock et al. (Ref. 146) reported that flatback turtles prefer habitats in proximity to the coast and at relatively shallow depths during internesting periods. The study found that internesting flatback turtles from all rookeries remained within water depths of <44 m, with a mean depth of <10 m (Ref. 146). Other studies (e.g. Ref. 147; Ref. 148; Ref. 149) have also presented findings that

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internesting behaviour was only observed in water depths of <40 m. This suggests that although the DA overlaps the extent of both the BIA and HCTS of flatback turtles, due to the distance offshore (at the closest ~50 km from Barrow Island, and ~45 km from Montebello Islands) and water depths within the DA (~100–1,400 m) it is considered highly unlikely that flatback turtles would be demonstrating internesting behaviour within the DA. Therefore, based on these observed habitat preferences, any presence of marine turtles within the DA is expected to be transitory in nature only. Similarly, as described in Section 6.3.3.2, any presence of marine turtle hatchlings within the DA is also expected to be of a transitory nature due to dispersal via ocean currents. The DA is in water depths of ~100–1,400 m and >45 km from the closest coast, and therefore the active-swimming phase (i.e. during frenzy and early-dispersal) of hatchlings would be over before reaching the DA (and if they reach they DA). While the threatened short-nosed sea snake was identified within the PMST as potentially being present within the DA, this species is not considered likely to be present. The short-nosed sea snake occurs primarily on reef flats or in shallow waters of the outer reef edges to depths of 10 m (Ref. 27). Furthermore, underwater sound has not been identified as a threat for the species (Ref. 27). Other EPBC marine listed sea snake species may occur in broader habitats within the NWMR; however, underwater sound emissions has not been identified as a pressure for sea snake species (Ref. 287). On this basis, change to behaviour to sea snakes is not considered credible and has therefore not been considered further. **Change to behaviour** Some field evidence suggests that marine turtles avoid impulsive sound, where change in diving behaviours have been interpreted as avoidance (Ref. 328). Acoustic modelling indicated that the maximum horizontal distance to marine turtles effect criteria for behavioural response and disturbance from VSP activities is predicted to be 1.03 km and 0.27 km respectively (Table 8-52). Therefore, behavioural responses of marine turtles to impulsive underwater sound during the Development is anticipated to be limited to within ~1 km of the DCs. The limited extent to marine turtle effect criteria ensures potential impacts will be within the DA. If individual transient marine turtles are present within proximity (i.e. <1.03 km) to VSP activities, behavioural responses such as temporary increased swimming activity and avoidance may occur. As such, the Development has the potential to cause temporary change to behaviour in transient marine turtles within the DA, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Unlikely (4). Overall, the risk of impulsive underwater sound resulting in a change to behaviour in marine reptiles is Very Low (9).
Auditory impairment (TTS and PTS) Acoustic modelling indicated that the maximum-over-depth PK effect criteria for marine turtles were not reached (Section 8.5.4.2.3; Ref. 297). Acoustic modelling indicated that the R_{max} from the VSP to PTS and TTS accumulated SEL_{24h} effect criteria for marine turtles was up to 0.03 km and 0.24 km, respectively (Table 8-52). Indicative ranges to the updated NMFS 2024 AUD-INJ and TTS onset effect criteria are up to ~0.17 km and ~1.38 km respectively (Section 8.5.4.1.1; Table 8-52). Note that SEL_{24h} is a cumulative metric that requires a receptor to be consistently exposed to sound at this received sound level for a 24-hour period before the associated auditory impairment (TTS) or injury (AUD-INJ or PTS) may occur. However, the onset of these TTS and AUD-INJ/PTS effects may also be reached by shorter durations of exposure at higher sound levels. . The consequence associated with the potential for accumulated exposure causing auditory impairment (TTS) or injury (AUD-INJ including PTS), as a result of impulsive underwater sound has been determined to be Incidental (6). The likelihood of the consequence occurring is assessed as Remote (5). Overall, the risk of non-impulsive underwater sound resulting in auditory impairment or injury effects in transient marine turtles is Very Low (10).
Marine mammals
Impulsive sources associated with the Development that may be audible to marine mammals include VSP (up to 24 hours each well)and use of SBPs during geophysical surveys (~3–4 weeks per survey). Several listed threatened and/or migratory cetaceans species have the potential to occur within the DA. The DA overlaps the humpback whale and pygmy blue whale migration BIAs. No other

Risk evaluation

BIAs were identified. There are no other known areas of aggregation or biologically important behaviours for other cetacean species within the DA; as such it is expected that the presence of any marine mammal species would be of a transitory nature.

Change to behaviour

McCauley et al (Ref. 331) reported humpback whales began avoidance manoeuvres in response to impulsive seismic generated sound and exhibited general avoidance responses likely due to the presence of vessels (Ref. 332). Goldbogen et al (Ref. 333) found blue whales changed orientation and horizontal displacement when exposed to mid-frequency sonar sound. Southall et al (Ref. 334) also found baleen whales showed directional avoidance of a stationary sonar sound source and were more likely to do this if there was not a concentrated food source present.

Acoustic modelling indicated the maximum horizontal distance over which the marine mammal behavioural response effect criteria may be reached from VSP activities is predicted to be 2.37 km (Table 8-53). Some variation was observed for distances to behavioural response effect criteria, with higher distances predicted for the shallow waters in Area 5 compared to the deeper offshore sites (Section 8.5.3.3.3).

The spreading loss modelling for SBP equipment predicts a maximum horizontal distance of ~4–180 m to the marine mammal behavioural response criterion (Section 8.5.4.3). Geophysical surveys have the longest duration of impulsive sound during the Development; however the ensonified areas are much smaller than the shorter duration (up to 24 hours) of VSP.

Humpback whales

The only ensonification from non-impulsive sound sources that would extent into the humpback whale BIA would occur from geophysical equipment in use within the DA at the Gorgon tie-in locations; which as per above is at the scale of tens to hundreds of metres from the source. No ensonified area from VSP operations extends into the BIA.

The energetic cost of avoiding a sound source associated with the Development (e.g. tens to hundreds of metres) is likely to be negligible in the context of the greater migratory movements (e.g. several thousands of kilometres) of humpback whales migrating between Antarctic and Kimberley waters (Section 6.3.3.1.1). Therefore, this level of behavioural avoidance within the humpback whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales.

Pygmy blue whales

To determine the largest intersect between a single predicted ensonified area and the pygmy blue whale migration BIA, the largest R_{max} to behavioural effect criteria was applied (i.e. from VSP as this is larger than geophysical sources), and assumed to wholly be within the BIA. Therefore, the ensonified area would intersect ~4.74 km of the pygmy blue whale migration BIA. The width of the BIA at this location is ~92.5–135.3 km, and so this ensonified area represents ~3.5–5.0% of the BIA width.

The energetic cost of avoiding the impulsive sound sources associated with the Development (e.g. kilometres) is likely to be negligible in the context of the greater migratory movements (e.g. several thousands of kilometres) of pygmy blue whales migrating between Southern Ocean and Indonesian waters (Section 6.3.3.1.2). The non-impulsive sound sources are also either of short duration (e.g. up to 24 hours for VSP), or ensonify a much smaller area with a moving sound source (e.g. ~3–4 weeks per survey). Therefore, this level of behavioural avoidance within the pygmy blue whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales. Further, as described previously, the actual migratory corridor utilised by pygmy blue whales is broader than just the BIA. Therefore, while predicted ensonified areas may take up a proportion of the designated migration BIA, the proportion of actual migration corridor used by pygmy blue whales would actually be lower.

The predicted ensonified areas from VSP or SBP geophysical equipment above behavioural effect criteria do not extend into the 'most important areas' for foraging for the pygmy blue whale as identified by Thums et al. (Ref. 135).

Other cetaceans

No BIAs for migration (or other biologically important behaviours) have been identified for other cetaceans within the vicinity of the DA, and as such it is expected that if they transit through the area they would also be able to avoid non-impulsive sound sources at comparatively little energetic cost to greater migratory or transit movements relevant to respective species.

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As outlined above, the DA intersects the pygmy blue whale and humpback whale migration BIAs. However, the presence of these and other cetaceans are expected to seasonal and transitory in nature. The Development has the potential to cause a change to behaviour in marine mammals

Risk evaluation
within ~2.37 km of stationary impulsive sound sources for short durations (i.e. VSP operations for up to 24 hours at each well), or within ~180 m of a moving impulsive sound sources for a longer duration (i.e. SBP geophysical equipment for ~3–4 weeks per survey). The potential energetic cost of avoiding impulsive sources is likely to be negligible in the context of the greater migratory movements of marine mammal species. The Development has the potential to cause limited change to behaviour in marine mammals within the DA, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Unlikely (4). Overall, the risk of impulsive underwater sound resulting in a change to behaviour in marine mammals is Very Low (9).
Auditory Impairment Underwater sound can cause auditory impairment (TTS, PTS, masking) of marine mammals. TTS is completely recoverable, with 24 hours thought to be sufficient for recovery to occur (Ref. 307; Ref. 306). However, for pygmy blue whales guidance from the Australian Government has defined TTS and PTS as an injury (Ref. 353). Auditory masking may occur when there is a reduction in audibility for one sound (signal) caused by the presence of another sound (noise), impeding the ability of an animal to perceive a signal (Ref. 335, Ref. 336). For this to occur, the noise must be loud enough and have a similar frequency to the signal and both signal and noise must occur at the same time. 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 (Ref. 337, Ref. 338, Ref. 339, Ref. 340). Currently, there are no specific received level thresholds for reliably assessing or regulating masking responses to underwater sound (Ref. 341). A study undertaken by Clark et al (Ref. 342), suggests that masking impacts from vessel noise can be extended to non-non-impulsive sources of noise (e.g. the low frequency energy from VSP). This study considers the potential for masking and communication impacts is classified as high near the vessel (within tens of metres), moderate within hundreds of metres, and low within thousands of metres (Ref. 342). Some cetaceans might respond acoustically to underwater sound in a range of ways, including by increasing the amplitude of their calls (Lombard effect), changing their spectral (frequency content) or temporal vocalisation properties, and in some cases, cease vocalising (Ref. 343, Ref. 344, Ref. 345, Ref. 346, Ref. 347). Given the relatively small predicted ensonified area for masking effects (i.e. tens hundreds of metres from a source), and the mobile nature of cetacean species, it is considered highly unlikely underwater sound associated with the Development will result in auditory masking. *VSP* Acoustic modelling indicated that the R_{max} from the VSP source to PTS and TTS maximum-over-depth PK effect criteria for low and high frequency cetaceans was not predicted to be exceeded. As such, it is not considered credible, and no further evaluation has been undertaken. Acoustic modelling indicated that the R_{max} from the VSP source to PTS and TTS maximum-over-depth PK effect criteria for very high frequency cetaceans was up to 0.06 km and 0.13 km, respectively. Acoustic modelling also indicated that the R_{max} from the VSP to the accumulated SEL_{24h} PTS and TTS effect criteria was up to 0.48 km and 3.2 km, respectively for low frequency cetaceans, and up to 0.02 km and 0.13 km, respectively for very high frequency cetaceans. The accumulated SEL_{24h} PTS and TTS effect criteria for high frequency cetaceans was not predicted to be reached. Indicative ranges to the updated NMFS 2024 SEL_{24h} effect criteria for AUD-INJ and TTS onset are up to ~0.54 km and ~3.58 km respectively for low frequency cetaceans, up to ~0.05 km and ~0.05 km respectively for high frequency cetaceans, and up to ~0.01 km and ~0.09 km respectively for very high frequency cetaceans (Section 8.5.4.1.1; Table 8-53). Note that the SEL_{24h} is a cumulative metric that requires a receptor to be consistently exposed to sound at o this received sound level for a 24-hour period before the associated auditory effect (TTS, PTS or AUD-INJ) may occur. However, the onset of these TTS, PTS, or AUD-INJ effects may also be reached by shorter durations of exposure at higher sound levels. Travel speed for pygmy blue whales during migration was estimated by Thums et al (Ref. 135), as ~2.4 km/h during northern migration, and ~4.0–5.0 km/h during southern migration. Based on a R_{max} of ~3.2 km (i.e. total diameter of ensonification at ~6.4 km), the duration a migrating pygmy blue whale is expected to remain in the ensonified area would be ~1.3–2.7 hours, i.e. substantially less than the 24 hours exposure required for TTS onset to occur at this sound level. Given the accumulated exposure required before TTS, PTS or AUD-INJ onset may occur, the short duration of the sound source (up to 24 hours per well), and the mobile nature of cetaceans

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within the vicinity of the DA, the risk of TTS and PTS/AUD-INJ considered unlikely to cetaceans from VSP sources. Instantaneous PTS and TTS effects to very high frequency cetaceans may occur; however, given the transient nature of cetaceans and limited spatial (up to 0.06 km and 0.13 km for PTS and TTS PK, respectively) and temporal (VSP activities are expected to take <24 hours each well) potential exposure, impacts would be limited to individuals. The consequence associated with the potential for accumulated exposure causing auditory impairment (TTS) or injury (AUD-INJ including PTS), as a result of VSP has been determined to be Incidental (6). The likelihood of the consequence occurring is assessed as Remote (5). Overall, the risk of non-impulsive underwater sound from VSP resulting in auditory impairment or injury effects in transient marine mammals is Very Low (10). *Geophysical (SBP) equipment* A spreading loss model was used to estimate sound propagation from geophysical SBP equipment (Section 8.5.4.3). The PK effect criteria for all marine mammal hearing groups may be exceeded at very short horizontal distances from the SPB sources: ~1–2 m and ~3–5 m for PTS onset and TTS onset, respectively. The risk of TTS or PTS from instantaneous exposure to an impulsive geophysical (SBP) source is not considered credible and no further evaluation is presented. The horizontal distances to accumulated SEL_{24} PTS and TTS onset effect criteria varied depending on the type and power of equipment used. Estimated distances to effect criteria were up to ~0.03 km, ~0.003 km, and ~0.30 km for PTS onset, and~0.81 km, ~0.07 km, and ~5.9 km for TTS onset for low, high, and very high frequency cetaceans respectively (Ref. 550; Section 8.5.4.3). Swim speeds for very high frequency cetaceans are not publicly available; therefore using swim speeds of pygmy blue whales as a proxy, the duration a transient is expected to remain in the largest ensonified area (i.e. R_{max} of ~5.9 km) would be ~2.4–4.97 hours, i.e. substantially less than the 24 hours exposure at this received level required for TTS onset to occur. Given the accumulated exposure required before TTS or PTS onset may occur, the moving nature of the sound source, and the mobile nature of cetaceans within the vicinity of the DA, the risk of TTS and PTS is not considered credible from geophysical (SBP) sources, and has not been evaluated further.
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from underwater sound includes indirect impacts to intangible Traditional Owner cultural heritage from a change to behaviour in marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1). No impact pathway to a change in access to Country from the emission of impulsive underwater sound is anticipated. The consequence evaluations for marine fauna are provided above and were assessed as having a localised and minor environmental impact and is not expected to affect the overall population of the species. Further, the source of impulsive underwater sound emissions within the DA is temporary and is not expected to affect the long-term underwater soundscape of the marine environment. As such, it is anticipated that intangible heritage values such as songlines and connection to Country would not be significantly adversely affected from impulsive underwater sound emissions within the DA. Given the offshore location of the DA and temporary nature of the activities, a significant adverse change to cultural heritage values attributed to the offshore marine area from impulsive underwater sound emissions is not predicted to occur. As such, CAPL has ranked the risk to intangible Traditional Owner cultural heritage values: consequence as Incidental (6), likelihood as Unlikely (4), and residual risk as Very Low (9).

8.5.6 determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-56 details the determination of acceptability for underwater sound.

Table 8-56: Determination of acceptability for underwater sound emissions

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-07**, **AL-12**, **AL-13**, **AL-14**, **AL-15**, and **AL-16**, as defined in Table 7-6 and shown below in Section 8.5.7). As described in the impact and risk evaluation (Section 8.5.5), the predicted environmental impact would be localised behavioural disturbances or auditory effects to individuals and would not be expected to result in impacts at a population level that prevent their long-term recovery or survival. Therefore, the predicted level of impact for these receptors is better than the acceptable levels (**AL-12, AL-14, AL-15**). Given the accumulated exposure required, the risk of auditory impairment or injury (TTS, PTS, AUD-INJ) to a blue whale from non-impulsive or impulsive sound was considered to be Low and Very Low respectively. The distances for instantaneous impulsive sound to result in TTS or PTS to very high frequency cetaceans were small, and the risk not considered credible (and PK effect criteria were not predicted to be reached for low or high frequency cetaceans). While ensonified areas may extend into HCTS or BIAs for flatback turtles, the internesting habitat preferences indicate that it is unlikely that a flatback turtle would be within these areas and thus disrupting from undertaking biologically important behaviours. Given the localised impacts predicted for marine fauna, no lasting effects were predicted to occur to the Montebello Marine Park such that it would prevent the long-term protection and conservation of marine park values. Therefore, the predicted level of impact to this receptor is better than the acceptable level (**AL-16**). Because of the temporary nature of sound emissions no lasting impact to Traditional Owner cultural values attributed is predicted. As such, the predicted level of impact is equal to **AL-07**.
Principles of ESD	**(b) 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 highest consequence for underwater sound was evaluated as Minor (5), for marine mammals. Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and therefore, no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • The acoustic propagation and animat modelling (appendix d) provides scientific certainty to inform the impact and risk evaluation for underwater sound emissions. • The above modelling was based on the best available quantitative effect criteria at the time the modelling was undertaken. It is acknowledged that some of these criteria (e.g. TTS and AUD INJ for marine mammals and marine turtles) have since been revised, and an analyses of the potential effect of these revisions was been assessed (Sections 8.5.3.2.1 and 8.5.4.1.1). • While quantitative underwater sound threshold criteria currently do not exist for fish, fish eggs and larvae and marine turtles, the qualitative criteria outlined in the Popper et al. (Ref. 305) are widely accepted as appropriate for use in impact and risk evaluations and have been used in this assessment. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
The Development is committed to applying measures to prevent the impact and risk of underwater sound based on relevant environmental legislation and other requirements as listed below.
The regulation and management of underwater sound in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence for underwater sound was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
Any relevant stakeholder feedback in relation to underwater sound has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans
The requirements to manage interactions between vessels and cetaceans are detailed in the EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans. These regulations describe strategies to ensure cetaceans are not harmed during offshore interactions with people.
Helicopters will adhere to EPBC Regulations 2000 – Part 8 Division 8.1 interacting with cetaceans in relation to distances to cetaceans.</td><td>Legislative requirements to manage underwater sound with cetaceans are addressed by adopting the following control measures:
CM-18
CM-19.</td></tr>
<tr><td></td><td>Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20)
<u>Action A.2.2</u>
Assessing the effect of anthropogenic noise on blue whale behaviour.
Section 8.5.3 assesses the effects of anthropogenic noise from the</td><td>EPBC management plan requirements to manage underwater sound with blue whales are addressed by adopting these EPOs and control measures:
EPO-19
EPO-23
CM-20
CM-21.</td></tr>
</table>

Determination of acceptability		
	Development on blue whale behaviour. <u>Action A.2.3</u> 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. Section 8.5.5 demonstrates that the Development can be conducted in a manner that is consistent with the conservation management plan and will not result in injury of pygmy blue whales from migration BIA or displacement of pygmy blue whales from a foraging BIA. For the purpose of interpreting and applying Action Area A.2 of the blue whale CMP, injury is both permanent and temporary hearing impairment (Permanent Threshold Shift and Temporary Threshold Shift) and any other form of physical harm arising from anthropogenic sources of underwater noise (Ref. 353).	Therefore, the Development is not considered to be inconsistent with this EPBC management plan.
	Recovery Plan for Marine Turtles in Australia (Ref. 24) *Action A1.5*: Manage anthropogenic activities to ensure marine turtles are not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24). *Action A1.6*: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	EPBC management plan requirements to manage anthropogenic activities are addressed by adopting these EPOs and control measures: • **EPO-20** • **EPO-21** • **EPO-23** • **CM-20** • **CM-21**. Therefore, the Development is not considered to be inconsistent with this EPBC management plan.
	National Recovery Plan for the Southern Right Whale (*Eubalaena australis*) (Ref. 23) <u>Management action A5.2</u> Actions within and adjacent to southern right whale BIAs and HCTS should demonstrate that it does not prevent any southern right whale from utilising the area or cause auditory impairment. <u>Management action A5.3</u> Actions within and adjacent to southern right whale BIAs and HCTS should demonstrate that the risk of behavioural disturbance is minimised. <u>Management action A5.4</u> Ensure environmental assessments associated with underwater noise generating activities include	The predicted ensonified areas from activities associated with the Development do not occur within or adjacent to BIAs or HCTS for southern right whales. Therefore, the Development is not considered to be inconsistent with this EPBC management plan.

Determination of acceptability		
	consideration of national policy (e.g. EPBC Act Policy Statement 2.1) and guidelines related to managing anthropogenic underwater noise and implement appropriate mitigation measures to reduce risks to southern right whales to the lowest possible level.	
	Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 22) Identifies anthropogenic noise and acoustic disturbance as a minor threat. No explicit relevant requirements.	These EPBC listing advice for species that may occur within the relevant spatial extent for underwater noise identify anthropogenetic noise/noise interference as a threat, but do not identify relevant actions.
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 21) Identifies anthropogenic noise and acoustic disturbance as a minor threat. No explicit relevant requirements.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 33) Identifies chronic noise as an information and research priority. No explicit relevant requirements.	
	Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin) (Ref. 663)	
	Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin) (Ref. 664)	
	North-west Marine Parks Network Management Plan 2018 The class approval for mining operations within a multiple use zone requires a NOPSEMA-accepted EP to be in place before activities commence.	As described in Section 2.1.1.1, EPs associated with the Development will be submitted after the OPP has been accepted by NOPSEMA.
Internal context	This procedure was identified as relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4).	

Determination of acceptability	
	Further, CAPL has also since included an adaptive management control measure for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to underwater sound emissions from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.

8.5.7 environmental performance

Table 8-57 provides the EPOs defined for underwater sound and the adopted control measures to achieve the outcome.

Table 8-57: Environmental performance for underwater sound emissions

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-12: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species. **AL-13**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act. **AL-14**: Impacts from the Development will not decrease the availability or quality of marine fauna habitat to the extent that it interferes with the recovery of the population of an EPBC Act listed threatened species. **AL-15**: Impacts from the Development will not decrease the availability or quality of important habitat[170] to the extent that it interferes with the survival	**EPO-17**: Sound emissions from planned Development activities will be managed such that EPBC Act listed species continue undertaking biological important behaviours[172]. **EPO-18**: Sound emissions from planned Development activities will be managed to prevent TTS or AUD-INJ onset to EPBC Act listed species. **EPO-19**: Any blue whale continues to utilise the biologically important area without injury[173], and is not displaced from a foraging area[174,175]. **EPO-20**: Any marine turtle is not displaced from identified habitat critical to the survival of the species[176]. **EPO-21**: Any marine turtle continues to undertake biologically important	**CM-18**: Vessels under transit[177] within the Development Area will implement caution and no approach zones as described in sections 8.05 and 8.06 of the EPBC Regulations 2000 (Cth). **CM-19**: Helicopters under transit within the Development Area will operate in alignment with section 8.07 of the EPBC Regulations 2000 (Cth). **CM-20**: Where there is a risk of behavioural, or auditory impairment or injury[178] to marine fauna from impulsive sound, CAPL will adopt an adaptive management approach which identifies activity-specific preventative mitigation measures such that the potential risks from impulsive sound emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will include: • sound source characteristics of selected (or indicative) equipment • seasonal presence and biologically important behaviours of marine fauna (e.g. Table 6-18) within indicative activity windows

[170] Where important habitat for migratory species are defined within the MNES Significant Impact Guidelines (Ref. 72).

[172] Where biologically important behaviours are defined as behaviour associated with critical life functions (e.g. reproduction, foraging, migration, and resting) (Ref. 719).

[173] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'injury to blue whales' is considered both PTS and TTS and any other form of physical harm arising from anthropogenic sources of underwater sound (Ref. 369).

[174] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'displaced from a foraging area' applies in relation to BIAs (Ref. 369); and these BIAs correspond to 'Foraging Area', 'Possible Foraging Area', and 'Known Foraging Area' as illustrated in Figure 1 of the Conservation Management Plan for the Blue Whale (Ref. 20; Ref. 369). There are no Foraging Area BIAs within or adjacent to the DA.

[175] In accordance with Australian Government guidance, activities outside designated Foraging Areas should adopt adaptive management approaches in the event that indicators (e.g. aggregation in a particular area) of whale foraging are evident to ensure that impacts are not unacceptable (e.g. no injury or biologically significant disturbance) (Ref. 369). EPO-17 incorporates foraging as one of the biologically important behaviours of marine fauna, and EPO-23 applies adaptive management.

[176] Where habitat critical to the survival of marine turtle species is defined in Table 6 of the Recovery Plan for Marine Turtles in Australia (Ref. 24).

[177] For safety reasons this control measure is not applied to vessels holding station or with limited manoeuvrability (e.g. during lifts, bunkering, etc.) or during emergency situations.

[178] Where 'auditory impairment or injury' includes physical or physiological changes to the auditory system that may be either recoverable or permanent (e.g. TTS, AUD-INJ).

Acceptable levels	Environmental performance outcomes	Adopted control measures
of the population of an EPBC Act listed migratory species. **AL-16**: No impact on the natural values of the Montebello Marine Park[171] from the Development that would prevent the conservation of biodiversity within the North-west Marine Parks Network.	behaviour within biologically important areas. **EPO-22**: Undertake underwater sound assessments based on acoustic modelling (or equivalent, as appropriate to the nature and scale of the sound source) and predictions of ensonified areas that consider effect criteria based on contemporary guidance as available at the time. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development. **EPO-23**: Implement an adaptive management approach (**CM-20**, **CM-21**) for underwater sound emissions from the Development such that it can be demonstrated that risks have been reduced to as low as reasonably practicable and can be managed to meet acceptable levels. The outcomes of this adaptive management approach will be incorporated into Environment Plans for the petroleum activities associated with this Development.	• location(s) of petroleum activity in relation to sensitive marine fauna habitats • type, location, and duration of any concurrent activities • existing (e.g. Conservation Management Plan for the Blue Whale 2015–2025 [Ref. 20]) or contemporary regulatory requirements as available at the time. Mitigation options may include use of visual surveillance (e.g. prior to starting an activity), temporal or spatial based modifications to activities (e.g. restricting use of VSP within BIAs/HCTS during peak seasonal periods). Noting that seismic surveys are not within scope of the OPP, the types of mitigation measures described within existing (e.g. EPBC Act Policy Statement 2.1) or contemporary guidance as available at the time for the management of impulsive underwater sound would also be considered. To further ensure the potential risks from impulsive underwater sound emissions on pygmy blue whales can be managed such that the risk is consistent with the relevant acceptable levels and EPOs, the adaptive management framework described in Section 10.4 will be applied. **CM-21**: Where there is a risk of behavioural or auditory impairment or injury to marine fauna from non-impulsive sound, CAPL will adopt an adaptive management approach which identifies activity-specific preventative mitigation measures such that the potential risks from non-impulsive sound emissions are reduced to as low as reasonably practicable and are managed to meet acceptable levels and EPOs. The type of mitigation measures will be determined based on the nature and scale of the activity-specific risk. Considerations guiding the selection of mitigation measures will include: • sound source characteristics of selected (or indicative) vessels and equipment • seasonal presence and biologically important behaviours of marine fauna (e.g. Table 6-18) within indicative activity windows • location(s) of petroleum activity in relation to sensitive marine fauna habitats

[171] Where the natural values of the Montebello Mark Park are described in the North-west Marine Parks Network Management Plan (Ref. 82).

Acceptable levels	Environmental performance outcomes	Adopted control measures
		• type, location, and duration of any concurrent activities • existing (e.g. Conservation Management Plan for the Blue Whale 2015–2025 [Ref. 20]) or contemporary regulatory requirements as available at the time. Mitigation options may include use of visual surveillance (e.g. prior to starting an activity), temporal or spatial based modifications to activities (e.g. reducing the number or types of activities occurring within peak seasonal migration periods), or in-field adaptive management (e.g. positioning support vessels further away from main construction/drilling vessel; pause or stop an activity when operationally safe and viable to do so). To further ensure the potential risks from non-impulsive underwater sound emissions on pygmy blue whales can be managed such that the risk is consistent with the relevant acceptable levels and EPOs, the adaptive management framework described in Section 10.4 will be applied.
AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

8.6 planned discharges—MODU and vessels

8.6.1 source

The MODU and support vessels produce discharges such as:

- sewage and greywater
- food waste
- cooling and brine water
- deck drainage and treated bilge
- firefighting foam.

These materials are discharged to the marine environment and have the potential to cause a localised and temporary change to the water quality within the DA.

The indicative personnel on board (POB) for the largest expected vessel was assumed for estimating discharge volumes. Personnel numbers will peak during drilling, installation and commissioning, and decommissioning phases, and will be lowest during operations.

Table 8-58 lists activities within each phase where MODU and vessel operations occur in the DA.

Table 8-58: Phases and activities that generate planned discharges—MODU and vessels

Phase	Activity
Support activities	MODU operations Vessel operations

8.6.1.1 support activities (all phases)

Vessels are present in the DA during all phases of the Development. The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). The MODU will move between fields but will spend most of the time at the DCs.

The types of planned vessel discharges include deck wash water, firefighting foam, sewage, greywater, food wastes, cooling water and oily bilge water.

8.6.1.1.1 sewage and greywater

Sewage and greywater will be produced as a result of ablution, laundry, and galley activities on the MODU and vessels. Sewage and greywater may include nutrients such as ammonia, nitrite, nitrate, and orthophosphate, which can lead to eutrophication (Ref. 356). This waste will be treated before discharge to the environment as per guidelines under the MARPOL 73/78 Annex IV and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cth).

MODUs and vessels typically discharge 0.04–0.45 m^3 of treated wastewater (comprising sewage and greywater) per day per person (Ref. 357). The largest vessel or facility that is expected to be used for the Development is a large PLV; with an indicative POB of ~700. This gives a maximum discharge of 28–315 m^3/day, for ~15 months (expected installation and commissioning duration).

Sewage has the potential to change water quality with subsequent impacts including change in fauna behaviour and change in aesthetic value.

8.6.1.1.2 food waste

Food waste will be produced by galley facilities on the MODU and vessels. The average volume of food waste discharged into the marine environment is expected to be ~1–2 kg per person per day (Ref. 356). Food waste will be disposed of overboard according to MARPOL requirements.

Food waste has the potential to change water quality with subsequent impacts including change in fauna behaviour and change in aesthetic value.

8.6.1.1.3 cooling water and brine

Cooling water and brine are used on the MODU and support vessels. They are routinely discharged to the marine environment where they are likely to interact with the ecosystem.

The processing facilities and the machinery on board MODUs and vessels require a cooling media, which will be circulated through a central cooling system. Once the cooling media has completed its cycle, it is discharged into the marine environment.

The cooling media most commonly used is sea water; however, a different fluid may be used within a closed circuit and further cooled by sea water within a separate seawater cooler. Sea water used for cooling is dosed with chlorine following intake and discharged with low residual chlorine concentrations that are rapidly diluted by prevailing water currents. Cooling water is typically 2–5 °C above ambient seawater temperature. However, upon discharge, it will be subjected to turbulent mixing and transfer of heat to the surrounding waters.

A study undertaken by Woodside (Ref. 358) detailed temperature dispersion modelling, which showed that the water temperature of discharged water will decrease rapidly as it mixes with the receiving waters. The study showed discharge waters were <1° C above background levels within 100 m (horizontally) of the discharge point. Vertically, the discharge was within background levels within 10 m of the discharge point (Ref. 358).

Most MODU and vessels used in the resources industry have capability for reverse osmosis, desalination, or distillation of sea water to produce demineralised potable water. The process of converting sea water to potable water will produce reject brine, which will be discharged to the marine environment.

Volumes of produced and discharged reject brine are relatively low, with salinity levels typically 20–50% higher than that of the surrounding sea water (depending on technique) (Ref. 285).

Cooling water and brine have the potential to cause a localised and temporary change in water quality.

8.6.1.1.4 deck drainage and treated bilge

Deck drainage generally comprises water and fluids from rainfall, ocean spray and water used for wash downs. Water used during wash downs may contain small amounts of particulate matter and dirt, plus chemicals such as cleaning fluids, lubricating oils and grease. These fluids are normally discharged directly to the marine environment.

Bilge water is a collective term for a mixture of fresh water, sea water, oil, sludge, chemicals and various other fluids from machinery and storage areas. The bilge system is designed to safely collect, contain, and dispose of oily water from

hazardous areas to avoid discharging hydrocarbons to the marine environment. These fluids may contain contaminants such as oil, detergents, solvents, chemicals, and solid waste, typically at low levels.

Bilge water will be processed via an oil-in-water separator, to meet MARPOL Annex 1 requirements. Treated bilge water is discharged to the marine environment. Discharge occurs infrequently.

Deck drainage and treated bilge have the potential to cause a localised and temporary change in water quality.

8.6.1.1.5 firefighting foam

The MODU and vessels will be equipped with firefighting foam extinguishing capability as required under international standards for fire equipment on vessels. Several types of firefighting foam are available, including aqueous film forming foam units, which are used on flammable and combustible liquids such as oil. These foam systems will be used in the event of an incident, and during infrequent fire system testing.

Firefighting foam has the potential to cause a localised and temporary change in water quality.

8.6.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by MODU and vessel discharges:

- water quality
- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- fish communities associated with KEFs.

Although fish may potentially be impacted by MODU and vessel discharges, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Four State- and two Commonwealth-managed fisheries have recorded historical fishing effort in the DA. Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the continental slope demersal fish communities KEF from MODU and vessel discharges are not expected; and are not evaluated further.

Table 8-59 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to Planned discharges—MODU and vessels in the DA.

Table 8-59: Impact and risk evaluation for planned discharges–MODU and vessels

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned discharges from the MODU and vessels may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • changes to predator–prey dynamics.	6	6	Very Low (10)

Impact evaluation
Water quality
Localised and temporary reduction in water quality Planned MODU and vessel discharges may impact ambient water quality as they can include chemicals and nutrients (e.g. ammonia, nitrite, nitrate, and orthophosphate), which may lead to an increased nutrient load and eutrophication. The number of vessels/ MODU will be dependent on the phase of the Development, with the highest number of vessels expected during the short-term drilling and installation phases. Fewer vessels will be required during the operations phase. Open marine waters, such as those in the DA, are typically influenced by regional winds and large-scale ocean current patterns resulting in the rapid mixing of surface and near-surface waters. Vessel discharges will occur in these surface and near-surface waters (Ref. 356). Therefore, nutrients from sewage, or other similar, discharges will not accumulate or lead to eutrophication due to the highly dispersive environment (Ref. 356). This outcome was verified by sewage discharge monitoring for another offshore project (Ref. 285), which determined that a 10 m^3 sewage discharge reduced to ~1% of its original concentration within 50 m of the discharge location. In addition, monitoring at distances 50 m, 100 m, and 200 m downstream, and at five different water depths, confirmed that discharges were rapidly diluted and no elevations in water quality monitoring parameters (e.g. total nitrogen, total phosphorous, and selected metals) were recorded above background levels at any station. The study states that this is a comparatively small discharge, but it shows that rates of dilution and mixing in the open ocean are highly likely to be enough to prevent larger discharges from causing long-term impacts. Discharged particulate matter in the form of macerated food plus sewage and greywater may cause an increase in turbidity. This increase will be localised and temporary—discharges will be diluted and dispersed by wave action and local currents. Monitoring of desalination brine and continuous wastewater discharges (including cooling water) undertaken by Woodside for its Torosa South-1 drilling program in the Scott Reef complex found that discharge water temperature decreases quickly as it mixes with the receiving waters, with the discharge water temperature being <1° C above ambient temperature within 100 m (horizontally) of the discharge point, and 10 m vertically (Ref. 285). Brine discharges are likely to sink through the water column, rapidly mix with receiving waters and be dispersed by currents. As a result, salinity differences are likely to be temporary and limited to the area close to the source. A vessel's bilge system is designed to safely collect, contain, and dispose of oily water so as to minimise or avoid discharging hydrocarbons to the marine environment. Bilge water is processed via an oil-water separator before being discharged to sea. Discharge is intermittent and occurs at or near surface waters. These oily bilge discharges are expected to readily dilute and disperse under the action of waves and currents in surface waters, and any volatile components of the oil will readily evaporate once exposed to air. The planned discharge of firefighting foam offshore is limited to the on-board testing of firefighting deluge systems. This testing may lead to a release of firefighting foams offshore. Toxicological effects from these types of foams are typically only associated with prolonged or frequent exposures, such as on land and in watercourses near firefighting training areas (Ref. 359; Ref. 360). These conditions are not consistent with the infrequent use of the systems over the life of the Development. In their diluted form (as applied in testing or if there is a fire), firefighting foams are generally considered to have a relatively low toxicity to aquatic species (Ref. 361; Ref. 362); further dilution of the foam mixtures in dispersive aquatic environments may then occur before there is any substantial demand for dissolved oxygen (Ref. 363).

Impact evaluation
Consequently, the change in water quality from these standard discharges is limited to a localised area, has low levels of toxicity, and is rapidly diluted, quickly returning to ambient conditions after the discharge has ceased; therefore, any impacts are Incidental (6).

Risk evaluation
Marine fauna
Changes to predator–prey dynamics The overboard discharge of sewage and macerated food waste has the potential to create localised eutrophication as well as a localised and temporary food source for scavenging marine fauna or seabirds. Eutrophication can result in increased growth of primary producers such as phytoplankton, which in turn results in changes in biological diversity. Numbers of these species may temporarily increase as a result of this food source, thus increasing the food source for predatory species. However, the rapid consumption of this food waste by scavenging fauna and physical and microbial breakdown ensures that the impacts of food waste discharges are insignificant and temporary and that all receptors that may potentially be in the water column are not impacted. The values and sensitivities within the DA with the potential to be affected by changes in predator–prey dynamics include: • humpback whale BIA (migration) • pygmy blue whale BIA (migration) • flatback turtle BIA (internesting buffer) and HCTS (internesting buffer) • whale shark BIA (foraging) • wedge-tailed shearwater BIA (breeding) • fish communities (associated with various KEFs). Effects on environmental receptors along the food chain—fish, reptiles, birds, and cetaceans—are not expected beyond the immediate vicinity of the discharge in open waters (Ref. 356). Studies into the effects of nutrient enrichment from offshore sewage discharges indicate that the influence of nutrients in open marine areas is much less significant than that experienced in enclosed areas (Ref. 364). These studies also suggest that zooplankton composition and distribution in areas associated with sewage dumping grounds are not affected. However, if any changes in phytoplankton or zooplankton abundance and composition occur, they are expected to be localised, typically returning to background conditions within tens to a few hundred metres of the discharge location (Ref. 365; Ref. 366; Ref. 367). Consequently, subsequent indirect impacts to other marine fauna are not expected, and thus are not considered further. Although the DA overlaps the flatback turtle internesting buffer, Whittock (Ref. 146) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Additionally, only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would be aggregating within the DA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Although fish are likely to be attracted to these discharges, any attraction and consequent change to predator–prey dynamics is expected to be limited to close to the release and thus is expected to result in localised impacts to species. Any increased predation is not expected to result in more than a limited environmental impact; therefore, the consequence is Incidental (6). As potential impacts are not expected beyond the immediate vicinity of the discharge, the likelihood that changes to predator–prey dynamics will be impacted is considered Rare (6). Overall, the risk of Planned discharges—MODU and vessels to changes to predator–prey dynamics is Very Low (10).

8.6.3 determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-60 details the determination of acceptability for Planned discharges—MODU and vessels.

Table 8-60: Determination of acceptability for planned discharges—MODU and vessels

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-01**, **AL-12**, **AL-13**, **AL-14, AL-15 and AL-17** as defined in Table 7-6 and shown below in Section 8.6.4. As described in the impact and risk evaluation (Section 8.6.4), changes to water quality are predicted to be incidental with localised and temporary impacts that quickly return to ambient levels. These impacts will not have lasting effect on biodiversity and ecosystem integrity. Therefore, the predicted level of impact is better than **AL-01**. Potential impacts to marine fauna from a change in predator-prey dynamics were also predicted to be localised to the immediate vicinity of the discharge and short-term. The predicted impacts would not decrease the availability or quality of important habitat, result in impacts at population level that would prevent long-term recovery or survival or have lasting effects on ecosystem integrity. As such, the predicted level of impact for these receptors is better than **AL-12**, **AL-13**, **AL-14, AL-15 and AL-17**.
Principles of ESD	**(b) 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 highest consequence level for Planned discharges—MODU and vessels was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Prevention measures for planned discharges from MODU and vessel operations are well regulated and managed in Australian waters (e.g. via implementation of MARPOL requirements). • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of Planned discharges—MODU and vessels based on relevant environmental legislation and other requirements as listed below. • The regulation and management of vessel discharges in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for Planned discharges—MODU and vessels was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage. • Any relevant stakeholder feedback in relation to planned discharges from MODU and vessels has been incorporated in the OPP and assessed in the external context acceptability criteria. • To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirement/action within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.</td><td rowspan="3">Legislative requirements to manage Planned discharges–MODU and vessels are addressed by adopting these control measures:
• CM-22
• CM-23
• CM-24.</td></tr>
<tr><td>Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth) – Section 26F (implements MARPOL Annex I)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution.
It also invokes certain MARPOL requirements including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution.
This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.</td></tr>
<tr><td>AMSA Marine Orders 91, 95 and 96
Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels and Australian recreational vessels.
Marine Order 91 (Marine Pollution Prevention – Oil)
Marine Order 95 (Marine Pollution Prevention – Garbage)
Marine Order 96 (Marine Pollution Prevention – Sewage)</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24)
Action A1.5: Manage anthropogenic activities to ensure marine turtles are</td><td>EPBC management plan requirements to minimise habitat degradation / modification are</td></tr>
</table>

Determination of acceptability		
	not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24). Note: This is also a specific action identified for the F-Pil individual stock. Action A1.6: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	addressed by adopting these EPOs and control measures: • **EPO-24** • **EPO-25** • **CM-22** • **CM-23** • **CM-24.** Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) Action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664) **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33). **Recovery Plan for the White Shark (*Carcharodon carcharias*)** (Ref. 34) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49) **Conservation Advice *Calidris canutus* Red knot** (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56).	These EPBC management plans for species that may occur within the DA identify habitat degradation / modification as a threat, but do not identify relevant actions.
Internal context	This procedure were identified as relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. No feedback was received in relation to planned discharges—MODU and vessels from Phase 1 stakeholder consultation.	

8.6.4 environmental performance

Table 8-61 lists the EPO defined for planned discharges—MODU and vessels and the adopted control measures to achieve the outcome.

Table 8-61: Environmental performance for planned discharges—MODU and vessels

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-01: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	**EPO-24**: Planned discharges from general MODU and vessels operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge.	**CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-23**: Vessels operating within the Development Area will comply with requirements within Marine Order 95—Marine pollution—garbage. **CM-24**: Vessels operating within the Development Area will comply with requirements within Marine Order 96—Marine pollution—sewage. **CM-25**: Vessels operating within the Development Area will comply with requirements within Marine Order 15—Construction—Fire protection, fire detection and fire extinction. **CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme (OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the location and nature of the receiving environment • requires the selection of the least hazardous material where technically and operationally feasible.
AL-12: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species. **AL-13**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act. **AL-14**: Impacts from the Development will not decrease the availability or quality of marine fauna habitat to the extent that it interferes with the recovery of the population of an EPBC Act listed threatened species. **AL-15**: Impacts from the Development will not decrease the availability or quality of important habitat[179] to the extent that it interferes with the survival of the population of an EPBC Act listed migratory species. **AL-17**: Impacts to fish communities associated with key ecological features will not prevent the conservation of biodiversity and maintenance of ecosystem integrity of the North-west Marine Region.	**EPO-25:** Planned discharges from general MODU and vessels operations within the Development Area will not cause lasting changes to marine fauna behaviour. Predator-prey dynamics will return to ambient state within seven days following the cessation of the discharge.	

[179] Where important habitat for migratory species are defined within the MNES Significant Impact Guidelines (Ref. 72).

8.7 planned discharges—subsea operations

8.7.1 source

Planned operational discharges will be released to the marine environment from Development subsea infrastructure during installation and commissioning, operations, and decommissioning.

The types of releases from these activities include:

- treated water (fresh water or sea water with chemical additives which may include biocide, oxygen scavenger, corrosion inhibitor, dye, and buffering solutions)
- hydraulic control fluids
- MEG
- marine growth removal fluids
- pigging fluids (treated water, gel, MEG)
- sea water with residual flushing and cleaning contaminants
- preservation fluids
- residual or trapped hydrocarbon
- nitrogen gas, methane, and compressed air.

The key discharge streams are discussed in further detail in Section 8.7.2 and are considered to represent the largest planned discharges associated with the Development. The full range of potential planned operational discharge sources that may be released at different phases of the Development will be assessed and defined as the engineering design progresses in subsequent EPs.

Table 8-62 lists the activities within each phase where planned discharges from subsea operations occur in the DA.

Table 8-62: Phases and activities that generate planned discharges—subsea operations

Phase	Activity
Installation and commissioning	Installation of subsea structures Hydrotesting and pre-commissioning Commissioning
Operations	Inspection Maintenance and repair Major repairs
Decommissioning	Flowline and MEG pipeline decommissioning Other subsea structures decommissioning

8.7.1.1 installation and commissioning

Following installation, the flowlines and MEG pipelines undergo FCGT, leak testing and pre-commissioning (conditioning). Planned discharges are predominantly subsea, at water depths ranging from 100–1,400 m depending on the field. The planned discharges will generally be released at controlled discharge rates.

Discharges include the following types.

8.7.1.1.1 treated water

Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, dye, and buffering solutions. These additives are required to maintain pipeline integrity by avoiding metal corrosion, preventing bacterial growth and the accumulation of scale on internal surfaces. All chemicals will be subject to CAPL's ABU Hazardous Materials Management Procedure (Ref. 368).

The expected largest volume of treated water released during FCGT, leak testing and dewatering is ~35,000 m^3, which is double the volume of the inventory of the longest flowline (Chandon)—it accounts for dewatering the full inventory once and a contingency for flushing a second time. This is also the largest volume likely for a single release of treated water.

In the unlikely event of a buckle or rupture during installation, sea water may enter the flowline or MEG pipeline and then be released. The expected discharge volume for a rupture event is also ~35,000 m^3 (based on double the inventory of the longest flowline).

Treated water will also be released before commissioning starts, during flowline and MEG pipeline conditioning; however, this would be a much smaller volume.

8.7.1.1.2 nitrogen and methane

During commissioning of the production flowlines, dry hydrocarbon gas (methane) may be used to pressurise the flowline in readiness for the start-up phase. This hydrocarbon gas will compress the nitrogen gas used during the pre-commissioning phase towards the end of the flowline. There may be a requirement to purge some or all of the pre-commissioning nitrogen gas and commissioning methane gas at the end of the flowline at the seabed. This would result in a controlled maximum subsea release of ~400 m^3 (equivalent to ~25,000 Sm^3 reported at 0 barg) of nitrogen gas, followed by a maximum of ~400 m^3 (equivalent to ~25,000 Sm^3 reported at 0 barg) of methane for the deep-water gas fields, () and a maximum of ~200 m^3 (equivalent to ~6,000 Sm^3 reported at 0 barg) nitrogen gas, followed by a maximum of ~200 m^3 (equivalent to ~6,000 Sm^3 reported at 0 barg) methane for the shallow-water gas field (Section 4.3.3.7).

A gas dispersion study was undertaken by Wood Group to investigate the gas plume behaviour of a subsea release of nitrogen and methane in deep water (1,200 m) and shallow water (150 m) (Ref. 553). For the deep-water scenarios, releases of 25,000 Sm^3 of nitrogen and 25,000 Sm^3 (reported at 0 barg) of methane were modelled; this volume is based on the longest flowline in the Development). For the shallow-water scenarios, 6,000 Sm^3 of nitrogen and 6,000 Sm^3 (reported at 0 barg) of methane were modelled; this volume is based on the indicative longest flowline for the WTR field. The gas dispersion study indicated that:

- the release of the nitrogen or methane gas did not create a large plume, instead occurring as bubbles through the water column
- no surface release of either nitrogen or methane gas was predicted for the deep-water release (methane gas was predicted to rise to ~650 m below water surface and nitrogen gas to ~800 m below water surface)
- some surface release of nitrogen and methane gas would occur for the shallow-water releases.

8.7.1.1.3 MEG

Volumes of up to ~1,750 m^3 of MEG may be discharged during the installation and commissioning phase from FCGT, leak testing or flowline and/or MEG pipeline pre-commissioning activities (Sections 4.3.3.6 and 4.3.3.7).

In the unlikely event of a wet buckle or rupture, contingency dewatering of the flowlines or MEG pipelines may result in residual MEG being discharged.

8.7.1.1.4 hydraulic control fluid

During the installation and commissioning phase, small volumes of hydraulic control fluid may be discharged during connection to the CDU, control system leak testing, valve function testing and umbilical installation.

The largest estimated release of hydraulic control fluid in a single event is ~2.5 m^3.

8.7.1.1.5 marine growth removal fluids

Before installing subsea structures, any marine growth and calcareous build-up present on existing structures will be removed via mechanical cleaning, acid wash or similar (Section 4.3.3.4). Only small volumes of chemicals will be used for acid washing, and these chemicals will be applied directly to infrastructure. The volume will depend on which infrastructure needs to be cleaned of marine growth but is expected to be no more than 1 m^3 per application.

8.7.1.1.6 preservation fluids

During tie-in of jumpers and spools, a small amount of preservation fluid will be released. The volume per tie-in is expected to be up to ~15 m^3. Preservation fluid generally comprises treated water, MEG, and conditioning chemicals. Given the low release volume of preservation fluids, the non-continuous nature and short duration of the release, assessment from treated water is considered appropriate (although extremely conservative) to cover preservation fluids. Consequently, preservation fluids are not discussed further.

During a tie-in to GFP infrastructure there is also potential for a small volume of trapped hydrocarbon (e.g. ~1.5–175 m^3 of gas and <1 m^3 of condensate[180]) to be released to the environment (Section 4.3.3.4.1). Any trapped gas released during a tie-in (i.e. up to ~175 m^3) is a smaller volume than that described above in Section 8.7.1.1.2 for the potential release of gas during commissioning activities (i.e. ~200–400 m^3); as such, the assessment for commissioning is considered appropriate to cover these smaller potential trapped gas releases during a tie-in activity. The potential for a release of <1 m^3 trapped condensate during a tie-in activity is evaluated within Section 8.7.3.

8.7.1.2 operations

8.7.1.2.1 treated water

Treated water may be released in the operations phase from maintenance and repair activities. The frequency of maintenance and repair activities depends on the results of inspections (Section 4.3.4.3).

[180] Note: These indicative volumes are based on subsea ambient pressures (~15 barg for Gorgon tie-ins, and ~135 barg for Jansz tie-ins).

Major repairs are very unlikely to be needed; however, worst-case discharges were assessed. Major repair of a flowline involves temporary decommissioning, repair, then recommissioning (Section 4.3.4.4).

Following a major defect or full-bore rupture, the flowline would be temporarily decommissioned. It would then be flooded with treated water that will propel a pig towards the defect. This may result in treated water, sea water, residual gas condensate and MEG discharges at the location of the defect. Discharges of treated water from this activity would be smaller than the two full line volumes assessed for pipeline recommissioning (~35,000 m^3).

Installing the replacement section would include leak testing and then dewatering and pre-commissioning the flowline (Section 4.3.3.6). As described for installation (Section 8.7.1.1), the largest expected discharges of treated water for these activities is ~35,000 m^3 (double the inventory of the longest flowline)—this accounts for dewatering the full line volume at least once and a contingency for flushing a second time.

8.7.1.2.2 MEG

MEG may be discharged from maintenance and repair activities during operations. In the worst-case event of a flowline or full-bore rupture, MEG would be released during a major repair from leak testing, pigging, and pre-commissioning of the repaired flowline.

As described for treated water, a major repair would involve temporarily decommissioning the flowline, then flooding the flowline with treated water that will propel a pig towards the defect. This may result in discharges of treated water, sea water, residual gas condensate and MEG at the location of the defect.

Installing the replacement section would include leak testing and then dewatering and conditioning the flowline (Section 4.3.3.6). The worst-case discharge of MEG from flowline recommissioning is ~1,750 m^3 (Section 8.7.1.1).

MEG will also be released during inspections, as outlined under pigging fluids.

Residual gas condensate may be discharged in the unlikely event that a major repair is required; this would be a much smaller volume than the pipeline rupture scenario, which is assessed in Section 8.15.

8.7.1.2.3 hydraulic control fluid

Operating the hydrocarbon system may result in discharges of hydraulic control fluid to the environment from valves located at the subsea electrohydraulic control systems and at production trees and manifolds (as described in Section 4.2). Each valve actuation is estimated to result in the loss of, on average, a few litres per actuation of hydraulic control fluid to the marine environment.

Hydraulic control fluid may also be released in the operations phase from leak testing during maintenance and repair activities, as described for treated water above.

8.7.1.2.4 pigging fluids (treated water, gel, MEG, and/or nitrogen slugs)

Pigging may be used to internally inspect the flowline to ensure the integrity of infrastructure is maintained (Section 4.3.4.2). Temporary pig launchers and receivers may use a combination of treated water, gel, MEG, and/or nitrogen slugs to complete pigging activities. The maximum volume of pigging fluids that may be discharged is ~4.5 m^3. Due to the low release volume of pigging fluids and

the low frequency of these discharges (during inspections, Section 4.3.4.2), the assessment from treated water is considered appropriate (although extremely conservative) to cover pigging fluids. Consequently, pigging fluids are not discussed further.

A small volume of trapped hydrocarbon (e.g. ~3 m^3 of gas and <0.5 m^3 of condensate[181]) may also be released from the end cap (Section 4.3.4.2). Any trapped gas released during a pigging activity (i.e. ~3 m^3) is a significantly smaller volume than that described above in Section 8.7.1.1.2 for the potential release of gas during commissioning activities (i.e. ~200–400 m^3); as such, the assessment for commissioning is considered appropriate to cover these smaller potential trapped gas releases during a pigging activity. The potential for a release of <0.5 m^3 trapped condensate during a tie-in activity is evaluated within Section 8.7.3.

8.7.1.2.5 marine growth removal fluids

Acid wash and chemicals may be used for removing marine biological growth and calcareous deposits during maintenance and repair activities. Structures with calcareous deposit accumulation may require acid washing or soaking (typically using <4.5 m^3 of water-soluble sulfamic acid or similar).

8.7.1.3 decommissioning

When the Development fields are ready for decommissioning, the flowline contents will be flushed to remove hydrocarbons then decontaminated, if necessary. Options for decontaminating the equipment will be considered in more detail when the final decommissioning solution and end state is further defined and will include offshore and onshore decontamination options.

Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

8.7.1.3.1 sea water with residual flushing and cleaning contaminants

Each flowline may be filled with sea water following flushing and cleaning, which will be released to the marine environment before flowline decommissioning. The sea water may contain residual hydrocarbon, mercury, NORMs, surfactants, hydrochloric acid, or MEG. The volume of sea water that is likely to be released is determined by the flowline inventory, which is an estimated volume of 17,500 m^3 (based on the longest flowline).

8.7.2 predicted exposure area

treated water scenario

As identified in Section 8.7.1.1.1, to prevent corrosion, hydrotesting water will be treated with biocide and oxygen scavenger and potentially other chemical additives. The specific discharge volumes and characteristics of treated water will be determined and assessed in detail closer to the time of the activity. However, to support the risk assessment, assumptions have been made using historical data and a conservative, worst-case scenario approach (

[181] Note: These are indicative in situ subsea release volumes (subsea ambient pressures are ~15 barg for shallow-water backfill fields and GFP tie-ins [WTR, Gorgon], and ~124–135 barg for deep-water backfill fields and GFP tie-ins [C&D, G&E, Semele, Chandon, and Jansz]).

Table 8-63). Activity-specific EPs will assess any deviations from initial risk assessments and will manage the activity to maintain or reduce the risk profile to what is assessed in the OPP.

Most additives to treated water are either consumed during testing, diluted upon discharge, or are non-toxic at residual concentrations (Ref. 713; Ref. 714; Ref. 715). The biocide, by nature, is generally associated with the highest toxicity of all additives, and is therefore the primary chemical of focus considered in dispersion modelling.

While synergistic interactions between biocides and other additives, such as oxygen scavengers, are possible, these effects have been reported to vary by additive, with some combinations enhancing toxicity and other reducing it (Ref. 735). Given the conservatism already built into modelling and risk assessments, any synergistic interactions are unlikely to increase the predicted worst-case area of effect. In addition, while the majority of additives are likely to be consumed within pipelines during hydrotesting, modelling of discharge concentrations was based on initial concentrations for conservatism.

A dispersion study for hydrotest water discharges from the Gorgon and Jansz pipeline, undertaken in 2010 (Ref. 85), was used to inform the predicted exposure area for treated water. This study is considered a representative analogue for the DA, based on the following:

- comparable discharge volumes: Total discharges from the Development are expected to be similar or smaller than those modelled
- relevant location: The modelling study was conducted at sites within the DA, across varying water depths, making it representative of both shallow and deeper water metocean conditions
- similar chemical concentrations: Initial biocide concentrations are expected to be comparable
- comparable discharge and pipe characteristics: Vertical outlet orientation were identified for both
- lower discharge rate: The Development's expected discharge rate (0.06 m^3/s) is lower than the modelled rate (0.25 m^3/s), result in likely greater dispersion and lower localised concentrations
- similar outlet constriction: Although the discharge rate is lower, the outlet diameter for the Development (0.05–0.1 m) is expected to be smaller than that modelled (0.15 m), resulting in a similar constriction (0.6 m down to 0.05–0.1 m vs. 0.8 m down to 0.15 m). This supports a comparable assumption of plume momentum and upward jetting.

Due to the conservatism built into modelling, minor differences in discharge characteristics are unlikely to result in an area of effect greater than the worst-case prediction.

Table 8-63 provides a comparison of key parameters.

Table 8-63: Key parameters for hydrotest modelling

Parameter	Analogue		DA
	Gorgon	Jansz	
Location	20° 29' 11.1849" S 114° 53' 53.2918" E (WTR and C&D tie-in location with Gorgon infrastructure [southern section of the DA])	19° 48' 34.7744" S 114° 36' 28.2344" E (G&E and Chandon tie-in location with Jansz–Io MPTS [northern section of the DA])	Refer to Sections 4.1.2 and 4.1.3
Water depth (m)	130	1,260	150-1,400
Total volume discharged (m^3)	30,000	60,000	Up to 35,000
Duration (hours)	33	67	96
Discharge rate (m^3/s)	0.25		0.06^
Initial concentration of biocide	Tetrakishydroxymethyl phosphonium sulphate (THPS) 480 ppm		480-600 ppm THPS[182]
Pipe configuration	Vertical upward		Vertical upward

^Based on expected pigging speed of 0.2 m/s on a 24" flowline

A conservative threshold of 3 ppm for THPS, representing the lower range of LC_{50} values (3–340 ppm) reported for fish species by Chen and Chen (Ref. 735) and significantly lower than Safety Data Sheet LC_{50} values for fish (65-119 ppm, [Ref. 722; Ref. 723]), was chosen for the modelling study. The LC_{50} value was used as it is the most commonly reported threshold for acute toxicity.

Ecotoxicological studies, including acute toxicity tests, typically determine LC_{50} values using constant exposure doses over 24 to 96 hours to establish relevant toxicity thresholds (Ref. 720; Ref. 721). The use of a 96 hour exposure threshold is considered conservative, as receptors are highly unlikely to experience continuous exposure to hydrotest discharge plumes for that duration. While a maximum discharge duration of 96 hours has been assumed, discharge durations are more likely to be shorter —similar to previous Gorgon (33 hours) and Jansz (67 hours) discharge (Table 8-63). It is likely that only receptors very close to the discharge point (within tens of metres) may experience constant exposure to the discharge plume, as plumes will change directions based on tidal currents (Ref. 85).

To further enhance conservatism, the 3 ppm threshold was reduced to 1 ppm to encompass threshold values for other biocides that may potentially be used[182]. For example, 1 ppm was considered a no-effect level for the biocide Hydrosure O—3670R, based on a range of toxicological studies (Ref. 736). Based on the results of the dispersion study, and interpolation for a 1 ppm threshold, dilutions equivalent to 1 ppm are unlikely to extend beyond ~2 km for Gorgon (shallow waters) and ~1.5 km for Jansz (deeper waters) (Ref. 85). The modelling results also predicted that the plume would rise upward immediately after discharge due

[182] While the specific biocide and dosage for the Development have not yet been determined, the biocide modelled in the dispersion study (Ref. 85) is commonly used in offshore applications. To account for other commonly used biocides, a more conservative threshold than that of modelled biocide was adopted. This combined approach is considered a representative basis for informing the impact and risk assessment in this OPP. The final product selection may vary and will be captured within the activity-specific EP.

to the plume momentum and vertical outlet orientation, creating a turbulent mixing zone with the receiving waters. Once the hydrotest water plume completely loses its upward momentum, the ambient currents will further mix and disperse the hydrotest wastewater (Ref. 85).

Other studies conducted in the region identified biocide discharges exposure extents. For shallow waters (~80 m) with discharges of 220,000 m^3, concentrations would dilute to below lethal levels (LC_{50}) up to 3.5 km from the discharge location (Ref. 369). For deeper waters (~930 m) with discharge of 238,800 m^3, concentrations are predicted to extend up to 1.38 km at the 99th percentile (Ref. 554). These results suggest that the selected approach is highly conservative and adequate.

8.7.3 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors that may be impacted by subsea discharges:

- water quality
- benthic habitats and associated communities
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- commercial fisheries
- KEFs
- cultural heritage value: Traditional Owners.

The accumulation of contaminants in sediments primarily depends on the volume and concentration of particulates in discharges or constituents that adsorb onto seawater particulates. It also depends on the area where these particles settle onto the seabed, and the resuspension, bioturbation, and microbial decay of those particulates in the water column and on the seabed. Subsea operational discharges are either positively buoyant, causing the plume to dilute and disperse upon release (Ref. 369; Ref. 555) or they mix rapidly and become diluted (Ref. 267; Ref. 371). Consequently, measurable accumulation in sediments is not expected to occur. Therefore, impacts to sediment quality from planned operational subsea discharges are not expected, and are not evaluated further.

Table 8-64 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to planned operational discharges.

Table 8-64: Impact and risk evaluation for planned discharges—subsea operations

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned subsea operational discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality to benthic habitats and associated communities.	–	–	–
		A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	–	–	–

Impact and/or risk level summary					
		A localised and temporary reduction in water quality may result in: • change to the functions, interests and activities of other marine users.	–	–	–
		Planned subsea operational discharges within a KEF may result in: • change to values and sensitivities of KEFs	–	–	–
		Planned subsea operational discharges may result in: • change to cultural heritage values: Traditional Owners	6	6	Very Low (10)

Impact evaluation

Water quality

Localised and temporary reduction in water quality

Planned operational subsea discharges include treated water, acid wash/cleaning chemicals, hydraulic control fluid, nitrogen and methane and MEG. These discharges are intermittent, non-continuous, and of short duration and may result in localised and temporary reduction in water quality during installation and commissioning, operations, and decommissioning phases of the Development.

The waters surrounding the DA are known for currents and surface waves that facilitate the mixing of surface waters (Section 6.3.4.1, Ref. 102). Current speeds in the DA range between 0.16 m/s - 0.27 m/s with maximums ranging from 0.54 m/s to 2.18 m/s (Section 6.3.4.1).

The worst-case discharge volumes are assessed for each discharge type.

Treated water

The highest volume discharge across installation, commissioning and operations phases for treated water, from either dewatering before commissioning, or the unlikely event of a major repair of a flowline resulting from a flowline or bore rupture is ~35,000 m^3. Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions.

Residual biocide in treated water has the potential to be acutely toxic to a range of marine biota associated with benthic habitats, including fish, molluscs, and echinoderms (Ref. 369). Dye, scale inhibitor and corrosion inhibitor are expected to be less toxic than the biocide (Ref. 370). As identified in Section 8.7.2, the largest discharge of treated water of the Development is predicted to result in exposures of ~2 km in shallow waters and ~1.5 km in deeper waters. Biocides routinely used in the oil and gas are usually biodegradable and non-bioaccumulative (Ref. 371). The plume will rise upward immediately after discharge and the waters surrounding the DA are known for surface waves that facilitate mixing. Consequently, treated water is expected to rapidly dilute once released into the surrounding environment, leading to limited (within the DA) and temporary reduction in water quality.

Nitrogen gas and methane

For the deep-water scenario, a maximum release of ~25,000 Sm^3 of nitrogen gas, followed by a maximum of ~25,000 Sm^3 of methane, may be discharged. For the shallow-water scenarios, 6,000 Sm^3 of nitrogen and 6,000 Sm^3 of methane may be discharged. As described in Section 8.7.1.1.2 the gas dispersion study indicated that nitrogen and methane gas did not create a large plume, instead occurring as bubbles through the water column. No surface release of either nitrogen or methane gas was predicted for the deep-water release and some surface release would occur for the shallow-water.

Methane will migrate upward through the water column either as dissolved methane or as bubbles (Ref. 555). The rising methane plume is subject to further dissolution and microbially-mediated aerobic and anaerobic oxidation (Ref. 556; Ref. 557).

Modelling undertaken in waters depths <800 m has found that gas dissolves quickly in the water column (Ref. 558; Ref. 559). Further offshore, ~1,400,000 m^3 of methane was injected into deep waters (~1,500 m) during the Deepwater Horizon oil spill event (Ref. 555). The methane plume

Impact evaluation

was trapped below 800 m depth, with methane concentrations roughly 20–50 times higher than background levels (Ref. 560). The trapped methane was consumed by methanotrophic bacteria within ~120 days from the onset of release (Ref. 560).

Nitrogen gas does not react with water and will dissolve (Ref. 562). Increasing nitrogen concentrations in the ocean may temporarily boost plankton production, leading to algal blooms (Ref. 562). Eutrophication may also occur; however, this requires the discharge of large amounts of nitrate.

Given the small discharges and infrequent release of methane and nitrogen, temporal deviations from water quality background levels are expected. Consequently, a limited short-term reduction in water quality is expected.

Hydraulic control fluid

During the installation and commissioning phase, as well as IMR activities during operations phase, control fluids discharges are intermittent, non-continuous and of short duration, and as such, frequency of exposure is limited. Up to 2.5 m^3 of control fluid is expected to be discharged.

During operations, a few litres of control fluids may also be released from valve actuation. These fluids are typically diluted (Ref. 267) and rapid dispersion is expected due to small discharge volumes within open marine waters.

BP undertook fluid dispersion modelling for subsea releases of control fluids at water depths between 70 m – 530 m, with current speeds of 0.1 m/s and a total volume of ~2.1 m^3. This analogue is considered appropriate given the similar discharges volume (up to 2.5 m^3 from the DA) and current speeds (~0.16 m/s - 0.27 m/s [Section 6.3.4.1]). The results estimated the residence time or plume persistence to be 77 minutes (Ref. 267). The spatial extent of these small discharges is expected to be limited to a small area in the water column around the source (up to 98 m) (Ref. 267). For smaller discharges (20 L over 0.5 min), plume persistency was up to 12 min with a maximum displacement of 13 m (Ref. 267), suggesting that low volume discharges will be rapidly diluted.

Given the low volume (up to 2.5 m^3 discharged intermittently during the installation, commissioning and operations phases, and few litres per actuation during operations) and the control fluids characteristics (diluted and rapidly dispersed), only limited short-term reduction in water quality is expected.

MEG

Discharges such as MEG (~1,750 m^3) will also be released (see Section 8.7.1 for the source of these fluids).

MEG is widely used by the oil and gas industry in wellheads and pipelines. The aquatic toxicity of MEG is very low, it is listed as an 'E' category fluid under the Offshore Chemical Notification Scheme (OCNS) It is rated as PLONOR (pose little or no risk) by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), is readily biodegradable, and has low potential for bioaccumulation (Ref. 372; Ref. 373). MEG is also completely miscible with water and would disperse quickly if released into the marine environment. Consequently, limited short-term reduction in water quality is expected.

Marine growth removal fluids

As previously mentioned, these discharges are intermittent, non-continuous and of short duration, and as such, frequency of exposure is limited. The volumes of the chemicals used for acid washing will be relatively small (~4.5 m^3 per application depending on infrastructure); these chemicals will be applied directly to the infrastructure. A typical growth removal (acid–water mix) discharge is expected to quickly dilute and neutralise as it reacts with the calcareous material being removed from the subsea infrastructure.

Given the low release volume and the low frequency of the discharges, they will disperse and dissolve within the water column within the proximity of the release location. Consequently, limited short-term reduction in water quality is expected.

Trapped hydrocarbons (condensate)

The estimated volume of condensate that may be released during a tie-in activity or during a pigging activity are small at <1 m^3 and <0.5 m^3 respectively. These types of discharges are discrete intermittent events of short duration.

Condensate released subsea would be buoyant and migrate upward through the water column. However, given the water depth, pressure, and the small volumes released, these volumes of condensate are not expected to reach the sea surface; rather, given the properties of the backfill fields condensates (e.g. low viscosity, and light to non-persistent oils; see Table 8-101 and Table 8-102), the condensate would disperse, dissolve, and dilute within the water column. The

Impact evaluation

condensate would also be subject to more gradual decay through biological and/or photochemical processes. If some of the condensate did reach the water surface, it is expected to rapidly evaporate (due to the high volatile and semi-volatile components; Table 8-101 and Table 8-102).

Therefore, given the intermittent, short duration, and low volume of condensate releases, and in conjunction with the subsequent dilution and dispersion that would occur in open ocean conditions, limited and short-term reduction to water quality may occur.

Sea water with residual flushing and cleaning contaminants

Following flushing and cleaning of flowlines during decommissioning, up to 17,500 m^3 of sea water (based on the longest flowline, Chandon [Section 8.7.1.3.1]) may be released. This sea water may contain residual hydrocarbons, mercury, NORMS, surfactants, hydrochloric acid or MEG.

Mercury naturally occurs in some oil and gas reservoirs (Ref. 561) and is present in low concentrations in the ocean. In the DA, mercury was identified in all sediment samples except at WTR DC-1 (Section 6.3.4.3; appendix a). Residual scale (which may contain traces of mercury, NORMS and other contaminants) may build up on the inner wall of flowlines over their operational life (Ref. 561). Mercury and NORMS in pipelines will not pose a risk to the marine ecosystem until released following corrosive breakthrough (Ref. 563; Ref. 564). Radium is one of the most significant radioactive elements found in NORM scale. Dissolved cations in seawater, especially calcium and magnesium, help prevent the bioaccumulation of radium (Ref. 564). Mercury concentrations depend on the pipeline material, the form of mercury, and the presence of any internal coatings (Ref. 561; Ref. 563).

Flushing activities may remove mercury species associated with mobile contaminants within the pipeline, such as liquid hydrocarbons, loose corrosion products or sludges (Ref. 563). Flushing and cleaning fluids themselves will not be discharged to the sea. Only minimal residual levels of any internal contaminants would remain and potentially be included when the flowlines are flushed with seawater. Consequently, very low quantities of scale are expected. Furthermore, after dissolved mercury is flushed, less soluble mercury species, such as Hg^0 and $HgS_{(s)}$, will disperse or mix into the surrounding of the pipeline footprint (Ref. 563).

Consequently, given the small discharges (potential traces of contaminants) and infrequent release (during decommissioning) limited short-term reduction in water quality is expected.

The other residual contaminants are assessed above; and any residual hydrocarbons in the discharge would be a lesser concentration than assessed in Section 8.15 for an unplanned release of condensate.

In summary, limited short-term reduction in water quality is expected from all subsea discharges, and therefore, has been evaluated as Incidental (6).

Risk evaluation

Injury or mortality to benthic habitats and associated communities

Subsea discharges are expected to result in temporary reductions in water quality within the immediate surroundings of the release location. The extent of this water quality reduction is limited to around the DA. A potential impact to benthic communities and habitats may occur through toxicity impacts. Note that potential impacts to KEFs are assessed below.

As described in Section 6.3.1.1, the BCH within the DA is predicted to comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity, typical of the Northern Carnarvon Basin. In close proximity to the proposed flowline/umbilicals, scarps with the presence of biota and discrete patches of depressions over bare substrate were also identified. No canyon features, limited epifauna, and no endemic benthic infauna were identified in the survey (Ref. 104; appendix a).

The largest volume of subsea fluid discharges is associated with treated water (~35,000 m^3 from either dewatering before commissioning, or the unlikely event of a major repair of a flowline resulting from a flowline or bore rupture). The biocides routinely used in the oil and gas industry are usually biodegradable and non-bioaccumulative (Ref. 371). Discharges are expected to rise upward (Ref. 85). Consequently, it is expected to rapidly dilute once released into the surrounding environment and unlikely to cause a change in habitats or communities at a measurable level and will not change the viability of the population or ecosystem.

Volumes of up to ~1,750 m^3 of MEG may also be discharged. The aquatic toxicity of MEG is very low, has a low bioaccumulation potential, and it is on the OSPAR list of substances that are

considered to pose little or no risk to the environment once released (PLONOR). Concentrated MEG is weakly negatively buoyant, however is not expected to accumulate in sediments (Ref. 570). As such, it is not expected to result in adverse impacts to benthic habitats or fauna.

Similarly, control fluids are typically diluted (Ref. 267). Rapid dispersion is expected due to small discharge volumes (up to 2 m^3 discharged intermittently during the installation, commissioning and operations phases, and few litres per actuation during operations) within open marine waters; and are therefore not expected to result in adverse impacts to habitats or fauna.

Sea water with potential residual contaminants may also be discharged during decommissioning activities. Traces of NORMS and Mercury, which may build up on the inner wall of flowlines over their operational life (Ref. 561), may be found in low quantities. Radium, the most significant radioactive elements found in NORM scale, has a very low concentration in solution in seawater and has a low bioavailability to marine organisms (Ref. 564). Any radium associated with precipitated barite would not be bioavailable to benthic organisms. If bioaccumulation occurs, radium concentrations are identified in calcified skeletal structures than in muscle and organ tissue (Oil and Gas UK 2016 as cited in Ref. 564). However, because of its low concentration, radium rarely accumulates to high concentrations in the tissues of marine plants and animals (Ref. 564). Consequently, impacts to benthic habitats or fauna are not expected.

As previously mentioned, after dissolved mercury is flushed, less soluble mercury species, such as Hg^0 (elemental mercury) and $HgS_{(s)}$, will disperse or mix into the surrounding of the pipeline footprint (Ref. 563). As such, adverse impacts to benthic habitats or fauna are not expected.

For the deep-water scenario, a maximum release of ~25,000 Sm^3 of nitrogen gas, followed by a maximum of ~25,000 Sm^3 of methane, may be discharged. For the shallow-water scenarios, 6,000 Sm^3 of nitrogen and 6,000 Sm^3 of methane may be discharged. As described in Section 8.7.1.1.2, the gas dispersion study indicated that nitrogen and methane gas did not create a large plume, instead occurring as bubbles through the water column. Gas will be buoyant and will rise through the water column; the released gas is also expected to dissolve into the water column with some surface release occurring for the shallow-water discharges. Natural gas has low inert toxicity to marine organisms (Ref. 571), whereas dissolved methane (the predominant component of natural gas) may have toxic effects to marine organisms (e.g. fish) if it occurs at sufficient concentrations and exposure (Ref. 572). However, naturally occurring methane seeps (i.e. minor and low volume leaks) are not considered a risk to the marine environment (Ref. 573; Ref. 574). Therefore, given the low volume and infrequency occurrence of any gas release, in conjunction with the subsequent dispersion and dilution occurring in open ocean, adverse impacts to benthic habitats or fauna are not expected.

A subsea discharge of trapped condensate would be buoyant and migrate upward through the water column. As described above these small volumes of condensate are expected to rapidly disperse, dissolve, and dilute within the water column. As such, the potential release of trapped condensate during a tie-in or pigging activity is not considered to cause a change in benthic habitats or communities.

Based on the previous details, impacts to benthic habitats and communities from planned subsea discharges from the DA are not expected and have not been evaluated further.

Marine Fauna

Injury or mortality to marine fauna

Planned release of subsea discharges are expected to result in temporary reductions in water quality within the surroundings of the release location which has the potential to cause lethal or sub-lethal effects (through toxicity) to marine fauna.

As described in Section 8.7.1.1.2, some surface release of nitrogen and methane gas would occur for the shallow-water releases. The gas plume is subject to dilution (Ref. 556; Ref. 557; Ref. 562) and only small volumes are expected to be released into the air. Given the location (open waters) and the small volumes, the gas is expected to rapidly mix with air and disperse. Therefore, injury or mortality to seabirds is not expected. Other subsea discharges are expected to disperse within the water column; thus, impacts to seabirds are not expected either and have not been evaluated further.

As identified in Section 6.3.3, several listed threatened and/or migratory marine species under the EPBC Act have the potential to occur within the DA (the area where planned discharges are predicted to occur). The BIAs identified within the DA include:

- humpback whale BIA (migration)
- pygmy blue whale BIA (migration)
- flatback turtle BIA (internesting buffer) and HCTS (internesting buffer)
- whale shark BIA (foraging).

Early life stages of fish (embryo and larvae) and other plankton are the most susceptible to toxicity as they have limited mobility, thus are more likely to be exposed to toxic effects. Low nutrient levels within the DA indicates sparse populations of plankton species throughout the NWS (Ref. 103). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 103). As previously described, discharges are expected to have limited and temporary reduction in water quality. Therefore, a change in water quality as a result of planned subsea discharges is unlikely to lead to injury or mortality of plankton at a measurable level and will not change the viability of the population or ecosystem. Consequently, potential changes to planktonic communities are not evaluated further.

The Recovery Plan for the white shark (Ref. 34), Conservation Advice for dwarf sawfish (Ref. 29) and Recovery Plan for grey nurse shark (Ref. 32) did not identified marine pollution as a threat. The approved Conservation Advice for whale sharks (Ref. 33) states that the main threat to this species occurs outside Australian waters (from intentional and unintentional mortality from fishing); however, within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat; however, no specific conservation actions are defined.

The Conservation Management Plan for the blue whale (Ref. 20), Conservation advice fin whale (Ref. 21) and Conservation advice sei whale (Ref. 22) list chemical discharge or pollution as a threat to the species; however, no specific conservation actions are defined. For fin and sei whales, this threat has been assessed as minor (Ref. 21; Ref. 22). For pygmy blue whales, this threat has been risk assessed as having a minor consequence, defined in the Plan as “individuals are affected but no affect at population level” (Ref. 20).

Fish, shark and marine mammal species identified within the PMST report as potentially occurring within the DA are highly mobile. No known aggregation sites were identified. Discharges are expected to rapidly dilute and disperse in the water column. To be impacted, the species would need to pass directly through the discharge plume immediately upon release and remain within the plume for almost the entire duration of the residence time.

The recovery plan for marine turtles (Ref. 24) list acute chemical discharge as a threat to the species. It also notes that is a concern to nesting habitats mainly from oil spills. Only the flatback turtle BIA (internesting buffer) and HCTS (internesting buffer) were identified within the DA. As identified in section 6.3.3.2.1, unsuitable flatback turtle internesting habitat was identified as waters >25 m deep and >27 km from the coast (Ref. 146). The DA is located in water depths of >100 m and is at closest ~50 km from the west coast of Barrow Island, and ~45 km from the Montebello Islands. Consequently, the DA is located in waters classified as unsuitable for internesting flatback turtles. As such, it is considered highly unlikely that internesting flatback turtles will occur within the DA. Only a small number of transient individuals are expected to be present.

Marine fauna found in the water column, such as fish, marine mammals, and marine reptiles, are expected to actively avoid discharge plumes and associated turbidity and toxicity within the water column (Ref. 484). In addition, given the highly mobile nature of these marine species, the infrequent release, and the dilution and dispersion nature of the discharges, potential impacts to marine fauna are not expected, and therefore are not discussed further.

Commercial fisheries

Change to the functions, interests and activities of other marine users

As impacts to fish are not expected from planned subsea discharges, indirect impacts to commercial fisheries are also not expected.

The maximum spatial extend where planned discharges are predicted to result in exposures is <2 km from the release source (from treated water, refer to localised and temporary reduction in water quality assessment). In comparison with the size and scale of commercial fisheries, this is an insignificant area.

Four State-managed fisheries with recorded fishing effort between 2014–2023 (Section 6.4.1.2) and two Commonwealth-managed fisheries with recorded fishing effort between 2013–2022 (Section 6.4.1.1) intersects with the DA. Historical fishing effort data shows limited activity with the vicinity of the DA (Section 6.4.1.1 and Section 6.4.1.2). Therefore, impacts to commercial fisheries from planned subsea discharges are not expected, and have not been evaluated further.

KEFs

Change to values and sensitivities

Subsea discharges are expected to result in temporary reductions in water quality within the immediate surroundings of the release location. This may lead to a potential change to values and

sensitivities of KEFs. The predicted maximum spatial extent of exposures from planned discharges is <2 km from the release source (i.e. within the DA). Three KEFs have been identified to intersect the DA (Section 6.3.6.1). The values of the ancient coastline at 125 m depth contour KEF and Exmouth Plateau KEF have been assessed as its unique sea floor feature with ecological properties of regional significance (Ref. 102).The continental slope demersal fish communities KEF is valued for its high biodiversity and endemism with a range of fish assemblages (Ref. 102; Ref. 374). As described in the consequence evaluation above, the subsea discharges are not expected to result in a lasting effect to water quality, and no change in sediment quality is predicted. These discharges are unlikely to cause a change in habitats or communities at a measurable level and will not change the viability of the population or ecosystem. Therefore, potential changes to values and sensitivities of the KEFs are not evaluated further.
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from planned release of subsea discharges includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from planned release of subsea discharges. As impacts to marine fauna are not expected from planned subsea discharges, no impact pathway to a change in indirect impacts to intangible Traditional Owners cultural values from planned subsea discharges within the DA is anticipated. Minor changes in water quality from planned subsea operational discharges will be localised and temporary as discharges will be rapidly diluted in open waters. Given the offshore location of the DA, an adverse change to cultural heritage values attributed to the offshore marine area from planned discharges within the DA is negligible. As such, CAPL has ranked the consequence for cultural heritage values as Incidental (6). The likelihood of the consequence occurring is evaluated as Rare (6). The risk of planned subsea operational discharges to Traditional Owner cultural heritage values is Very Low (10).

8.7.4 determination of acceptability

The acceptable level of impact and/or risk is a function of the magnitude of impact and/or residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-65 details the determination of acceptability for planned operational discharges.

Table 8-65: Determination of acceptability for Planned discharges—Subsea operations

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-01**, **AL-07**, **AL-12**, **AL-13**, **AL-14, AL-15 and AL-17** as defined in Table 7-6 and shown below in Section 8.7.4. Changes to water quality from subsea operations are predicted to be incidental with localised and short-term reduction in water quality. These impacts will not have lasting effect on biodiversity and ecosystem integrity. Therefore, the predicted level of impact is better than **AL-01**. As described in the impact and risk evaluation (Section 8.7.3), given the localised and short-term reduction in water quality, impacts to benthic habitats, marine fauna and to other marine users are not expected. As such, the predicted level of impact for these receptors is better than **AL-12**, **AL-13**, **AL-14, AL-15 and AL-17**. Given the offshore location of the DA and the localised, short-term reduction in water quality, subsea operations discharges are predicted to result in no lasting effect to cultural heritage values. Therefore, the predicted level of impact is better than **AL-07**.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6">Principles of ESD</td><td colspan="2">(b) 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</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (b) for this aspect as:
The highest consequence level for Planned discharges—Subsea operations was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and therefore, no further evaluation against principle of ESD (b) is required.
Notwithstanding, CAPL also notes that:
• The literature reviews on predicted exposure areas (Section 8.7.2) provides scientific certainty to inform the impact and risk evaluation for planned discharges from subsea operations.
• To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.</td></tr>
<tr><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the impact and risk of Planned discharges—Subsea operations based on relevant environmental legislation and other requirements as listed below.
• The management of Planned discharges—Subsea operations in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for Planned discharges—Subsea operations was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to planned discharges from subsea operations has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24)
Action A1.5:Manage anthropogenic activities to ensure marine turtles are</td><td>EPBC management plan requirements to minimise chemical discharges and habitat degradation/ modification are addressed by</td></tr>
</table>

Determination of acceptability		
	not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24). Note: This is also a specific action identified for the F-Pil individual stock. Action A1.6: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	adopting these EPOs and control measures: • **EPO-26** • **CM-26**. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) Action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664) **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33) **Recovery Plan for the White Shark (*Carcharodon carcharias*)** (Ref. 34) **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49) **Conservation Advice *Calidris canutus* Red knot** (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56).	These EPBC management plans for species that may occur within the DA identify pollution, habitat degradation / modification as a threat but do not have relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Hazardous Materials Management Procedure (Ref. 368)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian	

Determination of acceptability	
	waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to planned discharges—subsea operations from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.

8.7.5 environmental performance

Table 8-66 lists the EPOs defined for Planned discharges—Subsea operations and the adopted control measures to achieve the outcome.

Table 8-66: Environmental performance for Planned discharges—Subsea operations

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-01: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	**EPO-26**: Planned discharges from subsea operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge. **EPO-27**: Undertake hydrotest dispersion modelling (or equivalent) at sites representative of the deep water and shallow water environments within the Development Area. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development.	**CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme (OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the location and nature of the receiving environment • requires the selection of the least hazardous material where technically and operationally feasible.
AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

8.8 planned discharges—drilling operations

8.8.1 source

Drilling activities will result in planned discharges such as drilling cuttings, drilling fluids, additives, and cement. These materials are discharged to the marine environment at the sea surface or subsea.

The discharge streams assessed in Section 8.8.2 and identified in Table 8-68 are considered to represent the planned discharges associated with the Development's drilling activities based on Chevron's previous drilling activities. As identified in Section 4.3.2.3, if additional fluids are identified, they will be reviewed against the Hazardous Materials Management Procedure (Ref. 368) and captured in the activity-specific EP to maintain or reduce the risk profile as assessed in the following section.

Table 8-67 lists activities within each phase where planned drilling discharges occur in the DA.

Table 8-67: Phases and activities that generate planned discharges—drilling operations

Phase	Activity
Drilling	Drilling top- and bottom-holes Drilling fluids and cuttings handling Cementing operations Pressure-control equipment installation Completions installation Production tree installation Well clean-up and testing
Operations	Well intervention
Decommissioning	Well suspension and well P&A

8.8.1.1 drilling

Drilling activities may take an estimated 24 months per field (~3 months to drill each well). The maximum number of wells per field is 8.

The drilling phase involves multiple activities (described in Section 4.3.2). During these activities, drilling cuttings and fluids, completion fluids, control fluids, solid additives and cement will be discharged to the marine environment. Depending on the activity, cuttings, fluids, or cements may be discharged at the surface or subsurface, with the potential for additional bulk discharges at the surface. Discharges may also vary in composition and will often be discharged as a mixture of drilling cuttings and fluids, completion fluids, control fluids or cement and additives.

Details of these discharges are outlined below.

8.8.1.1.1 drilling fluids

Drilling fluids are a mix of sea water, clay (or gel) and additives such as barite, chalk, and polymer and polyamine to control fluid loss, viscosity and provide further formation inhibition.

Drilling additives typically used include:

- sodium chloride

- potassium chloride
- bentonite (clay)
- cellulose polymers
- guar gum
- barite
- calcium carbonate.

During the initial stages of drilling a combination of sea water and high-viscosity gel sweeps are typically used as drilling fluid (described in Section 4.3.2.3).

Throughout the drilling programs various fluids will be run through the closed circulation system including, but not limited to NADF, WBF, sea water and completion/suspension brine. When one fluid displaces another, they will mix. This NADF brine mixture may be discharged (Section 4.3.2.3 and Table 8-68).

Tanks used to store NADF will be emptied and cleaned after drilling is completed. NADF tank washing residue (<1% residual hydrocarbon) may be discharged to the marine environment. Table 8-68 lists estimates of fluid volumes.

8.8.1.1.2 drilling cuttings

The break-up of solid seabed material during drilling activities generates drilling cuttings, which can vary in size from very coarse to very fine.

During drilling, cuttings and drilling fluids will be released directly to the seabed near the well site. Although volumes of cuttings will depend on the final depth of each well, an indicative average cuttings volume of 440 m^3 for the top-hole section and 375 m^3 for the bottom-hole section (based on the volume of the previously drilled wells in these fields) is expected to be generated per well.

Indicative volumes of drilling fluids and cuttings discharged per well have been estimated based on historical data and well planning (Table 8-68).

8.8.1.1.3 cementing

Marine cement typically comprises of cement clinker, gypsum and ground granulated blast furnace slag.

Approximate volumes of cement discharges are:

- on liner cement jobs—occasionally small quantities (<20 m^3) of cement products and spacer (a WBF) may be circulated (discharged) out of the well from above the top of the liner
- cementing operations— up to 120 m^3 of cement discharged at the seabed
- equipment washing or flushing—small volumes of a cement/water mix may be released in surface waters (~100 m^3).

8.8.1.1.4 control fluids

Control fluids (hydraulic fluids) are required to operate pressure-control equipment such as the BOP. The BOP will be installed after the top-hole sections of the well have been completed; ~4.5 m^3 of water-based hydraulic control fluid will be released to the marine environment either at the surface or seabed during function and pressure tests.

Small amounts of control fluid may also be discharged to the marine environment during production tree installation and valve functionality testing.

8.8.1.1.5 completion fluids

Well completion fluids are required to ensure that the wellbores and casings are clear of solids, debris, and other contaminants. Completion fluids usually comprise a brine (often chlorides of calcium, potassium, or sodium) with additives that may include:

- biocide
- bromides
- hydrate inhibitor (methanol, MEG)
- oxygen scavenger
- surfactant.

Completion fluids may be discharged to the sea, with an expected volume of ~500 m^3 per well (Table 8-68). A similar volume may also be discharged during well testing and flowback activities. These fluids may contain a small proportion of produced water, which is expected to be present at very low concentrations due to the low formation water content of the reservoir.

8.8.1.2 operations

Throughout the life of the Development, well intervention activities, such as maintenance, repair and replacement of components will be required to maintain operational integrity. Maintenance and repair activities occur mainly within the wellbore and usually include well logging, well testing and flowback, and well workovers. Discharges, which may occur during maintenance and repair activities, are not expected to be different to those described above (Section 8.8.1.1) for drilling operations. The volumes may be similar or slightly smaller.

Discharged fluids during maintenance and repair activities include completion fluids (similar to during drilling).

8.8.1.3 decommissioning

At the end of a producing well's life, it will be permanently plugged and abandoned (P&A) in alignment with relevant requirements. P&A procedures are designed to permanently isolate the well and mitigate the risk of a potential release of wellbore fluids to the marine environment by setting a series of plugs or suitable barriers within the wellbore. These plugs are tested to confirm their integrity. These activities may lead to discharges that are not dissimilar to those described for drilling activities (Section 8.8.1.1); however, the volumes will be significantly smaller and may also include treated sea water (with caustic soda or soda ash).

8.8.1.4 discharge volumes

Table 8-68 lists indicative volumes of planned drilling discharges per well.

Table 8-68: Indicative volume of planned drilling discharges per well

Discharge type	Indicative volume per well (m^3)	Location	Timing
Drilling and completion fluids			
WBF	2,000	Seabed	Drilling of top-hole sections
	3,000	Sea surface	Drilling of bottom-hole sections
NADF	220	Sea surface	Drilling of bottom-hole sections. Includes residue on cuttings, displacement interface and residue from tank washing.
Suspension/ completion fluids	500	Sea surface	Completions
Completion fluids with a small proportion of produced water	500	Sea surface	Well testing and flowback
Formation			
Cuttings	440	Seabed	Drilling of top-hole sections
	375	Sea surface	Drilling of bottom-hole sections
Cement			
Cement slurry	120	Seabed	Drilling of top-hole sections
	20	Sea surface	Drilling of bottom-hole sections
Residual cement	100	Sea surface	Line flushing after the cement unit is cleaned
BOP installation and function testing			
Control fluids	4.5	Seabed or Sea surface	To operate pressure-control equipment, production tree installation and valve functionality testing.

8.8.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by planned drilling discharges:

- water quality
- sediment quality
- benthic habitats and associated communities
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- KEFs
- cultural heritage values: Traditional Owners.

Although fish (in particular demersal fish) may potentially be impacted by drilling discharges, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species. Four State- and two Commonwealth-managed fisheries have recorded historical fishing effort in the DA. Of these only three are trawl or trap-based fishing targeting

demersal fish species (the Commonwealth NWSTF and the State Pilbara Trap Managed Fishery and Pilbara Crab Managed Fishery). However, the DA is not regularly targeted by commercial fishing effort in the NWSTF or Pilbara Trap and Crab Managed Fisheries (Sections 6.4.1.1 and 6.4.1.2). Therefore, impacts to commercial fisheries from planned drilling discharges are not expected, and are not evaluated further.

Table 8-69 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to planned drilling discharges in the DA.

Table 8-69: Impact and risk evaluation for planned discharges—drilling operations

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned drilling discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	5	4	Low (8)
Planned drilling discharges may result in: • localised and temporary reduction in sediment quality.	6				
Planned drilling discharges may result in: • alteration of benthic habitats and associated communities.	5	Planned drilling discharges within a KEF may result in: • change to values and sensitivities of KEFs	5	4	Low (8)
		Planned drilling discharges may result in: • change to cultural heritage values: Traditional Owners	5	4	Low (8)

Impact evaluation
Water quality
Localised and temporary reduction in water quality (turbidity) Planned discharges from drilling activities (Table 8-68), which occur both at the seafloor (e.g. during drilling of the top-hole sections), and in surface waters, may result in localised and temporary reduction in water quality from either an increased turbidity or a change to the chemical content in the water column during the drilling, operations, and decommissioning phases of the Development. *Cuttings and drilling fluids* Discharges of cutting and drilling fluids at the seabed are expected to create a localised increase in turbidity immediately around the wellhead. In contrast, surface discharges are expected to result in a larger spatial change in water quality due to wider dispersal. The dispersion of the cuttings plume in the water column is influenced by two factors: fluid type (i.e. particle size) and ocean current speed (Ref. 375).When cuttings are discharged to the ocean from surface, the larger particles, which represent ~90% of the mass of the cutting and associated mud solids, form a plume that settles quickly to seabed close to the release point (Ref. 376). A similar finding was observed by Jones et al. (Ref. 380) where over 95% of the cuttings were greater than 1 mm (and >35% >2 mm) and the settling time to the seabed ranged from minutes to tens of minutes. The remaining solids form a plume in the upper water column that drifts with prevailing currents away from the platform and is diluted rapidly in the receiving waters (Ref. 375 Ref. 381). Neff (Ref. 375) state that in well-mixed oceanic waters, the drilling cuttings and fluid plume from a surface discharge is diluted by more than 100-fold within 10 m of the discharge.

Impact evaluation

Dispersion modellings and/or monitoring for cutting and drilling fluid discharges have been conducted in northern WA for several projects, including:

- Dorado development (off Port Hedland, ~90 m depth) with average current speeds of 0.26 m/s - 0.32 m/s and total cutting and drilling fluid discharges of 1,057 m^3 per well. The results identified that small particles (0.1-1 mm) were predicted to settle within up to 1,115 m while large particles (1-10 mm) settle within 837 m (Ref. 281). Modelling results (Ref. 281) also indicate that the greatest spatial extent of TSS occurs near the sea surface. The maximum distance from the release location for total suspended solids (TSS) concentrations of 5-10 mg/L threshold was ~7.5 km
- Crux development (northern Browse Basin, ~170 m depth) with average current speeds of 0.22 m/s - 0.28 m/s and total cutting and drilling fluid discharges of 891 m^3 per well. The results identified that smaller particles (0.015 mm) were predicted to settle within up to 2,002 m while large particles (1-10 mm) settle within 326 m (Ref. 371). Note that TSS was not modelled
- exploration wells (within the Exmouth Plateau, ~1,416 m depth) with average current speeds of 0.1 m/s - 0.3 m/s and total cutting and drillings of 360 m^3 (Ref. 672). Results from monitoring during the drilling campaign found that spoil-print extended to areas greater than 100 m, with heavy spoil-print concentrated only around the well (~20 m) (Ref. 673).

The modelling results indicate that particle dispersion is primarily influenced by current speed and particle size (as previously noted), rather than water depth. Given the indicative total volume of cutting discharges in the Development (~440 m^3 at the seabed and ~375 m^3 at the surface, Table 8-68) and average surface current speeds of 0.16 m/s - 0.27 m/s (Section 6.3.4.1), these model results are considered suitable analogues. To ensure a conservative approach, the largest exposure areas from the three modelling scenarios—837 m for large particles (1-10 mm), 2,002 m for small particles (<1 mm)—have been used to inform the risk assessment.

A study conducted in the NWS (~70 km to 90 km east of the Development's proposed well locations) modelled and surveyed the fate of drilling cuttings and fluids (Ref. 380). The study found sporadic and intermittent TSS concentrations (<15 mg/L) ~1,000 m from the discharge point lasting over a period of minutes. By comparison, during cyclones and storms TSS concentrations of tens or hundreds of mg/L over a few hours are common in tropical shallow-water reef environments (Ref. 380).

WBF cuttings and adhered fluids typically disperse more widely and settle slower than NADF thus covering a wider seafloor area (Ref. 377). IOGP suggests that WBF cuttings discharged from a single well within waters deeper than 300 m disperse widely and when settle they may not be detected in sediment at any distance from the well (Ref. 377). Discharges of NADF from the surface settle rapidly (in clumps), under and downstream from the discharge source and may be patchy in distribution, covering a smaller area than WBF discharge plumes (Ref. 378; Ref. 379).

Consequently, changes in water quality associated with increased turbidity from cutting and drilling discharges are restricted to close proximity to the discharge source and/or sporadic and intermittent lasting for a short period of time.

Suspension and completion fluids

Suspension and completion fluids are generally brine with additives (Section 8.8.1.1.5). The indicative discharge volume is ~500 m^3 per well. These discharged fluids are expected to have a similar behaviour as cutting and drilling discharges. Consequently, localised and short-term reduction in water quality is expected.

Produced water, may be present in very low concentrations in the completion fluids (Section 8.8.1.1.5) and may contain a variety of metals (zinc, lead, copper, cadmium), BTEX compounds, production chemicals, and occasionally naturally occurring radioactive materials (Ref. 711). These discharges are expected to disperse and dilute in the receiving environment (Ref. 712). Given the low discharge volumes and limited release (i.e. during flowback activities only), any changes in water quality are anticipated to be localised and short-term.

Control fluids

Water-based hydraulic control fluid will be released to the marine environment either at the surface or seabed during function and pressure tests, production tree installation, and valve functionality testing (Section 8.8.1.1.4). Up to 4.5 m^3 of control fluid is expected to be discharged.

As described in Section 8.7.3, results from a control fluids dispersion modelling (Ref. 267) identified a temporary and localised spatial extent in change of water quality. Given these fluids are typically diluted (Ref. 267), rapid dispersion is expected due to small discharge volumes within open marine waters. Consequently, only limited short-term reduction in water quality is expected.

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Cement and bulk product

A release of cement at the water surface may also contribute to turbidity in the water column. Small volumes of a cement (up to ~100 m^3), cement slurry (up to ~120 m^3) or bulk product may be released at both the seabed and the surface. Cement discharges increase the volume of suspended material in the water column, which can temporarily reduce water quality in a localised area. A surface discharge is expected to result in a larger spatial change to water quality than a seabed discharge because there is a greater possibility for wider dispersal given influence by surface currents and wind speeds.

Modelling undertaken by BP (Ref. 267) of cement discharges (~78 m^3 over a one-hour period) for wells in waters 70—530 m deep, suggested that within 2 hours of discharge, suspended solid concentrations ranged between 5–50 mg/L within the extent of the plume (~150 m horizontal and 10 m vertical). Four hours after discharge, the modelling indicated the plume will have completed dispersed to particulate concentrations <5 mg/L. Consequently, the change to water quality is expected to be highly localised and temporary.

Given the intermittent nature of planned drilling discharges and the rapid mixing potential for these discharges influenced by oceanic currents, changes in water quality associated with increased turbidity will be very limited in area and duration with water quality expected to rapidly recover following cessation of the discharges. Consequently, it has been assessed as Incidental (6).

Localised and temporary reduction in water quality (toxicity)

Planned discharges of drilling cuttings, drilling fluids, additives, cement and completion fluids may result in localised and temporary reduction in water quality through chemical toxicity and oxygen depletion during the drilling, operations, and decommissioning phases of the Development.

Cuttings and drilling fluids

The whole fluids and fluid components of the WBFs currently in use are ‘non-toxic’ or ‘almost nontoxic’ (Ref. 376). Similarly, WBF additives that are typically used are either completely inert in the marine environment, naturally occurring benign materials, or rapidly biodegradable organic polymers (Ref. 375) i.e. barite, bentonite and guar gum, which are listed as an “E” Category fluids under the Offshore Chemical Notification Scheme (OCNS) and considered to pose little or no risk to the environment (PLONOR). Given their inert nature, adverse impacts to water quality from additives to WBF are not predicted to occur.

NADF use a non-aqueous base fluid, with water and chemical additives. These components are extremely low-aromatic base oils and low toxicity (Ref. 674, Ref. 675). The environmental effects of NADF are determined by the base fluid used; however, the additives typically adsorb particles in the cuttings (Ref. 377). NADF cuttings are hydrophobic and do not disperse or dissolve in the water column (Ref. 377).

Most of the metals detected in drilling muds are primarily trace impurities in barite, bentonite clay, or the sedimentary rocks (drill cuttings) in the formations penetrated by the drill bit (Ref. 375). Barite, in particular, comprises a significant component of drilling fluid systems (Ref. 384). A study investigating barite solubility and the release of trace metal compounds to the marine environment found that during one week of exposure of barite in seawater, <1% of the mercury, lead and cooper, and 15% of cadmium dissolved from the barite (Ref. 389). However, barite has very low concentrations of these components to begin with (Ref. 581) and it is referred to as practically inert from a toxicological perspective (Ref. 389). Considering the low concentrations of heavy metals within stock barite, changes in water quality via the dissolution of these metals are expected to be limited.

Cement and bulk product

Chemical releases from cement are not anticipated since it will be effectively chemically inert (Ref. 267). However, the risk of toxicity may occur from discharges of cement additives (added to dry cement mix). Cement additives are only considered bioavailable before the cement hardens on the seabed. These discharges are designed to set in a marine environment and will therefore set in situ. These discharges are limited to the subsea release (i.e. not discharge of dry cement or slurry). Terrens et al. (Ref. 382) suggest that once the cement has hardened, the chemical constituents are locked into the cement. CHARM Implementation Network (Ref. 383) also states that once cement has set it is essentially inert and not likely to have chronic toxicity effects. Before the cement hardens, toxic chemical levels from cement additives will also be subject to rapid dispersion and high dilution rates in the open ocean. The impact of cement additives discharges will therefore be limited to a small area immediately around the well.

Impact evaluation

Control fluids, suspension and completion fluids

Water-based hydraulic control fluids are typically diluted (Ref. 267) and rapid dispersion is expected due to small discharge volumes within open marine waters. Suspension and completion fluids are expected to be similar to or less toxic than that of drilling fluids. Likewise, given the low volumes of produced water present in the completion fluids, these discharges are expected to disperse and dilute within the receiving environment (Ref. 712). As a result, changes to water quality are expected to be localised as these fluids will rapidly disperse within the DA.

The waters surrounding the DA are known for currents and surface waves that facilitate the mixing of surface waters (Section 6.3.4.1, Ref. 102). As these are limited and intermittent discharges, any change in water quality that may lead to toxicity will also be temporary and short term, due to rapid dilution from ocean currents.

Discharges of drilling cuttings, drilling fluids, solid additives, cement, control fluids and completion fluids will occur at both the surface and seabed intermittently over short periods (~3 months per well) in each field, with no planned concurrent drilling activities in the same field. This will allow water quality to quickly recover, with no long-term changes to ambient water quality expected.

Given the potential for dilution for these discharges and currents surrounding the DA, which facilitate the mixing of surface waters, impacts to water quality through very low (to no) toxicity will be limited in duration. Water quality is expected to rapidly recover following cessation of the discharges. As the potential for limited environmental impact (i.e. within close proximity to the discharge point and/or short period of time), the consequence of planned drilling discharges causing localised and temporary reduction in water quality through chemical toxicity has been evaluated as Incidental (6).

Sediment quality

Localised and temporary reduction in sediment quality (toxicity)

Changes in sediment quality may occur as a result of both subsea discharges and surface discharges. Contaminants may accumulate within benthic sediment as a result of chemical additives within drilling fluids and cement, cementing fluids, or bulk product. Sediment deposition is expected to be highly localised around the well site (Ref. 375). Drilling cuttings tend to clump together and settle rapidly, with thicker cuttings piles generally located immediately downstream from the discharge and increased sedimentation as a result of cuttings material and cement deposition may alter the sediment quality (e.g. physicochemical or composition).

Wells are planned to be drilled with WBF, with NADF used as a contingency or when technical requirements require its use. WBF additives that are typically used are either completely inert in the marine environment, naturally occurring benign materials, or rapidly biodegradable organic polymers (Ref. 375).

As previously identified, cuttings and drilling fluids discharges may generate an exposure area of up to ~2,002 m for small particles (<1 mm), 837 m for large particles (1-10 mm) and elevated TSS concentrations directly beneath the discharge point.

Barite comprises a significant component of drilling fluid systems and therefore barium has been frequently used as a tracer of drilling fluid discharges (Ref. 384). Field studies summarised by IOGP (Ref. 377) found that cuttings and adhered WBF discharged at the seabed could be detected visually or through increases in barium concentrations within 10–150 m of the source, whereas cuttings discharged near the surface accumulated on the seabed at distances of ~0.1–1 km.

Jones et al. study (Ref. 380) suggests a zone of high impact is likely to be observed 50 – 75 m in all directions from drilling locations and elevated sediment barium concentrations of up to 3 g/kg may be detected at 50 m, decreasing to 1.2 g/kg and 0.75 g/kg at 100 m and 200 m, respectively. Other studies including Ellis et al. (Ref. 384) indicate barium sediment concentrations may be slightly elevated (10s of mg/kg) up to 3,000 m from drilling locations before decreasing to background levels. There are no sediment quality guidelines for barium, however the drilling additive barite has a low solubility in seawater (Ref. 385), and has been referred to as practically inert from a toxicological perspective (Ref. 386) and remains on the Oslo and Paris (OSPAR) commission list of PLONOR substances.

Barite and bentonite may contain some heavy metal concentrations. Most of the metals detected in drilling muds are present primarily as trace impurities in barite, bentonite clay, or the sedimentary rocks (drill cuttings) in the formations penetrated by the drill bit (Ref. 387). The metals of environmental concern (because of their potential toxicity and persistence) that may be present in some drilling mud barites include cadmium, chromium, copper, mercury, lead, and zinc. These metals are present in barite primarily as inorganic, insoluble sulphide minerals and have limited environmental mobility and low bioavailability (Ref. 387). The Environmental, Health, and

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Safety Guidelines Offshore Oil and Gas Development (Ref. 388) set stock barite limits of 1 mg/kg and 3 mg/kg for mercury and cadmium respectively. These values are representative of the total heavy metal concentrations in barite (both soluble and insoluble) and a study investigating barite solubility and the release of trace metals to the marine environment recorded that <1% of the mercury and 15% of the cadmium dissolved from the barite after one-week exposure in sea water (Ref. 389). Given the low concentrations of heavy metals including mercury and cadmium in stock barite, and due to the sparingly, low solubility of barite and metal sulphides in seawater, it is expected that environmental consequences associated with the presence of trace heavy metals in barite will be negligible. Consequently, due to the localised area of effect for sedimentation, and trace amounts of constituents of concern in drilling fluids, no lasting effect on sediment quality is expected.

Bulk products such as barite and bentonite may be discharged during or at the end of the activity if they cannot be reused or taken back to shore. An overboard bulk discharge is expected to disperse over a wide area. As previously mentioned, trace amounts of constituents of concern (i.e. mercury and other trace metals) are not expected to have lasting effect on sediment quality.

Most discharges from cement operations will be at the seabed. These discharges are not expected to disperse since cement is designed to set in a marine environment and thus will set in situ, limiting its impact to the area directly around the well. BP (Ref. 267) modelled a 200 tonnes seabed cement discharge and determined that impacts would be limited to a radius of ~10 m (depending on the height of the discharge) from the well.

Cement discharges from overflow during drilling operations may permanently affect the seabed within a 10-50 m radius around the well (Ref. 382). Terrens et. al (Ref. 382) suggest that once the cement has hardened, the chemical constituents are locked into the cement. And therefore, toxicological risk to the marine environment is not expected. Consequently, the extent of the discharge is limited to the waters directly adjacent to the displaced cement.

Given planned discharges from drilling activities during the Development are expected to result in localised and temporary reduction in sediment quality, the consequence has been evaluated as Incidental (6).

Benthic habitats and associated communities

Alteration of benthic habitats and associated communities

A change in water or sediment quality as a result of planned discharges from drilling activities has the potential to cause alteration of the benthic habitats and associated communities.

Neff (Ref. 381) suggests that synthetic-based mud-coated cuttings, such as NADF, tend to clump and settle rapidly as large particles over a small area near the discharge point and tend not to disperse rapidly, indicating that when drilling with synthetic-based muds, the extent of dispersion is expected to decrease, but the thickness of cuttings piles is expected to increase.

The main environmental disturbance from discharging drilling cuttings and drilling fluids is associated with smothering and burying sessile benthic and epibenthic fauna (Ref. 376; Ref. 380). Elevated TSS levels are also a hazard for filter feeder communities (Ref. 380). Kjeilen-Eilertsen et al. (Ref. 582) identified that depositional thicknesses >9.6 mm are likely to cause smothering impacts on benthic ecosystems, including corals. Smit et al. (Ref. 583) established that a thickness threshold of >6.5 mm would be needed before potential harm to benthic macrofauna occurs.

As previously identified, cuttings and drilling fluids discharges may generate an exposure area of up to 837 m for large particles (1-10 mm) and elevated TSS concentrations directly beneath the discharge point.

Results of the mapping habitat and survey sites (Section 6.3.1.1.3) across the indicative DCs (i.e. where the potential impacts may occur) identified that the dominant BCH is bare substrate with no biota. Bioturbation in bare sediment was also observed. Overall, the proposed DCs are considered to be relatively devoid of epifauna. The ground-truthing conducted at the indicative DCs confirmed the lack of complex seafloor structures (Ref. 104; appendix a).

In addition, limited number of benthic infauna (a total of five individuals) were found, primarily in deep-sea sediments (1,100–1,200 m) around proposed DCs Semele DC-1 and Semele DC-2, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected included marine worms, polychaete worms and molluscs. No endemic benthic infauna was identified in the survey (Ref. 104; appendix a).

Surveys in the NWMR have recorded a diverse species inventory dominated by marine worm, polychaete worms and crustaceans (Section 6.3.1). Consequently, the benthic infauna identified in or around the proposed DCs location are widespread in the region and are not considered

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regionally significant due to their ubiquity and the sparseness of biota supported. Chemicals are often detectable in the sediment around the discharge site; however, impacts on benthic flora and fauna are generally subtle (Ref. 592; Ref. 593; Ref. 594; Ref. 595; Ref. 596; Ref. 597; Ref. 598). Oxygen depletion in surface layers may occur due to an increase in NADF, leading to hypoxia. This, along with higher concentrations of ammonia and sulfide, often decreases benthic community diversity (Ref. 377). Terrens et al. (Ref. 382) found that NADF was undetectable in sediments after 11 months, While some components of WBM or NADF can potentially bioaccumulate in organisms, they can oxidise and expel aromatic hydrocarbons, making them bioavailable but not likely to bioconcentrate (Ref. 390). Monitoring undertaken during a drilling program (Ref. 672) identified that no infauna or *lebensspuren* was observed immediately adjacent to the well (0-5 m), where the heaviest smothering occurred. However, within 100 m of the well, spoil cover had little effect on the activity of benthic organisms (Ref. 672).

As previously mentioned, although metals of environmental concern (because of their potential toxicity and persistence) may be present in some drilling mud barites, laboratory testing on industrial barite samples indicates low concentrations of heavy metals including mercury and cadmium are released into seawater (Ref. 389). As such, it is expected that environmental consequences associated with the presence of these traces of metals in barite will be negligible.

A study on the impacts of drilling in Bass Strait by Terrens et al. (Ref. 382) observed biological effects within 100 m of the drilling site shortly after drilling; recovery of seabed communities across the area were reported within 4 months. Neff (Ref. 381) found that recolonisation of NWBM cuttings piles in cold-water marine environments began within one to two years of ceasing discharges, after the hydrocarbon component of the cutting piles had biodegraded. The studies reviewed in IOGP (Ref. 377) reported varying recovery times, but substantial recovery within one year post-drilling was common. Although recovery time may differ, species present in soft sediment are well adapted to changes in substrate, especially burrowing species (Ref. 582), and they recover quickly.

Bulk products such as barite and bentonite may be discharged during or at the end of the activity if they cannot be reused or taken back to shore. An overboard bulk discharge is expected to disperse over a wide area. As previously mentioned, it is expected that environmental consequences associated with trace amounts of constituents of concern (i.e. mercury and other trace metals) are not expected to have lasting effect on sediment quality; consequently, it is not likely that discharges of bulk products will cause environmental effects to organisms living on or near the seafloor.

Cement overspill during drilling activities has the potential to permanently smother and alter the benthic substrate. The extent would be limited to 10–50 m radius around each wellbore (Ref. 382) and is considered a highly localised impact.

Given the intermittent and temporary nature of the discharges, the localised alteration of the benthic habitat, the lack of complex seafloor structures and the dominant soft sediment habitats with limited benthic infauna, which are widespread in the region, identified in or around the proposed DCs, the planned discharges of drilling activities are expected to result in highly localised alteration of marine habitats or associated communities. Consequently, the consequence has been assessed as Minor (5).

Risk evaluation

KEFs

Change to values and sensitivities

Planned discharges from drilling activities are expected to result in localised reduction in water and sediment quality. Potential changes to the values and sensitivities of KEFs may occur.

As previously identified, cuttings and drilling fluids discharges may generate an exposure area of up to 837 m for large particles (1-10 mm) and elevated TSS concentrations directly beneath the discharge point. The potential extent of impact from subsea discharges of cement operations would be limited to 10–50 m radius on the seabed around each wellbore (Ref. 382).

Three KEFs were identified as overlapping with or in close proximity to (i.e. ≤1 km) proposed DCs within the DA:

- ancient coastline at 125 m depth contour KEF (overlapping WTR DC-1 and WTR DC-2)
- Exmouth Plateau KEF (overlapping Chandon DC-1 and Chandon DC-2)
- continental slope demersal fish communities KEF (overlapping C&D DC-2 and C&D DC-3).

No other DCs were identified as overlapping the KEFs.

Chemical pollution is identified as a "not of concern" pressure for these three KEFs and physical habitat modification as "not of concern" for the ancient coastline at 125 m depth contour KEF and "of less concern" for Exmouth Plateau KEF (Ref. 102). For the continental slope demersal fish communities KEF, physical habitat modification is identified as "of potential concern" pressure; however, this modification has been associated with fishing activities (Ref. 102).

Although values for both the ancient coastline at 125 m depth contour and Exmouth Plateau KEFs have been identified as unique benthic habitat with ecological properties of regional significance (Table 6-20), the mapping habitat and survey sites (Section 6.3.1.1.3) across the indicative DCs sites within these KEFs (i.e. where the potential impacts may occur) identified that the dominant BCH was bare substrate with no biota (Table 6-7).

BCH at Chandon DC-1 consists of bioturbated, irregular seabed with large patches of depressions over bare substrate (Section 6.3.1.1.3). WTR DC-1 was primarily characterised by smooth seabed. Overall, the proposed DCs are considered to be relatively devoid of epifauna. The lack of complex seafloor structures within the DCs located in these KEFs, supported by ground-truthing, suggests limited to no biota or epifaunal communities are likely to be present and therefore, unlikely to be impacted.

In addition, only a limited number of benthic infauna were identified within the KEFs, primarily at WTR DC-1. These included Sipuncula (Sipuncula) and Polychaeta (Annelida) (Ref. 104; appendix a). Broader surveys conducted in the NWMR have recorded a diverse species inventory dominated by these taxa (Section 6.3.1), indicating that the infauna communities identified are representative of those found across the region. Consequently, the benthic fauna identified in or around these proposed DCs are widespread in the region and are not considered regionally significant due to their ubiquity and the sparseness of biota supported.

Values for the continental slope demersal fish communities KEF were identified as high levels of endemism with a diversity of fish assemblages (Ref. 102). Results of the benthic survey (Section 6.3.1.1.3) across the indicative C&D DC-2 and C&D DC-3 sites within this KEF (i.e. where the potential impacts may occur) identified that the dominant benthic habitat is irregular seabed with bare substrate (Section 6.3.1.1.3). As such, no site attached species are expected to occur. A total of 468 fish belonging to 25 taxa were recorded (Ref. 104; appendix a). The fish species observed were predominantly pelagic and demersal species (Ref. 104; appendix a), which are generally considered transient and highly mobile as they are adapted to living and moving through open water habitats (Ref. 264).

Fauna found in the water column, such as fish, are expected to actively avoid discharge plumes and associated turbidity and toxicity within the water column (Ref. 484). Given the highly mobile nature of the fish species identified and small size of the plume, potential impacts are expected to be limited to individuals. The planned release of drilling cuttings, drilling fluids, and cement has the potential to cause injury or mortality to benthic organisms mainly by smothering. Previous studies on benthic disturbance from discharges are outlined above and indicate localised alteration of marine habitats. Furthermore, six out of the ten DCs are identified within or in close proximity to the KEFs, meaning the extent of any potential impact is highly localised.

Given the temporary and intermittent nature of the discharge, the predicted spatial extent of exposure (localised), and the benthic habitat (bare substrate with limited number of benthic infauna), the planned discharges from drilling activities and cement operations are not expected to affect the diversity or ecosystem function of the KEFs; therefore, the consequence level is ranked as Minor (5).

The benthic survey found the DA to predominantly contain soft sediments, sparsely distributed epibenthic and infaunal invertebrates highly represented throughout the region, and highly mobile pelagic and demersal fish species; therefore, the likelihood of planned drilling discharges is assessed as Unlikely (4).

Overall, the risk of planned drilling discharges to KEFs is Low (8).

Marine Fauna

Injury or mortality of marine fauna

The planned release of drilling cuttings, drilling fluids and cement has the potential to cause injury or mortality to marine fauna including plankton, fish, marine reptiles, and marine mammals through toxicity. As previously identified, cuttings and drilling fluids discharges may generate an exposure area of up to 837 m for large particles (1-10 mm) and elevated TSS concentrations directly beneath the discharge point. The potential extent of impact from subsea discharges of cement operations would be limited to 10–50 m radius on the seabed around each wellbore (Ref. 382).

As identified in Section 6.3.3, several listed threatened and/or migratory marine species under the EPBC Act have the potential to occur within the DA. The values and sensitivities with the potential to be exposed to chemical toxicity from discharges from drilling activities include:

- humpback whale BIA (migration)
- pygmy blue whale BIA (migration)
- flatback turtle BIA (internesting buffer) and HCTS (internesting buffer)
- whale shark BIA (foraging).

The risk of toxicity from cement activities may occur from discharges of cement additives (added to dry cement mix), which will only occur at the seabed. The proposed DCs are located in water depths ranging from ~150 m to 1,200 m (Table 4-1). The dominant benthic category is bare substrate with no biota. and are considered to be relatively devoid of epifauna, as confirmed by ground-truthing (Ref. 104; appendix a). The foraging BIA for the whale shark is associated with foraging behaviours during northward migration from Ningaloo Reef / North West Cape along the 200 m isobath (Ref. 33); thus, the species is expected to be highly mobile. As such, given the highly mobile nature of these marine species, the infrequent release, the highly localised extent from cement operations in the seabed, impacts from these discharges will be negligible and therefore are not discussed further.

Drilling cuttings and drilling fluids released at the sea surface will be subject to rapid dilution and dispersion within the water column (as described in previous risk assessment). Because of this, potential impacts to marine fauna is considered unlikely (Ref. 375). Neff (Ref. 381) states that the lack of toxicity and low bioaccumulation potential of the drilling fluids in particular means that the effects of the discharges are highly localised and are not expected to spread through the food web. Several metal bioaccumulation bioassays of WBM cuttings found that metal concentrations in the tissues of exposed animals were very similar to those in the tissues of unexposed animals (Ref. 377).

The Conservation Management Plan for blue whales, the Recovery Plan for marine turtles in Australia (Ref. 24) and the Conservation Advice for whale sharks (Ref. 33) do not list water quality as a key threat to the species. The relevant BIAs do not suggest sedentary behaviour within the DA. Consequently, only transient individuals would have the potential to be exposed to these discharges.

Based on the nature of receptors, extent of exposure and duration of the activity, these discharges are expected to result in localised, short-term impacts to a small number of individuals, and as such the consequence has been evaluated as Minor (5).

Given the drilling cuttings and fluid discharges will be localised and rapidly diluted, and marine fauna species will be transitory, the likelihood of this potential impact occurring has been evaluated as Unlikely (4).

Overall, the risk of planned drilling discharges to marine fauna is Low (8).

Cultural heritage value: underwater cultural heritage

No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken.

Cultural heritage value: Traditional Owners

Change to cultural heritage values

No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the DA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. archaeology) are expected; and no further evaluation has been undertaken.

Potential changes to cultural heritage values from planned drilling discharges includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna.

Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from planned drilling discharges.

The consequence level for the potential injury or mortality of marine fauna from planned drilling discharges was evaluated as Minor (5). As such, the consequence of changes to cultural heritage values from planned discharges from drilling activities is also evaluated as Minor (5).

Marine habitats across the potential DC sites are considered to be relatively devoid of epifauna with limited number of benthic infauna which is widespread in the region. Therefore, the likelihood of the consequence occurring is assessed as Unlikely (4).

The risk of planned drilling discharges to Traditional Owner cultural heritage values is Low (8).

8.8.3 determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of impact and residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-70 details the determination of acceptability for planned drilling discharges.

Table 8-70: Determination of acceptability for planned discharges—drilling operations

Determination of acceptability	
Comparison with acceptable level	The acceptable levels for this aspect are **AL-01**, **AL-02**, **AL-07**, **AL-12**, **AL-13**, **AL-14, AL-15 and AL-17** as defined in Table 7-6 and shown below in Section 8.8.4. As described in the impact and risk evaluation (Section 8.8.2), changes to water and sediment quality are predicted to be localised and temporary with short-term impacts to benthic habitats and a small number of individual marine fauna. As such, these impacts are not expected to substantially affect the biodiversity, ecosystem function, or integrity of the DA or result in impacts at population level that would prevent long-term recovery or survival. As such, the predicted level of impact for these receptors is better than **AL-01**, **AL-02**, **AL-12**, **AL-13**, **AL-14**, **AL-15** and **Al-17**. Given the short term impacts to a small number of individual marine fauna, a change to cultural heritage is considered unlikely. Therefore, the predicted level of impact is equal to or better than **AL-07.**
Principles of ESD	**(b) 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 highest consequence level for planned drilling discharges was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Consideration of industry standard measures addresses the Minamata Convention requirement to implement the best available techniques and best environmental practices to control releases of drilling cuttings containing mercury. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of planned drilling discharges based on relevant environmental legislation and other requirements as listed below.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">

The management of planned drilling discharges in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence level for planned drilling discharges was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
Any relevant stakeholder feedback in relation to planned drilling discharges has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Environmental, Health, and Safety Guidelines: Offshore Oil and Gas Development (Ref. 388)
Industry guidance for good drilling practices including:
no overboard discharge of whole NADF
chemical selection process
cuttings requirements</td><td rowspan="2">Legislative requirements to manage planned drilling discharges are addressed by adopting these control measures:
CM-26
CM-27
CM-28
CM-29
CM-30.</td></tr>
<tr><td>Minamata Convention
The use of best available techniques and best environmental practices to control releases from relevant sources.</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24)
Action A1.5: Manage anthropogenic activities to ensure marine turtles are not displaced from identified HCTS (as per section 3.3 Table 6 of Ref. 24).
Action A1.6: Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.</td><td rowspan="2">EPBC management plan requirements to minimise habitat degradation/ modification/ disruption are addressed by adopting these control measures:
CM-26
CM-27
CM-28
CM-29
CM-30.
Therefore, the Development is not considered to be inconsistent with the EPBC management plans</td></tr>
<tr><td>Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39)
Action 3f: Ensure all areas important to migratory shorebirds in Australia</td></tr>
</table>

Determination of acceptability		
	continue to be considered in development assessment processes	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664) **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33). **Recovery Plan for the White Shark (*Carcharodon carcharias*)** (Ref. 34) **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49) **Conservation Advice *Calidris canutus* Red knot** (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56)	These EPBC management plans for species that may occur within the DA identify pollution, habitat degradation / modification as a threat, but do not identify any relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Hazardous Materials Management Procedure (Ref. 368) • Wells fluid field guidelines offshore (Ref. 391)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to planned drilling discharges from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.8.4 environmental performance

Table 8-71 lists the EPO defined for planned drilling discharges and the adopted control measures to achieve the outcome.

Table 8-71: Environmental performance for planned discharges—drilling operations

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-01: Impacts on marine environmental quality from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	**EPO-28**: Planned discharges from drilling operations within the Development Area will not cause lasting changes to water quality. Water quality will return to ambient state within seven days following the cessation of the discharge. **EPO-29:** Planned discharges from drilling operations within the Development Area will only cause localised changes to sediment quality (i.e. within the vicinity of the drill centres). **EPO-30**: Undertake drill cuttings dispersion modelling (or equivalent) at sites representative of the deep water and shallow water environments within the Development Area. These assessments will be incorporated into Environment Plans for the petroleum activities associated with this Development.	**CM-26:** Planned discharges to the marine environment are subject to selection and environmental assessment as per CAPL's Hazardous Materials Management Procedure (Ref. 368). The environmental assessment process: • identifies the Chemical Hazard and Risk Management (CHARM) colour banding or the Offshore Chemical Notification Scheme (OCNS) group for non-CHARM products • evaluates the dosage, quantity, and frequency of the discharge, and the location and nature of the receiving environment • requires the selection of the least hazardous material where technically and operationally feasible. **CM-27:** Where selected for use, NADFs are managed in accordance with CAPL's Wells Fluid Field Guidelines Offshore (Ref. 391), including: • no whole NADF will be discharged to the environment • maintain a <10% w/w synthetic base fluid on dry cuttings averaged over the combined well sections drilled with NADF • NADF will not be used to drill top holes • ensure that any displaced fluids potentially contaminated with NADF have <1% v/v residual synthetic based oil prior to discharge. **CM-28**: Mercury and cadmium concentrations in stock barite will be limited to: • mercury: maximum 1 mg/kg dry weight
AL-02: Impacts on benthic habitats and associated communities from the Development will not prevent the conservation of biodiversity and maintenance of ecosystem integrity within the Development Area.	**EPO-31:** Planned discharges from drilling operations within the Development Area will only cause localised changes to benthic habitats and communities (i.e. within the vicinity of the drill centres).	
AL-08: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species. **AL-09**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act. **AL-10**: Impacts from the Development will not decrease the availability or quality of marine fauna habitat to the extent that it interferes with the recovery of the population of	**EPO-32:** Planned discharges from drilling operations within the Development Area will not cause toxicity effects to benthic habitats or marine fauna.	

Acceptable levels	Environmental performance outcomes	Adopted control measures
an EPBC Act listed threatened species. **AL-11**: Impacts from the Development will not decrease the availability or quality of important habitat[183] to the extent that it interferes with the survival of the population of an EPBC Act listed migratory species. **AL-13**: Impacts to fish communities associated with key ecological features will not prevent the conservation of biodiversity and maintenance of ecosystem integrity of the North-west Marine Region.		• cadmium: maximum 3 mg/kg dry weight. **CM-29:** Implement CAPL's management process for unused bulk product (barite, cement, and bentonite). **CM-30**: Any produced water circulated to the MODU during well flowback or well intervention activities will have <30 ppm oil-in-water concentration prior to discharge.
AL-07: No interference with known Sea Country values (as identified from engagement with First Nations peoples) to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder.	**EPO-09:** No interference with First Nations cultural heritage values from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-07**: Ongoing consultation with First Nations people and/or representative bodies is undertaken as per the respective engagement plan and/or consultation protocols. **CM-08**: If new information on First Nations cultural values or features is identified during ongoing consultation, this will be incorporated into Environment Plans for the petroleum activities associated with this Development.

8.9 physical presence—other marine users

8.9.1 source

After installation, subsea infrastructure will remain in the DA for the life of the Development. This infrastructure has the potential to interact with other marine users by disrupting commercial activities.

Additionally, the presence of the MODU and vessels in the DA has been identified as having the potential to result in interaction with other marine users.

The DA has a 5 km radius around the outermost expected position of subsea infrastructure.

Table 8-72 lists activities within each phase where interactions with other marine users may occur in the DA.

[183] Where important habitat for migratory species are defined within the MNES Significant Impact Guidelines (Ref. 72).

Table 8-72: Phases and activities that generate physical presence—other marine users

Phase	Activity
Installation and commissioning	Pre-lay works
Operations	Operation of the hydrocarbon system
Decommissioning	Other subsea structure decommissioning
Support activities	MODU operations Vessel operations

8.9.1.1 installation and commissioning

An initiation anchor (deadman anchor) or suction pile will be deployed to fix the end of the flowline in place at the beginning of pipelay. The anchor or pile is installed up to 3,000 m behind the flowline or MEG pipeline and the initiation wire is laid out on the seabed to the end of the flowline or MEG pipeline. These anchors and wires are recovered from the seabed at the end of the pipelay process.

For any third-party infrastructure present in the DA before pre-lay activities occur at Chandon (i.e. the Vocus cable and the Scarborough Trunkline), CAPL will work with the third-party to manage potential interactions.

8.9.1.2 operations

The hydrocarbon infrastructure associated with this activity will be installed in the DA and will remain in place for the life of the Development. The DA provides a conservative 5 km buffer around the outermost extent of the infrastructure and activities; however, this is not an exclusion zone preventing other marine users from accessing the area.

The potential for interactions with other marine users is limited to where these users interact with the seabed. As a result, only commercial fisheries that use trawl or trap fishing methods were identified as having the potential to interact with the hydrocarbon infrastructure.

To protect a petroleum well, structure or any equipment in an offshore area, NOPSEMA can specify a petroleum safety zone (PSZ), which prohibits vessels from entering or being present in that specified area and up to within 500 m from it. A PSZ may be implemented for the infrastructure in the WTR field as this field is shallower (~150 m water depth) than the others.

The potential risks to trawling vessels from subsea infrastructure includes disrupting fishing efforts (because vessels must avoid the infrastructure) and damaging trawling gear that contacts the infrastructure.

8.9.1.3 decommissioning

All subsea infrastructure (above the mudline) associated with the Development will be designed to be removable when no longer in use in connection with operations, in accordance with CAPL's decommissioning philosophy, as described in Section 4.3.5.

8.9.1.4 support activities (all phases)

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well

interventions). A SNA will be established around the MODU (or hydraulic workover unit [HWU] if used for well interventions or decommissioning). This is a temporary area with a 500 m radius that requests the exclusion of other marine users from the MODU for safety reasons.

An SNA is also likely to be implemented for the PLV and other large construction vessels. Any SNA will be in place for the duration of the relevant activities. A larger (2 km) cautionary zone may also be established.

Vessels will be present in the DA during all phases of the Development. The number of vessels working concurrently across a field or co-developed field within the DA is estimated to vary between ~2–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation and commissioning may take as long as ~12–15 months per field or co-developed field and while concurrent activities are possible during this time, they will typically be intermittent and would occur for only a small portion of the overall duration.

These vessels have the potential to disrupt other marine users, including commercial shipping, fishing vessels and other industries. For any third-party infrastructure (i.e. the Vocus cable and Scarborough Trunkline) installed in the DA before activities begin at Chandon, CAPL will work with the third-party to manage potential interactions.

8.9.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by interaction with other marine users:

- commercial fisheries
- petroleum activities
- commercial shipping.

Due to the distance offshore (~47 km at the closest point from the Montebello Islands, ~55 km at the closest point from Barrow Island and ~125 km from Onslow) and ~100–1 400 m water depths, tourism and recreation activities within the DA are expected to be unlikely. The DA does not overlap any designated Department of Defence areas. Therefore, these impacts are not expected and are not evaluated further.

Table 8-73 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to interaction with other marine users in the DA.

Table 8-73: Risk evaluation for physical presence—other marine users

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Unplanned interactions with commercial fisheries may result in: • change to the functions, interests, and activities of other marine users.	6	4	Very Low (9)
		Unplanned interactions with petroleum activities may result in: • change to the functions, interests, and activities of other marine users.	6	3	Low (8)

Impact and/or risk level summary					
		Unplanned interactions with petroleum activities and commercial shipping may result in: • change to the functions, interests, and activities of other marine users.	6	3	Low (8)

Risk evaluation

Commercial fisheries

Change to the functions, interests and activities of other marine users

The loss of fishing grounds due to the presence of the SNA is limited to a small area (500 m radius) around specific vessels and the MODU during certain activities (e.g. drilling, pipelay). These activities are not long-term, with drilling taking ~3 months per well (and up to ~24 months per field or co-developed field) and installation taking ~12–15 months per field or co-developed field.

A 500 m PSZ may be established for safety purposes around certain infrastructure (e.g. the shallower WTR wells), which would be in place for the life of the Development.

A 2 km radius cautionary zone may also be established around the MODU and large construction vessels to ensure that fishing and third-party vessels are aware of the presence of vessels and infrastructure but does not necessarily exclude them from the area.

Commonwealth-managed Fisheries:

Several Commonwealth-managed fisheries have management areas that overlap the DA and thus have the potential to be displaced from the DA. However, as identified in Section 6.4.1, only two Commonwealth-managed commercial fisheries recorded fishing effort within the DA between 2013–2022 (Ref. 228), based on the most recent data available. The permit and vessel details for these two fisheries are:

- North West Slope Trawl Fishery—2021–2022 season: 7 permits with 3 active vessels.
- Western Tuna and Billfish Fishery—This is a pelagic longline and minor-line fishery, which may be impacted by the Development's support activities. In 2022 the WTBF had 96 fishing permits, 2 pelagic longline and 3 minor line vessels were active during this season.

Fishing activity within the Commonwealth NWSTF is restricted to waters between the 200 m isobath and the outer boundary of the Australian Fishing Zone (Ref. 392, Ref. 393). Therefore, no trawl fishing is expected to occur around the WTR field, which is only ~150 m deep.

State-managed Fisheries:

As identified in Section 6.4.1.2, four State-managed commercial fisheries had recorded fishing effort with the DA between 2014-2023. Fishing effort records obtained from DPIRD (Ref. 394) for State-managed commercial fisheries indicate that fishing effort within the DA varies each year:

- Mackerel Managed Fishery—<3 active vessels per year, fishing effort recorded in 2014, 2016, 2017 and 2018
- Pilbara Line Fishery— active vessels varied between <3 to 6 per year, fishing effort recorded all years
- Pilbara Trap Managed Fishery—≤3 active vessels per year, fishing effort recorded all years
- Pilbara Crab Managed Fishery—<3 active vessels, with fishing effort only recorded in 2016.

Commercial fishing activity will be excluded from the SNAs (within 500 m of the MODU or large construction vessels) for temporary periods only, e.g. during specific activities such as drilling, P&A and pipelay. This SNA represents a very small portion of the managed fishery areas, and fishing effort within the DA has historically been low. This is considered an insignificant area in relation to the size of the fishing management areas across the NWS. In addition, prior notification through stakeholder consultation and the issuing of a notice to mariners will inform fishers of operations to minimise impacts on their activities.

Infrastructure will be installed on the seabed and remain throughout the life of the Development, resulting in potential interaction where users interact with the seafloor where these structures exist. This infrastructure includes manifolds, wellheads and other infrastructure around tie-in and DC locations, plus production flowlines, MEG pipelines and umbilicals.

A 7-year field survey on sedimentation-induced burial of marine pipelines was undertaken in the NWS region, and indicated that subsea pipelines experienced significant lowering into the seabed

Risk evaluation
due to sediment mobility and scour, mostly within 2 years of pipelay (Ref. 261; Ref. 262). Biological activity such as crustaceans and demersal fish tunnelling under equipment also contributed to embedment. The relatively low profile of flowlines (~24″ pipeline diameter) and structures (maximum height of ~13 m) means that partial burial of some objects will likely occur over time (depending on size). The presence of the subsea infrastructure and support activities is expected to have a low impact on Commonwealth or State commercial fishing operations (i.e. catch losses; equipment damage), therefore, CAPL has ranked the consequence to commercial fishing from unplanned interactions as Incidental (6). Offshore construction of the GFP began in 2010, and included drilling, installation, commissioning, and start-up activities, with operations beginning in 2016. The vessel fleet used for the construction phase of the GFP was very large. At the time of writing, no incidences of commercial fishing activities interacting with the infrastructure or with support activities has been communicated to CAPL since GFP construction began in 2010. The DA is located in areas of low commercial trawl or trap fishing activity and overlaps only ~0.2 % of fishery management areas. Exclusion areas are small (500 m around some vessels and the MODU) and are temporary. If any permanent PSZs are implemented, they would also have a small spatial extent (500 m). Based on GFP experience, commercial fishing interaction with subsea infrastructure is expected to be limited. Therefore, CAPL has ranked the likelihood of unplanned interactions with commercial fishing as Unlikely (4). Overall, the risk of interaction with commercial fisheries is Very Low (9).
Petroleum activities
Change to the functions, interests and activities of other marine users The DA is in the Northern Carnarvon Basin which is one of Australia's premier hydrocarbon-producing provinces containing an established network of oil, condensate, and gas production infrastructure. The closest platform to the DA is Santos' John Brookes WHP, which is ~15.6 km from the DA. The DA for the Development has been defined to include the extent of all planned activities across multiple fields. Existing pipelines—the CAPL-operated Wheatstone trunkline, and the Woodside Scarborough trunkline—cross the DA. An existing submarine cable—the Vocus-operated Highclere Cable—also crosses the DA. CAPL will work with Woodside, Vocus and any other third-parties who may have future development plans in the vicinity of the DA, to safely manage any interactions. Because the DA does not prohibit access to other marine users. Exclusion areas are small (500 m around some vessels and the MODU) and are temporary. If any permanent PSZs are implemented, they would also have a small spatial extent (500 m). The physical presence of vessels or installed subsea infrastructure is not expected to cause significant impacts to other petroleum activities and the risks are considered limited. Therefore, CAPL has ranked the consequence of interaction with petroleum activities to be Incidental (6). The operation of support vessels is commonplace and well-practised nationally and internationally—the risks associated with interactions are well understood by the industry. Therefore, CAPL has ranked the likelihood of unplanned interactions with other petroleum activities as Seldom (3). Overall, the risk of interaction with petroleum activities is Low (8).
Commercial shipping
Change to the functions, interests and activities of other marine users The presence of support vessels and the MODU within the DA may disturb shipping activity in the region. Although the DA is predominantly outside major shipping fairways and commercial vessel traffic density, a portion of the DA near the proposed G&E pipeline overlaps part of the NWS shipping fairway system (Figure 6-45). The presence of the MODU and vessels within the DA is not expected to affect commercial shipping operators; however, intermittent deviations may be required within the DA as the Development unfolds, in particular during drilling and decommissioning activities when an SNA is required around the MODU. SNAs are temporary and comprise a small radius (500 m) around the MODU; therefore, any deviations would be minor and thus have a negligible impact on commercial shipping vessels.

Risk evaluation
Because of the small overlap with the shipping fairway and the relative low-density shipping activity throughout the rest of the DA, the presence of support vessels for the Development is not expected to impact the functions, interests, or activities of commercial shipping. Therefore, CAPL has ranked the consequence of unplanned interaction with shipping activities as Incidental (6) and the likelihood as Seldom (3). Overall, the risk of interaction with shipping activities is Low (8).

8.9.3 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-74 details the determination of acceptability for interaction with other marine users.

Table 8-74: Determination of acceptability for physical presence—other marine users

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect **AL-18** as defined in Table 7-6 and shown below in Section 8.9.4. As described in the impact and risk evaluation (Section 8.8.2), the predicted impact would have negligible to low impact to other marine users with no lasting effects on the functions, interests, or activities of other marine users in the area in the area. Therefore, the predicted level of impact for these receptors is better than **AL-18**.
Principles of ESD	**(b) 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 highest consequence level for unplanned interaction with other marine users was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Offshore commercial vessel operations are commonplace and well-practised nationally and internationally. Prevention measures for unplanned interaction with other marine users are well regulated and managed in Australian waters. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the risk of unplanned interaction with other marine users based on relevant environmental legislation and other requirements as listed below. • The regulation and management of interactions with other marine users in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for unplanned interaction with other marine users was evaluated as Incidental (6). Therefore, in accordance

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to unplanned interaction with other marine users has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="4">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Navigation Act 2012 (Cth), MARPOL and various Marine Orders (as appropriate to vessel class) enacted under this Act.
Regulates navigation and shipping including Safety of Life at Sea, and specific requirements for navigational lighting. Several Marine Orders enacted under this Act apply directly to offshore petroleum exploration and production activities</td><td rowspan="3">Legislative requirements to manage interaction with other marine users are addressed by adopting these control measures:
• CM-03
• CM-04
• CM-16
• CM-31
• CM-32
• CM-33
• CM-34
• CM-35.</td></tr>
<tr><td>Chapter 6, Part 6.6 of the OPGGS Act
Safety Zones and the Area to be Avoided NOPSEMA Guidance Note (Ref. 395)
For the protection of petroleum wells, structure and equipment, safety zones of up to 500 m can prohibit unauthorised vessels from entering or being present.</td></tr>
<tr><td>Offshore Petroleum Decommissioning Guideline (Ref. 75)
Applies to all petroleum structures, equipment, wells, and property brought onto the area under the authority of a title granted under the OPGGS Act, during any stage of operations. Decommissioning activities are the responsibility of the registered holder of the title under which the activities take place.</td></tr>
</table>

Determination of acceptability		
	Section 572 Maintenance and removal of property Policy (Ref. 80) States that: • all property is designed, installed and operated with the intention of being removed when it is no longer in use • when a field permanently ceases production, all remaining property is removed if it is not to be used in connection with the operations • a comparative assessment may be used in an EP as a method to evaluate feasible alternatives to removing property • when an evaluation of impacts and risks are required by the OPGGS(E)R, they must incorporate a holistic evaluation of the impacts and risks of the alternative arrangements (including those impacts and risks that may arise from removing or relocating property outside the title area) and consider community interest.	
Internal context	These procedures were identified as relevant for this aspect: • Stakeholder engagement (Section 3) • Maritime Safety Information • Chevron Shipping's Marine Standard Non Tankers (Ref. 265) • Control of Work (CoW) Process	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. No feedback was received in relation to interaction with other marine users from Phase 1 stakeholder consultation.	

8.9.4 environmental performance

Table 8-75 lists the EPOs defined for unplanned interaction with other marine users and the adopted control measures to achieve the outcome.

Table 8-75: Environmental performance for physical presence—other marine users

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-18: No interference with other lawful marine users within the petroleum title areas to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties as conferred to the titleholder	**EPO-33:** No interference with other lawful marine users from planned activities associated with the Development to a greater extent than is necessary for the reasonable exercise of the rights and performance of duties.	**CM-31**: Vessels operating within the Development Area will comply with any Notice to Mariners requirements under the *Navigation Act 2012* (Cth). **CM-32**: Vessels operating within the Development Area will comply with requirements

Acceptable levels	Environmental performance outcomes	Adopted control measures
under section 280 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth).		within Marine Order 27—Safety of navigation and radio equipment. **CM-33**: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-34**: Apply for petroleum safety zones for relevant Development infrastructure in accordance with section 616 of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth). **CM-35**: CAPL will comply with any Notice to Mariners requirements under the *Navigation Act 2012* (Cth) regarding notifications of installed subsea infrastructure. **CM-03**: Remove all property above the mudline unless an alternative decommissioning approach has been accepted by NOPSEMA. **CM-04**: If property is accepted to be decommissioned in situ, a sea dumping permit will be acquired in accordance with the *Environmental Protection (Sea Dumping) Act 1981* (Cth).

8.10 physical presence—marine fauna

8.10.1 source

Vessel, helicopter and flowline flooding operations have the potential to result in unplanned interactions with marine fauna. Unplanned interactions include vessel strike (collision between marine fauna and a moving vessel), bird strike (collision between a bird and a helicopter) and marine fauna entrainment and impingement.

Water intake for flowline flooding operations during hydrotesting and pre-commissioning has the potential to entrain and impinge marine fauna. Entrainment is the unwanted passage of marine fauna through a water intake, which is generally caused by an absent or inadequate water intake screen. Impingement is the physical contact of marine fauna with such a barrier structure (screen) due to intake velocities that are too high to allow marine fauna to escape.

These unplanned interactions with marine fauna are considered credible threats to EPBC Act listed marine fauna during the Development.

Table 8-76 lists the activities within each phase that have the potential for unplanned interactions with marine fauna in the DA.

Table 8-76: Phases and activities that interact with Physical presence—Marine fauna

Phase	Activity
Installation and commissioning	Hydrotesting and pre-commissioning
Operations	Maintenance and repairs
Support activities	MODU operations Vessel operations Helicopter operations

8.10.1.1 installation and commissioning

Marine fauna entrainment and impingement is possible during flowline flooding operations conducted for hydrotesting (FCGT, leak testing) and pre-commissioning activities during the installation and commissioning phase. Flowline reflooding operations conducted for major repair activities during the operations phase can also be a source of marine fauna entrainment and impingement.

FCGT activities require flowlines to be flooded with FCGT media to send gauge pigs from one end of the flowline to the other. FCGT media comprises sea water sourced from the marine environment, MEG and freshwater conditioning chemicals. Freshwater conditioning chemicals generally comprise oxygen scavengers, biocides, corrosion inhibitor, which are added to the sea water to prevent the risk of corrosion and microorganism growth in the flowlines. The flowlines remained filled with FCGT media for leak testing and pre-commissioning activities.

Sea water intake for flooding operations is expected to be a one-off activity per field, planned to occur during hydrotesting and pre-commissioning activities (these activities are estimated to take one month per field).

8.10.1.2 operations

In the unlikely event major repairs are required for the flowlines, pipeline repair activities may require the flowlines to be dewatered and reflooded. Water for reflooding will again be sourced from the marine environment and freshwater conditioning chemicals added.

Pipeline repair reflooding operations may occur during the operations (for ~1 month). Leak testing of the repaired flowline may involve hydrotesting and pre-commissioning techniques to determine the flowline's structural integrity.

8.10.1.3 support activities (all phases)

Vessel strike may occur during vessel movements within the DA. Vessels undertaking Development activities within the DA include support vessels, anchor-handling tugs, installation vessels and MODU.

Locations where there is a co-occurrence of high numbers of vessels occurring simultaneously in marine fauna aggregation areas are considered high-risk for vessel strike (Ref. 396). The number of vessels working concurrently across a field or co-developed field within the DA is estimated to vary between ~2–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation and commissioning may take as long as

~12–15 months per field or co-developed field and while concurrent activities are possible during this time, they will typically be intermittent and would occur for only a small portion of the overall duration.

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). The MODU will move between fields but will spend most of the time at the DCs, where it will be stationary. The MODU has minimal movement capability and likely will require ~2 support vessels to help move and position it. If the MODU is towed, the tow speed will be slow at ~2 knots.

The potential for bird strike from helicopter operations is generally limited to the drilling, installation, and decommissioning phases of the Development[184]. Installation vessels and the MODU will be serviced by helicopters (estimated ~15-16 flights per week for the largest vessel; ~5 flights per week for the MODU).

8.10.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that are susceptible to unplanned interactions with marine fauna:

- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- cultural heritage values: Traditional Owners.

Table 8-77 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to unplanned interactions with marine fauna in the DA.

Although fish may potentially be impacted by unplanned interactions with marine fauna (from vessel strike or entrainment/entrapment) (Table 8-77), it would only have individual impacts, and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the continental slope demersal fish communities KEF from unplanned interactions with marine fauna are not expected, and are not evaluated further.

Table 8-77: Risk evaluation for physical presence—marine fauna

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Unplanned interactions with birds may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Unplanned interactions with fishes, including sharks and rays may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Unplanned interactions with marine reptiles may result in: • injury or mortality of marine fauna.	6	3	Low (8)

[184] Helicopters may also be used during longer IMR campaigns during the operational phase of the Development.

Impact and/or risk level summary					
		Unplanned interactions with marine mammals may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Injury or mortality of marine fauna may result in: • change to cultural heritage values: Traditional Owners.	6	3	Low (8)

Risk evaluation

Birds

Injury or mortality of marine fauna (aerial strike)

Bird strikes may occur on the helidecks of the MODU and large installation vessels during helicopter passenger transfer/crew change operations. Locations where there is a co-occurrence of high number of helicopter flights in bird resting areas are considered high-risk areas for bird strike (Ref. 397). Helicopter transfer frequency may be ~15-16 times per week for a large vessel and ~5 flights per week on the MODU during the drilling, installation, and decommissioning phases. The DA does not overlap known bird resting BIAs. Despite the potential high number of helicopter flights in the DA during short-term Development phases (i.e. not operations), the absence of known bird resting BIAs in the DA will reduce the likelihood for bird strike.

Unmanned offshore installations are found to attract large number of birds for use as a resting location (Ref. 397). Vessels in the DA may act as temporary resting locations for birds. The MODU and installation vessels used for the Development will be manned and their presence in the DA will be sporadic and temporary during the Development. Given the temporary presence and manned status of vessels equipped with helidecks in the DA, large numbers of resting birds are not expected—people are a deterrent for birds.

Deaths recorded from instances of bird strike highlight the potential for injury and death to individual EPBC Act listed marine fauna. The DA contains EPBC Act listed bird species that may, or are known to, occur, and it overlaps the breeding BIA for the wedge-tailed shearwater.

The Wildlife Conservation Plan for Seabirds (Ref. 38) identifies aircraft as a key threat; however, this plan focuses on aircraft flying close to onshore breeding colonies.

If a bird strike occurred during the Development, injury and death to individual EPBC Act listed species would not decrease the population size (at a local or regional scale). As individual deaths are not expected to have a detrimental effect on the overall population; this event would result in a limited environmental impact (individual impacts).

Therefore, unplanned interactions between helicopters and marine fauna was evaluated as Incidental (6).

During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of bird strike were reported (Ref. 398). Since GFP operations began in 2016, no incidents of bird strike have been reported (Ref. 198; Ref. 399; Ref. 400). Based on previous experience in the DA, CAPL considers the likelihood of the consequence occurring is Seldom (3).

The risk ranking for unplanned interactions between helicopters and marine fauna for birds is Low (8).

Fishes, including sharks and rays

Injury or mortality of marine fauna (vessel strike)

Vessels undertaking Development activities in the DA have the potential for unplanned vessel strike with large fish species that commonly dwell at or near surface waters. A review of EPBC Act listed fish species in the DA found the whale shark to be the only fish species susceptible to vessel strike, with the Conservation Advice Rhincodon typus Whale Shark (Ref. 33) identifying vessel disturbance as a key threat to the species. Whale sharks tagged off Western Australia (Ref. 164; Ref. 168) spend ~25% of their time <2 m from the surface and >40% of their time in the upper 15 m of the water column.

The eastern edge of the DA (Figure 6-30) overlaps the whale shark foraging BIA in the deeper oceanic waters along the 200 m isobath, where seasonal migration of whale sharks occurs mainly between July to November (Ref. 33). However, as there are no known aggregation areas within

Risk evaluation
the DA and given the seasonal and transient presence of the species, whale shark numbers are not expected be significant. Laist et al. (Ref. 401) identify that larger vessels with reduced manoeuvrability that move >10 knots may cause fatal or severe injuries from vessel strike, with the most severe injuries caused by vessels travelling >14 knots. Although the DA overlaps the whale shark foraging BIA, vessels will be slow-moving whilst implementing the activities associated with the Development, therefore vessel strike resulting in fauna death or severe injuries is not anticipated. If a vessel strike occurred during the Development, causing the injury and death of an individual whale shark, this is not expected to have a detrimental effect on the overall whale shark population, and would result in a limited environmental impact (individual impacts); thus, unplanned interactions between vessels and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence. During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of vessel strike to fish, including whale sharks, were reported (Ref. 398). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 198; Ref. 399; Ref. 400), and the National Ship Strike Database (Ref. 19) does not identify any previous incidents of whale shark strikes in the DA. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between vessels and fish is Low (8). **Injury or mortality of marine fauna (entrainment and impingement)** Flooding and reflooding flowlines with sea water in the DA has the potential for unplanned entrainment and impingement of juvenile fish, eggs, and larvae. Fish may be subject to impingement (fauna trapped against plant intake screens by force of the flowing water) and/or entrainment (fauna actively drawn into plant intake). A 40-year literature review on the impacts of entrainment and impingement of fish by Barnthouse (Ref. 402) found substantial evidence that impacts related to entrainment and impingement are generally small compared to natural mortality rates of susceptible life stages and impacts to populations from fishing. Water winning for hydrotesting would only be undertaken once for each field, during commissioning of flowlines, and if major repairs were required. Because the impact of entrainment and impingement of fish is insignificant relative to natural mortality, unplanned interactions between flooding and reflooding operations and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence. There are no known fish nursery and/or aggregation areas in the DA, which reduces the potential for fish entrainment and impingement. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between flooding and reflooding operations and fish is Low (8).
Marine reptiles
Injury or mortality of marine fauna (vessel strike) Vessels undertaking Development activities in the DA have the potential for unplanned vessel strike with marine reptile species when these species surface to breathe. A review of EPBC Act listed marine reptile species in the DA found marine turtles to be susceptible to vessel strike. The DA overlaps the flatback turtle internesting buffer but does not overlap critical habitat or aggregation areas for sea snakes. Although the DA overlaps the flatback turtle internesting buffer, Whittock (Ref. 146) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km from the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate in the DA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Marine turtles are known to avoid vessels by rapidly diving; however, their ability to respond varies greatly depending on the speed of the vessel. Hazel et al. (Ref. 329) reported that the number of turtles that fled vessels decreased significantly as vessel speed increased. Slow vessel speeds combined with marine turtles vessel avoidance behaviours will reduce the likelihood of lethal collisions during internesting periods in the DA. Given the offshore location of the DA, only a small number of transient marine turtles are expected to be present. If a vessel strike occurred during the Development, injury, and death to individual EPBC Act listed species would not decrease population size (at a local or regional scale) and would result in a limited environmental impact (individual impacts).

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Therefore, unplanned interactions between vessels and marine reptiles is evaluated as Incidental (6).

During the 3-year construction period for the GFP feed gas pipelines, extending ~200 km to Barrow Island, no incidents of vessel strike to marine reptiles were reported (Ref. 398). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 198; Ref. 399; Ref. 400). Marine turtles are also not expected to be common as far offshore as the DA, reducing the probability of a vessel strike. The likelihood of the consequence occurring is Unlikely (4).

The risk ranking for unplanned interactions between vessels and marine reptiles is Very Low (9).

Injury or mortality of marine fauna (entrainment and impingement)

Flooding and reflooding flowlines with sea water in the DA has the potential for unplanned entrainment and impingement of marine turtle hatchlings. Marine turtle hatchlings may be subject to impingement and entrainment because hatchlings are known to drift passively within ocean currents and are unlikely to out-swim the current generated by water intake for pipeline flooding (Ref. 403).

If entrainment and impingement of marine turtle hatchlings occurred during the Development, injury and death to individual EPBC Act listed species would not decrease population size (at a local or regional scaled) any more than would usually occur due to natural variation. Because the impact of entrainment and impingement to marine turtle hatchlings is insignificant relative to natural mortality, unplanned interactions between flooding and reflooding operations and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence.

As mentioned above, only a small number of transient marine turtles are expected to be present in the DA despite overlap with marine turtle internesting BIA and HCTS—the DA is offshore (>60 km from Barrow Island at its closest point) and with increasing water depths (up to ~1,400 m). Marine turtles prefer the proximity of the coast and relatively shallow water depths during internesting periods, which reduces the potential for entrainment and impingement. The likelihood of the consequence occurring is Seldom (3).

The risk ranking for unplanned interactions between flooding and reflooding operations and marine reptiles is Low (8).

Marine mammals

Injury or mortality of marine fauna (vessel strike)

Vessels undertaking Development activities in the DA have the potential for unplanned vessel strike with marine mammals. A review of EPBC Act documents for listed marine mammal species in the DA found humpback whales and pygmy blue whales are susceptible to vessel strike because the DA overlaps their respective BIAs for migrating. The southern edge of the DA overlaps the humpback whale migration BIA where migration is predicted from June to October (Section 6.3.3.1.1). Satellite tracking and acoustic detection studies indicate that pygmy blue whales are likely to travel predominantly to the north-west of the DA in deeper waters, particularly on their southern migration (November to December), but also during the northern migration (April to August) (Section 6.3.3.1.2).

Entrainment and entrapment in water intakes is only a risk for small marine fauna, and not credible for marine mammals. Hence it is not evaluated further.

Cetaceans are naturally inquisitive marine mammals that are often attracted to offshore vessels and facilities. The reaction of whales to the approach of a vessel is quite variable. Some marine mammal species, such as humpback whales, can detect and change course to avoid a vessel (Ref. 404), some species remain motionless when near a vessel, while others are curious and often approach vessels that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster-moving vessels (Ref. 401).

As described above, severe or lethal injuries to marine fauna from vessel strike are more likely to occur with larger or faster vessels travelling >10 knots. For large whale populations, the probability of lethal injuries resulting from collisions decreased to <50% when vessels travelled at speeds ≤10 knots (Ref. 401). Stationary or slow-moving vessels have an extremely low risk of colliding with marine mammals. While it is likely that greater numbers of individuals would be encountered during the short duration survey or installation activities, if these occur during migration periods, vessels undertaking these Development activities in the DA will move slowly.

There have been few recorded instances of cetacean deaths in Australian waters. Mackay et al. (Ref. 405) report that four fatal and three non-fatal collisions with southern right whales were recorded in Australian waters between 1950 and 2006, with one fatal and one non-fatal collision reported between 2007 and 2014. The death of a Bryde's whale in Bass Strait in 1992 (Ref. 406)

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was also recorded, noting this data indicates deaths are more likely to be associated with container ships and fast ferries. Due to the stationary or slow speeds of vessels undertaking Development activities in the DA, the generally low number of vessels within the DA at any time, and as incidents have been demonstrated to be very rare, vessel strike resulting in death or severe injuries to marine mammals is not anticipated. If a vessel strike occurred during the Development, and injury or death to individual EPBC Act listed species occur, it will not decrease population size (at a local or regional scale) and would result in a limited environmental impact (individual impacts). Therefore, unplanned interactions between vessels and marine fauna has been evaluated as Incidental (6). During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of vessel strike to marine mammals were reported (Ref. 398). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 198; Ref. 399; Ref. 400), and the National Ship Strike Database (Ref. 19) does not identify any previous incidents of vessel strikes in the DA. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between vessels and marine mammals is Low (8).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned interactions with marine fauna includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from unplanned interactions. The consequence evaluations to these receptors are provided above; and the highest consequence level for unplanned interactions with marine fauna was evaluated as Incidental (6) from the potential for injury or mortality of marine fauna resulting from vessel or aerial strike; or impingement or entrainment. As such, the consequence of changes to cultural heritage values from unplanned interactions with marine fauna is also evaluated as Incidental (6). Given the limited environmental impact (individual impacts), and no incidents of vessel or helicopter strike on the Gorgon Gas Development to date; the likelihood of the consequence occurring is assessed as Seldom (3). The risk ranking for unplanned interactions with marine fauna to Traditional Owner cultural heritage values is Low (8).

8.10.3 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-78 details the determination of acceptability for interaction with marine fauna.

Table 8-78: Determination of acceptability for physical presence—marine fauna

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect **AL-19** as defined in Table 7-6 and shown below in Section 8.10.4. The intent of adopting and implementing preventative control measures (Section 8.10.4) is to prevent an occurrence of an unplanned interaction with marine fauna. This preventative approach ensures **AL-19** is met. In the event an unplanned interaction the above risk evaluation (Section 8.10.2), demonstrates that the predicted impact is incidental with individual impacts that will not decrease population size (at a local or regional scale).

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6">Principles of ESD</td><td colspan="2">(b) 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</td></tr>
<tr><td colspan="2">The highest consequence level for unplanned interaction with marine fauna was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required.
Notwithstanding, CAPL also notes that:
• Prevention measures for unplanned interaction with marine fauna are well managed in Australian waters.
• To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.</td></tr>
<tr><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the risk of unplanned interaction with marine fauna based on relevant environmental legislation and other requirements as listed below.
• The management of unplanned interaction with marine fauna in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for unplanned interaction with marine fauna was evaluated as Incidental (6). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to unplanned interaction with marine fauna has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans
The requirements to manage interactions between vessels and cetaceans are detailed in the EPBC Regulations 2000 – Part 8 Division 8.1</td><td>Legislative requirements to manage vessel interactions with protected marine fauna are addressed by adopting these control measures:
• CM-18
• CM-19.</td></tr>
</table>

Determination of acceptability		
	– Interacting with cetaceans. These regulations describe strategies to ensure cetaceans are not harmed during offshore interactions with people.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 33) 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 WA coastline along the 200 m isobath.	The DA is outside of whale shark aggregation areas (i.e. Ningaloo Reef, Christmas Island and the Coral Sea). The south-eastern section of the DA, associated with WTR field, overlaps the 200 m isobath. However, based on analysis of satellite tagging data, whale sharks more commonly use an area outside of the DA (and associated with subsea pinnacle features). Therefore, this activity is not considered to be inconsistent with the Conservation Advice Rhincodon typus Whale Shark.
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) Action A.4.2: Ensure all vessel strike incidents are reported in the National Ship Strike Database Action A.4.3: 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	An impact and risk evaluation is provided above for vessel strikes on marine fauna. To manage vessel interactions with protected marine fauna are addressed by adopting these control measures: • **CM-18** • **CM-19** • **CM-36**. Requirements to report vessel strike incidents are included in Section 10.5.2. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	National Recovery Plan for the Southern Right Whale (*Eubalaena australis*) (Ref. 23) Action A6.5: Ensure all vessel strike incidents are reported in the National Ship Strike Database managed through the Australian Marine Mammal Centre, Australian Antarctic Division.	
	Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 22) Minimise vessel collisions: • ensure all vessel strike incidents are reported in the National Vessel Strike Database	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 21) Minimise vessel collisions: • ensure all vessel strike incidents are reported in the National Vessel Strike Database	

Determination of acceptability		
	National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 19) Objectives are to acquire data, determine risks of vessel strike, and identify mitigation measures, with the target audience being government agencies: • ensure all vessel strike incidents are reported in the National Vessel Strike Database • adopt best-practice mitigation measures.	
	Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin) (Ref. 663) • Ensure all vessel strike incidents are reported in the National Ship Strike Database. • Ensure the risk of vessel strike on Australian humpback dolphins is considered when assessing actions that increase vessel traffic on areas Australian humpback dolphins occur and, if required, appropriate mitigation measures are implemented.	
	Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin) (Ref. 664) • Ensure all vessel strike incidents are reported in the National Ship Strike Database. • Ensure the risk of vessel strike on Australian snubfin dolphins is considered when assessing actions that increase vessel traffic on areas Australian snubfin dolphins occur and, if required, appropriate mitigation measures are implemented	
	Recovery Plan for Marine Turtles in Australia (Ref. 24) **Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle)** (Ref. 25) **Wildlife Conservation Plan for Seabirds** (Ref. 38) **National Recovery Plan for Albatrosses and Petrels** (Ref. 40)	These EPBC management plans for species that may occur within the DA identify unplanned interaction with marine fauna as a threat, but do not identify relevant actions.
Internal context	No CAPL procedures were identified as relevant for this aspect.	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as	

Determination of acceptability	
	part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to unplanned interaction with marine fauna from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.

8.10.4 environmental performance

Table 8-79 lists the EPO defined for unplanned interaction with marine fauna and the adopted control measures to achieve the outcome.

Table 8-79: Environmental performance for physical presence—marine fauna

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-19: No death or injury to an EPBC Act listed threatened species, migratory species, marine species or cetacean species within the Commonwealth marine area attributable to the Development.	**EPO-34**: No death or injury of an EPBC Act listed threatened, migratory, or cetacean species from Development activities within the Development Area.	**CM-18**: Vessels under transit[185] within the Development Area will implement caution and no approach zones as described in sections 8.05 and 8.06 of the EPBC Regulations 2000 (Cth). **CM-19**: Helicopters under transit within the Development Area will operate in alignment with section 8.07 of the EPBC Regulations 2000 (Cth). **CM-36**: Inlet screens will be used when winning water from the sea during flowline flooding and pre-commissioning activities.

8.11 introduction of invasive marine pests

8.11.1 source

When new species are introduced into environments in which they do not occur naturally, they may be able to survive, reproduce and establish. IMPs are introduced species that become pests by outcompeting endemic marine species.

IMPs may be introduced to, and translocated within, Australian waters in various ways, including ballast water discharged from vessels and facilities, biofouling on hulls and inside internal seawater systems of vessels and facilities, as well as by ocean currents and attached to marine debris.

[185] For safety reasons this control measure is not applied to vessels holding station or with limited manoeuvrability (e.g. during lifts, bunkering, etc.) or during emergence situations.

These stages are required to successfully introduce, establish, and spread IMPs (Ref. 73):

- colonise and establish on a vector (e.g. vessel, MODU, equipment) in a donor region (e.g. port, harbour, project site)
- survive on the vector during the voyage from the donor to the recipient region
- colonise the recipient region (e.g. by reproduction or dislodgement), then successfully establish a viable new local population.

Several pathways exist for potentially introducing, establishing, and spreading IMPs:

- vessel/MODU/equipment to marine habitat within the DA
- vessel to vessel; or vessel to MODU followed by spread to marine habitat within the DA
- subsequent spread from marine habitat within the DA to outside the DA.

To become established within the DA, IMPs need suitable habitat and conditions. Hard substrates such as rocks or subsea infrastructure in shallow waters (where photosynthesis can occur) are suitable habitats. Most activities associated with the Development occur in deep water with strong currents and soft sediment on the seabed, conditions which are not considered suitable for IMP establishment.

The major vector pathways for introducing IMPs are described below.

Ballast water

Vessels may need to adjust their ballast to maintain stability, balance, and trim—they use ballast water to achieve this, either by taking in the surrounding water, or expelling it from the vessel. The water taken in may contains IMPs from all life stages, including adults, eggs, and larvae. This biota may then be discharged at the vessel's new location during ballast water exchange. The risk of species introduction is greatest when coastal water is taken up in one location and discharged at another with similar physical and environmental characteristics (Ref. 406).

Biofouling

Biofouling occurs when organisms attach and grow on the submerged parts of a vessel or MODU, like the hull, propellers, anchors, mooring lines, and niche areas. Immersible equipment and infrastructure such as subsea tieback systems (i.e. flowlines, umbilicals, spools, manifolds) may provide IMPs with submerged surfaces they can attach to (Ref. 406). Many structures can remain undisturbed for long periods (e.g. decades) before they are retrieved for decommissioning.

Table 8-80 lists the activities within each phase that have the potential for introducing IMPs in the DA.

Table 8-80: Phases and activities that have the potential for Introduction of IMP

Phase	Activity
Decommissioning	Other subsea structures decommissioning
Support activities	MODU operations Vessel operations

8.11.1.1 decommissioning

When structures are retrieved to the deck during decommissioning, biofouling may become dislodged and fall to the seabed. Lifting points of structures may also be cleaned to remove marine growth, releasing organisms into the marine environment.

8.11.1.2 support activities (all phases)

Any of the vessels or the MODU may enter the DA directly from international waters or come from domestic ports. If IMPs are introduced to the DA by one of these pathways, it is also possible that these support vessels moving between the facility and the coastal waters could act as a vector for spreading IMPs from the DA into port environments.

Vessels are the most important vector for transporting IMPs, mostly by biofouling (Ref. 407; Ref. 408, Ref. 409). It is estimated that 25% of Australia's established IMP was the result of ballast water exchange (Ref. 60).

The Australian Ballast Water Management Requirements (Ref. 60) set out the legislative obligations for managing ballast water, when operating within Australian seas to comply with the Commonwealth *Biosecurity Act 2015*. Key requirements are that ballast water exchange is conducted in an acceptable area, use of low risk ballast water and retention of any high-risk ballast water onboard the vessel. All vessels must have a Ballast Water Management Plan and Certificate. These requirements for ballast water exchange greatly reduces the risk introducing IMPs.

During the Development, vessels will transit between the DA and international and domestic ports. Each vessel has the potential to host IMPs if it is not managed appropriately. IMPs may translocate into the DA or from one vessel to another through ballast exchange or be dislodged or spawned from biofouling.

The time a vessel spends in a location (residence time) affects the likelihood of species attachment or uptake. The longer the residence time, the more likely the vessel will be colonised by biofouling species. The residence time can also affect the performance of some types of antifouling coatings (Ref. 406).

The Development does not have any permanent platforms or moored facilities. Of all the Development vessels or facilities, the MODU has the greatest risk of accumulating biofouling, as it will be stationary for the longest period while it drills multiple wells at a DC (~3 months per well, estimated ~24 months in total).

The MODU will be in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). It will move between fields but will spend most of the time at the DCs.

Vessels will be present in the DA during all phases of the Development. The number of vessels working concurrently across a field or co-developed field within the DA is estimated to vary between ~2–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation and commissioning may take as long as ~12–15 months per field or co-developed field and while concurrent activities are possible during this time, they will typically be intermittent and would occur for only a small portion of the overall duration.

The National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (Ref. 73) states that ROVs should not pose a threat of biofouling-mediated IMP transfers because they are routinely deployed (typically from a deck), retrieved, washed down, and maintained.

8.11.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified receptors within the DA that are susceptible to the introduction of IMPs, including:

- benthic habitats and associated communities
- KEFs (benthic habitats and associated communities)
- cultural heritage values: Traditional Owners.

Table 8-81 evaluates and assigns levels of consequence and likelihood to determine the residual risk of introducing IMPs to each susceptible receptor.

Table 8-81: Risk evaluation for introduction of IMPs

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Introduction of an IMP to a benthic habitats and associated communities or KEF may result in: • displacement of, or competition with, endemic species.	3	6	Low (8)
		Introduction of an IMP to a KEF may result in: • change to values and sensitivities.	3	6	Low (8)
		Introduction of an IMP may result in: • change to cultural heritage values: Traditional Owners.	3	6	Low (8)

Risk evaluation
Benthic habitats and associated communities
Displacement or competition with endemic species IMPs are likely to have little or no natural competition or predators, thus potentially outcompeting endemic species for food or space, preying on endemic species, or changing the nature of the environment. It is estimated that Australia has >250 IMP species, and that approximately one in six introduced marine species becomes a pest (Ref. 410). Risks to marine habitat from the introduction of IMPs depends on the successful reproduction and establishment of IMP populations, which leads to displacement of, or competition with, endemic species. IMP colonisation requires a suitable habitat in which to establish, such as rocky and hard substrates or subsea infrastructure, especially that with pre-existing biofouling. (Ref. 411). Many IMP primarily occur in shallow areas within the photic zone (upper 200 m of ocean), with high nutrient levels. Therefore, soft sediment habitat, deep water areas below the photic zone and nutrient-poor oceanic waters are likely to limit establishment for a number of IMP species (Ref. 412). Most of the benthic habitat in the DA is not considered suitable for establishing IMP habitat because water depths are mostly below the photic zone where photosynthesis does not occur, the BCH is mostly dominated by bare and irregular bare sediment (soft sediment habitats). No canyon features and no endemic benthic infauna were identified in the survey (Ref. 104; appendix a). The WTR DCs flowline and part of the umbilical section, which is located in water depths ranging from 100 m to 200 m, is the only section of the DA within the euphotic zone. Consequently, the risk evaluation for IMP focused on the WTR field, the worst-credible case, where photosynthesis is possible. The WTR flowline corridor runs mostly parallel to the ancient coastline at 125 m depth contour KEF. Although the entire KEF is identified as having unique seafloor features comprising areas of hard substrate (Ref. 102), these values were not identified within the area of the KEF that overlaps with the DA (Ref. 104; appendix a). Overall, WTR to Gorgon corridor was characterised by low structural habitats (Ref. 104; appendix a). Consequently, WTR field and associated

Risk evaluation
infrastructure are located in an area with low topographic features and is unlikely to provide significant habitat to biota. WTR also contains natural dispersal barriers for IMPs, such as internal waves and enhanced vertical mixing of water layers (Ref. 413). The presence of soft sediments and water currents at WTR is expected to limit the successful reproduction and establishment of founder IMP populations in the DA. Benthic habitat may serve as spawning sites for marine fauna, and these habitats are at risk from IMPs through competition for resources and being subject to predation (Ref. 410). The DA contains mostly bare and irregular bare sediment with no epibenthic biota observed. The presence of sparse benthic populations makes it difficult for IMPs to spread. Based on sparse benthic cover observations during the survey, IMP spawning and colonisation is not anticipated. Successful IMP establishment also depends on distance from coastal habitats. Highly disturbed shallow-water and coastal marine environments (such as marinas) are more susceptible to colonisation than open-water environments, where the number of dilutions and the degree of dispersion is high (Ref. 411; Ref. 414; Ref. 415; Ref. 416). The Bureau of Rural Sciences (BRS) calculated the risk of IMP incursion along Australian coastlines decreases with distance from the shoreline. Modelling conducted by BRS (Ref. 417) estimates that the median risk of establishment[186] is: • 40% chance of colonisation at 3 nm • 28% chance at 12 nm • 9% chance at 24 nm. The DA is ~50 km (~27 nm) from the closest shore; therefore, there is a very low likelihood that any IMP incursion would become established in the DA based on the risk estimates by BRS (Ref. 417). Once established, some IMPs can be difficult to eradicate (Ref. 418) and therefore there is the potential for a long-term change in habitat structure. If an IMP was introduced, and if it did colonise an area, there is the potential for that colony to spread outside the DA resulting in a widespread long-term impact, therefore resulting in a Major (3) consequence. Since IMP can be difficult or impossible to eradicate, once established, the main focus of managing IMP risks is to minimise the likelihood that incursions will occur in the first place. As the vessels associated with the Development will be operated and maintained in accordance with CAPL's Quarantine Procedure Marine Vessels (Ref. 74) and a vessel-specific biofouling management plan they should be able to effectively withstand large-scale settlement of marine organisms, including when vessels are exposed to locations of IMP infestation (Ref. 406). Given these control measures and the low likelihood of IMP incursion in the DA based on the BRS risk estimates (Ref. 406), the likelihood of introduced IMPs displacing or competing with endemic species is assessed as Rare (6). Overall, the risk of introducing IMPs to benthic habitats and associated communities and causing a change in the values and sensitivities of a KEF is Low (8).
KEFs
Changes to the values and sensitivities The introduction of IMPs may result in changes to the values and sensitivities of KEFs through displacement or competition with endemic species. Risks to KEFs from the introduction of IMPs depends on successful reproduction and establishment of IMP populations, leading to displacement of, or competition with, endemic species. The DA overlaps with three KEFs: ancient coastline at 125 m depth contour, Exmouth Plateau, and continental slope demersal fish communities. The values of the ancient coastline and Exmouth Plateau KEFs have assessed as its unique sea floor feature with ecological properties of regional significance (Ref. 102); and therefore have values that may be impacted by an IMP. Benthic habitat mapping of the Exmouth Plateau KEF within the DA predicted that most dominant BCH were identified as relatively uniform and dominated by irregular seabed with bioturbation or bare substrates, with some patchy areas of mound and scarps and have a low likelihood of providing epibiota. Scarps are usually characterised by raised hard structures and other structural features; these scarps however, are devoid of epibenthic fauna as observed in the ground-truthing videos . The area of the Exmouth Plateau KEF overlapping the DA is in water depths

[186] In this context, establishment refers to an organism being able to find suitable habitat and survive.

Risk evaluation
>1,200 m and is ~140 km from the nearest shore. This area is characterised by soft benthic habitat, also reduces the likelihood of IMPs becoming established. Although the entire ancient coastline at 125 m depth contour KEF is identified as having unique seafloor features comprising areas of hard substrate (Ref. 102), these values were not identified within the area of the KEF that overlaps with the DA (Ref. 104; appendix a). The area where the DA overlaps with this KEF is predicted to comprised of smooth seabed, with bioturbation and bare substrate, and appears to be devoid of epibenthic biota (Ref. 104; appendix a). Although the seabed, at ~150 m, is not as deep as some areas of the DA, the distance from the shore (~50 km), the soft seabed habitat and internal waves reduce the likelihood of IMPs becoming established. As for the benthic habitats assessed above, IMP introduction primarily occurs in shallow waters with high levels of slow-moving or stationary shipping traffic (e.g. ports), not in environments like the DA. IMP colonisation also often requires a suitable habitat in which to establish, such as rocky and hard substrates or subsea infrastructure, which were not identified in the DA. Once established, some IMPs can be difficult to eradicate (Ref. 418) and therefore there is the potential for a long-term change in habitat structure. If an IMP was introduced, and if it did colonise an area, there is the potential for that colony to spread outside the DA resulting in a widespread long-term impact to the values and sensitivities of a KEF, therefore resulting in a Major (3) consequence. As the benthic environment where the DA and KEFs overlap contains natural dispersal barriers unfavourable to IMP survival, the water depths of the DA and the requirement for vessels to implement CAPL's Quarantine Procedure Marine Vessels (Ref. 74) and a vessel-specific biofouling management plan , the likelihood of introduced IMPs displacing or competing with endemic species and causing a change in the values and sensitivities of a KEF is assessed as Rare (6). Overall, the risk of introducing IMPs to KEFs is Low (8).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from the introduction of IMPs includes indirect impacts to intangible Traditional Owner heritage from alterations to benthic habitats and associated communities. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of benthic habitats and associated communities (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural heritage values may occur due to alterations to benthic habitats and associated communities from the introduction of IMPs. The highest consequence level for the introduction on an IMP was evaluated as Major (3), from the potential for widespread, long-term displacement of, or competition with, endemic species. As such, the consequence of changes to cultural heritage values from introduction of IMPs is also evaluated as Major (3). Given the control measures that will be in place and the location of the benthic environment of the DA (i.e. contains natural dispersal barriers unfavourable to IMP survival); a change to cultural heritage values is not predicted to occur. Therefore, the likelihood of the consequence occurring is assessed as Rare (6). The risk of introducing IMPs to Traditional Owner cultural heritage values is Low (8).

8.11.3 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-82 details the determination of acceptability for introduction of IMPs.

Table 8-82: Determination of acceptability for Introduction of IMPs

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-20**, as defined in Table 7-6 and shown below in Section 8.11.4. The intent of adopting and implementing preventive control measures (Section 8.11.4) is to prevent the occurrence of an introduction and establishment of an IMP. This preventative approach ensures that **AL-20** is met.
Principles of ESD	**(b) 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 highest consequence level for introduction of IMPs was evaluated as Major (3). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Prevention measures for introduction of IMPs are well regulated and managed in Australian waters. • Commercial vessel operations are commonplace and well-practised nationally and internationally. The control measures to manage the risks of IMP introduction are well defined via legislative requirements that are considered standard industry practice. These are well understood and implemented by the petroleum industry and CAPL. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the risk of IMPs based on relevant environmental legislation and other requirements as listed below. • The regulation and management of IMPs in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for introduction of IMPs was evaluated as Major (3). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage. • Any relevant stakeholder feedback in relation to introduction of IMPs has been incorporated in the OPP and assessed in the external context acceptability criteria. • To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option. The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5). The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Biosecurity Act 2015 (Cth)
Vessels entering into the Australian territorial seas from outside Australian territory must complete pre-arrival reporting.</td><td rowspan="5">Legislative requirements to manage the introduction of IMPs are addressed by adopting these control measures:
• CM-37
• CM-38
• CM-39.</td></tr>
<tr><td>Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 (Cth)
Marine vessels greater than 400 gross tonnes with an antifouling coating are to maintain up-to-date international antifouling coating certification.</td></tr>
<tr><td>Australian Ballast Water Management Requirements (Ref. 60)
Details Australia’s commitment to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention) (Ref. 419). International marine vessels must comply with these key requirements:
• non-discharge of ‘high-risk’ ballast water in Australian ports or waters
• full ballast exchange outside Australian territorial seas
• documentation of all ballast exchange activities.</td></tr>
<tr><td>Control and Management of Ships’ Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) 2011 (Ref. 70)
Internationally agreed guidance for operators to develop vessel-specific biofouling management plans.</td></tr>
<tr><td>National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Ref. 73)
Guides operators on:
• evaluating biofouling risk of types of structure/facilities
• biofouling management and decommissioning.</td></tr>
</table>

Determination of acceptability		
	Reducing marine pest biosecurity risks through good practice biofouling management (Ref. 78) Guides operators on: • biosecurity requirements relevant to offshore activities • coordinated good practice advice that is consistent with the expectations of all jurisdictions responsible for regulating biofouling management within the Australian marine environment • the industry's contribution to marine pest risk management consistent with Australia's MarinePestPlan 2018–2023 (Ref. 79).	
	Australian Biofouling Management Requirements (Ref. 61) Guides operators on biofouling management of vessels.	
Internal context	These CAPL procedures were deemed relevant for this aspect: • Quarantine Procedure Marine Vessels (Ref. 74).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to introduction of IMPs from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.11.4 environmental performance

Table 8-83 lists the EPO defined for the introduction of IMPs and the adopted control measures to achieve the outcome.

Table 8-83: Environmental performance for the introduction of IMPs

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-20: No introduction and establishment of an invasive marine pest attributable to the Development.	**EPO-35**: No introduction and establishment of an invasive marine pest attributable to the Development.	**CM-37:** Vessels operating within the Development Area will comply with ballast water management as required under the *Biosecurity Act 2015* (Cth) and best practice guidance within the Australian Ballast Water Management Requirements (Ref. 60). **CM-38:** Vessels operating within the Development Area will comply with biofouling management as required under the *Biosecurity Act 2015* (Cth) and best practice guidance within the Australian Biofouling Management Requirements (Ref. 61). **CM-39**: Vessels operating within the Development Area will comply with requirements within Marine Order 98—Marine pollution—anti-fouling systems.

8.12 unplanned release—solid objects

8.12.1 source

Hazardous and non-hazardous waste stored on board facilities and vessels may be accidentally lost overboard. Solid materials that are lifted or handled during Development activities have the potential to be accidentally released overboard. Seabed disturbance can occur if the waste or solid material reaches the seabed. There is also potential for a dropped object to cause a LOC of hydrocarbons if the object damages a live pipeline; this event is assessed separately in Section 8.13.

Table 8-84 lists the activities within each phase where unplanned release of solid objects may occur in the DA.

Table 8-84: Phases and activities that generate unplanned release—solid objects

Phase	Activity
Installation and commissioning	Pre-lay works
	Installing subsea structures
Operations	Major repairs
Decommissioning	Flowline and MEG pipeline decommissioning
	Umbilical decommissioning
	Other subsea structures decommissioning
Support activities	MODU operations Vessel operations

8.12.1.1 installation and commissioning

Infrastructure such as trees, manifolds, pipeline termination structures, PLETs/PLEMs, spools, jumpers, foundations, and pipeline stabilisation materials (e.g. concrete mattresses) may be lowered by crane to the seabed, and there is the potential for structures to be accidentally dropped during this installation process.

This equipment is typically made of steel or concrete and will sink onto the seabed. Although these items will be retrieved from the seabed, they may disturb the marine environment as a result of the release and when being retrieved.

The largest individual structure that will be installed is likely to be a slug catcher or overpressure protection system, which will be no more than ~2,100 m^2. This type of infrastructure will only be installed in the vicinity of the Jansz field. In other parts of the DA the largest infrastructure that will be installed is likely to be a manifold or pipeline termination structure with an estimated footprint of ~900 m^2.

8.12.1.2 operations

Major repairs are a consequence of a significant infrastructure defect or failure. If major repairs are required, solid objects and equipment have the potential to be accidentally dropped during installation or retrieval.

These materials are likely to be non-buoyant and therefore are expected to sink through the water column and settle on the seabed in the DA.

8.12.1.3 decommissioning

Multiple options for flowline and umbilical decommissioning are included in this OPP (as per Section 5). The methods with the highest risk of unplanned release of solid objects are assessed in this section.

The cut and lift flowline decommissioning method involves cutting the flowline into sections on the seabed, then using a crane to lift them onto a vessel. Cut sections of pipe have the potential to be accidentally released or dropped due to manual handling errors or as a consequence of inappropriately secured or unbalanced loads during lifts.

The recover and cut on deck method involves recovering the umbilicals from the seabed before cutting them into sections on the vessel deck. Cut sections may be released overboard as a result of handling or lifting errors.

These materials are non-buoyant and will sink through the water column and settle on the seabed in the DA.

8.12.1.4 support activities (all phases)

Vessels are present in the DA during all phases of the Development. The MODU will be present in the DA during drilling and decommissioning phases and potentially during operations for well intervention.

Solid waste is handled and stored on board the MODU and vessels, before being transported to shore for disposal at licensed facilities. If waste is inappropriately handled or stored while offshore, it may be accidentally discharged to the marine environment. This accidental release of waste may be due to improper or unsuitable waste storage, human error, or failure of waste storage equipment. Accidental releases may be more likely in rough ocean conditions and high winds when items have the potential to roll or be blown off the deck if not appropriately stored or secured.

Solid waste may be considered hazardous due to toxic, reactive, corrosive, or ignitable properties. Hazardous waste includes:

- contaminated material (e.g. rags, oil filters, personal protective equipment)
- paint cans, printer cartridges, batteries, fluorescent tubes, aerosol cans.

Non-hazardous waste may still pose a threat to receptors (via ingestion, entangling or smothering) if released to the environment, and includes:

- plastics
- glass
- wood, paper, cardboard
- metal (e.g. cans, scrap steel, aluminium).

Solid objects and equipment, such as handheld tools, may also be released overboard due to manual handling errors.

All non-buoyant solid waste material or dropped objects are expected to remain in the DA as they will sink through the water column and settle on the seabed. Buoyant waste material lost overboard has the potential to be carried by ocean currents beyond the DA.

8.12.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by an unplanned release of solid objects:

- water quality
- benthic habitats and associated communities
- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- KEFs
- cultural heritage values: Traditional Owners.

Although fish may potentially be impacted by an unplanned release of solid objects, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species. Four State- and two Commonwealth-managed fisheries have recorded historical fishing effort in the DA. Therefore, impacts to commercial fisheries from an unplanned release of solid objects is not expected; and are not evaluated further.

Table 8-85 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to an unplanned release of solid objects in the DA.

Table 8-85: Risk evaluation for unplanned release—solid objects

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned release of solid objects in the marine environment may result in: • localised and temporary reduction in water quality.	6	5	Very Low (10)
		Unplanned release of solid objects may interact with marine fauna to result in: • injury or mortality of marine fauna	6	5	Very Low (10)
		Unplanned release of solid objects may result in: • alteration of benthic habitats and associated communities.	5	5	Very Low (9)
		Unplanned release of solid objects in a KEF may result in: • change to values and sensitivities.	6	5	Very Low (10)
		Unplanned release of solid objects may result in: • change to cultural heritage values: Traditional Owners.	5	5	Very Low (9)

Risk evaluation
Water quality
Localised and temporary reduction in water quality Unplanned loss of hazardous or non-hazardous solid waste from vessels and the MODU may have the potential to cause a localised and temporary reduction in water quality. The magnitude of water quality change depends on the nature of the waste. These losses usually comprise solid waste items such as oily rags and residue from paint cans lost overboard and therefore have relatively low levels of toxicity. Due to wave action and local ocean currents, minor releases of residual hazardous material from dropped objects will be rapidly mixed and diluted. Therefore, no long-term changes in water quality are expected. Unplanned release of solid objects offshore has occurred previously in the industry but a resulting impact to water quality is considered highly unlikely. Given the details above, the consequence of an unplanned release of a solid object causing a change in water quality has been evaluated as Incidental (6). CAPL considers the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to water quality is Very Low (10).
Seabirds and shorebirds
Injury or mortality of marine fauna Unplanned release of non-hazardous waste may impact marine fauna via ingestion or entanglement. Between 1974 and 2008, 77 individuals (of various species) were reported to have been entangled in, or ingested, plastic debris within Australian waters according to a study commissioned by DEWHA. Records were dominated by humpback whales, marine turtles, Australian pelicans, and a range of cormorant species, with the sources of waste unknown (Ref. 420). The marine fauna most at risk from ingestion or entanglement is seabirds (Ref. 24, Ref. 40). Ingestion or entanglement has the potential to limit feeding or foraging behaviours and thus can result in marine fauna injury or mortality. Seabirds that feed at the surface and at the top of the water column are vulnerable to buoyant waste (e.g. plastics). Threatened and migratory listed seabird and shorebird species were identified in the PMST report for the DA. The southern giant petrel is the only threatened bird species that was identified as

Risk evaluation
being sensitive to interactions with marine debris and listed in the EPBC PMST report (Ref. 122; appendix b) for the DA. The DA overlaps a BIA for the wedge-tailed shearwater; however, there is no recovery plan for this species. Because of the distance of the Development activities from land (the closest infrastructure is ~60 km from Barrow Island and ~130 km from the mainland), any seabirds and shorebirds present within the DA are only expected to be transitory and incidental. Unplanned release of solid objects offshore has occurred previously in the industry but, impacts to seabirds and shorebirds would be to individuals, with no population or ecosystem impacts expected. Based on this information, CAPL assessed the consequence of an unplanned discharge of a solid object causing injury or mortality to seabirds and shorebirds as Incidental (6). CAPL considers the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to birds is Very Low (10).
Marine reptiles, marine mammals and fishes, including sharks and rays
Injury or mortality of marine fauna Unplanned release of non-hazardous waste may impact marine fauna via ingestion or entanglement, with seabirds and marine reptiles most at risk (Ref. 24, Ref. 40). Ingestion or entanglement has the potential to limit feeding or foraging behaviours and thus can result in marine fauna injury or death. Plastics released into the marine environment degrade over time into microplastics, which can bioaccumulate within species, in particular in higher trophic levels. However, any unplanned release of plastic material from the Development would be infrequent and comprise small objects that could be lost overboard—these would contribute a negligible amount to the ubiquitous microplastics found in the marine environment. Although marine debris is identified as being of concern to marine reptile species under the Marine bioregional plan for the NWMR (Ref. 102), the risk documented in that plan is associated with 'land-sourced plastic garbage, fishing gear from recreational and commercial fishing abandoned into the sea, and ship-sourced, solid non-biodegradable floating materials disposed of at sea'. This type of waste is not associated with the activities described in this OPP and given the limited quantity of waste with the potential to cause marine pollution that is expected to be generated from petroleum activities, it is expected that any impacts from marine pollution would result in limited impacts to individuals. Debris most likely to affect marine fauna through entanglement or ingestion in the open ocean comprises floating non-degradable debris, such as lost or discarded fishing gear (e.g. discarded nets, crab pots, synthetic ropes, floats, hooks, fishing line and wire trace). The values and sensitivities within the DA with the potential to be affected by injury or mortality include: • humpback whale BIA (migration) • pygmy blue whale BIA (migration) • flatback turtle (internesting buffer) and HCTS (internesting buffer) • whale shark BIA (foraging) • fish communities (associated with the various KEFs). Five species of turtle listed as Vulnerable (green, hawksbill and flatback) or Endangered (loggerhead and leatherback) are known or are likely to occur in the DA—all are identified as being sensitive to interactions with marine debris under the Threat Abatement Plan (Ref. 18) and Recovery Plan for Marine Turtles in Australia (Ref. 24). The Conservation Advice for the Whale Shark (Ref. 33) and the Conservation Management Plan for the Blue Whale (Ref. 20) also identify marine debris as a threat to the species. Marine debris ingested by marine reptiles may result in ecotoxicological effects, physical blockage, and internal injuries (Ref. 421). For marine turtles, this threat has been risk assessed as having either a moderate consequence (defined as 'stock recovery stalls or reduces') for Loggerheads or a minor consequence (defined as 'individuals are affected but no effect at stock level') for green, flatback, hawksbill and leatherback turtles (Ref. 24). Although the DA overlaps the flatback turtle internesting buffer, Whittock (Ref. 146) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and

Risk evaluation
further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate within the DA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Marine mammals, marine reptiles and fish may ingest buoyant wastes and microplastics. Studies show that 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 (Ref. 422). Unplanned release of solid objects offshore has occurred previously in the industry, but impacts to marine reptiles, marine mammals and fish are considered to be individual, with no population or ecosystem impacts expected. Based on the above the consequence of an unplanned release of a solid object causing injury or mortality to marine reptiles, marine mammals, and fish as Incidental (6), and the likelihood of the consequence occurring Remote (5). Overall, the risk of an unplanned release of solid objects to marine reptiles, marine mammals, and fishes, including sharks and rays is Very Low (10).
Benthic habitats and associated communities
Alteration of benthic habitats and associated communities BCH may be altered via physical disturbance or indirectly by the temporary increase in suspended sediment near the seabed as a result of the physical seabed disturbance. The area of impact would correspond to the footprint of the particular object, with the benthic sediments and communities beneath the object subject to physical disturbance. The footprint of any released object would be significantly smaller than the total planned footprint of the Development. If any equipment is dropped, it is expected to settle on the seabed in or near the infrastructure. Results of the benthic survey (Section 6.3.1.1) predicted that the DA is comprises mostly by a mixture of flat sediment terrain with bioturbation or bare sediment, along with isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 108; Ref. 111. In close proximity to the proposed flowline/umbilicals BCH where characterised by low structural habitats, with isolated areas where scarps with the presence of biota and discrete patches of depressions over bare substrate may occur. No canyon features and no endemic benthic infauna were identified in the survey (Ref. 104; appendix a). Unplanned release of solid objects offshore has occurred previously in the industry but is considered highly unlikely. Data compiled from a number of platforms in the United Kingdom and published in the OREDA-84 handbook gives dropped load frequency of 0.095 per year of crane service (Ref. 423). This suggests a dropped load from a crane is likely to happen once in ~10 years of crane service. Dropping an object during major repairs is even more unlikely because major repairs have an extremely low probability of occurring. Given the above, the consequence of an unplanned release of solid objects causing alteration of benthic habitats and associated communities has been evaluated as Minor (5), and the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to benthic habitats and associated communities is Very Low (9).
KEFs
Change to values and sensitivities An unplanned release of solid objects may result in changes to the values and sensitivities of KEFs through alteration of benthic habitats and associated communities The area of impact would correspond to the footprint of the particular object, with the benthic sediments and communities beneath the object subject to physical disturbance. The footprint of any released object would be significantly smaller than the total planned footprint of the Development. The DA overlaps with three KEFs: ancient coastline at 125 m depth contour, Exmouth Plateau, and continental slope demersal fish communities. The values of the Ancient coastline and Exmouth Plateau KEFs have been assessed as its unique sea floor feature with ecological properties of regional significance (Ref. 102). The only fields that may overlap these KEFs are the Chandon and WTR fields and associated infrastructure. Therefore, only two of the seven fields in the Development have the potential to impact these KEFs by dropped non-buoyant objects. Benthic habitat surveys the Ancient coastline KEF predicted that the BCH at Gorgon MPTS and the entire DA is predicted to comprised of smooth seabed with bioturbation and bare substrate and appeared to be devoid of epibenthic biota (Section 6.3.1.1.1). For the Exmouth Plateau KEF,

Risk evaluation
the most dominant BCH were predicted as relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota. Although the entire KEFs are identified for unique seafloor features with hard substrate (Ref. 102), these values were not identified within the area of the KEFs that overlaps with the DA. Values for the continental slope demersal fish communities KEF were identified as high levels of endemism with a diversity of fish assemblages (Ref. 102). The continental slope demersal fish communities KEF overlaps with sections of the DA associated with the C&D DC-3, sections of the C&D flowline, WTR umbilical and one of the Gorgon tie-in points. The benthic survey identified the following (Ref. 104; appendix a): • mixed benthic habitats comprising irregular and smooth seabed of bare substrates, discrete depressions over bare substrate and scarps with bare substrate are the most dominant benthic features were predicted • topographically complex scarps with both low and high likelihood of biota are predicted to be present traversing through the DA • a total of 468 fish belonging to 25 taxa, with the fish assemblage dominated by Trevallies (Carangidae) with four species from three genera accounting for 256 of the individuals were recorded. In comparison to the other KEFs within the DA, there was no significant difference in the mean number of fish taxa within the continental slope demersal fish communities KEF. These BCH are widespread and well represented throughout the region (Ref. 104; appendix a), and as such any potential impact is expected to be highly localised. Unplanned release of solid objects offshore has occurred previously in the industry, but is considered highly unlikely, and the footprint of a dropped object would constitute a very small proportion of the KEFs. The consequence to habitats within the KEFs is considered to be highly localised and negligible. Given the above, the consequence of an unplanned release of a solid object causing a change in the values and sensitivities of a KEF was ranked as Incidental (6), and the likelihood of the consequence Remote (5). Overall, the risk of an unplanned release of solid objects to KEFs is Very Low (10).
Cultural heritage value: underwater cultural heritage
No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken.
Cultural heritage value: Traditional Owners
Change to cultural heritage values No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the DA (Section 6.6). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the DA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. archaeology) are expected; and no further evaluation has been undertaken. Potential changes to cultural heritage values from unplanned release of solid objects includes indirect impacts to intangible Traditional Owner heritage from alteration of benthic habitats and associated communities. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of benthic habitats and associated communities (Section 6.3.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural heritage values may occur due to alterations to benthic habitats and associated communities from unplanned release of solid objects. The consequence level for the alteration of benthic habitats and associated communities from unplanned release of solid objects was evaluated as Minor (5). As such, the consequence of changes to cultural heritage values from unplanned release of solid objects is also evaluated as Minor (5). Given the extremely small footprint of any dropped object; a significant adverse change to cultural heritage values is not predicted to occur. Therefore, the likelihood of the consequence occurring is assessed as Remote (5).

Risk evaluation
The risk of an unplanned release of solid objects to Traditional Owner cultural heritage values is Very Low (9).

8.12.3 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-86 details the determination of acceptability for an unplanned release of solid objects.

Table 8-86: Determination of acceptability for unplanned release—solid objects

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-21**, as defined in Table 7-6 and shown below in Section 8.12.4. The intent of adopting and implementing preventive control measures (Section 8.12.4) is to prevent the occurrence of an unplanned release of solid objects to the environment. This preventative approach ensures that **AL-21** is met. In the event that an unplanned release of solid objects did occur, the above risk evaluation demonstrates that the predicted impact is expected to be minor and recoverable.
Principles of ESD	**(b) 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 highest consequence level for unplanned release of solid objects was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Commercial vessel operations are commonplace and well-practised nationally and internationally. The control measures to manage the risks of unplanned release of solid objects are defined via legislative requirements and/or industry best practice. These are well understood and implemented by the petroleum industry and CAPL. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the risk of Unplanned release—Solid objects based on relevant legislation and other requirements as listed below. • The regulation and management of unplanned releases of solid objects in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for unplanned release of solid objects was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage. • Any relevant stakeholder feedback in relation to unplanned release of solid objects has been incorporated in the OPP and assessed in the external context acceptability criteria.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">• To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>AMSA Marine Order 95 (Marine Pollution Prevention – Garbage)
Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels.</td><td rowspan="2">Legislative requirements to manage the unplanned release of solid objects are addressed by adopting this control measure:
• CM-23.</td></tr>
<tr><td>Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24)
Action A3.5:
Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on the vertebrate marine life</td><td>EPBC management plan requirements to reduce impacts from marine debris are addressed by adopting these control measures:
• CM-23
• CM-40
• CM-41.
Therefore, the Development is not considered to be inconsistent with the EPBC management plan.</td></tr>
<tr><td>Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia’s coasts and oceans (Ref. 18)
Wildlife Conservation Plan for Seabirds (ref. 38)
Conservation Advice for the Abbott's Booby (Papasula abbotti) (Ref. 41)</td><td>These EPBC management plans for species that may occur within the DA identify marine debris as a threat, but do not identify any relevant actions.</td></tr>
</table>

Determination of acceptability		
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 33). **Conservation Management Plan for the Blue Whale 2015–2025** (Ref. 20) **National Recovery Plan for the Southern Right Whale (*Eubalaena australis*)** (Ref. 23) **Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle)** (Ref. 25) **Sawfish and River Sharks Multispecies Recovery Plan** (Ref. 28) **National recovery plan for albatrosses and petrels (Ref.** 40**)** **Conservation Advice for *Thalassarche cauta* (Shy Albatross)** (Ref. 57)	
Internal context	These procedures were identified as relevant for this aspect: • ABU – Lifting and Rigging Control of Work Manual (Ref. 424) • Chevron Shipping's Marine Standard Non Tankers (Ref. 265) (details the requirements for lifting and installing heavy equipment. Installation risk is minimised by ensuring lifting plans are in place for heavy and complicated lifts).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to unplanned release of solid objects from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.12.4 environmental performance

Table 8-87 lists the EPO defined for the unplanned release of solid objects and the adopted control measures to achieve the outcome.

Table 8-87: Environmental performance for unplanned release—solid objects

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-21: No unplanned release of solid objects to the environment from the Development.	**EPO-36**: No unplanned release of solid objects to the environment attributable to the Development.	**CM-23**: Vessels operating within the Development Area will comply with requirements

Acceptable levels	Environmental performance outcomes	Adopted control measures
		within Marine Order 95—Marine pollution—garbage. **CM-40**: Develop and implement a Lift Plan (or equivalent) for Development activities. **CM-41**: Dropped equipment will be retrieved wherever practicable within operational and safety constraints.

8.13 unplanned release—minor LOC

8.13.1 source

The LOC of minor volumes of hydrocarbons and chemicals may result in an unplanned release to the marine environment.

Table 8-88 lists activities within each phase where credible minor LOC scenarios may occur in the DA.

Note: Major unplanned release scenarios are not included in this section; they are assessed in:

- unplanned release—vessel collision (MDO): Section 8.14
- unplanned release—hydrocarbon system (condensate): Section 8.15.

Table 8-88: Phases and activities that may generate an Unplanned release—Minor LOC

Phase	Activity
Installation and commissioning	Installation of subsea structures Hydrotest and pre-commissioning
Operations	Maintenance and repairs
Support activities	MODU operations Vessel operations ROV operations

8.13.1.1 installation and commissioning

A minor LOC of hydrocarbons and chemicals during this phase may result from:

- dropped objects (and interaction with the Development subsea infrastructure) resulting in a loss of various fluids including treated sea water, hydraulic fluids, or MEG
- hydrotesting and pre-commissioning activities, resulting in a loss of hydraulic fluid.

The various fluids that could be released include treated sea water, hydraulic fluids and MEG. Treated water may contain a range of commercial chemicals such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions. MEG is a category ‘E’ OCNS chemical with no substitution warning, is readily biodegradable and has a low potential for bioaccumulation.

During installation of subsea infrastructure, a minor LOC of hydraulic control fluid may occur. The maximum volume of hydraulic control fluid accidentally released is anticipated to be <100 L at the pipeline/GFP tie-in point for each field.

Failure of hydrotesting and pre-commissioning activities may result in a maximum 50 m^3 LOC of both MEG and treated water and <100 L of hydraulic control fluid.

The duration for the installation and commissioning phase for the Development is expected to be ~12–15 months, per field or co-developed field.

8.13.1.2 operations

During maintenance and minor repairs (and any associated testing), LOC of hydraulic control fluid may also occur. The maximum volume of hydraulic control fluid accidentally released is anticipated to be <100 L at the flowline/GFP tie-in point for each field.

The duration for the operations phase is expected to be 10–30 years, depending on the field.

8.13.1.3 support activities (all phases)

Routine support operations include handling, using, and transferring hydrocarbons and chemicals, which may lead to these LOC events:

- poor use, handling and transfer of hydrocarbons and chemicals on board (deck spill)
- transferring hydrocarbons and chemicals between vessels and MODU
- hydraulic line failure from ROV.

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). It will move between fields but will spend most of the time at the DCs.

Vessels will be present in the DA during all phases of the Development. The number of vessels working concurrently across a field or co-developed field within the DA is estimated to vary between ~2–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation and commissioning may take as long as ~12–15 months per field or co-developed field and while concurrent activities are possible during this time, they will typically be intermittent and would occur for only a small portion of the overall duration.

8.13.1.3.1 deck spill

Various chemicals and hydrocarbons are used or stored on the deck of vessels and the MODU. Causes of a minor LOC can include mechanical integrity failures, poor process design, inadequate hazard analysis, unexpected or uncontrolled reactions, mishandling or human error. In most cases, a minor LOC on deck will be captured by a drainage system and diverted to a bilge tank or similar where it can be treated or transported to the mainland for safe disposal. If a minor LOC is not captured within a closed system (an unlikely event), it will likely be discharged to the marine environment.

The maximum volume expected is ~1 m^3 based on the loss of an entire intermediate bulk container due to rupture while handling.

8.13.1.3.2 bunkering / bulk transfer

Bulk transfer of MDO and chemicals will be done throughout all phases, both between vessels and between supply vessels and the MODU. During bunkering, an accidental release of MDO to the marine environment may occur if there is partial or total failure of the bulk transfer hose or associated dry-break couplings.

The predicted maximum volume of MDO lost (50 m^3) is based on assuming failure of dry-break couplings and an assumed 200 m^3/h transfer rate (based on previous operations) for 15 minutes.

This volume is expected to be less than that released during vessel collision (~500 m^3), therefore modelling of a 50 m^3 release of MDO was not undertaken to support the impact assessment.

Drilling fluids, MEG and cement may also be released during bulk transfer. A single release of these materials is expected to be ~25 m^3.

8.13.1.3.3 ROV hydraulic hose

ROVs, which can operate hydraulic tools/equipment, may be used during all phases of the development. Hydraulic fluids are likely to be relatively non-toxic and water-based. Fluid volumes on the ROV units are limited (typically <50 L) with shutdown systems designed to limit the loss of fluid if a leak occurs in the hydraulic system.

8.13.2 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the DA that may be impacted by a minor LOC:

- water quality
- fishes, including sharks and rays
- marine reptiles
- marine mammals.

Table 8-89 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to a minor LOC in the DA.

Although fish may potentially be impacted by a minor LOC, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Four State- and two Commonwealth-managed fisheries have recorded historical fishing effort in the DA. The spatial extent of impact from a <0.05–50 m^3 LOC is an insignificant area compared to the size and scale of commercial fisheries, and is not expected to damage fish stocks, displace fishing effort, or result in the inability to sell catch due to perceived or actual fish tainting.

Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the continental slope demersal fish communities KEF from an unplanned minor LOC are not expected, and are not evaluated further.

Table 8-89: Risk evaluation for unplanned release—minor LOC

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Minor loss of containment may result in: • localised and temporary reduction in water quality.	5	5	9 (Very Low)
		Minor loss of containment may result in: • injury or mortality of marine fauna.	5	5	9 (Very Low)

Risk evaluation

Water quality

Localised and temporary reduction in water quality

A minor LOC of hazardous substances has the potential to result in a localised and temporary reduction in water quality at the release location.

The various fluids that could be released include treated sea water, MEG, hydraulic fluids, MDO, as well as various chemicals and hydrocarbons stored on the deck of vessels and the MODU.

The worst-case credible scenario for MEG, treated water and MDO is 50 m^3.

Treated water may contain various commercial chemicals such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions.

MEG is widely used by the oil and gas industry in wellheads and pipelines. It is rated as PLONOR by CEFAS and is readily biodegradable with low potential for bioaccumulation (Ref. 372, Ref. 373). MEG is also completely miscible with water and would disperse quickly if released into the marine environment.

MDO is required to fuel the vessel's main engines, as well as power equipment on board, such as pumps, cranes, and generators. As a light hydrocarbon, MDO evaporates quickly and spreads rapidly in warm waters, indicating that a surface release would result in a temporary surface slick.

Smaller quantities of other chemicals also have the potential to be released during support activities, including:

- ~1 m^3 of wash chemicals, cleaning chemicals and solvents
- ~100 L of hydraulic fluid from machinery (hoses/ROV)
- ~25 m^3 of drilling fluids (WBF/NADF), MEG and cement.

Any impacts to surface and pelagic waters are expected to be less than those associated with planned discharges (Sections 8.6, 8.7 and 8.8) or unplanned larger spill events resulting from a vessel collision (Section 8.14) or a full-bore rupture of a flowline (Section 8.15).

Due to the small volumes associated with an unplanned minor LOC (up to 50 m^3), impacts to water quality will be localised and temporary. Any hydrocarbons or chemicals released to the marine environment are expected to evaporate quickly or be mixed and diluted due to wave action and local currents. Therefore, the consequence of this scenario has been evaluated as Minor (5).

With the implementation of relevant control measures including the implementation of Chevron Shipping's Marine Standard Non-Tankers as well as MARPOL requirements, the likelihood of a minor LOC arising during the Development is assessed as Remote (5).

Overall, the risk of Unplanned release—Minor LOC to water quality is Very Low (9).

Marine fauna

Injury or mortality of marine fauna

Impacts to ambient water quality are likely to be localised and temporary based upon the volumes associated with minor releases (typically <0.05 m^3 but up to 50 m^3) of:

- chemicals (MEG, treated water, hydraulic fluid, drilling fluids, cement)
- hydrocarbons.

A change to ambient water quality could lead to short-term impacts on marine fauna, with chronic impacts not expected due to short exposure time and small volumes.

Risk evaluation
Small volumes (up to 50 m^3) of hydrocarbons and chemicals released in a minor LOC event within the DA will be mixed and diluted rapidly by wave and current action. As a result, fauna would need to pass directly through the plume almost immediately upon release to be impacted. A minor LOC event would have a very localised effect on plankton in the water column within the plume. Low nutrient levels within the DA indicates sparse populations of plankton which is representative of the sparse populations of plankton species throughout the NWS (Ref. 103). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 103). Therefore, plankton populations are expected to recover quickly from any impacts of a minor LOC event. Fish, marine mammal and marine turtle species are also unlikely to be affected by a minor LOC because they are highly mobile and will move away from any temporary release of a hydrocarbon or chemical. The DA overlaps the following BIAs; however, impacts from a minor LOC are extremely unlikely as discharges will be rapidly mixed and diluted by natural processes. The values and sensitivities within the DA with the potential to be affected injury or mortality include: • humpback whale BIA (migration) • pygmy blue whale BIA (migration) • flatback turtle BIA and HCTS (internesting buffer) • whale shark BIA (foraging) • fish communities (associated with the various KEFs). The approved Conservation Advice for Whale Sharks (Ref. 33) states that the main threat to the species occurs outside Australian waters (from intentional and unintentional mortality from fishing). Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. The recovery plans for marine turtles (Ref. 24) and the blue whale (Ref. 20) lists acute chemical discharge from various pollutants as a threat to the species. Although the DA overlaps the flatback turtle internesting buffer, Whittock (Ref. 146) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate within the DA during their internesting period and only transient individuals would be present. The small volumes combined with the dilution and dispersion that occurs from natural weathering processes such as ocean currents, indicates that the extent of exposure will be limited in area and duration. Given the highly mobile nature of the identified species, only pelagic fauna present in the immediate vicinity of the release would likely be at risk of impact; therefore, the only potential impact would occur to individuals, with no population impact expected. The potential consequence of an Unplanned release—Minor LOC of hazardous substances within the DA would be limited to the potential change to fauna behaviour (e.g. avoidance) within surface waters affected by the release. Any potential impact is expected to be short term and limited to a small number of individuals; therefore, the consequence has been evaluated as Minor (5). With the implementation of relevant control measures including the implementation of Chevron Shipping's Marine Standard Non-Tankers as well as MARPOL requirements and given the transient nature of values and sensitivities the likelihood of a minor LOC arising during the Development is assessed as Remote (5). Overall, the risk of Unplanned release—Minor LOC to marine fauna is Very Low (9).

8.13.3 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-90 details the determination of acceptability for an unplanned minor LOC.

Table 8-90: Determination of acceptability for Unplanned release—Minor LOC

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-22**, as defined in Table 7-6 and shown below in Section 8.13.4. The intent of adopting and implementing preventive control measures (Section 8.13.4) is to prevent the occurrence of an unplanned minor LOC release to the environment. This preventative approach ensures that **AL-22** is met. In the event that an unplanned minor LOC did occur, the above risk evaluation demonstrates that the predicted impact is expected to be minor and recoverable.
Principles of ESD	**(b) 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 highest consequence level for an unplanned minor LOC was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that: • Commercial vessel operations are commonplace and well-practised nationally and internationally. The control measures to manage the risks of unplanned release of solid objects are defined via legislative requirements and/or industry best practice. • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the risk of an unplanned minor LOC based on relevant legislation and other requirements as listed below. • The regulation and management of loss of containment in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for an unplanned minor LOC was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage. • Any relevant stakeholder feedback in relation to unplanned minor LOC has been incorporated in the OPP and assessed in the external context acceptability criteria. • To manage impacts to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option. The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5). The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.

Determination of acceptability		
Relevant environmental legislation and other requirements	Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.	
	Requirement	**Demonstration of requirement**
	***Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).** Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution. This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.	Legislative requirements are addressed by adopting this control measure: • **CM-22**.
	***Navigation Act 2012* – Chapter 4 (Prevention of Pollution).** Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	
	Guidelines for Offshore Marine Operations (Ref. 425) The objective of this document is to provide guidance in the best practices that should be adopted to ensure the safety of personnel on board all vessels servicing and supporting offshore facilities, and to reduce the risks associated with such operations.	
	AMSA Marine Orders 91 and 94 Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels. Marine Order 91 (Marine Pollution Prevention – Oil) Marine Order 94 (Marine pollution prevention – packaged harmful substances)	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) • Action 3f: Ensure all areas important to migratory shorebirds	EPBC management plan requirements to minimise habitat degradation / modification are

Determination of acceptability		
	in Australia continue to be considered in development assessment processes	addressed by adopting these control measures: • **CM-22** • **CM-40** • **CM-42.** Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **Recovery Plan for the White Shark (*Carcharodon carcharias*)** (Ref. 34) **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33). **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664) **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49) **Conservation Advice *Calidris canutus* Red knot** (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56)	These EPBC management plans for species that may occur within the DA identify pollution, habitat degradation, loss and/or modification as a threat, but do not identify any relevant actions.
Internal context	This environmental performance standard/procedure was deemed relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265)	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. No feedback was received in relation to an unplanned minor LOC from Phase 1 stakeholder consultation.	

8.13.4 environmental performance

Table 8-91 lists the EPO defined for an unplanned minor LOC and the adopted control measures to achieve the outcome.

Table 8-91: Environmental performance for Unplanned release—Minor LOC

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-22: No minor loss of containment of hydrocarbons or chemicals to the environment from the Development.	**EPO-37**: No unplanned release of hydrocarbons or chemicals to the environment attributable to the Development.	**CM-40**: Develop and implement a Lift Plan (or equivalent) for Development activities. **CM-42**: Develop and implement a Bunkering and Bulk Transfer Procedure (or equivalent) for Development activities. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil.

8.14 unplanned release—vessel collision (MDO)

8.14.1 source

Vessels and the MODU will use a light marine fuel such as MDO or MGO as fuel (Section 4.3.6.2).

A vessel collision event within the DA is considered a credible (but unlikely) unplanned event. A major marine spill because of vessel collision is only likely to occur under exceptional circumstances (e.g. loss of DP, navigational error, inclement weather conditions). Collision could potentially occur between Development vessels and/or the MODU or third-party vessels.

Given the location, water depths, and lack of submerged features within the DA, grounding is not considered credible, and is not considered further.

CAPL commissioned RPS to conduct stochastic spill modelling to predict the extent of hydrocarbon exposure associated with a vessel collision event.

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA for MDO modelling represent the outer area where hydrocarbons above impact concentration thresholds (Table 6-1 and Figure 6-2 respectively) may be present in the environment if a spill resulted from a vessel collision (refer to Figure 12.1 in appendix c; Ref. 426 and Table 6-1 in Section 6.1 of this OPP).

Table 8-92 lists activities within each phase where a vessel collision resulting in a loss of MDO could occur in the DA.

Table 8-92: Phases and activities that generate Unplanned release—Vessel collision (MDO)

Phase	Activity
Support activities	MODU operations Vessel operations

8.14.1.1 support activities

The MODU and various vessels will be present in the DA during the Development.

The MODU will be present in the DA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). Drilling of each well will take ~3 months.

An SNA will be established around the MODU (or HWU if used for well interventions or decommissioning). This is a temporary area that requests the exclusion of other marine users from a 500 m radius around the MODU/HWU for safety purposes. An SNA is also likely to be requested for the PLV and other large construction vessels. Any SNA will only be in place for the duration of the relevant activities. A larger (2 km) cautionary zone may also be established.

Vessels will be present in the DA during all phases of the Development. The number of vessels working concurrently across a field or co-developed field within the DA is estimated to vary between ~2–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation and commissioning may take as long as ~12–15 months per field or co-developed field and while concurrent activities are possible during this time, they will typically be intermittent and would occur for only a small portion of the overall duration.

A vessel collision between these vessels and/or the MODU, and/or third-party vessels may result in a hydrocarbon spill.

The calculation of discharge volume and timing aligns with the methodology recommended in AMSA's Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities (Ref. 427).

Based upon the types of vessels present in the DA during the Development, CAPL identified the credible worst-case scenario (as per AMSA guidelines; Ref. 427) as a surface release of 1,500 m^3 of MDO following a vessel collision.

8.14.2 stochastic spill modelling

Stochastic modelling was performed using a 3D trajectory and fates model, Spill Impact Mapping Analysis Program (SIMAP) (Ref. 426; appendix c). The SIMAP model calculates the transport, spread, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

Stochastic modelling was completed for three seasons, defined by the unique prevailing wind and general current conditions: summer (September to March), the transitional periods (April and August) and winter (May to July).

Because spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (random or non-deterministic) approach, which involved running 100 spill simulations per season for each scenario using random start times and the same release information (spill volume, duration, and composition of the oil). This ensured that each simulation was subject to different wind and current conditions and, in turn, movement and weathering of the hydrocarbon.

Stochastic modelling was conducted for a 1,500 m^3 surface release of MDO over 24 hours, which represents a loss of inventory from the largest fuel tank on a vessel or MODU as a result of a hypothetical vessel collision.

Stochastic modelling for a vessel collision was done for the WTR field because it is the closest field to shore and represents the worst-case spill location for hydrocarbon exposure to sensitive receptors (i.e. shoreline hydrocarbon exposure).

Table 8-93 summarises the model settings. Table 8-94 summarises the hydrocarbon properties for MDO. The modelled impact thresholds for social and ecological receptors are defined in Table 6-2.

Table 8-93: Vessel collision spill scenario model settings

Parameter	Details
Release location	WTR Well 5
Latitude	20.23666° S
Longitude	115.04357° E
Water Depth	150 m
Oil type	MDO
Simulation spill type	Surface
Simulation spill volume	1,500 m^3
Simulation spill duration	24 hours
Total simulation duration	60 days
Number of randomly selected spill simulation start times	100 per season (300 total)
Seasons modelled	Summer (September to March) Transitional (April and August) Winter (May to July)

Table 8-94: Physical properties and boiling point ranges for MDO

Characteristic	Value			
Density	829 kg/m^3 (at 25 °C)			
Dynamic viscosity	4 cP (at 25 °C)			
Pour point	−14 C			
API gravity	37.6 API			
Classification	Group II, light persistent oil			
Boiling point	**Volatile <180 °C**	**Semi-volatile 180–265 °C**	**Low volatility 265–380 °C**	**Residual >380 °C**
	6.0%	34.6%	54.4%	5.0%

8.14.2.1 hydrocarbon characteristics

MDO is a light persistent fuel oil used in the maritime industry (Table 8-94). The low viscosity (4 cP) indicates that this oil will spread quickly when released and will form a thin film on the sea surface, increasing the evaporation rate.

Generally, about 6.0% of the MDO mass should evaporate within the first 12 hours (boiling point <180 °C); a further 34.6% should evaporate within the first 24 hours (boiling point 180 °C–265 °C); and an additional 54.4% should evaporate over several days (boiling point 265 °C–380 °C). Approximately 5% (by mass) of MDO will not evaporate at atmospheric temperatures. These compounds will persist in the environment.

While MDO will typically remain on the water surface (where it is subject to evaporation), it is noted that some of the heavy components have a strong tendency to physically entrain into the upper water column in the presence of

moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate.

8.14.2.2 modelling outputs

Stochastic modelling outputs (Ref. 426; appendix c) are summarised in Table 8-95, having regard to the relevant values and sensitivities, as identified in Section 6.

The outputs of from the 300 simulations modelled for the 1,500 m^3 MDO release within the WTR are summarised below:

- 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) threshold for floating condensate was 167.0 northeast (summer), 59.6 km south-southwest(winter) and 17.6 km north-northeast (summer), respectively.
- Excluding the receptors that the release location resides within, the humpback whale - migration BIA and continental slope demersal fish communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate floating oil thresholds. The probabilities of low and moderate exposure at the humpback whale - migration BIA ranged between 16–22% and 3–4%, whilst the probabilities of low and moderate exposure to the continental slope demersal fish communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before exposure at the low threshold for the humpback whale - migration BIA and continental slope demersal fish communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.
- The probability of accumulation on any shoreline at, or above, the low threshold (≥10 g/m^2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore above the low threshold was 35.1 m^3. No high (≥1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.
- In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed to dissolved hydrocarbons at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the four BIAs that the release location resides within, the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the humpback whale - migration BIA.
- In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all three seasons. Excluding the four BIAs that the release location resides within, the highest probabilities of exposure for the low threshold were predicted for the humpback whale - migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).
- During all three seasons, three AMPs were predicted to be exposed at the low entrained hydrocarbon threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

Table 8-95: Vessel collision (MDO) stochastic modelling receptor exposure summary

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	Hydrocarbon Ecological EMBA ≥10 g/m²	Hydrocarbon Social and Ecological EMBA ≥50 ppb	Hydrocarbon Social and Ecological EMBA ≥100 ppb	Hydrocarbon Social EMBA ≥10 g/m²	Hydrocarbon Ecological EMBA ≥100 g/m²
		(probability of exposure[187], minimum time to exposure)		(probability of exposure[187])	(probability of exposure[187])	(probability of exposure[187], minimum time to exposure, mean length of shoreline)	
AMP	Gascoyne	—	—	—	3–8%	—	—
	Montebello	1–4%, 1.96 days	—	0–1%	2–11%	—	—
	Ningaloo	—	—	—	2–6%	—	—
State protected areas	Barrow	—	—	—	—	0–2%, 10.63 days, 16.4 km	0–2% 12.42 days, 2.4 km
	Muiron	—	—	—	—	3–4%, 6.5 days, 6.7 km	0–1%, 12.92 days, 1 km
KEF	Ancient coastline at 125 m depth contour[188]	100%, 0.04 days	100%, 0.04 days	25–35%	90–97%	—	—
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula		—	—	5–13%	—	—
	Commonwealth waters adjacent to Ningaloo Reef		—	—	2–6%	—	—

[187] Ranges in values shown are due to the different results between seasons.

[188] The release location resides within the receptor boundaries.

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	**Hydrocarbon Ecological EMBA ≥10 g/m²**	**Hydrocarbon Social and Ecological EMBA ≥50 ppb**	**Hydrocarbon Social and Ecological EMBA ≥100 ppb**	**Hydrocarbon Social EMBA ≥10 g/m²**	**Hydrocarbon Ecological EMBA ≥100 g/m²**
		(probability of exposure[187], minimum time to exposure)		**(probability of exposure[187])**	**(probability of exposure[187])**	**(probability of exposure[187], minimum time to exposure, mean length of shoreline)**	
	Continental slope demersal fish communities	35–54%, 0.38 days	4–13%, 0.58 days	0–1%	36–44%	—	—
	Exmouth Plateau	0–1% 7.04 days	—	—	0–3%	—	—
World Heritage properties / National Heritage places	The Ningaloo Coast World Heritage Area	—	—	—		3–7%, 6. 5 days, 4.3 km	1–2%, 12.46 days, 3.8 km
Commonwealth Heritage properties	Ningaloo Marine Area – Commonwealth Waters *(inferred from Ningaloo IMCRA)*	—	—	—	3–8%	—	—

8.14.3 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA that may be impacted by hydrocarbon exposure as a result of a vessel collision event:

- water quality
- coastal habitats and associated communities: rocky coasts and sandy beaches
- coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses
- marine mammals
- marine reptiles
- fishes, including sharks and rays
- seabirds and shorebirds
- KEFs
- commercial fisheries
- tourism and recreation
- AMPs
- cultural heritage values: Ningaloo Coast
- cultural heritage values: Traditional Owners.

Based on the surface release of MDO and in-water hydrocarbon exposure is limited to the upper 10 m of the water column, benthic habitats and associated communities will not be exposed to MDO and will not be evaluated in this section.

The likelihood of an unplanned release of MDO from a vessel collision event was assessed using data from AMSA's Annual Report 2021–22 (Ref. 428) relating to serious pollution incidents from marine operations in Australia. For all marine operations within Australia, two serious marine pollution incidents have been reported in the last four years. Reportable unplanned releases of MDO from vessel collisions have been heard of within the industry but are not a common occurrence at the magnitude of a serious pollution event.

Based on industry data (Ref. 428), vessel collisions are considered rare. Most vessel collisions involve the loss of containment of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volume used in stochastic modelling (i.e. 1,500 m^3 surface release of MDO over 24 hours) is unlikely.

Offshore vessel operations are dictated by legislative requirements to prevent and manage unplanned releases from vessel collisions. The inherent legislative requirements ensure unplanned releases of MDO from vessel collisions as an uncommon occurrence, as backed by industry data.

Table 8-96 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible hydrocarbon exposure from a vessel collision event. The hydrocarbon environmental exposure thresholds used in this evaluation are detailed in Table 6-2.

Table 8-96: Risk evaluation for unplanned release—vessel collision (MDO) event

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Unplanned release of MDO due to a vessel collision event may result in: • change in water quality.	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • alteration of coastal habitats and associated communities.	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • injury or mortality of marine fauna	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • change to the functions, interests and activities of other marine users	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of Australian Marine Parks	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of KEFs	–	–	–
		Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of the Ningaloo Coast	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • change to cultural heritage values: Traditional Owners	5	5	Very Low (9)

Risk evaluation

Water quality

Change in water quality

An unplanned release of MDO from a vessel collision may result in a reduction in water quality in offshore waters surrounding the release location. Impacts to water quality are likely to be localised and short-term based on the maximum potential volume released (1,500 m^3) and weathering properties of MDO.

On release to the marine environment, MDO spreads quickly and evaporates rapidly in warm waters. Stochastic modelling of 300 simulated vessel collision events predicts potential hydrocarbon exposure at the low surface threshold to extend up to 167 km from the release location (Ref. 426; appendix c). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 912 km^2 at the low threshold (1 g/m^2) and 256 km^2 at the moderate threshold (10 g/m^2) across the 60 day simulation. This predicted impact is very short in duration. At the low threshold (1 g/m^2), floating oil on the surface peaks at an area of ~105 km^2 on the third day following the release, but rapidly reduces to zero on day 4. At the moderate threshold (10 g/m^2) floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. By day 4 there was no predicted surface exposure above these thresholds.

Risk evaluation
Surface and in-water hydrocarbons would be exposed to processes such as evaporation, dispersion, dilution, and physical and biological degradation, Within the localised area of exposure, rapid evaporation and biological and photochemical degradation of MDO will lead to exposure being limited to short periods, with up to ~40% of the mass lost within the first 24 hours and ~95% of the mass lost over several days (Section 8.14.2.1) (Ref. 426; appendix c). Approximately 5% of the mass will not evaporate and persist in the environment. This fraction will be subject to hydrodynamic forces and will decay over time. In the event of a vessel collision event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of MDO will ensure exposure is limited in areas impacted and duration. As such, only a small, localised area will be subject to potential changes in water quality over short-term durations. Therefore, the consequence of a vessel collision event resulting in an MDO spill has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, and the safeguards in place, including enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to water quality is Very Low (9).
Coastal habitats and associated communities: Rocky coasts and sandy beaches
Alteration of coastal habitats and associated communities Based on the maximum potential volume released (1,500 m^3) and weathering properties of MDO, an unplanned release of MDO from a vessel collision event may result in alterations to rocky coasts and sandy beaches resulting from shoreline accumulation of hydrocarbons. Stochastic modelling predicted a 2% probability of shoreline accumulation above the impact (moderate) threshold at Barrow Island and the Ningaloo Coast World Heritage Area and a 1% probability of contact along the Exmouth and Muiron Island coastlines (Table 8-95). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation above the moderate threshold predicted a peak of ~ 20 m^3 and a maximum length of ~10 km. There was no predicted accumulation ≥1,000 g/m^2 predicted to occur. As a result, hydrocarbon exposure to rocky coasts and sandy beaches from a vessel collision event is likely to be localised to a small number and sections of shorelines. Further, based on the natural biological and mechanical processes of shorelines and the rapid weathering of MDO, this localised impact is expected to be short term in duration. Rocky coasts and sandy beaches across the Pilbara range from soft sand beaches to exposed rocky shores (Ref. 429). Oil deposited on soft sandy beaches may penetrate the sand; however, natural processes (e.g. wave action) help disperse stranded oils and mix them into the water column, thus helping sandy beaches recover from light oiling (Ref. 430). Sun and wind can also help break down oil over time, reducing its toxicity and allowing it to be metabolised and degraded by microorganisms in the sand (Ref. 431). At exposed rocky shores, oil is typically helped offshore by reflecting waves—any oil deposited is rapidly removed by wave action. Hydrocarbons present on rocky shores are generally only there for a short period (Ref. 430). Physical dispersion and microorganism degradation processes on shorelines limit changes in sediment quality from hydrocarbon exposure to a short-term period. Given these natural biological and mechanical processes, and the predicted localised area of impact, the consequence has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and communities: rocky coasts and sandy beaches is Very Low (9).
Coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses
Alteration of coastal habitats and associated communities Shoreline hydrocarbons can have smothering and toxic effects on intertidal mudflats, mangroves and seagrasses. Intertidal mudflats, which are typically sheltered and have a large surface area for oil absorption, can trap oil, potentially causing toxicity impacts to infauna. Intertidal mudflats are very sensitive to oil pollution because the oil enters lower layers of the mudflats where a lack

Risk evaluation
of oxygen prevents it from decomposing (Ref. 432). Acute and chronic impacts to the health of mangrove communities can occur via pneumatophore smothering and exposure to the toxic volatile fraction of the hydrocarbons (Ref. 432). Intertidal seagrasses are vulnerable to smothering, which can lead to mortality if oil coats their flowers, leaves and stems (Ref. 433; Ref. 434). Stochastic modelling showed that in-water (entrained) hydrocarbons were predicted to remain within the surface layers only. Therefore, exposure to benthic habitat in deeper waters are not predicted to occur. However, smothering of benthic habitat communities may occur if a surface slick occurs in the intertidal area. Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shorelines. No accumulation ≥1,000 g/m^2 was predicted to occur at any location. This higher threshold is typically associated with impacts to coastal vegetation communities. Observations by Lin and Mendelssohn (Ref. 98) demonstrated that loadings of >1,000 g/m^2 of oil would be required to impact plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (e.g. Grant et al. [Ref. 99], Suprayogi and Murray [Ref.100]). Based on these findings, and limited shorelines where accumulation is predicted above impact thresholds (Hydrocarbon Ecological EMBA), shoreline exposure to intertidal mudflats, mangroves and seagrasses are anticipated to result in localised sublethal effects. As such shoreline exposure to mangroves and intertidal mudflats is not discussed further. The deterministic model for the largest swept area of floating oil above 10 g/m^2 indicates that surface hydrocarbons concentrations ≥10 g/m^2 (i.e. impact threshold) are present for <3 days following the spill event, with a maximum area of coverage of ~30 km^2 occurring 24 hours after the spill commenced. Further, the deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. These deterministic scenarios are considered most relevant for nearshore waters and subsequent impacts to seagrasses. Therefore, as the extent and duration of exposure to nearshore environments is expected to be limited, the potential for environmental impacts would also be limited. Based on an assessment of the predicted magnitude and duration of surface oil, and entrained oil, it is expected that only a small proportion of any seagrass would be exposed above the defined impact thresholds. Therefore, the potential impacts of oil to cause smothering was ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses is Very Low (9).
Coastal habitats and associated communities: Intertidal and subtidal corals
Alteration of coastal habitats and associated communities Shoreline and entrained hydrocarbons can have smothering and toxic effects on intertidal and subtidal corals. Direct contact of hydrocarbons to coral can cause smothering, resulting in a decline in metabolic rate, and may cause varying degrees of tissue decomposition and death. A range of impacts may also result from toxicity, including partial mortality of colonies, reduced growth rates, bleaching, and reduced photosynthesis (Ref. 435; Ref. 436). The release of MDO in offshore waters and presence of in-water hydrocarbons is predicted in the surface layers (<10 m water depth) only. Therefore, exposure to coral reefs or other subtidal habitat types in waters deeper than 10 m (e.g. Rankin Bank or Glomar Shoal) are not predicted occur and therefore are not evaluated further. Smothering of nearshore benthic habitat communities may occur if a surface slick occurs in the intertidal area. A review of modelling predictions for shoreline oil across the Ningaloo Coast and Barrow and Montebello Islands were used as indicators for consequence evaluation. A review of shoreline hydrocarbons is considered most relevant for nearshore waters and subsequent impacts to nearshore intertidal and subtidal corals. Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast and Barrow Island. Based on the modelling, coral habitats along

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the Ningaloo Coast and those on the western side of Barrow Island in 0–10 m water depths have a low probability of impact. Review of shoreline hydrocarbons is considered most relevant for nearshore waters and subsequent impacts to nearshore intertidal and subtidal corals. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. This deterministic scenario is considered most relevant for nearshore waters and subsequent impacts to corals. Therefore, as the extent and duration of exposure to nearshore environments is expected to be limited the potential for environmental impacts would also be limited. Based on an assessment of the predicted magnitude and duration of surface and shoreline oil, it is expected that only a small proportion of any coral habitat would be exposed above the defined impact thresholds over very short durations. Therefore, the potential impacts of oil to cause smothering was ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and associated communities: intertidal and subtidal corals is Very Low (9).
Marine mammals
Injury or mortality of marine fauna Marine mammals can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing oil, consuming oil-affected prey/vegetation, or inhaling volatile oil-related compounds) (Ref. 92). Direct contact with hydrocarbons may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (Ref. 437). However, direct contact with surface hydrocarbons is considered to have little deleterious effect on marine mammals because their smooth skin surfaces are less likely to suffer from hydrocarbon adherence (Ref. 438). The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable. Depending upon the amount and composition of the ingested oil, the effects could range from acute, to subtle, to progressive organ damage. The susceptibility of marine mammals varies with feeding habits. Baleen whales are susceptible to ingesting oil in the water column and surface waters as they lunge feed at depth and also feed by skimming the surface (i.e. they are more susceptible to surface slicks). Toothed whales and dolphins may be susceptible to ingesting dissolved and entrained oil as they gulp feed at depth. Dugongs may also suffer from long-term chronic effects such as liver problems if they consume oil droplets or oil-affected sea grasses (Ref. 438). Marine mammals are vulnerable if they inhale volatile hydrocarbons when they surface within a hydrocarbon slick. For the short period that they persist, vapours from the spill are a significant risk to mammal health, with the potential to damage mucous membranes in eyes and airways, which will reduce the health and potential survivability of an animal. Inhaled volatile hydrocarbons are transferred rapidly to the bloodstream and may also accumulate in tissues (Ref. 437). The Hydrocarbon Ecological EMBA includes BIAs for marine mammals including: • humpback whale BIA (migration) • pygmy blue whale BIA (migration, foraging) • southern right whale (reproduction, migration) • dugongs (breeding, calving, foraging, nursing). Cetacean species are considered most sensitive to surface hydrocarbon exposures, whereas dugongs are considered more sensitive to oil droplets and oil-affected seagrass as a result of entrained hydrocarbon exposure. Deterministic analyses for surface hydrocarbons for cetaceans and in-water entrained hydrocarbons for dugongs were used to understand the potential extent of exposure. Stochastic modelling of 300 simulated vessel collision events predicts a potential hydrocarbon exposure at the moderate (impact) threshold (10 g/m^2) to extend up to ~60 km the from the release location (Ref. 426; appendix c). The deterministic run for the largest swept area of floating

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oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. Compared to the total area encompassed by the humpback and pygmy blue whale BIAs, the predicted extent of surface exposure was predicted to be significantly <1% of either BIA. This information indicates that if an unplanned release of MDO from a vessel collision event occurred, it is unlikely to impact entire humpback and pygmy blue whale populations, resulting in only a localised impact. Dugongs undertaking breeding, calving, foraging, nursing behaviours in nearshore waters demonstrate high site fidelity to habitats required to facilitate these behaviours (Ref. 439). This high-site fidelity when undertaking critical behaviours increases their sensitivity to hydrocarbon exposures as they are less likely to be transient. Stochastic modelling predicted a 2% probability (winter) of the dugong BIA being contacted by entrained hydrocarbons in the 0-10 m layer and the high (impact) threshold. The deterministic model for the largest area of entrained hydrocarbons above 100 ppb indicates that entrained hydrocarbons were present across a maximum peak area of ~200 km^2, occurring 6 days after the spill. After 13 days there is no further predicted exposure to entrained hydrocarbons at this threshold. Using the dugong BIA area, modelling indicates that the extent of entrained exposure was predicted to be limited to ~2% of the entire BIA. As the extent and duration of exposure to nearshore environments is expected to be limited the potential for significant environmental impacts would also be limited. However, it is acknowledged that behaviours in nearshore waters will result in increased sensitivity to hydrocarbon exposures as the species are not expected to be transient. As surface and in-water hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation, surface and in-water hydrocarbon exposure to marine mammals will be limited to a short-term period. Therefore, it has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to marine mammals is Very Low (9).
Marine reptiles
Injury or mortality of marine fauna Reptiles may be exposed to surface and shoreline hydrocarbons from an unplanned release of MDO from a vessel collision event. Reptiles can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing oil, consuming oil-affected prey, or inhaling volatile oil-related compounds) (Ref. 440). Hydrocarbon exposure has the potential to cause injury or mortality to reptiles. Marine turtles are vulnerable to the effects of oil at all life stages—eggs, hatchlings, juveniles, and adults. Several aspects of turtle biology and behaviour place them at risk, including a lack of avoidance behaviour, indiscriminate feeding in convergence zones, and large pre-dive inhalations (Ref. 438). Oil effects on turtles can include impacts to skin, blood, digestive, and immune systems, and increased mortality due to oiling. Shoreline hydrocarbons can impact turtles coming ashore at nesting beaches. Eggs may also be exposed during incubation, potentially resulting in increased egg mortality and detrimental effects on hatchlings. Hatchlings may be particularly vulnerable to toxicity and smothering as they emerge from the nests and make their way over the intertidal area to the water (Ref. 440). Light oils, such as unweathered MDO, expose marine reptiles to volatile polycyclic aromatic hydrocarbons (PAHs) which may result in breathing, sight, or gastro-intestinal injuries (Ref. 24). The volatile PAHs can penetrate the skin of sea snakes and carapace of marine turtles affecting respiration, salt gland function and blood chemistry (Ref. 24). These injuries to marine reptiles can result in decreased health, starvation, increased stranding, and decreased breeding condition (Ref. 24). Sudden high toxic contaminant load during pre-dive inhalations have caused instantaneous death to marine turtles and is to be expected with sea snakes (Shigenaka 2021 cited in Ref. 441). The Hydrocarbon Ecological EMBA (Table 6-2; Figure 6-1) includes BIAs for flatback, loggerhead, green and hawksbill turtles, based on predicted shoreline hydrocarbons exposure at concentrations greater than the impact thresholds. The flatback turtle internesting BIA is predicted to be exposed to surface hydrocarbon concentrations greater than impact thresholds due to the

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fact that the receptor overlaps with the release location. The behaviours associated with these BIAs include aggregation, basking, foraging, internesting, mating, and nesting. The Ningaloo Coast, Barrow Island, the Montebello Islands and Muiron Islands are areas are identified as HCTS of flatback, green and hawksbill turtles (Section 6.3.3.2). Nesting adult turtles and hatchlings may be exposed as they traverse the intertidal area, resulting in potential smothering and acute impacts to some hatchlings during that nesting season. As a result, a small proportion of any reptile population would be exposed above the defined impact thresholds, for a limited duration. Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. Based on the rapid weathering of the MDO, the volatile PAHs which are known to cause breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off out of the stranded oils, leaving mostly waxy residues that don't result in the same level of impacts. The deterministic model for the largest swept area of floating oil above 10 g/m^2 indicates that surface hydrocarbons concentrations ≥10 g/m^2 (i.e. impact threshold) are present for <3 days following the spill event, with a maximum area of coverage of ~30 km^2 occurring 24 hours after the spill commenced. Using the flatback turtle internesting BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. This information indicates that if a vessel spill event occurred during the nesting season, it is unlikely to impact entire local nesting populations, resulting only in a localised impact. The EPBC threatened short-nosed sea snake, and other EPBC marine listed sea snake species, may be present within the Hydrocarbon EMBAs. Oil pollution has been identified as a pressure 'of potential concern' (Ref. 287) to sea snakes[189]. Sea snakes are susceptible to oil on the sea surface (Ref. 287; Ref. 442; Ref. 443). Being air breathers and obligate bottom feeders, oil may be either inhaled or ingested (Ref. 287; Ref. 444). As described above, surface oil exposure above impact thresholds is predicted to only be present for a short (<3 days) duration and over a relatively small (maximum ~30 km^2) area. Any exposure to benthic habitats is only predicted to occur within nearshore (<10 m water depth) areas. Using the shoreline exposure described above as indicative of oil presence in a nearshore environment, the duration and extent of exposure from a single spill event is predicted to be limited. Surface hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation; shoreline hydrocarbons on sandy beaches would be exposed to physical dispersion and microorganism degradation processes. These processes will limit in-water and shoreline hydrocarbon exposure to a short-term period. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any reptile population would be exposed above the defined impact thresholds, and only for a limited time. Given the localised, short-term impact to a small proportion of any marine reptile population the consequence of this scenario has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to marine reptiles is Very Low (9).
Fishes, including sharks and rays
Injury or mortality of marine fauna Fishes, including sharks and rays, may be exposed to surface and in-water hydrocarbons from an unplanned release of MDO from a vessel collision event. Although most fishes do not break the sea surface, some shark species (including whale sharks) feed in surface waters, so there is also the potential for surface hydrocarbons to be ingested.

[189] The pressure analysis distinguished between oil pollution from shipping ('of less concern') and oil rigs ('of potential concern') (Ref. 292). Although the aspect source for this risk assessment is a spill from a vessel, the higher pressure concern has been adopted.

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Potential effects include damage to the liver and lining of the stomach and intestine, and toxic effects on embryos (Ref. 435). Fishes are most vulnerable to oil during embryonic, larval, and juvenile life stages. However, very few studies have demonstrated increased mortality of fish as a result of oil spills (Ref. 436; Ref. 432; Ref. 445). Demersal fishes are not expected to be impacted because in-water hydrocarbons are only predicted in the surface layers (<10 m water depth). Pelagic free-swimming fishes and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (Ref. 82). Pelagic species are also generally highly mobile and thus are not likely to suffer extended exposure (e.g. >48–96 hours) at concentrations that would lead to chronic effects. Near the sea surface, fish can detect and avoid contact with surface slicks—fish mortalities are rare near hydrocarbon spills in open waters (Ref. 446). Fish exposed to dissolved hydrocarbons can eliminate the toxicants once they are in clean water; hence, individuals exposed to a spill are likely to recover (Ref. 426). Marine fauna with gill-based respiratory systems, including whale sharks, are expected to have higher sensitivity to exposures of entrained oil. The Hydrocarbon Ecological EMBA includes the whale shark foraging BIA. As these species are considered most sensitive to surface exposures, deterministic analyses were used to understand the potential extent of exposure. Stochastic modelling predicts a potential hydrocarbon exposure at the moderate (impact) threshold (10 g/m^2) to extend up to ~60 km from the release location (Ref. 426; appendix c). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. Using the whale shark BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. Based on an assessment of the predicted magnitude (localised and short-term) and impact of surface hydrocarbons at levels above impact thresholds, it is expected that only a small proportion of any fish population would be exposed. Therefore, the consequence of this scenario has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to fishes, including sharks and rays is Very Low (9).
Seabirds and shorebirds
Injury or mortality of marine fauna Seabirds that rest at the water's surface (e.g. shearwaters) or surface-plunging birds (e.g. terns, boobies) may be exposed to surface hydrocarbons from an unplanned release of MDO from a vessel collision event (Ref. 91); shorebirds may be exposed to shoreline hydrocarbons. Damage to external tissues, including skin and eyes, can occur, along with internal tissue irritation in lungs and stomachs (Ref. 447). Acute and chronic toxic effects may result where the product is ingested as the bird attempts to preen its feathers (Ref. 447). The Hydrocarbon Ecological EMBA includes fairy Tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs (Table 6-17). Wedge-tailed shearwaters forage relatively close to their breeding islands, which in the NWMR include Dampier Archipelago, Passage Island, Lowendal Island, islands off Barrow Island among others; (Ref. 170). Breeding populations of roseate terns have been recorded at the Lowendal Islands (Ref. 183). Northern Australia white-tailed tropicbirds forage in warm waters and over long distances (up to 1,500 km from breeding sites) (Ref. 171). Roosting gulls and terns (including fairy terns and lesser crested terns) have been recorded along sandy parts of the Ningaloo Coast (Surman & Nicholson 2015 cited in Ref. 448). Barrow Island, Boodie Island, Ningaloo Coast (Exmouth), Middle Island and Muiron Islands are the only areas predicted to be exposed to shoreline hydrocarbon accumulations ≥100 g/m^2 (Hydrocarbon Ecological EMBA: shoreline ecological impact threshold). Stochastic modelling predicts a potential hydrocarbon exposure at the moderate threshold (10 g/m^2) to extend up to ~60 km from the release location (Ref. 426; appendix c). The

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deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. A review of these areas against the total areas encompassed by fairy tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs, indicates that the extent of shoreline and surface exposures was predicted to be <1% of all breeding BIAs. This information indicates that if a spill from a vessel collision event occurred during seasonal roosting or breeding season, it is unlikely to impact entire local populations. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any seabird or shorebird population would be exposed above the defined impact thresholds, and only for a limited time. Given the localised, short-term impact to a small proportion of any seabird or shorebird population the consequence of this scenario has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to seabirds and shorebirds is Very Low (9).
KEFs
Change to values and sensitivities An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of KEFs. As per Section 6.3.6.1, there are a number of KEFs present in the Hydrocarbon Ecological EMBA. As identified in Section 6.3.6.1, the values of these KEFs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as identified BIAs for regionally significant marine fauna. The consequence evaluations for these values have been detailed separately. Stochastic modelling (Ref. 426; appendix c) predicts that entrained hydrocarbon exposure is limited to the upper water column (0–10 m), and therefore the hydrocarbon exposure is limited to values within the upper water column of these KEFs, and not the benthic habitat or values within the KEFs. For example, the ancient coastline at 125 m depth contour KEF resides within the release location, however the modelling did not predict any exposure to its benthic values. Given the consequences of all values that reside within these KEFs have been evaluated in other sections of this chapter, and due to no predicted impact of oil below the 10m depth contour, this aspect has not been evaluated further.
Commercial fisheries
Change to functions, interests and activities An unplanned release of MDO from a vessel collision event may result in changes to the functions, interests or activities of commercial fisheries within the Hydrocarbon Ecological and Social EMBAs. As identified in Section 6.4.1, several commercial fisheries have management areas and recent fishing effort recorded within the Hydrocarbon Ecological and Social EMBAs (Section 6.4.1). Commercial fishing may be impacted by exclusion zones associated with the unplanned release of MDO, and subsequent reduction in fishing effort. Exclusion zones may impede access to commercial fishing areas for a short time, and nets and lines may become oiled. However, the impacts to commercial fishing from a public perception may be much more significant and longer term than the actual spill. Fishing areas may be temporarily closed for fishing because of the risks of the catch being tainted by hydrocarbons. Concentrations of petroleum contaminants in fish, crustacean and mollusc tissues could pose a significant potential for adverse human health effects, and until these products are cleared by health authorities, they could be restricted for sale and human

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consumption. Toxicity in adult fish has been reported in response to diesel exposure (Ref. 449; Ref. 450). Uptake of hydrocarbons has been demonstrated in bony fish after exposure to water-accommodated fraction of between 24 and 48 hours. Davis et al (Ref. 451) reported detectable tainting of fish flesh after a 24-hour exposure to marine fuel oil concentrations of 0.33 ppm and diesel concentrations of 0.25 ppm. Most studies, from laboratory trials or of fish collected after release events (including the *Hebei Spirit*, *Macondo*, and *Sea Empress* spills), find evidence of elimination of PAHs in fish, with tissues returning to reference levels within 2 months of exposure (Ref. 451; Ref. 452; Ref. 453; Ref. 454; Ref. 455; Ref. 456; Ref. 457). If there are impacts to fish stocks associated with impacts to the larval life phase of fish, there is the potential for reduced profits for commercial fisheries over a longer time, and potential for reduced fishing quotas or exclusion zones which could exclude fishing effort. The Montara spill of a light gas condensate (the most recent [2009] example of a large hydrocarbon spill in Australian waters) occurred over an area fished by the Northern Demersal Scalefish Managed Fishery (11 licences held by 7 operators), with goldband snapper, red emperor, saddletail snapper and yellow spotted rockcod being the key species fished (Ref. 458). As a precautionary measure, the then WA Department of Fisheries (now part of DPIRD) advised the commercial fishing fleet to avoid fishing in oil-affected waters. Testing of fish caught in areas of a visible slick (November 2009) found no detectable petroleum hydrocarbons in fish muscle samples, suggesting fish were safe for human consumption. Limited ill effects were only detected in a small number of individual fish (Ref. 458). No consistent effects of exposure on fish health could be detected within 2 weeks of the end of the well release. Follow-up sampling in areas affected by the spill during 2010 and 2011 (Ref. 458) found negligible ongoing environmental impacts from the spill. If an MDO spill occurred as the result of a vessel collision, a temporary fisheries closure may be put in place by DPIRD's Fisheries division (or voluntarily by the fishers themselves). MDO may foul the hulls of fishing vessels and associated equipment, such as gill nets. A temporary fisheries closure, combined with oil tainting of target species (actual or perceived), may lead to financial losses to fisheries and economic losses for individual licence holders. Fishery closures and the flow-on losses from the lack of income derived from these fisheries are likely to have short-term and localised socio-economic consequences, such as reduced employment (in fisheries service industries, such as tackle and bait supplies, fuel, marine mechanical services, accommodation etc.). A temporary fishing exclusion zone may be implemented by AFMA or DPIRD. For most fisheries described in Section 6.4.1, a precautionary exclusion from fishing grounds can be expected until water quality monitoring verifies the absence of residual hydrocarbons, thus providing confidence to consumers related to fish tainting. The minor loss of revenue for commercial fisheries in the Hydrocarbon Ecological and Social EMBAs has been evaluated as Minor (5) because the area of potential impact to fishes is localised (evaluation provided above), and the loss of revenue is short-term (based on temporary exclusion zones that may be implemented). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to commercial fisheries is Very Low (9).
Tourism and recreation
Change to functions, interests and activities Tourist destinations in the Hydrocarbon Social EMBA may be exposed to shoreline, surface, and in-water hydrocarbons from an unplanned release of MDO from a vessel collision event. Hydrocarbon presence in these tourist destinations may reduce the visual amenity of the area, and, because these destinations offer exclusively nature-based tourism, potential environmental impacts to these places may also reduce visitor numbers. Several tourism destinations are within the Hydrocarbon Social EMBA, including Ningaloo Reef and Pilbara Inshore Islands Nature Reserves and other marine parks, management areas and reserves listed in Table 6-26, Table 6-27 and Table 6-28. Reduced visitor numbers may lead to a minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures).

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On release to the marine environment, MDO spreads quickly and evaporates rapidly in warm waters. Stochastic modelling of 300 simulated vessel collision events predicts potential hydrocarbon exposure at the low surface threshold to extend up to 167 km from the release location (Ref. 426; appendix c).The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 912 km^2 at the low threshold (1 g/m^2) and 256 km^2 at the moderate threshold (10 g/m^2) across the 60 day simulation. This predicted impact is very short in duration. At the low threshold (1 g/m^2), floating oil on the surface peaks at an area of ~105 km^2 on the third day following the release, but rapidly reduces to zero on day 4. At the moderate threshold (10 g/m^2) floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. By day 4 there was no predicted surface exposure above these thresholds.

Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km.

Shoreline and surface hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation, which will ensure hydrocarbon exposure to tourist destinations is limited to a short-term period.

Minor loss of revenue from reduced tourist numbers in the Hydrocarbon Social EMBA, has been evaluated as Minor (5) given the localised, short-term impact.

As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5).

Overall, the risk of Unplanned release—Vessel collision event (MDO) to tourism and recreation is Very Low (9).

AMPs

Change to values and sensitivities

An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of AMPs.

Modelling predicts surface exposure ≥1 g/m^2 (4% probability) and entrained exposure ≥100 ppb (11% probability) within the Montebello Marine Park (Table 8-95). Modelling predicted a low probability (<37%) of entrained oil exposure at the low threshold (10 ppb) within the Abrolhos, Argo–Rowley Terrace, Carnarvon Canyon, Gascoyne, Montebello, Ningaloo, and Shark Bay Marine Parks (Ref. 426; appendix c). No seabed hydrocarbon exposure was predicted, based on the surface release of MDO in deep offshore waters.

As identified in Section 6.5.1, the natural values of the AMPs listed above include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, and BIAs for regionally significant marine fauna. Social and economic values of the listed AMPs include commercial fishing.

The consequence evaluations to specific marine fauna and commercial fisheries are provided above.

Based on the temporary and localised hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds, the potential risks of an unplanned release of MDO from a vessel collision event to the values and sensitivities of the listed AMPs has been evaluated as Minor (5).

As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5).

Overall, the risk of Unplanned release—Vessel collision event (MDO) to AMPs is Very Low (9).

Risk evaluation
Cultural heritage value: Ningaloo Coast
Change to values and sensitivities An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of heritage values of the Ningaloo Coast (a World Heritage property and listed under the National Heritage listing). Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shoreline. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km (Table 8-95). As identified in Section 6.6.1, heritage values for the Ningaloo Coast include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, and BIAs for regionally significant marine fauna. The intertidal systems of the Ningaloo Coast World Heritage Area are also considered high-diversity habitats, which sustain the species listed under the EPBC Act and the resultant tourism in the area. The consequence evaluations to marine fauna, marine habitat and tourism and recreation are provided above. Based on the temporary and localised exposure of hydrocarbons along the Ningaloo Coast, the risks of an unplanned release of MDO from a vessel collision event to the values and sensitivities of the Ningaloo Coast has been ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to the Ningaloo Coast is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned release of MDO from a vessel collision includes: • potential indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna • potential impacts to tangible Traditional Owner heritage from hydrocarbon exposure of protected First Nation sites or artefacts. As discussed in Section 6.6.4, at the time of writing this OPP, CAPL understands through consultation with Traditional Owners that there are no known artefacts or specific sites on the seabed within the EMBAs that have, or are associated with, cultural heritage values. As identified from literature and/or consultation (Section 6.3.5.2.1), Sea Country is a value for First Nations people. The waters of the NWMR (and therefore the waters within the Hydrocarbon EMBAs) are acknowledged as potentially having some cultural and spiritual significance to First Nations as well as providing natural resources (Section 6.3.5.2.1). The Hydrocarbon EMBAs intersect with the coast of the North West Cape peninsula, along or adjacent to which, cultural heritage sites or artefacts are located. Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shoreline. **T**he deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km (Table 8-95). If shoreline contact occurs, it is expected that any impacts from this type of event would be localised, non-continuous and short term in duration. As such, given the volume, type of oil (marine fuel) and predicted weathering, no prolonged impact pathway to a change in access to Country is anticipated. Based on the temporary and localised exposure of hydrocarbons along the Ningaloo Coast, the risks of potential changes to Traditional Owner cultural heritage values from an unplanned release of MDO from a vessel collision event has been ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is

Risk evaluation
unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to Traditional Owner cultural heritage values is Very Low (9).

8.14.4 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-97 details the determination of acceptability for Unplanned release—Vessel collision (MDO).

Table 8-97: Determination of acceptability for Unplanned release—Vessel collision (MDO)

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-23**, as defined in Table 7-6 and shown below in Section 8.14.5. The intent of adopting and implementing preventive control measures (Section 8.14.5) is to prevent the occurrence of an unplanned hydrocarbon release to the environment. This preventative approach ensures that **AL-23** is met. In the event that an unplanned release of MDO did occur, the above risk evaluation demonstrates that the predicted impact is expected to be minor and recoverable.
Principles of ESD	**(b) 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 highest consequence level for unplanned release of MDO from vessel collision was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes: • The spill modelling (appendix c) provides scientific certainty to inform the risk evaluation for unplanned release of MDO. • The literature review undertaken as part of the risk evaluation provides scientific certainty for the types of effects and recovery of receptors that may be at risk. • Prevention measures for unplanned release of MDO from vessel collision are well regulated and managed in Australian waters (e.g. implementation of Marine Orders). • To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational 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 Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the risk of unplanned release of MDO from vessel collision based on relevant legislation and other requirements as listed below. • The regulation and management of vessel collisions in Australian waters ensures the health, diversity and productivity of the environment

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">is maintained for future generations through application of prevention measures.
• The highest consequence level for unplanned release of MDO from vessel collision was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
• Any relevant stakeholder feedback in relation to unplanned release of MDO from vessel collision has been incorporated in the OPP and assessed in the external context acceptability criteria.
• To manage impacts to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>OPGGS(E)R
An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity before commencing activities.</td><td rowspan="3">Legislative requirements are addressed by adopting these control measures:
• CM-16
• CM-22
• CM-31
• CM-32
• CM-33
• CM-43
• CM-44 (see Section 8.14.5).</td></tr>
<tr><td>Protection of the Sea (Prevention of Pollution from Ships) Act 1983 – Section 26F (implements MARPOL Annex I).
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution.
It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage, and air pollution.
This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.</td></tr>
<tr><td>Navigation Act 2012 – Chapter 4 (Prevention of Pollution).
Gives effect to international conventions for maritime issues</td></tr>
</table>

Determination of acceptability		
	where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Maintaining and disseminating navigational charts and publications, including providing safety-critical information to mariners via the Notice to Mariners system.	
	Guidelines for Offshore Marine Operations (Ref. 425) The objective of this document is to provide guidance in the best practices that should be adopted to ensure the safety of personnel on board all vessels servicing and supporting offshore facilities, and to reduce the risks associated with such operations.	
	AMSA Marine Orders 91 and 94 Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels. Marine Order 91 (Marine Pollution Prevention – Oil) Marine Order 94 (Marine pollution prevention – packaged harmful substances)	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24) Action A4.2: • Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs. Note: This is also a specific action identified for the G-NWS, LH-WA, and F-Pil individual stocks.	EPBC management plan requirements to minimise habitat degradation / modification, including marine pollution, are addressed by adopting this control measure: • **CM-44**. Response and recovery of habitats and marine fauna is within the scope of the approved OSMP. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 27) Action: Ensure there is no disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	

Determination of acceptability		
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 26) Action: Ensure there is no anthropogenic disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 28) Action 5c: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 40) Action 5c: Risk based response strategies for marine pollution incidents are developed. Action 5b (adapted): undertake as feasible, monitoring of breeding colonies for marine pollution impacts including, as a priority: • incidence of oiled birds at nest • effect of marine pollution.	
	Wildlife Conservation Plan for Seabirds (Ref. 38) Action 2h: Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) Action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes	
	Conservation Advice for *Sternula nereis nereis* (Fairy Tern) (Ref. 43) Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **Approved Conservation Advice on *Pristis clavata* (Dwarf Sawfish)** (Ref. 29)	These EPBC management plans for species that may occur within the Hydrocarbon Social and Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat, but do not identify any relevant actions.

Determination of acceptability		
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 34). **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33). **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **National Recovery Plan for the Southern Right Whale (*Eubalaena australis)*** (Ref. 23) **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49) **Conservation Advice *Calidris canutus* Red knot** (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56) **Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit)** (Ref. 52) **Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover)** (Ref. 50) **Conservation Advice for *Tringa nebularia* (Common Greenshank)** (Ref. 47) **Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher)** (Ref. 42) **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664)	
	North-west Marine Parks Network Management Plan (Ref. 82) The Plan requires that 'actions required to respond to oil pollution incidents, including environmental monitoring and remediation, in connection with mining operations authorised under the OPGGS Act may be conducted in all zones. The Director should be notified in the event of an oil pollution incident that occurs within, or may impact upon, an Australian Marine Park and, so far as reasonably practicable, prior to a response action being taken within a marine park.'	Protected area requirements to respond to an Unplanned release–Vessel collision (MDO) event, including notifying, environmental monitoring, and remediation, authorised under the OPGGS Act are addressed by adopting this control measure: • **CM-44**.

Determination of acceptability	
Internal context	This procedure was deemed relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265).
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to Unplanned release–Vessel collision (MDO) from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.

8.14.5 environmental performance

Table 8-98 lists the EPO defined for unplanned release of MDO from vessel collision and the adopted control measures to achieve the outcome.

Table 8-98: Environmental performance for unplanned release—vessel collision (MDO)

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-23: No unplanned release of hydrocarbons to the environment from the Development.	**EPO-38**: No unplanned release of hydrocarbons to the environment attributable to the Development.	**CM-32**: Vessels operating within the Development Area will comply with requirements within Marine Order 27—Safety of navigation and radio equipment. **CM-33**: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-31**: Vessels operating within the Development Area will comply any Notice to Mariners requirements under the *Navigation Act 2012* (Cth).

Acceptable levels	Environmental performance outcomes	Adopted control measures
		CM-43: Vessel crew will hold a current Standards of Training, Certification and Watchkeeping for Seafarers (or equivalent) certificate as appropriate to duties. **CM-44**: Develop (and implement in the event of an unplanned hydrocarbon release) an Oil Pollution Emergency Plan and Operational Scientific Monitoring Plan that satisfies the requirements under regulation 22 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth).

8.15 unplanned release—hydrocarbon system (condensate)

8.15.1 source

The Development introduces the potential for an unplanned release of gas and condensate into the environment. An evaluation of all spill scenarios associated with the hydrocarbon system was completed and the following event scenarios identified:

- loss of well integrity
- loss of effective well control
- minor defect in flowline
- major defect in flowline.

The LOWC presents the worst-case credible unplanned release from the hydrocarbon system (condensate) scenario under this OPP and has been used as the basis for the risk assessment.

Note that minor unplanned release scenarios are not included in this section. These scenarios are assessed in:

- unplanned release—minor LOC (Section 8.13).

CAPL commissioned RPS to conduct stochastic spill modelling (stochastic modelling) of LOWC events in all fields to predict the extent of hydrocarbon exposure to inform the definitions of the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA. The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA considers hydrocarbon exposure from both LOWC and vessel collision events resulting in unplanned release of hydrocarbons.

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA represent the outer area where hydrocarbons above impact concentration thresholds (Table 6-1) may be present in the environment in the event of an unplanned release of condensate (refer to Figure 6-1 and Figure 6-2 respectively; Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462 and Table 6-1).

Table 8-99 identifies activities within each phase where an unplanned release of condensate could occur from the hydrocarbon system in the DA.

Table 8-99: Phases and activities that generate Unplanned release—Hydrocarbon system (condensate)

Phase	Activity
Drilling	Drilling top and bottom holes Pressure control equipment—installation and testing Completions
Installation and commissioning	Installation of flowlines, MEG pipelines and PLETs/PLEMs Installation of subsea infrastructure
Operations	Operation of the hydrocarbon system Well intervention
Decommissioning	Flush and clean Well suspension and P&A

8.15.1.1 drilling

Drilling of subsea wells introduces the potential for an unplanned release of gas and condensate. CAPL categorise well control into two categories:

- loss of well integrity—where integrity of the well has been compromised, but the well remains under control
- loss of effective well control—where control of the well has been lost (which would require a Level 3 well control emergence response).

Well control events are credible risks during the drilling phase and have the potential to occur by:

- dropped objects onto the well envelope
- mechanical failure
- corrosion
- loss of effective well control
- loss of station keeping
- operating error.

Well operation management plans (WOMPs) will be developed for the wells detailing risk controls (e.g. casing and formation integrity testing, well control system standards) to mitigate well control events during the drilling phase of the Development.

Based upon the feasible risks identified during the Development's drilling phase, a loss of effective well control was deemed to present the worst-case credible spill scenario and has been used as the basis for the following risk assessment.

8.15.1.2 installation and commissioning

Loss of well integrity events during this phase may result from:

- dropped objects onto the well envelope (potential damage to wellhead).

Lifting of flowlines and subsea structures for installation activities near DCs introduces the risk of dropped objects onto the wellhead resulting in a loss of well integrity event.

8.15.1.3 operations

Defects in flowlines during the operations phase may result from:

- third-party interference (potential damage to flowline)
- materials fatigue (including corrosion leading to loss of flowline integrity).

CAPL categorises defects in flowlines into two categories:

- minor defect in flowline—defects of up to 25 mm is indicative of the largest defect that can be fixed using pipe clamps; therefore, defects of this size are considered as minor defect events.
- major defect in flowline—full-bore rupture is considered the worst-case major defect event.

Studies undertaken for the Gorgon and Jansz pipelines (Ref. 446) indicate that a minor defect could lead to a loss of ~574 m^3 for a two week un-isolated leak. A major defect on the Gorgon and Jansz pipelines (Ref. 446) could lead to a loss of between ~276 m^3 and ~529 m^3. The Gorgon and Jansz pipelines are 48″ in diameter as compared to the 24″ flowlines planned for the Development. Accordingly, the losses from a major or minor defect for the Development flowlines are not expected to exceed these values.

8.15.1.4 decommissioning

Decommissioning of subsea wells introduces the potential for well control events as described in Section 8.15.1.1.

8.15.2 spill modelling

The LOWC presents the worst-case credible unplanned release from the hydrocarbon system (condensate) scenario under this OPP. Other unplanned release from the hydrocarbon system (condensate) scenarios have potential release volumes significantly smaller in comparison to LOWC spill volumes. As a result, LOWC events at each field in the Development has been modelled to predict the extent of potential hydrocarbon exposure to inform the risk assessment.

Stochastic modelling for LOWC was performed using two models: OILMAP-DEEP was used to simulate the nearfield multiphase plume rise dynamics from the subsea release, and a three-dimensional oil spill model (SIMAP) was used to simulate the drift, spread, weathering and fate of the spilled oil (Ref. 463). Modelling was conducted using a stochastic approach, where multiple simulations (using the same spill parameters) were conducted, but under varying meteorological and oceanographic conditions. For further details on SIMAP and the stochastic modelling method refer to Section 8.14.1 and appendix c for full modelling reports for all fields.

A LOWC scenario evaluation was undertaken to determine all possible LOWC events for the Development. Based on the scope of the Development, CAPL identified five possible LOWC event scenarios to represent all fields, drilling locations and hydrocarbon types within the Development. The five LOWC event scenarios were defined based on hydrocarbon types expected to be extracted from the seven fields:

- WTR scenario: WTR field predicted to contain WTR condensate

- G&E scenario: combined Geryon and Eurytion fields predicted to contain similar condensate, represented by Geryon condensate
- C&D scenario: combined C&D fields predicted to contain similar condensate represented by Chrysaor condensate
- Semele scenario: Semele field predicted to contain Semele condensate*
- Chandon scenario: Chandon field predicted to contain Chandon condensate.

*The Semele field is a prospect at this time and as a result, no composition data is available. The field is contained within retention lease permits WA-14-R and WA-15-R, which also cover the C&D fields. All Semele values presented this this section are interpretations from analogues, not data.

Response Time Models (RTMs) indicate that it is reasonable to expect that all LOWC scenarios could be killed within ~13 weeks (90 days). The RTMs take into account the preparation, assessment, and approval of the Safety Case revisions for the relief well rig and support vessels. Further details on the RTM are provided in the Source Control Emergency Response Plan (SCERP) (Ref. 464).

Stochastic modelling was conducted for each field for a subsea release of condensate over 90 days representing the worst-case LOWC events:

- WTR scenario: a 684 m^3/day subsea release totalling 61,555 m^3 (Ref. 426)
- G&E scenario: a 557 m^3/day subsea release totalling 50,165 m^3 (Ref. 459)
- C&D scenario: a 208 m^3/day subsea release totalling 18,715 m^3 (Ref. 460)
- Semele scenario: a 388 m^3/day subsea release totalling 34,927 m^3 (Ref. 461)
- Chandon scenario: a 829 m^3/day subsea release totalling 74,604 m^3 (Ref. 462).

A total of 300 simulations were modelled per LOWC scenario. Including the 300 simulations modelled for the vessel collision scenario, the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBAs are defined as the combined hydrocarbon exposure spatial extent of 1800 simulations.

Table 8-100 summarises the model settings. Table 8-101 and Table 8-102 summarise the hydrocarbon properties for each field. Table 6-2 describes the modelled impact thresholds for social and ecological receptors.

Table 8-100: Subsea release scenario model settings

Parameter	Details				
	WTR	**G&E**	**C&D**	**Semele**	**Chandon**
Latitude	20.23666° S	19.56º S	20.23988º S	19.99726° S	19.56712° S
Longitude	115.04357° E	114.53º E	114.87716º E	114.94312° E	114.12603° E
Water Depth	150 m	1,100 m	800 m	800 m	1,100 m
Oil type	WTR condensate	Geryon condensate	Chrysaor condensate	Semele condensate	Chandon condensate
Simulation spill volume	61,555 m^3	50,165 m^3	18,715 m^3	34,927 m^3	74,604 m^3
Simulation spill type	Subsea				
Simulation spill duration	90 days				
Total simulation duration	104 days				
Number of randomly selected spill simulation start times	100 per season (300 total)				
Seasons modelled	Summer (September to the following March) Transitional (April and August) Winter (May to July)				

Table 8-101: Physical properties for hydrocarbons of each field

Characteristic	WTR	G&E	C&D	Semele	Chandon
Density	817 (at 15°C)	810.0 (at 15°C)	824 (at 15°C)	816 (at 15°C)	789 (at 15°C)
Dynamic viscosity	5.9 (at 15°C)	5.2 (at 15°C)	5.6 (at 15°C)	6.7 (at 15°C)	2.6 (at 15°C)
Pour point	0	−20	−9	−9	−20
API gravity	41.2	42.67	40.20	41.9	47.8
Classification	Group II (Light-persistent)	Group II (Light-persistent)	Group II (Light-persistent)	Group I (Non-persistent)	Group I (Non-persistent)

Table 8-102: Boiling point ranges for hydrocarbons of each field

Field	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	**<180 C4 to C10**	**180-265 C11 to C15**	**265-380 C16 to C20**	**>380 >C20**
WTR	% of total	31.1	29.9	19.4	19.6
	% of aromatics	3.2	0.0	0.0	0.0
G&E	% of tot	31.5	27.1	31.7	9.7
	% of aromatics	2.9	0	0	0
C&D	% of total	23.8	33.0	32.9	10.3
	% of aromatics	3.0	0	0	0
Semele	% of total	33.0	32.5	27.9	6.5
	% of aromatics	3.9	0	0	0
Chandon	% of total	45.9	26.3	22.4	5.4
	% of aromatics	2.5	0	0	0

8.15.2.1 hydrocarbon characteristics

All field condensate properties (Table 8-101 and Table 8-102) are either light-persistent or non-persistent hydrocarbons with low viscosity levels. These condensates will spread quickly when released and form a thin film on the sea surface, increasing the evaporation rate.

Generally, approximately 23 - 46% of the mass of the condensates should evaporate within the first 12 hours (boiling point <180°C); a further ~27 - 33% should evaporate within the first 24 hours (boiling point 180°C–265°C); and an additional ~19 - 33% should evaporate over several days (boiling point 265°C–380°C). Approximately 5 - 20% (by mass) of condensates will not evaporate at atmospheric temperatures. These compounds will persist in the environment. Boiling point ranges for hydrocarbons of each field are summarised in Table 8-102 and further information on fate and weathering of the products can be found in the individual modelling reports (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462).

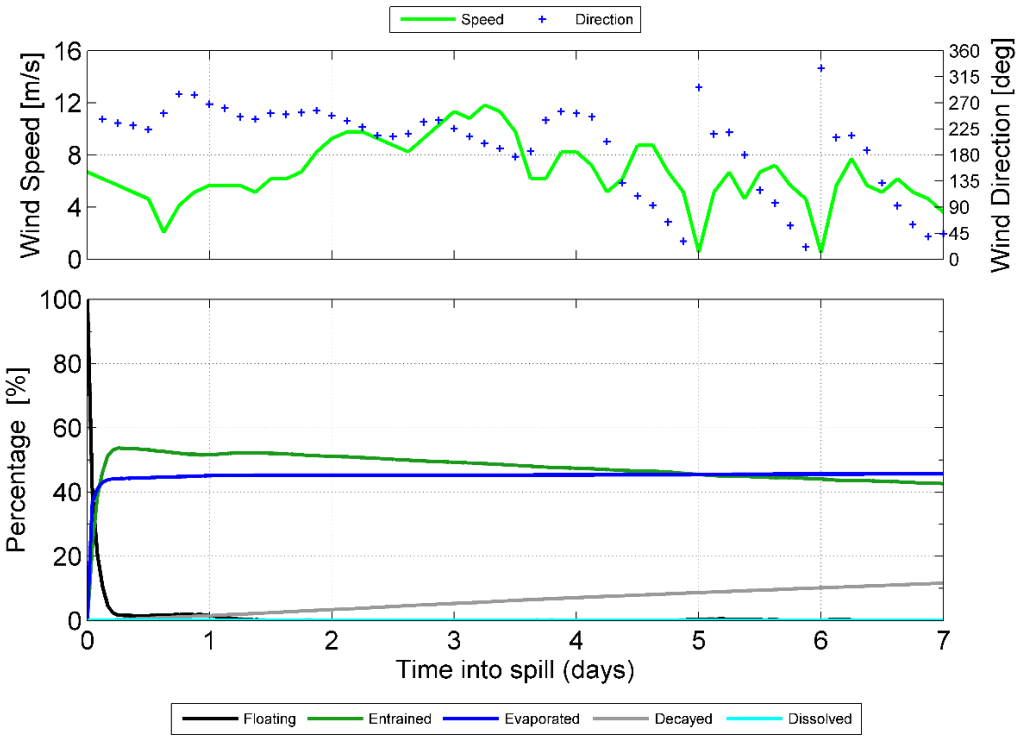


Figure 8-33: Proportional mass balance plot representing the weathering of WTR condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27 °C water temperature

8.15.2.2 modelling outputs

Stochastic modelling outputs for the 1,500 LOWC simulations are summarised in Table 8-100 having regard to the relevant values and sensitivities, as identified in Section 4.

Table 8-103 shows the predicted maximum probability and minimum time to exposure for the listed relevant values and sensitivities. The maximum probability or minimum time values are assigned superscript text to identify which scenario/field it was derived from. If a scenario predicts exposure to a particular

value or sensitivity at or below the maximum values cited, the field is mentioned below the values.

The outcomes of stochastic modelling for each scenario were compared, and the WTR scenario was identified as the worst-case scenario. Table 8-103 shows all values and sensitivities with the potential for hydrocarbon exposure is predicted from the WTR scenario, with the exception of Exmouth Plateau KEF for the Hydrocarbon Ecological EMBA.

For the worst-case WTR LOWC scenario:

- The maximum distance from the release location to the ≥1 g/m^2 visible impact threshold was ~252 km west-southwest (summer), and ~46 km north-northwest (transitional) for the ≥10 g/m^2 impact threshold.
- The probability of contact to any shoreline at ≥10 g/m^2 was greatest during summer at 59%, while the minimum time before shoreline accumulation was ~7 days and the maximum volume of oil ashore above the low threshold was 128 m^3 across Barrow Island and Montebello Islands. No high (≥1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.
- Dissolved oil at ≥50 ppb impact thresholds was predicted to occur; however, remained in the surface layer (<10 m water depth) only. The maximum instantaneous dissolved oil concentration was 56 ppb in the offshore area. No high threshold (≥400 ppb) dissolved oil concentrations were predicted in the modelling results.
- Entrained oil at ≥10 ppb and ≥100 ppb impact thresholds was predicted to occur. The maximum instantaneous entrained oil concentration was 3,989 ppb in the offshore area.

Full stochastic modelling results for the WTR LOWC event and other fields are provided in appendix c.

Table 8-103: Hydrocarbon system stochastic modelling receptor exposure summary

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	Hydrocarbon Ecological EMBA ≥10 g/m²	Hydrocarbon Social and Ecological EMBA ≥50 ppb	Hydrocarbon Social and Ecological EMBA ≥100 ppb	Hydrocarbon Social EMBA ≥10 g/m²	Hydrocarbon Ecological EMBA ≥100 g/m²
		(probability of exposure[190], minimum time to exposure, field source of exposure)[191]		(probability of exposure[190], field source of exposure)[191]	(probability of exposure[190], field source of exposure)[191]	(probability of exposure[190], minimum time to exposure, maximum length of shoreline, field source of exposure)[191]	
AMP	Gascoyne	—	—	—	0–45%[WTR] (Chandon, C&D, G&E, WTR)	—	—
	Montebello	0–77%, 1.21 days[WTR] (C&D, WTR)	—	—	0–78%[WTR] (C&D, G&E, WTR)	—	—
	Ningaloo	—	—	—	0–39%[WTR] (WTR)	—	—
	Shark Bay	—	—	—	0–2%[WTR] (WTR)	—	—
State protected areas	Barrow	—	—	—	—	0–26%, 7.63 days[WTR], 20.1 km[WTR] (C&D, G&E, Semele, WTR)	0–15%, 8.5 days[WTR], 8.3 km[WTR] (WTR)
	Montebello	—	—	—	—	0–36%, 6.5 days[WTR], 16.6 km[WTR]	0–15%, 8.5 days[WTR], 3.3 km[WTR] (WTR)

[190] Ranges in values shown are due to the different results between seasons.

[191] The maximum probability or minimum time values are assigned superscript text to identify which scenario/field it was derived from. If a scenario predicts exposure to a particular value or sensitivity at or below the maximum values cited, the field is mentioned below the values.

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	**Hydrocarbon Ecological EMBA ≥10 g/m²**	**Hydrocarbon Social and Ecological EMBA ≥50 ppb**	**Hydrocarbon Social and Ecological EMBA ≥100 ppb**	**Hydrocarbon Social EMBA ≥10 g/m²**	**Hydrocarbon Ecological EMBA ≥100 g/m²**
		(probability of exposure[190], minimum time to exposure, field source of exposure)[191]		**(probability of exposure[190], field source of exposure)[191]**	**(probability of exposure[190], field source of exposure)[191]**	**(probability of exposure[190], minimum time to exposure, maximum length of shoreline, field source of exposure)[191]**	
						(C&D, G&E, Semele, WTR)	
	Muiron	—	—	—	—	0–29%, 9 days [WTR], 4.1 km [WTR] (C&D, G&E, Semele, WTR)	—
KEF	Ancient coastline at 125 m depth contour	0–100%, 0.3 day [WTR] (C&D, G&E, Semele, WTR)	—	—	0–100% [WTR] (C&D, G&E, Semele, WTR)	—	—
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	—	—	—	0–53% [WTR] (WTR, G&E)	—	—
	Commonwealth waters adjacent to Ningaloo Reef	—	—	—	0–39% [WTR] (WTR)	—	—
	Continental slope demersal fish communities	0–100%, 0.46 days [WTR] (C&D, G&E, Semele, WTR)	0–99%, <0.46 days [C&D] (C&D, WTR)	—	0–100% [WTR] (Chandon, C&D, G&E, Semele, WTR)	—	—
	Exmouth Plateau	0–100%, 0.5 days [Chandon] (Chandon)	0–37%, 1.21 days [Chandon] (Chandon)	—	0–100% [Chandon] (Chandon, G&E, WTR)	—	—

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	**Hydrocarbon Ecological EMBA ≥10 g/m²**	**Hydrocarbon Social and Ecological EMBA ≥50 ppb**	**Hydrocarbon Social and Ecological EMBA ≥100 ppb**	**Hydrocarbon Social EMBA ≥10 g/m²**	**Hydrocarbon Ecological EMBA ≥100 g/m²**
		(probability of exposure[190], minimum time to exposure, field source of exposure)[191]		**(probability of exposure[190], field source of exposure)[191]**	**(probability of exposure[190], field source of exposure)[191]**	**(probability of exposure[190], minimum time to exposure, maximum length of shoreline, field source of exposure)[191]**	
	Glomar Shoals	—	—	—	0–7%[WTR] (WTR)	—	—
World Heritage Properties / National Heritage Places	Ningaloo Coast *(inferred from Ningaloo Coast World Heritage Area IAA)*	0–1%, 10.38 days[WTR] (WTR)	—	—	0–39%[WTR] (WTR)	0–35%, 4.29 days[C&D], 41.4 km[Semele] (C&D, G&E, Semele, WTR)	0–6%, 10.54 days[WTR], 5.8 km[WTR] (WTR)
World Heritage Properties	Murujuga Cultural Landscape *(inferred from Dampier Archipelago IAA)*	–	–	–	0–3%[WTR] (WTR)	0–10%, 16.08 days[WTR] 19.2 km[Semele] (C&D, G&E, Semele, WTR)	–
National Heritage Places	Dampier Archipelago *(inferred from Dampier Archipelago Island Group)*	–	–	–	–	0–4% 34.79 days[WTR] 5.8 km[WTR] (G&E, Semele, WTR)	–
Commonwealth Heritage Properties	Ningaloo Marine Area – Commonwealth waters *(inferred from Ningaloo IMCRA)*	0–1%, 10.38 days[WTR] (WTR)	—	—	0–41%[WTR] (WTR)	—	—

Deterministic analysis of stochastic modelling outputs for each scenario was conducted to determine the largest area exposed by hydrocarbons at impact thresholds for single worst-case simulations. The deterministic analysis provides context of the potential area affected during a single LOWC event as opposed to stochastic modelling, which shows all potential areas affected based on 1,500 LOWC simulation run.

The outcomes of deterministic analyses for each scenario were compared, and the WTR scenario was identified as the clear worst-case scenario.

As such the worst-case deterministic outputs for the WTR scenario will be used in conjunction with the stochastic modelling outputs to inform the following impact and risk evaluation.

8.15.3 impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA that may be impacted by hydrocarbon exposure as a result of an unplanned release of condensate from the hydrocarbon system:

- water quality
- coastal communities and habitats: rocky coasts and sandy beaches
- coastal communities and habitats: intertidal and subtidal corals
- coastal communities and habitats: intertidal mudflats, mangroves, seagrasses
- marine mammals
- reptiles
- fishes, including sharks and rays
- seabirds and shorebirds
- KEFs
- commercial fisheries
- commercial shipping
- petroleum activities
- defence
- tourism and recreation
- AMPs
- cultural heritage values
- cultural heritage value: Traditional Owners.

In-water hydrocarbon exposure above impact thresholds (Hydrocarbon Ecological EMBA) is limited to the upper 30 m of the water column in the offshore area i.e. offshore benthic habitats and associated communities are not predicted to be exposed to in-water hydrocarbons as a result of LOWC. As a result, offshore benthic marine communities and habitats and benthic sediment quality in deeper waters are not expected to be exposed to hydrocarbons during a LOWC event (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462).

Therefore, impacts to benthic sediment quality and benthic habitats and communities from an unplanned release of condensate are not expected and will not be evaluated further.

The likelihood of a LOWC event was assessed using blowout frequencies data (Ref. 465). The frequency of blowouts from normal development wells is estimated to be 6.0 x 10^{-5} per development well. The occurrence of the Montara blowout in 2009 is evidence that a LOWC event from a development well has occurred in Australian waters (Ref. 466).

Offshore drilling operations are dictated by legislative requirements to prevent and manage LOWC events. The inherent legislative requirements ensure unplanned release of hydrocarbons from a hydrocarbon system as an uncommon occurrence, as backed by industry data.

Table 8-104 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to an unplanned release of hydrocarbons in the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA. The hydrocarbon environmental exposure thresholds used in this evaluation are detailed in Table 6-2.

Table 8-104: Risk evaluation for unplanned release—hydrocarbon system (condensate)

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	–	Unplanned release of condensate from the hydrocarbon system may result in: • change in water quality	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • alteration of coastal habitats and associated communities	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • injury or mortality of marine fauna	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of KEFs	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • change to the functions, interests and activities of other marine users	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of Australian Marine Parks	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • change to cultural heritage values	5	5	Very Low (9)

Impact and/or risk level summary					
		Unplanned release of condensate from the hydrocarbon system may result in: • change to cultural heritage values: Traditional Owners.	4	5	Low (8)

Risk evaluation

Water quality

Change in water quality

Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 3,033 km^2 at the low threshold (1 g/m^2) and 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. Within this worst-case modelled run, there are several (seven) periods where floating oil peaks then rapidly declines over the 104 day simulation. For example, the largest swept area of floating oil above 10 g/m^2 predicts a peak impacted area of ~220 km^2 at the low threshold (1 g/m^2) on day 9, which was reduced to ~15 km^2 by day 11. This rapid increase and decrease in area is driven by high rates of spreading and evaporation; and would likely result in impacts to water quality being limited to these short duration spikes. As such, the impact to surface water quality would be expected to be short-term and localised.

The WTR scenario is a subsurface release, and based on the physical composition of the condensate, water quality may also be impacted through the presence of entrained hydrocarbons. These impacts may include increased toxicity and reduced oxygen exchange, and result in bioaccumulation in marine organisms. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb predicts a total impacted area of 45,223 km^2 across the 104 day simulation. During this simulation, the peak area impacted at any one time is ~1,250 km^2. Without any response options applied, entrained condensate may remain suspended in the water column, and naturally degrade and disperse. As a result, hydrocarbon exposure within the water column from a LOWC event is likely to be localised and have short-term changes to water quality. In the event of a LOWC event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of condensate will ensure exposure is limited in areas impacted and duration (Ref. 426). As such, the consequence has been evaluated as Minor (5).

The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5).

Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to water quality is Very Low (9).

Coastal habitats and associated communities: Rocky coasts and sandy beaches

Alteration of coastal habitats and associated communities

Rocky coasts and sandy beaches across the Pilbara range from soft sand beaches to exposed rocky shores (Ref. 429). Oil deposited on soft sandy beaches may penetrate the sand; however, natural processes (e.g. wave action) help disperse stranded oils and mix them into the water column, thus helping sandy beaches recover from light oiling (Ref. 430). Sun and wind can also help break down oil over time, reducing its toxicity and allowing it to be metabolised and degraded by microorganisms in the sand (Ref. 431). At exposed rocky shores, oil is typically helped offshore by reflecting waves—any oil deposited is rapidly removed by wave action. Hydrocarbons present on rocky shores are generally only there for a short period (Ref. 430). Physical dispersion and microorganism degradation processes on shorelines limit changes in sediment quality from hydrocarbon exposure to a short-term period.

Stochastic modelling predicted the greatest probability of shoreline contact above the moderate threshold (10 g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. Further, the modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and

Risk evaluation
Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold) (Section 8.15.2.2). There was no predicted accumulation ≥1,000 g/m^2 predicted to occur. The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). As a result, hydrocarbon exposure to rocky coasts and sandy beaches from a LOWC event is likely to be localised to a small number and sections of shorelines. Further, based on the natural biological and mechanical processes of shorelines and the rapid weathering of condensate, this localised impact is expected to be short term in duration. As such, the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to coastal communities and habitats: rocky coasts and sandy beaches is Very Low (9).
Coastal communities and habitats: intertidal and subtidal corals
Alteration of marine habitats Shoreline and entrained hydrocarbons can have smothering and toxic effects on intertidal and subtidal corals. Direct contact of hydrocarbons to coral can cause smothering, resulting in a decline in metabolic rate, and may cause varying degrees of tissue decomposition and death. A range of impacts may also result from toxicity, including partial mortality of colonies, reduced growth rates, bleaching, and reduced photosynthesis (Ref. 435; Ref. 436). Stochastic modelling predicted that following the LOWC event the presence of in-water hydrocarbons above impact levels are predicted in the surface layers (<10 m water depth) only. As such, exposure to coral reefs or other subtidal habitat types in waters deeper than 10 m (e.g. Rankin Bank or Glomar Shoal) are not predicted occur and therefore are not evaluated further. Smothering of nearshore benthic habitat communities may occur if a surface slick occurs in the shallower subtidal and intertidal area. Given that shoreline contact above ecological impact threshold (≥100 g/m^2) was predicted to occur only in the WTR LOWC scenario (Table 8-103), Modelling predictions for oil ashore from the WTR LOWC scenario were used as indicators for consequence evaluation. Stochastic modelling predicted the greatest probability of shoreline contact above the moderate threshold (10 g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. Further, the modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). This modelling is considered most relevant for nearshore waters and subsequent impacts to subtidal and intertidal corals. Based on the majority of oil becoming stranded onshore and way from subtidal and intertidal corals, and the rapid weathering of condensate, this localised impact is expected to be short term in duration. Therefore, as the extent and duration of exposure to subtidal and intertidal corals in nearshore environments is expected to be limited the potential for environmental impacts would also be limited. As a result, hydrocarbon exposure to subtidal and intertidal corals from a LOWC event is likely to be localised to a small number and sections of shorelines over short term durations. As such, the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to coastal communities and habitats: intertidal and subtidal corals is Very Low (9).
Coastal communities and habitats: intertidal mudflats, mangroves, seagrasses
Alteration of marine habitats Shoreline hydrocarbons can have smothering and toxic effects on intertidal mudflats, mangroves, and seagrasses. Intertidal mudflats, which are typically sheltered and have a large surface area for oil absorption, can trap oil, potentially causing toxicity impacts to infauna. Intertidal mudflats

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are very sensitive to oil pollution because the oil enters lower layers of the mudflats where a lack of oxygen prevents it from decomposing (Ref. 432). Acute and chronic impacts to the health of mangrove communities can occur via pneumatophore smothering and exposure to the toxic volatile fraction of the hydrocarbons (Ref. 432). Intertidal seagrasses are vulnerable to smothering, which can lead to mortality if oil coats their flowers, leaves and stems (Ref. 433; Ref. 434). Stochastic modelling of 300 simulated LOWC events predicted the greatest probability of shoreline contact above the moderate threshold (10g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. No accumulation ≥1,000 g/m^2 was predicted to occur at any location. This higher threshold is typically associated with impacts to coastal vegetation communities. Observations by Lin and Mendelssohn (Ref. 98) demonstrated that loadings of >1,000 g/m^2 of oil would be required to impact plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (e.g. Grant et al. [Ref. 99], Suprayogi and Murray [Ref. 100]). Based on these findings, and limited shorelines where accumulation is predicted above impact thresholds (Hydrocarbon Ecological EMBA), shoreline exposure to intertidal mudflats, mangroves and seagrasses are anticipated to result in localised sublethal effects. As such shoreline exposure to mangroves and intertidal mudflats is not discussed further. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). This modelling is considered most relevant for nearshore waters and subsequent impacts to seagrasses. Based on the majority of oil becoming stranded onshore and away from subtidal seagrasses, and the rapid weathering of condensate, this localised impact is expected to be short term in duration. Therefore, as the extent and duration of exposure to seagrasses in nearshore environments is expected to be limited the potential for environmental impacts would also be limited. As a result, hydrocarbon exposure to intertidal mudflats, mangroves, seagrasses from a LOWC event is likely to be localised to a small number and sections of shorelines over short term durations. As such, the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of an Unplanned release—Hydrocarbon systems (condensate) event to coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses is Very Low (9).
Marine mammals
Injury or mortality of marine fauna Marine mammals can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing the oil, consuming oil-affected prey/vegetation, or inhaling of volatile oil related compounds) (Ref. 92). Direct contact with hydrocarbons may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (Ref. 437). However, direct contact with surface hydrocarbons is considered to have little deleterious effect on marine mammals, given smooth skin surfaces are less likely to suffer from hydrocarbon adherence (Ref. 438). The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable. Depending upon the amount and composition of the ingested oil, the effects could range from acute, to subtle, to progressive organ damage. the susceptibility of marine mammals varies with feeding habits. Baleen whales are not particularly susceptible to ingestion of oil in the water column as they feed by skimming the surface (i.e. they are more susceptible to surface slicks). Toothed whales and dolphins may be susceptible to ingestion of dissolved and entrained oil as they gulp feed at depth. Dugongs may also suffer from long-term chronic effects such as liver problems if they consume oil droplets or oil-affected sea grasses (Ref. 438). Marine mammals are vulnerable if they inhale volatiles when they surface within a hydrocarbon slick. For the short period that they persist, vapours from the spill are a significant risk to mammal health, with the potential to damage mucous membranes of the airways and the eyes, which will

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reduce the health and potential survivability of an animal. Inhaled volatile hydrocarbons are transferred rapidly to the bloodstream and may also accumulate in tissues (Ref. 92). The Hydrocarbon Ecological EMBA includes the presence of BIAs for marine mammals including: • humpback whale BIA (migration) • pygmy blue whale BIA (migration, foraging) • southern right whale BIA (reproduction, migration) • dugongs (breeding, calving, foraging, nursing). Cetacean species are considered most sensitive to surface hydrocarbon exposures, whereas dugongs are considered more sensitive to oil-droplets and oil-affected seagrass as a result of entrained hydrocarbon exposure. Deterministic analyses for surface hydrocarbons for cetaceans and in-water entrained hydrocarbons for dugongs were utilised to understand the potential extent of exposure. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Compared to the total area encompassed by the humpback and pygmy blue whale BIAs, the predicted extent of surface exposure is predicted to be significantly <1% of either BIA. This information indicates that if an unplanned LOWC event occurred, it is unlikely to impact entire humpback and pygmy blue whale populations, resulting in only a localised impact. As such, the impact to surface water quality would be expected to be short-term and localised. Dugongs undertaking breeding, calving, foraging, nursing behaviours in nearshore waters have shown high site fidelity to habitats required to facilitate these behaviours (Ref. 439). This high-site fidelity when undertaking critical behaviours increases their sensitivity to hydrocarbon exposures as they are less likely to be transient. Stochastic modelling predicted a 34% probability of the dugong BIA being contacted by entrained hydrocarbons in the 0-10 m layer and the high (impact) threshold. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb within the dugong BIA predicts the cumulative swept area above 100 ppb to be ~800 km^2 and the peak (largest area impacted at any one time) to be ~100 km^2. Using the dugong BIA area, modelling indicates that the extent of entrained exposure was predicted to be limited to ~7% of the entire BIA. In the event of a LOWC event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of condensate will ensure exposure to dugongs is limited in areas impacted and duration. Based on an assessment of the predicted magnitude of surface and in-water hydrocarbons at levels above impact thresholds, it is expected that there is potential for short-term and localised impact to marine mammals. Given the localised, short-term impact to a marine mammal population the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to marine mammals is Very Low (9).
Marine Reptiles
Injury or mortality of marine fauna Reptiles may be exposed to surface and shoreline hydrocarbons from an unplanned release of condensate from a LOWC event. Reptiles can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds) (Ref. 440). Hydrocarbon exposure has the potential to cause injury or mortality to reptiles. Marine turtles are vulnerable to the effects of oil at all life stages: eggs, hatchlings, juveniles, and adults. Several aspects of turtle biology and behaviour place them at risk, including a lack of avoidance behaviour, indiscriminate feeding in convergence zones, and large pre-dive inhalations

Risk evaluation

(Ref. 438). Oil effects on turtles can include impacts to the skin, blood, digestive, and immune systems, and increased mortality due to oiling.

Shoreline hydrocarbons can impact turtles coming ashore at nesting beaches. Eggs may also be exposed during incubation, potentially resulting in increased egg mortality and detrimental effects on hatchlings. Hatchlings may be particularly vulnerable to toxicity and smothering as they emerge from the nests and make their way over the intertidal area to the water (Ref. 440).

Light oils, such as unweathered condensate, expose marine reptiles to volatile polycyclic aromatic hydrocarbons (PAHs) which may result in breathing, sight, or gastro-intestinal injuries (Ref. 24). The volatile PAHs can penetrate the skin of sea snakes and carapace of marine turtles affecting respiration, salt gland function and blood chemistry (Ref. 24). These injuries to marine reptiles can result in decreased health, starvation, increased stranding, and decreased breeding condition (Ref. 24). Sudden high toxic contaminant load during pre-dive inhalations have caused instantaneous death to marine turtles and is to be expected with sea snakes (Shigenaka 2021 cited in Ref. 441).

The Hydrocarbon Ecological EMBA includes BIAs for flatback, loggerhead, green and hawksbill turtles, based on predicted shoreline hydrocarbons exposure at concentrations greater than the impact thresholds. The flatback turtle internesting BIA is predicted to be exposed to surface hydrocarbon concentrations greater than impact thresholds due to the fact that the receptor overlaps with the release location. The behaviours associated with these BIAs include aggregation, basking, foraging, internesting, mating, and nesting. The Hydrocarbon Ecological EMBA does not overlap sea snake BIAs.

Table 6-12 lists key nesting areas in the Hydrocarbon Ecological EMBA predicted to be exposed to shoreline hydrocarbons concentrations greater than the impact thresholds. These areas are identified as HCTS of flatback, green, hawksbill and loggerhead turtles (Section 6.3.3.2). As such nesting adult turtles and hatchlings may be exposed as they traverse the intertidal area, resulting in potential smothering and acute impacts to some hatchlings during that nesting season. As a result, a small proportion of any reptile population would be exposed above the defined impact thresholds, for a limited duration.

Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Based on the rapid weathering of the condensate, volatile PAHs which are known to cause breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off out of the stranded oils, leaving mostly waxy residues that don't result in the same level of impacts.

Further, the deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Using the flatback turtle internesting BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA over limited timeframes. This information indicates that if a LOWC event occurred during the nesting season, it is unlikely to impact entire local nesting populations.

The EPBC threatened short-nosed sea snake, and other EPBC marine listed sea snake species, may be present within the Hydrocarbon EMBAs. Oil pollution has been identified as a pressure 'of potential concern' (Ref. 287) to sea snakes[192]. Sea snakes are susceptible to oil on the sea surface (Ref. 287; Ref. 442; Ref. 443). Being air breathers and obligate bottom feeders, oil may be either inhaled or ingested (Ref. 287; Ref. 444). As described above, surface oil exposure above impact thresholds is predicted to only be present for a short duration and over localised

[192] The pressure analysis distinguished between oil pollution from shipping ('of less concern') and oil rigs ('of potential concern') (Ref. 292). Although the aspect source for this risk assessment is a spill from a vessel, the higher pressure concern has been adopted.

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areas. Any exposure to benthic habitats is only predicted to occur within nearshore (<10 m water depth) areas. Using the shoreline exposure described above as indicative of oil presence in a nearshore environment, the duration and extent of exposure from a single spill event is predicted to be limited. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any reptile population would be exposed above the defined impact thresholds over a short-term period. Given the localised, short-term impact to a small proportion of any reptile population the consequence of this scenario has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to marine reptiles is Very Low (9).
Fishes, including sharks and rays
Injury or mortality of marine fauna Fishes, including sharks and rays, may be exposed to surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. Although most fishes do not break the sea surface, some shark species (including whale sharks) feed in surface waters, so there is also the potential for surface hydrocarbons to be ingested. Potential effects include damage to the liver and lining of the stomach and intestine, and toxic effects on embryos (Ref. 435). Fishes are most vulnerable to oil during embryonic, larval and juvenile life stages. However, very few studies have demonstrated increased mortality of fish as a result of oil spills (Ref. 432; Ref. 436; Ref. 445). Demersal fishes are not expected to be impacted given the presence of in-water hydrocarbons is predicted in the surface layers (<30 m water depth) only, outside of the plume cone at the subsea release location. Pelagic free-swimming fishes and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (Ref. 82). Pelagic species are also generally highly mobile and as such are not likely to suffer extended exposure (e.g. >48–96 hours) at concentrations that would lead to chronic effects due to their patterns of movement. Near the sea surface, fish can detect and avoid contact with surface slicks meaning fish mortalities rarely occur in the event of a hydrocarbon spill in open waters (Ref. 446). Fish that have been exposed to dissolved hydrocarbons can eliminate the toxicants once placed in clean water; hence, individuals exposed to a spill are likely to recover (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). Marine fauna with gill-based respiratory systems, including whale sharks, are expected to have higher sensitivity to exposures of entrained oil. The Hydrocarbon Ecological EMBA includes the presence of whale shark foraging BIA. As these species are considered most sensitive to surface exposures, stochastic and deterministic analyses were utilised to understand the potential extent of exposure. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Using the whale shark BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. Based on an assessment of the predicted magnitude of surface hydrocarbons at levels above impact thresholds, it is expected that only a small proportion of any fish population would be exposed above the defined impact thresholds. Therefore, the consequence of this scenario has been evaluated as Minor (5) given the localised, short-term impact to a small proportion of any fish population. The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in

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place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to fishes, including sharks and rays is Very Low (9). **Injury or mortality of marine fauna (fish eggs and larvae)** Plankton may be exposed to surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. Plankton can be exposed to hydrocarbons through ingestion, inhalation, and dermal contact (Ref. 468). Plankton is a collective term for all marine organisms that are unable to swim against a current. This group is diverse and includes zooplankton (animals) such as fish eggs and larvae. Zooplankton are typically sensitive to oil (Ref. 469). Exposure of zooplankton to surface and in-water hydrocarbons can cause immediate mortality or declines in reproduction (Ref. 469). Lethal and sublethal effects on zooplankton include narcosis, alterations in feeding, development, and reproduction (Ref. 470). As a result, plankton within the Hydrocarbon Ecological EMBA are potentially susceptible to injury or mortality. Low nutrient levels within the Hydrocarbon Ecological EMBA indicates sparse populations of plankton species as represented throughout the NWS (Ref. 103). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 103). Plankton populations have evolved to respond to environmental perturbations by copious production within short generation times (Ref. 471). Plankton have rapid recovery and growth rates (Ref. 472; Ref. 473). Once background water quality conditions have re-established post well kill, the plankton community may recover within weeks to months (Ref. 471). An assessment of surface and in-water hydrocarbon modelling is considered most relevant of this receptor. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 30 imulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb predicts a total impacted area of 45,223 km^2 across the 104 day simulation. During this simulation, the peak area impacted at any one time is ~1,250 km^2. Without any response options applied, entrained condensate may remain suspended in the water column, and naturally degrade and disperse. As a result, hydrocarbon exposure within the water column from a LOWC event is likely to be localised and have short-term changes to water quality. Based on an assessment of the predicted magnitude and duration of surface and in-water hydrocarbons, it is expected that sparse plankton populations would be exposed above the defined impact thresholds over a short-term period. In addition, recovery of plankton populations is expected over a short-term period. Therefore, the consequence of this scenario has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to plankton is Very Low (9).
Seabirds and shorebirds
Injury or mortality of marine fauna Seabirds that rest at the water's surface (e.g. shearwaters) or surface-plunging birds (e.g. terns, boobies) may be exposed to surface hydrocarbons from an unplanned release of condensate from a LOWC event (Ref. 91; Ref. 438). Whereas shorebirds may be exposed to shoreline hydrocarbons from an unplanned release of condensate from a LOWC event. Damage to external tissues, including skin and eyes, can occur, along with internal tissue irritation in lungs and stomachs (Ref. 447). Acute and chronic toxic effects may result where the product is ingested as the bird attempts to preen its feathers (Ref. 447).

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The Hydrocarbon Ecological EMBA includes the presence of breeding BIAs for seabirds and shorebirds including:

- fairy tern
- lesser crested tern
- roseate tern
- wedge-tailed shearwater
- white-tailed tropicbird.

Roosting gulls and terms along sandy parts of the Ningaloo coast have been recorded including fairy terns, lesser crested terns, (Surman & Nicholson 2015 cited in Ref. 448). Breeding population of roseate terns have been recorded at the Lowendal Islands (Ref. 183). Wedge-tailed shearwaters forage relatively close to their breeding islands, which in the NWMR include Dampier Archipelago, Passage Island, Lowendal Island, islands off Barrow Island among others (Ref. 170). Northern Australia white-tailed tropicbird forages in warm waters and over long distances, moving up to 1,500 km from breeding sites (Ref. 171).

Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). With the exception of the wedge-tailed shearwater BIA, in which the release location resides, there were no other BIAs impacted at or above the moderate threshold. Further, the deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Based on the size of the fairy tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs, the modelling indicates that the extent of surface exposures was predicted to be limited to <1% of all breeding BIAs.

Birds can also be impacted by oil stranded on shorelines. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~ 90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Based on the rapid weather of the condensate, the volatile PAHs which are known to breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off leaving mostly waxy residues that don't result in the same level of impacts.

Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small, localised proportion of any seabird or shorebird population would be exposed above the defined impact thresholds over a short-term period. Given the localised, short-term impact to a small proportion of any seabird or shorebird population the consequence of this scenario has been evaluated as Minor (5).

The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to seabirds and shorebirds is Very Low (9).

KEFs

Change to values and sensitivities

Section 6.3.6.1 lists the KEFs present in the Hydrocarbon Social EMBA. Stochastic modelling (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462; appendix c) predicts entrained hydrocarbon exposure at the high (impact) threshold is limited to the upper water column (0–30 m). Given this extent of hydrocarbon exposure within the water column, potential impacts are limited to values within these KEFs:

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- Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula
- Commonwealth waters adjacent to Ningaloo Reef

As identified in Section 6.3.6.1, the values of these KEFs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as identified BIAs for regionally significant marine fauna.

The consequence evaluations to marine fauna and commercial fisheries are provided above.

The following KEFs, whilst also present in the Hydrocarbon Social EMBA; have values that relate to benthic habitats or demersal fish, and therefore hydrocarbon exposure is not feasible for an unplanned LOWC event in offshore waters:

- Glomar shoals KEF contains a submerged littoral feature found in water depths of 33–77 m (Ref. 109)
- ancient coastline at 125 m depth contour and Exmouth Plateau KEFs have benthic habitat values
- continental slope demersal fish communities KEF has values relating to fishes that live and feed near the seabed.

Based on the modelling, the predicted area of entrained oil above the high threshold is mostly limited to the upper 10m of the water column. As such, any impact would be localised to the upper layers of the KEFs and not impact any values and sensitivities that exist below this surface layer. Given the localised and short-term, hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds, the risks of a LOWC event to the values and sensitivities of the listed KEFs has been evaluated as Minor (5).

The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5).

Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to KEFs is Very Low (9).

Commercial fisheries

Change to the functions, interests and activities

An unplanned release of condensate from a LOWC event may result in changes to the functions, interests, or activities of commercial fisheries within the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA.

Commercial fishing has the potential to be impacted through exclusion zones associated with the unplanned release of condensate from a LOWC event, and subsequent reduction in fishing effort. Exposure of commercially targeted marine species to in-water hydrocarbons can have economic impacts to the industry. Exclusion zones may impede access to commercial fishing areas, for a short period of time, and nets and lines may become oiled. Actual or potential contamination of seafood can affect commercial fisheries and can impact seafood markets long after any actual risk to seafood from a spill has subsided (Ref. 474). Such that, the impacts to commercial fishing from a public perception may be much more significant and longer term than the actual spill.

As identified in Section 6.4.1, several Commonwealth- and State-managed commercial fisheries have management areas and recent fishing effort recorded within the Hydrocarbon Ecological and Social EMBAs:

- Commonwealth—NWSTF, WDTF, and WTBF
- State—
  - wild catch fisheries—Mackerel Managed Fishery, Nickol Bay Prawn Managed Fishery, Onslow Prawn Managed Fishery, Pilbara Crab Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery (Condition), Pilbara Trap Managed Fishery, West Australian Sea Cucumber (Beche-De-Mer) Fishery, Exmouth Gulf Prawn Managed Fishery, Gascoyne Demersal Scalefish Fishery. West Coast Deep Sea Crustacean Fishery, Open Access in the North Coast, Gascoyne Coast and West Coast Bioregions
  - collector fisheries—Marine Aquarium Fish Managed Fishery, Specimen Shell Managed Fishery, Hermit Crab Fishery.

Concentrations of petroleum contaminants in fish and crustacean and mollusc tissues could pose a significant potential for adverse human health effects, and until these products cleared by the health authorities, they could be restricted for sale and human consumption. Uptake of

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hydrocarbons has been demonstrated in bony fish after exposure to water-accommodated fraction (WAF) of between 24 and 48 hours. Davis et al (Ref. 451) reported detectable tainting of fish flesh after a 24 hour exposure to marine fuel oil concentrations of 0.33 ppm and diesel concentrations of 0.25 ppm. Most studies, either from laboratory trials or of fish collected after release events (including the Hebei Spirit, Macondo, and Sea Empress spills) find evidence of elimination of PAHs in fish tissues returning to reference levels within two months of exposure (Ref. 451; Ref. 452; Ref. 453; Ref. 454; Ref. 455; Ref. 456; Ref. 457). The Montara spill of a light gas condensate, (as the most recent [2009] example of a large hydrocarbon spill in Australian waters) occurred over an area fished by the Northern Demersal Scalefish Managed Fishery (with 11 licences held by seven operators), with goldband snapper, red emperor, saddletail snapper and yellow spotted rockcod being the key species fished (Ref. 458). As a precautionary measure, the WA Department of Fisheries advised the commercial fishing fleet to avoid fishing in oil-affected waters. Testing of fish caught in areas of a visible slick (November 2009) found that there were no detectable petroleum hydrocarbons in fish muscle samples, suggesting fish were safe for human consumption. Limited ill effects were detected in a small number of individual fish only (Ref. 458). No consistent effects of exposure on fish health could be detected within two weeks following the end of the well release. Follow up sampling in areas affected by the spill during 2010 and 2011 (Ref. 458) found negligible ongoing environmental impacts from the spill. Any acute impacts to commercially targeted marine species are expected to be limited to small numbers of juvenile fish, eggs and larvae (refer to plankton evaluation in Fishes, including sharks and rays section above), which are not expected to affect population viability or recruitment. Impacts from in-water hydrocarbon exposure are unlikely to manifest at a fish population viability level (refer to Fishes, including sharks and rays section above). In an unplanned release of condensate from a LOWC event, any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to vessels is unlikely to be a significant impact. However commercial fishers themselves may voluntarily implement an exclusion zone until water quality monitoring verifies the absence of residual hydrocarbons, as such providing confidence to consumers in fisheries tainting. Residual condensate may foul the hulls of fishing vessels and associated equipment, such as gill nets. A temporary fisheries closure, combined with oil tainting of target species (actual or perceived), may lead to financial losses to fisheries and economic losses for individual licence holders. Fishery closures and the flow on losses from the lack of income derived from these fisheries are likely to have short-term socio-economic consequences, such as reduced employment (in fisheries service industries, such as tackle and bait supplies, fuel, marine mechanical services, accommodation and so forth). Minor loss of revenue for commercial fisheries in the Hydrocarbon Ecological and Social EMBAs and acute impacts juvenile fish, eggs and larvae of commercially targeted marine species in the Hydrocarbon Ecological EMBA has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to commercial fisheries is Very Low (9).
Commercial shipping
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests or activities of commercial shipping within the Hydrocarbon Social EMBA. Commercial shipping has the potential to be impacted through exclusion zones associated with the unplanned release of condensate from a LOWC event. Exclusion zones may impede access to areas, for a short-term period. Any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to vessels is unlikely to be a significant impact. As a result, physical displacement of commercial vessels will be limited to a temporary and localised area. Therefore, it has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to

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1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to commercial shipping is Very Low (9).
Petroleum activities
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests, or activities of petroleum activities within the Hydrocarbon Social EMBA. Following the Deepwater Horizon incident in the Gulf of Mexico in 2011, the US Government placed a moratorium on new drilling permits, and other regulatory actions. The number of rigs drilling for oil dropped for a period and recovered slowly. However, by 2016, oil production in the Gulf of Mexico hit a record high (Ref. 475). Based on the slow recovery rate of regulatory actions in the Gulf of Mexico following the Deepwater Horizon incident, it is assumed that petroleum activities within the Northern Carnarvon Basin will also have a slow recovery following a moratorium on petroleum activities. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). Petroleum operators and activities within 50 km of the DA are described in Table 6-25. The potential placement of a moratorium on these petroleum activities is considered a localised area considering the numerous active oil, condensate, and gas facilities in the Northern Carnarvon Basin. The moratorium established would likely be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted. The duration of the potential moratorium is considered short-term. Change to the functions of petroleum activities in the Hydrocarbon Social EMBA has been evaluated as Minor (5) because of the localised, short-term impact. The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to petroleum activities is Very Low (9).
Defence
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests or activities of Defence activities within the Hydrocarbon Social EMBA. Defence practice and training areas in the Hydrocarbon Social EMBA include: • Defence—Exmouth VLF transmitter station • Defence—Exmouth admin and HF transmitting • Defence—Learmonth radar site, Vlamingh Head • Defence—Learmonth air weapons range. The Learmonth RAAF base extend offshore as a designated maritime firing practices and exercise area. In-water hydrocarbon exposure is not expected to adversely impact the use of these areas. Any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to Defence activities is unlikely to be a significant impact. A LOWC event duration is anticipated to be 90 days until well kill. Post well kill, remaining surface hydrocarbons would be exposed to processes such as dispersion, dilution, physical and biological degradation. These processes will ensure surface hydrocarbon exposure is limited to several

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weeks post well kill. As a result, change to the functions of Defence activities in the Hydrocarbon Social EMBA has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to Defence activities is Very Low (9).
Tourism and recreation
Change to the functions, interests and activities Tourist destinations present in the Hydrocarbon Social EMBA may be exposed to shoreline, surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. The presence of hydrocarbons in these tourist destinations may reduce the visual amenity in the area; and given these destinations are exclusively nature-based tourism, potential environmental impacts to these places may also reduce tourism visitation numbers. A number of tourism destinations occur within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA, including: • Great Sandy Islands • Montebello Islands • Passage Islands • Cape Range National Park • Ningaloo Coast • Point Cloates / Ningaloo Station area • Dampier Archipelago islands. The reduction of tourist visitation numbers may lead to a minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures). Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). Based on the distance between the tourism receptors listed above, it is not possible that all locations would be impacted from a single event, and any impacts to be localised at the particular location. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Shoreline, surface, and in-water hydrocarbons would be exposed to processes such as dispersion, dilution, physical and biological degradation. These processes will ensure hydrocarbon exposure to tourist destinations is limited to a short-term period. Therefore, it has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to tourism and recreation is Low (9).

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AMPs
Change to values and sensitivities An unplanned release of condensate from a LOWC event may result in change to values and sensitivities of AMPs. As detailed in Table 8-103, the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA overlap the following AMPs: • Gascoyne • Montebello • Ningaloo • Shark Bay Stochastic modelling predicts a 13% probability of surface condensate exposure to the Montebello AMP. No other AMPs were predicted to be contacted by surface hydrocarbons at any threshold. Values and receptors of AMPs within the water column may also be impacted. At the moderate threshold, modelling predicted 2% (summer) probability of dissolved oil exposure within the Gascoyne Marine Park, 3% (winter) probability within the Montebello Islands Marine Park, and a 1% (transitional) probability within the Ningaloo Marine Park. With respect to entrained hydrocarbons, the modelling predicted a probability of contact at the high threshold (100 ppb) of 45% (transitional) for the Gascoyne Marine Park, 78% (transitional) for the Montebello Islands Marine Park, 39% (winter) for Ningaloo Marine Park and 2% (summer) for the Shark Bay Marine Park. As identified in Section 6.5.1, the natural values of the above listed AMPs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for regionally significant marine fauna. Social and economic values of the listed AMPs include commercial fishing. The consequence evaluations to specific marine fauna and commercial fisheries are provided above. Given the temporary and localised hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds the potential risks of an unplanned release of condensate from a LOWC event to the values and sensitivities of the listed AMPs has been ranked as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to AMPs is Very Low (9).
Cultural heritage values
Change to values and sensitivities An unplanned release of condensate from a LOWC event may result in change to values and sensitivities of heritage values. As identified in Table 6-29 there are heritage listed places or sites within the Hydrocarbon EMBAs, including World and National Heritage listed Ningaloo Coast, World Heritage listed Murujuga Cultural Landscape, Commonwealth Heritage listed Ningaloo Marine Area, National heritage listed Dampier Archipelago, Native Title determination areas, as well as several protected First Nation sites or artefacts along (or adjacent to) the coast. Note: The risk assessment of changes to cultural heritage values for Traditional Owners is conducted separately and is therefore not further discussed in this section. This includes the Murujuga Cultural Landscape World Heritage property (inscribed on the World Heritage list for outstanding cultural significance) and Dampier Archipelago National Heritage place (listed as an Indigenous place). Protected UCH sites have been identified within the Hydrocarbon EMBAs; these sites are related to shipwrecks, with no other types (e.g. aircraft or other artefacts) identified (Table 6-29). Stochastic modellings did not predict interaction with seabed in offshore waters. Therefore, no impacts to seabed-based UCH are expected. Stochastic modelling for LOWC events in all fields predicted up to a 6% probability of shoreline contact at the ecological impact threshold (≥100 g/m^2), and up to a 35% probability of shoreline

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contact at the social impact threshold (≥10 g/m^2) for the Ningaloo Coast World Heritage Area (Table 8-103). The stochastic modelling also predicted up to a 39% probability of exposure to entrained oil (≥100 ppb) and up to a 1% probably of exposure to surface oil at the visual (≥1 g/m^2); there was no exposure at ecological surface oil (≥10 g/m^2) or dissolved oil (≥50 ppb) thresholds (Table 8-103). As identified in Section 6.6.1, heritage values for the Ningaloo Coast include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for regionally significant marine fauna. The intertidal systems of the Ningaloo Coast World Heritage Area are also considered high diversity habitats that sustains the presence of species listed under the EPBC Act and resultant tourism in the area. The consequence evaluations to marine fauna, marine habitat and tourism and recreation are provided above and were assessed as having a minor environmental impact. Given the temporary and localised hydrocarbon exposure along the Ningaloo Coast and Dampier Archipelago, the risks of an unplanned release of condensate from a LOWC event to the values and sensitivities has been ranked as Minor (5). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to Cultural heritage values is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned release of condensate from a LOWC event includes: • potential indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna • potential impacts to tangible Traditional Owner heritage from hydrocarbon exposure of protected First Nation sites or artefacts As discussed in Section 6.6.4, at the time of writing this OPP, CAPL understands through consultation with Traditional Owners that there are no artefacts or specific sites on the seabed within the EMBAs that have, or are associated with, cultural heritage values. As identified from literature and/or consultation (Section 6.3.5.2.1), Sea Country is a value for First Nations people. The waters of the NWMR (and therefore the waters within the Hydrocarbon EMBAs) are acknowledged as potentially having some cultural and spiritual significance to First Nations as well as providing natural resources (Section 6.3.5.2.1). The Hydrocarbon EMBAs intersect with the coast of the North West Cape peninsula and Dampier Archipelago, along or adjacent to which, cultural heritage sites or artefacts are located. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 426). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 3,033 km^2 at the low threshold (1 g/m^2) and 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. Within this worst case modelled run, there are several (seven) periods where floating oil peaks then rapidly declines over the 104 day simulation. For example, the deterministic run for the largest swept area of floating oil predicts a peak impacted area of ~220 km^2 at the low threshold (1 g/m^2) on day 9, which was reduced to ~15 km^2 by day 11. The low threshold represents presence of oil. Any ecological impact is not predicted to occur until oil gets above the moderate threshold. Using the same deterministic run, the analysis predicts that on most days the floating oil at the impact threshold impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. As such, potential impacts would be expected to be short-term and localised. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared

Risk evaluation
with the other LOWC scenarios modelled. (Ref. 426; Ref. 459; Ref. 460; Ref. 461; Ref. 462). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Cultural heritage values of both the Murujuga Cultural Landscape (Section 6.6.2) and the Dampier Archipelago (Section 6.6.3) include one of the densest and most diverse collections of petroglyphs in the world. Both heritage listed areas hold cultural and spiritual significance to the Traditional Owners. Stochastic modelling for LOWC events in all fields predicted up to a 10% probability of shoreline exposure at the social impact threshold (≥10 g/m^2) for Murujuga Cultural Landscape, and up to 4% at Dampier Archipelago; there was no exposure predicted to occur above the ecological (≥100 g/m^2) shoreline threshold (Table 8-103). Shoreline loading can impact the visual amenity of coastal areas and limit beach access. However, if shoreline contact occurs, based on stochastic modelling it is expected to result in a limited volume accumulating ashore. As such, given the volume, type of oil (condensate) and predicted weathering, no prolonged impact pathway to a change in access to Country is anticipated. Given the volume, type of oil (condensate) and predicted weathering, no prolonged impact pathway to a change in access to Country is anticipated. Based on the temporary and localised, exposure of hydrocarbons, the risks of potential changes to Traditional Owner cultural heritage values from an unplanned release of condensate from a LOWC event has been ranked as Moderate (4). The blowout frequencies data from IOGP (Ref. 467) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to Traditional Owner cultural heritage values is Low (8).

8.15.4 determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-105 details the determination of acceptability for Unplanned release—Hydrocarbon system (condensate).

Table 8-105: Determination of acceptability for Unplanned release—Hydrocarbon system (condensate)

Determination of acceptability	
Comparison with acceptable level	The acceptable level for this aspect is **AL-23**, as defined in Table 7-6 and shown below in Section 8.15.5. The intent of adopting and implementing preventive control measures (Section 8.15.5) is to prevent the occurrence of an unplanned hydrocarbon release to the environment. This preventative approach ensures that **AL-23** is met. In the event that an unplanned release of condensate did occur, the above risk evaluation demonstrates that the predicted impact is expected to be minor and recoverable.
Principles of ESD	**(b) 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 highest residual risk level for unplanned release of condensate from the hydrocarbon system was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage, and no further evaluation against principle of ESD (b) is required. Notwithstanding, CAPL also notes that:

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">

The spill modelling (appendix c) provides scientific certainty to inform the risk evaluation for unplanned release of condensate. The literature review undertaken as part of the risk evaluation provides scientific certainty for the types of potential effects and recovery for receptors that may be at risk.
Prevention measures for unplanned release of condensate from the hydrocarbon system are well regulated and managed in Australian waters (e.g. implementation of Marine Orders).
To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the EPOs and control measures detailed below will be adopted.

</td></tr>
<tr><td></td><td colspan="2">(c) the principle of inter-generational 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</td></tr>
<tr><td></td><td colspan="2">
The Development is consistent with principle of ESD (c) for this aspect as:

The Development is committed to applying measures to prevent the risk of unplanned release of condensate from the hydrocarbon system based on relevant legislation and other requirements as listed below.
The regulation and management of unplanned releases of hydrocarbons in Australian waters ensures health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest residual risk level for unplanned release of condensate from the hydrocarbon system was evaluated as Minor (5). Therefore, in accordance with Table 7-7, this does not represent a threat of serious or irreversible environmental damage.
Any relevant stakeholder feedback in relation to unplanned release of condensate from the hydrocarbon system has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">
Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk to the environment (Section 5).
The Development is consistent with principle of ESD (d) for this aspect through the consideration of conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.
</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address relevant item/objective/action within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>OPPGS(E)R
An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity prior to activities commencing.</td><td rowspan="2">Legislative requirements are addressed by adoption of the following control measures:
• CM-16
• CM-22
• CM-31
• CM-32
• CM-33</td></tr>
<tr><td></td><td>Navigation Act 2012 – Chapter 4 (Prevention of Pollution).</td></tr>
</table>

Determination of acceptability		
	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Maintaining and disseminating navigational charts and publications, including providing safety-critical information to mariners via the Notice to Mariners system.	• **CM-43** • **CM-44** • **CM-45** • **CM-46** (see Section 8.15.5).
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 24) Action A4.2: • Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs. Note: This is also a specific action identified for the G-NWS, LH-WA, and F-Pil individual stocks.	EPBC management plan requirements to minimise habitat degradation / modification, including marine pollution, are addressed by adoption of the following control measure: • **CM-44**. Response and recovery of habitats and marine fauna is within the scope of the approved OSMP. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 27) Action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 26) Action: Ensure there is no disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 28) Action 5c: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 40) Action 5c: Risk based response strategies for marine pollution incidents are developed. Action 5b (adapted): Undertake, as feasible, monitoring of breeding	

Determination of acceptability		
	colonies for marine pollution impacts, including as a priority: • incidence of oiled birds at nest • effect of marine pollution.	
	Wildlife Conservation Plan for Seabirds (Ref. 38) Action 2h: Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 39) Action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes	
	Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 43) Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 20) **Conservation Advice *Balaenoptera physalus* Fin Whale** (Ref. 21) **Conservation Advice *Balaenoptera borealis* Sei Whale** (Ref. 22) **National Recovery Plan for the Southern Right Whale (*Eubalaena australis)*** (Ref. 23) **Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish)** (Ref. 29) **Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*)** (Ref. 32) **Recovery Plan for the White Shark (*Carcharodon carcharias*)** (Ref. 34). **Conservation Advice *Rhincodon typus* Whale Shark** (Ref. 33). **National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*)** (Ref. 44) **Conservation Advice *Calidris ferruginea* curlew sandpiper** (Ref. 48) **Conservation Advice *Numenius madagascariensis* eastern curlew** (Ref. 49)	These EPBC management plans for species that may occur within the Hydrocarbon Social or Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat; but do not identify any relevant actions.

Determination of acceptability		
	Conservation Advice *Calidris canutus* Red knot (Ref. 54) **Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper)** (Ref. 56) **Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit)** (Ref. 52) **Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover)** (Ref. 50) **Conservation Advice for *Tringa nebularia* (Common Greenshank)** (Ref. 47) **Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher)** (Ref. 42) **Conservation Advice for *Sousa sahulensis* (Australian humpback dolphin)** (Ref. 663) **Conservation Advice for *Orcaella heinsohni* (Australian snubfin dolphin)** (Ref. 664)	
	North-west Marine Parks Network Management Plan The Plan requires that "[a]ctions required to respond to oil pollution incidents, including environmental monitoring and remediation, in connection with mining operations authorised under the OPGGS Act may be conducted in all zones. The Director should be notified in the event of an oil pollution incident that occurs within, or may impact upon, an Australian Marine Park and, so far as reasonably practicable, prior to a response action being taken within a marine park."	Protected area requirements to respond to an Unplanned release—Hydrocarbon system (condensate), including notifying, environmental monitoring, and remediation, authorised under the OPGGS Act are addressed by adoption of the following control measure: • **CM-44**.
	Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves The plan requires that: • "there are appropriate predictive models and specific management plans (given location and weather conditions) for oil spills to assist the State Committee for Combating Oil Pollution in managing any pollution event that occurs" against the water quality KPI. • "Ensure the State Committee for Combating Oil Pollution has access to data relevant to the management of oil spills" against the coral reef communities KPI	

Determination of acceptability		
	Nyinggulu (Ningaloo) Coastal Reserves: Red Bluff to Winderabandi joint management plan 101 The plan requires that: • "Implement the regional response plan for wildlife affected by shipping and boating pollution, such as oil spills in line with national and state plans"	Protected area requirements to respond to an Unplanned release—Hydrocarbon system (condensate), including notifying, environmental monitoring and remediation, in accordance with National Plan for maritime environmental emergencies (Ref. 476), State hazard plan for maritime environmental emergencies (Ref. 477) and Western Australian oiled wildlife response plan (Ref. 478) are addressed by adoption of the following control measure: • **CM-44**.
	Management Plan Jurabi and Bundegi Coastal Parks, and Muiron Islands The plan generally states: • "Minimise adverse impact on flora and fauna from management actions or visitor activities."	
Internal context	This procedure was deemed relevant for this aspect: • Chevron Shipping's Marine Standard Non Tankers (Ref. 265).	
External context	CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since the inception of engagement during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation where relevant as part of Phase 1 consultation undertaken during the development of the OPP and Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.3.5 and 6.6.4). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM-07** and **CM-08**). No further feedback was received in relation to unplanned release of condensate from the hydrocarbon system from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

8.15.5 environmental performance

Table 8-106 provides the EPO/s defined for unplanned release—hydrocarbon system and the adopted control measures to achieve the outcome.

Table 8-106: Environmental performance for unplanned release—hydrocarbon system (condensate)

Acceptable levels	Environmental performance outcomes	Adopted control measures
AL-23: No unplanned release of hydrocarbons to the marine environment from the Development.	**EPO-38**: No unplanned release of hydrocarbons to the environment attributable to the Development.	**CM-32**: Vessels operating within the Development Area will comply with requirements within Marine Order 27—Safety of navigation and radio equipment.

Acceptable levels	Environmental performance outcomes	Adopted control measures
		CM-33: Vessels operating within the Development Area will comply with requirements within Marine Order 28—Operations standard and procedures. **CM-16**: Vessels operating within the Development Area will comply with requirements within Marine Order 30—Prevention of collisions. **CM-22**: Vessels operating within the Development Area will comply with requirements within Marine Order 91—Marine pollution—oil. **CM-31**: Vessels operating within the Development Area will comply any Notice to Mariners requirements under the *Navigation Act 2012* (Cth). **CM-43**: Vessel crew will hold a current Standards of Training, Certification and Watchkeeping for Seafarers (or equivalent) certificate as appropriate to duties. **CM-44**: Develop (and implement in the event of an unplanned hydrocarbon release) an Oil Pollution Emergency Plan and Operational Scientific Monitoring Plan that satisfies the requirements under regulation 22 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth). **CM-45**: Develop and implement a Wells Operations Management Plan that satisfies the requirements under Part 5 of the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 (Cth). **CM-46**: Develop and implement a facility Safety Case that satisfies the requirements under Part 2 of the Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009 (Cth).

9 cumulative impact assessment

Cumulative impacts are a result of incremental, sustained, and combined effects of human action and natural variations over time and can be both positive and negative. They can be caused by the compounding effects of a single project or multiple projects in an area, and by the accumulation of effects from past, current and future activities as they arise (Ref. 479; Ref. 480).

Cumulative impacts and risks of the project may include:

- additive effects of activities within the same project
- additive effects from other activities within the region or potentially affecting the same environmental receptors
- long-term cumulative effects of a project lasting many years or decades (Ref. 16).

The assessment of cumulative impacts at the strategic level and site-specific level (or project-level) is termed cumulative impact assessment (CIA).

Cumulative impacts may arise from causes such as (Ref. 481):

- 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.
- 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.

9.1 cumulative impact assessment methodology

There is no specific guidance on CIA provided by NOPSEMA or the Australian Government for the OPGGS Act or EPBC Act assessment regimes. Other relevant guidance has been used to inform the CIA methodology for this OPP, including:

- NSW CIA Guidelines for State significant projects (Ref. 479)
- UK Advice Note Seventeen: Cumulative effects assessment relevant to nationally significant infrastructure projects (Ref. 480).

The key principles of CIA are:

- setting the assessment boundaries
- identification of relevant existing and future projects and activities that may have a cumulative impact
- assessing the nature and scale of the cumulative impacts on the values and sensitivities.

The CIA only considers the impacts from planned activities associated with the Development. Given the low likelihood of unplanned events (e.g. unplanned releases) occurring during the Development and other relevant projects/activities, impacts from unplanned events have not been considered in the CIA.

The methodology for undertaking CIA follows the same steps as those used for the environmental impact and risk assessment, described in Section 7.

9.1.1 scoping the assessment

The level of assessment within CIA should be proportionate to the nature and scale, and potential significance of the cumulative impacts of the Development, combined with the impacts of other relevant projects/activities (Ref. 482). The NSW Department of Planning and Environment (Ref. 479) states that CIA is to focus on the key matters that could be materially affected by the cumulative impacts of the project and other relevant future projects—not on every conceivable cumulative impact on every matter.

For the Development, a matter may be considered a key matter because of the potential for cumulative impact on relevant values and sensitivities as described in Section 7.2.

The NSW Department of Planning and Environment (Ref. 479) also states that the CIA only focuses on the key matters that are within the immediate geographical area of influence of a project (i.e. within proximity to the project site) and within the relevant strategic context.

9.1.1.1 set the assessment boundaries

Two types of boundaries are required for the CIA:

- spatial (i.e. how far)
- temporal (i.e. how long into the past or future).

9.1.1.1.1 spatial boundary

The spatial boundary selected for the CIA will vary depending on the specific characteristics of the assessment matter and the nature and scale of the potential impacts on the matter resulting from the project with other relevant projects/activities.

For example, the study area selected for the CIA on biodiversity may be based on the range and distribution of the listed threatened species within the relevant bioregion, and only focus on those species that are at risk of serious or irreversible harm due to the cumulative impacts of the project with other relevant projects/activities (Ref. 479).

The spatial boundary is designed to capture all possible aspect interactions from planned activities (i.e. spatial extent for each aspect described in Sections 8.1 to 8.8).

While the spatial boundary chosen for each matter must be broad enough to capture all relevant cumulative impacts, it should not be unnecessarily large or include areas where the cumulative impacts are likely to be negligible relative to the baseline condition of the relevant matter (Ref. 479).

The largest potential impact area for any planned aspect of the Development is associated with a change in ambient light caused by non-routine short-term flaring activities, for which a conservative spatial extent of ~42.4 km was adopted

(Section 8.4). The next largest potential impact area was associated with a change in fauna behaviour which may be caused by non-impulsive underwater sound emissions, for which a conservative spatial extent of ~18.3 km was adopted (Section 8.5).

Overall, in order to be conservative, a spatial extent of ~50 km around the DA has been used for the purposes of identifying existing and future projects and activities which may have effects that overlap with those of the Development and result in potential cumulative impacts.

Commonwealth-managed commercial fisheries which are within this spatial extent are the NWSTF (Figure 6-38) and WTBF (Figure 6-40). State-managed commercial fisheries within this spatial extent include Mackerel Managed Fishery, Pilbara Line Fishery, Pilbara Trap Managed Fishery, and the Pilbara Crab Managed Fishery (Figure 6-41 to Figure 6-44), as well the West Coast Deep Sea Crustacean Fishery, Onslow Prawn Managed Fishery, Western Australian Sea Cucumber Fishery, Marine Aquarium Fish Managed Fishery and Specimen Shell Managed Fishery. Petroleum activities and submarine cables within the ~50 km spatial extent are shown in Figure 6-46.

Depending on the nature and scale of potential cumulative impacts, larger spatial extents were considered for highly migratory species where the area covered by migratory routes may overlap other relevant projects/activities outside of the ~50 km spatial extent.

9.1.1.1.2 temporal boundary

The temporal boundary selected for the CIA considers the complete duration of the Development and an additional ~2 years post-decommissioning to allow for receptor recovery to pre-disturbance conditions. The estimate of recovery timeframes was based on:

- <1 year for the majority of benthic habitats and communities to recover from seabed disturbance (Ref. 260; Section 8.1).
- <1 year for ambient sediment quality to recover from planned discharges of drilling cuttings and fluids (Ref. 382). Although cement discharges can cause a more permanent change to the sediment, due to the very localised nature (<50 m) of the area affected, this has not been evaluated further.
- An allowance of a further year of recovery time given the early phase of decommissioning planning (Section 4.3.5) at the time of writing this OPP.

Therefore, the temporal end date selected for the CIA has been conservatively set as 2072. This temporal boundary considers the end of life for the Development notionally as ~2070 and ~2 years post-decommissioning for receptor recovery. The duration of decommissioning activities has been estimated for the purpose of the CIA and the actual duration may be different.

9.1.1.2 identification of third-party activities

CAPL has identified third-party activities that are known to occur, or are reasonably expected to occur, in the spatial boundary during the temporal extent of the Development based on the information available to CAPL during the preparation of this OPP.

Note: For the purpose of this CIA, the GFP and any other CAPL activities not covered by this OPP are considered a third-party activity.

Methods used to identify third-party activities included:

- stakeholder consultation undertaken for this OPP, and CAPL's other EPs and activities in the NWS
- review of regulatory submission websites, including for submissions under the EPBC Act and the OPGGS Act
- public announcements of future projects, in media and industry publications
- review of publicly available data (e.g. AMSA's craft tracking system, fisheries reports)
- predicting future activities that may reasonably occur based on CAPL's knowledge of the known resources and existing uses in the region.
- CAPL 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 spatial boundary that may not be considered as they are unknown or due to the inherent uncertainty of the future—and the long temporal boundary with the end date of 2074.

The activity-specific EPs that will be prepared subsequent to this OPP will provide an opportunity to undertake additional CIAs that consider activities known to, or reasonably expected to, occur in the future that are identified at a later date.

CAPL has defined third-party projects that are certain or reasonably foreseeable as:

- certain:
  - relevant approval document accepted by regulator (e.g. EP, EPBC Act referral)
  - data shows relevant activities occurring at time of writing (e.g. commercial shipping data, active commercial fishing data and licences)
- reasonably foreseeable:
  - relevant approval document under assessment by regulator (e.g. OPP, EP, or EPBC Act referral under assessment)
  - fishing licence even if no active fishing has occurred in last ~10 years
  - publicly announced project (e.g. another titleholder has announced future petroleum activity, e.g. exploration drilling, seismic survey).

Following the methodology above, CAPL has identified third-party activities that may result in a cumulative impact with the Development. Table 9-1 provides a summary and evaluation of whether activities are relevant for CIA and are carried through into the assessment.

For third-party activities to be carried through to the cumulative assessment, both the spatial and temporal boundary of the third-party activity must have the potential to overlap that of the Development. Some of the petroleum activities described in Table 9-1 may not overlap in temporal scale, however, they have been carried through to the assessment in the event changes in timing result in an overlap.

Different aspects of the activity will have different spatial and temporal EMBAs, for example light emissions have a different footprint and impact duration to seabed disturbance. This is taken into account in the identification of aspect overlap in Table 9-1.

Table 9-1: Identification of third-party activities within the spatial boundary

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
Commercial fisheries					
North West Slope Trawl Fishery (Ref. 392)	• Bottom (or demersal) trawl method used by fishery operators to target deep-water prawn and scampi typically at depths of 350–600 m. • Data shows only one reporting grid overlaps the DA in 2010–2014 and 2016–2019. In 2015 and 2020 the DA overlapped two reporting grids. Twelve reporting grids overlap for the DA + 50 km from 2020–2011 to 2019–2020. • Intensity data for 2020 shows no overlap with DA or DA plus 50 km. All other reporting periods had <5 vessels operating and therefore data is considered confidential. • 12 month fishing season commenced 1 July each year	Active	Yes 12 month fishing season presents a potential temporal overlap with Development activity timings.	Yes. The North-west Slope Trawl Fishery may actively fish within the DA and surrounds which presents a potential spatial overlap.	Aspects related to vessel operations: • light emissions • underwater sound emissions • seabed disturbance • physical presence • planned discharges – vessels.
Western Tuna and Billfish Fishery (Ref. 228)	• Pelagic longline and low levels of minor-line fishing used by fishery operators to target species including bigeye tuna, yellowfin tuna, broadbill swordfish and striped marlin. • Two reporting grids overlap the DA and four overlap the DA plus 50 km (2013 season). • No intensity data available as all reporting periods had less than five vessels operating and therefore data considered confidential. • 12 month fishing season commenced 1 July each year	Active	Yes. 12 month fishing season presents a potential temporal overlap with Development activity timings.	Yes. The Western Tuna and Billfish Fishery may actively fish within the DA and surrounds which presents a potential spatial overlap.	Aspects related to vessel operations: • light emissions • underwater sound emissions • physical presence • planned discharges – vessels.
State-managed commercial fisheries	• Several State-managed commercial fisheries with historical fishing effort that occurs within, or within the vicinity of the DA	Active	Yes. Commercial fishing seasons present a	Yes. The commercial fisheries may	Aspects related to vessel operations: • light emissions

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• Fishing methods vary (e.g. trap, trawl, line)		potential temporal overlap with Development activity timings.	actively fish within the DA and surrounds which presents a potential spatial overlap.	• underwater sound emissions • physical presence • planned discharges – vessels.
Petroleum activities					
CAPL –GFP (Ref. 9; Ref. 10; Ref. 578)	• Initial commissioning and start-up activities occurred in 2015, and operations are expected to continue for the nominal operational design life of 50 years. • Ongoing operations for the Gorgon and Jansz-Io fields, including IMR and well interventions as required. • The Development ties into the GFP and is within the DA.	Ongoing	Yes Operational life of the GFP overlaps with the Development activity timings	Yes. The Development ties into the GFP and there is spatial overlap between the GFP footprint and the Development DA.	Aspects related to vessels associated with the GFP: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure operations: • physical presence • underwater sound emissions • planned subsea discharges (from IMR activities and operational planned subsea releases).

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
CAPL—GFP J-IC installation and pre-commissioning (Ref. 14; Ref. 15)	• Construction and installation of a floating FCS, subsea compression infrastructure and a ~135 km submarine power cable linked to Barrow Island. It is considered part of the GFP. • J-IC installation and pre-commissioning is scheduled to occur from late-2024 to mid-2027. • The first of the J-IC installation campaigns was completed between December 2024 and March 2025.	Ongoing	Yes. The indicative schedule for J-IC installation and pre-commissioning extends to mid-2027. This overlaps with the indicative commencement of Development activities in the G&E field (Table 4-2).	Yes. There is spatial overlap between J-IC Operational Area and the Development's DA.	Aspects related to vessels associated with GFP J-IC: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure associated with GFP J-IC: • seabed disturbance.
CAPL – GFP J-IC operations (Ref. 10).	• Operation of the FCS, subsea compression infrastructure and a ~135 km submarine power cable linked to Barrow Island. • Commissioning is anticipated to commence from 2026, with start-up and operations expected from 2027 or 2028. • Results from the most recent acoustic models indicate the following: – accumulated exposure to received levels above marine mammal effect criteria TTS and PTS onset (SEL_{24h}), are not anticipated to occur. – the predicted ensonified area above the effect criteria for behavioural response for marine mammals occurs in the lower water column and does not extend to the surface (modelling indicated the maximum horizontal distance from the subsea compression	Proposed	Yes. J-IC is expected to be operational during the Development and therefore presents a potential temporal overlap with Development activity timings.	Yes. J-IC is expected to be operational during the Development and therefore presents a potential spatial overlap with Development activities.	Aspects related to vessels associated with the GFP J-IC: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure operations: • physical presence • underwater sound emissions

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	station to the is ~1.1 km, extending vertically ~950 m from the seabed to ~400 m from the sea surface.				• planned subsea discharges (from IMR activities and operational planned subsea releases).
CAPL – Wheatstone Project (Ref. 245; Ref. 577)	• The Wheatstone offshore facilities gather and partially process gas and associated condensate from the Wheatstone and Iago fields at the platform and then transport and delivers it onshore via trunkline for further processing. • The platform also receives fluids from the Julimar Development . • The platform is~29 km east of the DA (WA-3-IL), in water depth of 71 m deep and is ~213 m tall. • The platform has a flare system that includes a small, constantly lit low pressure flare, with the high pressure flare used for upset conditions only (non-continuous and infrequent use). The flare tip is ~150 m above sea level. • The trunkline is ~221 km long and ~44 inches in diameter, part of the trunkline is within the DA running along the south-eastern border. • Additional production well drilling within existing production licences for Wheatstone and Iago fields will occur in the future (drilling activities do not occur within the DA, indicative manifold locations are >22 km from the DA). • Indicative duration for Wheatstone Project operations is until 2046, with operations 24 hours a day every day and IMR (including well intervention) activities when required.	Ongoing	Yes. The Wheatstone Project is ongoing and will continue throughout the life of the Development.	Yes. Part of the Wheatstone trunkline runs along the south-eastern border of the DA, therefore IMR activities may overlap with those of the Development.	Aspects related to Wheatstone vessels/MODUs: • physical presence of the vessel(s) or MODU • planned discharges • light emissions • atmospheric emissions • underwater sound. Other aspects generated during platform operations include: • light emissions (from flaring).

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
CAPL – Legacy Wellhead Decommissioning	• CAPL is planning to decommission several non-operational legacy wellheads and associated infrastructure. • An EP is currently in preparation.	Proposed.	Yes. Indicative schedules for the legacy wellhead removal are not yet known; as such it has been assumed that it may overlap with Development activities.	Yes. There are legacy Gorgon and Jansz wellheads in GFP titles (WA-36-L and WA-37-L); these titles are within the Development's DA.	Aspects related to vessels associated with the wellhead decommissioning: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.
Woodside – Scarborough Development (Ref. 239; Ref. 575; Ref. 240; Ref. 670)	• Development of Scarborough will include the installation of a FPU with eight wells drilled in the initial phase and 13 wells drilled over the life of the Scarborough field, with all wells tied back to the semi-submersible FPU moored in ~950 m of water close to the Scarborough field. • The proposed Scarborough and North Scarborough fields are located in permits WA-61-L and WA-62-L. Wells may also be drilled and tied back to the FPU from the Thebe and Jupiter fields. • The FPU is ~95 km from the DA, with a 32″ trunkline running ~430 km from the FPU to Pluto LNG on the Burrup Peninsula. The trunkline route crosses the Chandon flowline. The trunkline was installed in 2024. • Hook-up and commissioning of the FPU is indicatively scheduled to commence from 2H 2025 and take up to ~11.5 months, followed by up to ~6 months for initial start-up, and then operations.	Ongoing	Yes. Based on the indicative schedule, there may be some overlap with initial start-up and then operations.	No. Spatial overlap is limited to the trunkline crossing the Chandon flowline, and trunkline installation has already been completed.	Not applicable. Given there is no temporal overlap in these scopes, no aspects have been identified.

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• Decommissioning is expected in 2055.				
Woodside – Goodwyn Area Infill Development (Ref. 576)	• The Goodwyn Area Infill Development will include multiple subsea tiebacks to existing Greater Western Flank subsea infrastructure. The OPP covers the life cycle (drilling, subsea installation, operations, and decommissioning) of the infill development. • Only activities associated the development of the Wilcox Prospect are within the 50 km buffer from the DA. • Estimated EOFL ~2040. •	Not commenced.	Yes. Preliminary schedule for the Goodwyn Infill Development is from activities commencing during 2027.	Yes. The Development's DA is ~36.8 km from the Goodwyn Infill Development's Project Area.	Aspects related to vessels/MODUs: • physical presence of the vessel(s) or MODU • planned discharges • light emissions • atmospheric emissions • underwater sound.
Woodside – Julimar Development operations (Ref. 241)	• Operation of the Julimar field production system and Julimar Phase 2 includes inspection, monitoring, maintenance, and repair during operations. • Infrastructure includes eight wells and associated subsea infrastructure (including production trees, manifolds, flowlines/pipelines, umbilicals). • Initial start-up of production in 2016 with a field life of 25 years and operates 24 hours a day, every day of the year. • Located within licence areas WA-49-L, WA-26-PL, WA-29-PL, and WA-536-P. Vessel based operations may be undertaken within WA-34-L. • The western edge of WA-49-L overlaps the DA with several production wells and associated subsea infrastructure within the DA. The wells are linked to the JULA manifold with the flowlines and umbilicals connected to the Wheatstone Platform, in a north-easterly direction away from the DA.	Ongoing	Yes. Operations are ongoing and will continue throughout the life of the Development.	Yes. Small spatial overlap at the edge of the DA with operational subsea infrastructure.	Aspects related to vessels associated with IMR activities: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure operations: • planned subsea discharges • physical presence

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
Woodside –JDP3 (Ref. 242; Ref. 676)	• Activities to be undertaken in WA-49-L include drilling of up to five new wells, subsea installation, pre-commissioning, and cold commissioning activities up to the point of hydrocarbon introduction. • Activities are planned to commence in Q3 2024 and will take ~60 days per well. Subsea installation activities are planned to commence Q1 2025 and are likely to take 60 days, with production targeted for the second half of 2025. There is contingency for two campaigns, resulting in production from the second campaign wells in 2026 or 2027. • The western edge of WA-49-L overlaps the DA with some of the indicative locations for wells and subsea infrastructure occurring within the DA. The wells will be connected back to existing JULA or to the new JULB manifold which will tie into the existing in-line tee (ILT) assembly connected to the Wheatstone Platform, in a north-easterly direction away from the DA. • Flaring is included as a contingency activity. • Commissioning and start-up of JDP3 wells and associated infrastructure to commence H1 2026; ~20 days per well (over single or multiple campaigns) commence H1 2026.	Drilling of 4 wells has been completed. Commissioning and start-up indicatively scheduled for H1 2026.	Yes. Commissioning and start-up of the JDP3 wells may overlap with Development timings.	Yes	Aspects related to vessels with JDP3 commissioning activities: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.
Woodside – Pluto LNG Project (Ref. 244; Ref. 580)	• The Pluto offshore facility has been in production since 2012. • The Pluto offshore facility currently produces gas and condensate from the Pluto, Xena and Pyxis gas fields which is transported via a 36 inch 180 km trunk line to the onshore Pluto Gas Plant for processing and export to customers.	Ongoing	Yes. Operations are ongoing and are expected to continue throughout the life of the Development.	Yes Underwater sound and light (during flaring) extents from Pluto operations may overlap with those of	Aspects related to Pluto operations activities: • underwater sound emissions • light emissions (during flaring). Aspects related to Pluto IMR vessels:

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• The platform has a relatively small quantity of gas that is required to be continuously flared. • The Pluto platform is not-normally manned, is more than 211 m tall and stands in a water depth of 85 m. • Drilling and subsea installation activities at Pluto (WA-34-L) commenced in January 2025 with an estimated duration of 50 days therefore will not overlap with the Development. However, well intervention or workover activities may be undertaken at any time during the EP in-force period. • Estimated end of life of the Pluto, Xena and Pyxis fields is expected in 2032, subject to reservoir performance. • ~28 km from DA.			the Development.	• physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.
Woodside – NWS and Julimar Exploration Wellhead Decommissioning (Ref. 579)	• Activities includes ongoing IMR. P&A, and removal of historical exploration wells. • Activities commenced June 2025 and may occur any time during in-force period of the EP. • Removal of wellheads estimated to take up to 10 days per well. • One (Julimar South East-1) out of the 36 wells is within the southeastern section of the DA. Another five wells are <50 km from the DA.	Ongoing.	Yes. Operations are currently ongoing.	Yes. One well (Julimar South East-1) is within the southeastern section of the DA. Another five wells are <50 km from the DA.	Aspects related to vessels: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.
Santos – Varanus Island Hub Operations (Ref. 243; Ref. 671)	• Consists of the John Brookes and Wonnich WHPs and associated subsea infrastructure within the John Brookes, Spartan, GES, and Wonnich gas fields which export well fluids from the production wells to the processing facilities on Varanus Island (Varanus Island is >65 km from the DA).	Ongoing	Yes Operations are currently ongoing however decommissioning is also anticipated to	Yes. Overlap in spatial extent is limited to the WHPs and	Aspects related to Varanus Island Hub IMR vessels: • physical presence • planned discharges - vessels

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• Infrastructure includes WHPs, wells, umbilicals, and flowlines for all fields. • The closest topsides facility to the DA is the John Brookes WHP (~15 km), normally unmanned. Exports gas from four wells via an 18″ pipeline to Varanus Island. There is no flare on the platform. • Production is suspended from the Wonnich WHP. • There are no topsides infrastructure associated with other fields. • Estimated EOFL for John Brookes is ~2043, Spartan ~2029, GES ~2025–2027.		occur throughout the life of the Development.	subsea infrastructure.	• light emissions • atmospheric emissions • underwater sound emissions.
Submarine cables					
Vocus – Highclere Cable	• Vocus operate a fibre optic cable (Highclere Cable) which connects the existing North West Cable System and Australia Singapore Cable. Part of the Darwin-Jakarta-Singapore cable. • The cable crosses the DA ~2.2 km from Chandon infrastructure.	Ongoing	Yes. Operation is ongoing and will continue throughout the life of the Development.	Yes. Part of the cable intersects with the northern tip of the DA.	Aspects related to operation of the Highclere Cable: • physical presence of the cable.
Commercial Shipping					
Shipping fairways	Vessel traffic data from AMSA shows that a portion of the DA within the vicinity of the G&E to Jansz flowline overlaps part of the NWS shipping fairway system (Section 6.4.4).	Ongoing	Yes. Shipping operations are ongoing and will continue throughout the life of the Development.	Yes. NWS shipping fairway system runs through the DA (~23 km).	Aspects related to Commercial shipping vessels: • physical presence of the vessel(s) • light emissions • noise emissions • planned discharges • air emissions.

9.1.2 identification of values and sensitivities

A detailed description of the values and sensitivities of the existing environment is provided in Section 6. Based on the spatial and temporal boundaries established, this description is sufficient to support the assessment of cumulative impacts.

9.1.3 identification of interactions

To identify where aspects may result in cumulative impacts to values and sensitivities, the potential interactions have been considered in two ways:

- could values and sensitivities be impacted by multiple aspects as a result of the Development?
- could values and sensitivities be impacted by the same or multiple aspects as a result of the Development in combination with the third-party activities (Table 9-2) within the relevant spatial and temporal boundary?

Table 9-2 identifies the interactions of aspects generated by the Development and by third-party activities with values and sensitivities. Note that as the largest spatial extent does not overlap any coastal areas, land-based values and sensitivities are not included.

Table 9-2: Values and sensitivities that may be subject to cumulative impacts

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine users		Commercial fishing	Commercial Shipping	Petroleum industry	
Ecosystems and their constituent parts														
Water quality	✓					✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.1)
Sediment quality								✓		No			✓	Yes (9.2.2)
Air quality		✓								No	✓	✓	✓	Yes (9.2.3)
Atmospheric GHG concentrations			✓							No	✓	✓	✓	Yes (9.2.4)
Ambient light				✓						No	✓	✓	✓	Yes (9.2.5)
Ambient sound					✓					No	✓	✓	✓	Yes (9.2.6)
Benthic habitats and associated communities	✓							✓		Yes			✓	Yes (9.2.7)
Seabird and shorebirds				✓		✓				Yes	✓	✓	✓	Yes (9.2.8)

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine users		Commercial fishing	Commercial Shipping	Petroleum industry	
Fish	✓			✓	✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.9)
Marine reptiles				✓	✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.10)
Marine mammals					✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.11)
Heritage	✓			✓	✓		✓	✓		Yes	✓	✓	✓	Yes (0)
Commonwealth marine area (KEFs)	✓							✓		Yes			✓	Yes (9.2.13)
Natural and physical resources														
Commercial fisheries							✓		✓	Yes	N/A			Yes (9.2.14)
Recreational fisheries										No				No
Traditional fisheries										No				No
Commercial shipping									✓	No		N/A		No

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine users		Commercial fishing	Commercial Shipping	Petroleum industry	
Petroleum activities									✓	No			N/A	No
Tourism and recreation										No				No
Other maritime industries										No				No
Qualities														
AMPs										No				No

9.1.4 assessment of cumulative impact

Once potential cumulative impacts have been identified, the methodology for undertaking CIA follows the same overarching process and criteria as those used for the environmental impact and risk assessment, described in Section 6, with additional consideration of how impact pathways may interact and whether this may result in a higher consequence/likelihood than was assessed for the individual Development aspect (Section 8). The overarching steps are:

- evaluation of cumulative impacts from the Development i.e. where multiple aspects have potential to impact a value/ sensitivity,
- evaluation of cumulative impacts from third-party activities combined with the Development,
- and consideration of any change to consequence/likelihood level as a result of cumulative effects,
- where a change in the consequence/ risk level has occurred and where the Development is a material contributor to the cumulative impact, demonstration of acceptability and evaluation of whether the existing EPO/s and adopted control measures associated with the Development, for that receptor, are sufficient to manage cumulative impacts to acceptable levels; and if not, identify additional performance objectives or control measures.

9.2 cumulative impact assessment

For all environmental values and sensitivities identified in Table 9-2 as potentially being affected by cumulative impacts, an evaluation of potential cumulative impacts has been undertaken in the subsections below. Where further evaluation indicated that a cumulative impact was considered credible, the aspect was carried through to the acceptability assessment. Note that only relevant phases e.g. drilling, operations etc. of third party activities identified in Table 9-1 have been carried through to the evaluation.

9.2.1 water quality

Table 9-3 provides the CIA and demonstration of acceptability for water quality.

Table 9-3: CIA and demonstration of acceptability—Water quality

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in a localised and temporary reduction in water quality: • seabed disturbance (evaluated in Section 8.1) • planned discharges–MODU and vessels (evaluated in Section 8.6) • planned discharges–subsea operations (evaluated in Section 8.7) • planned discharges–drilling (evaluated in Section 8.8). The impact of each aspect to water quality was evaluated individually and the highest consequence ranking assigned was Incidental (6). This evaluation is based on the small scale discharges planned, the low level of toxicity of planned discharges and the rapid return to ambient conditions due to the well-mixed offshore environment within the DA. The largest spatial and temporal extent of planned changes that would result in the localised and temporary reduction in water quality from the Development will occur during FCGT activities. As identified in Section 8.7, the largest discharge of treated water for the Development is predicted to result in exposures <2 km in shallow water and <1.5 km in deeper waters. The extent of other

Cumulative impact evaluation
planned discharges from vessel / MODU operations and during drilling and installation phases will be more localised. It is likely that some planned discharges from the Development may occur concurrently e.g. planned discharges from the MODU may occur at the same time as planned drilling discharges. As each of these impacts are localised and temporary and given the high levels of dispersion in the marine environment, the effect on water quality of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact assessed for any individual aspect, with the overall cumulative impact consequence ranked as Incidental (6).
Cumulative impacts from the Development and third-party industries
Aspects from third party activities in the region, when combined with the Development's aspects, may result in cumulative impacts to water quality. These third parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6. • Petroleum activities which could result in changes to water quality: – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – proposed Goodwyn Infill Development – Woodside – Julimar Development – Woodside – JDP3 commissioning and start-up. Third-party-generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, with no additional impact pathways. The consequence of impacts from third parties in isolation are predicted to be short-term and localised, and therefore evaluated as Incidental (6). The spatial and temporal extent of both the Development and third-party aspects is such that overlap in impacts is unlikely. Impact durations are sufficiently short-term, and the receiving environment is sufficiently robust, in that any changes to water quality resulting from cumulative sources will be fully recoverable, with impacts restricted to short-term and localised changes. Subsequently, the worst-case consequence of any cumulative impacts to water quality are not expected to have a consequence above that already assessed as the worst-credible impact to water quality from any individual aspect of the Development (Incidental (6)).
Demonstration of acceptability
The evaluation of potential cumulative impacts to water quality from the Development and third-party activities indicates that potential cumulative impacts are no greater than those already assessed for the Development in isolation. Consequently, potential cumulative impacts to water quality are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for water quality.

9.2.2 sediment quality

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to sediment quality:

- localised and temporary reduction in sediment quality, from planned discharges during drilling (Section 8.8).

The largest spatial extent of a change in sediment quality for the Development is for drilling cuttings discharged at the sea surface. A study by IOGP (Ref. 377)

found that cuttings discharged at surface accumulated on the seafloor at distances of ~0.1–1 km, depending on water depth (Ref. 377). Dispersion modelling for other WA projects (Ref. 331, Ref. 371, Ref. 672) identified that cuttings and drilling fluids discharges may generate an exposure area of up to ~2,002 m for small particles (<1 mm), 837 m for large particles (1-10 mm). These results were used as a conservative estimate of the exposure area for the Development (Table 8-69).

Cement discharges from overflow during drilling operations may affect the seabed within a 10-50 m radius around the well (<0.007 km^2 per well).

Similar to the Development, it is assumed that third-party activities that cause a reduction in sediment quality would be planned discharges that accumulate at the seabed—most likely drilling discharges.

The largest spatial extent of a reduction in sediment quality is ~2 km from each well location. While there are third-party petroleum pipelines and wells within the DA, there are no third-party wells or proposed drilling within 2 km of the expected Development well locations. Furthermore, third-party drilling activities could not be undertaken within CAPL held permits (Figure 1-1).

In summary, sediments in the DA are representative of the wider NWS region, there is no overlap of spatial extents of the Development and third party petroleum activities, and the small footprint of impacts to sediment quality from the Development will not result in a change to the overall health of sediment quality in the region. Therefore, cumulative impact to sediment quality from the Development and Third-party activities are not expected.

9.2.3 air quality

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to air quality:

- localised and temporary reduction in air quality (Section 8.2).

A localised and temporary reduction in air quality may result from the burning of MDO on vessels, helicopters and the MODU, ODS release, and flaring of reservoir fluids during well clean-up and flowback, and well intervention. If flaring is required, it will only occur from one well at a time and may take ~1 day to complete.

Air emissions by third-party activities are expected to be similar to the scale described above for the Development.

Wind conditions experienced in the open, offshore marine environment of the DA, located more than 115 km from the Pilbara coast, are generally expected to rapidly disperse air emissions temporarily generated during the Development. Air quality is expected to return to baseline levels after air emissions cease.

Therefore, cumulative impacts to air quality from the Development and third-party activities are not expected.

9.2.4 greenhouse gas emissions

The detailed impact assessment provided in Section 8.3 includes the assessment of cumulative impacts of GHG emissions resulting from anthropogenic and natural emissions from a range of sources.

9.2.5 ambient light

Table 9-4 provides the CIA and demonstration of acceptability for ambient light.

Table 9-4: CIA and demonstration of acceptability—ambient light

Cumulative impact evaluation
Cumulative impact from the Development and third-party activities
Third party activities in the region, when combined with the Development's activities, may result in cumulative impacts to ambient light. These third parties include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing and commercial shipping vessels will use navigational and operational lighting. • Petroleum activities which could result in changes to ambient light: – CAPL – GFP (vessel operations during IMR) – CAPL – GFP J-IC installation (vessel operations during installation and pre-commissioning) – CAPL – GFP J-IC operations (vessel operations during IMR; FCS lighting) – CAPL – Wheatstone Project (vessel operations during IMR; MODU operations during drilling or well intervention; platform lighting; flaring) – CAPL – Legacy wellhead decommissioning (vessel operations) – Woodside – proposed Goodwyn Infill Development (vessel or MODU operations) – Woodside – Julimar Development Project (vessel operations during IMR) – Woodside – JDP3 commissioning and start-up (vessel operations) – Woodside – Pluto LNG Project (vessel operations during IMR; platform lighting; flaring) – Woodside – Julimar wellhead decommissioning (vessel operations) – Santos – Varanus Hub operations (vessel operations during IMR; platform lighting; flaring. Navigational and operational lighting generated by the Development will result in localised impacts—for the larger pipelay and construction vessels this was estimated at up to ~5.2 km from the vessel and up to ~12.6 km from a MODU (for routine operations); this distance was larger at up to ~42.4 km during intermittent and short-term flaring operations (Section 8.4.2). Vessel and MODU presence from the Development will peak during drilling, installation and commissioning, and decommissioning phases. During operations, vessel presence will be low (and intermittent) for IMR activities. Commercial fishing within the DA is relatively low (Section 6.4.1). One of the NWS shipping fairways does intersect with the DA (Figure 6-45). Any commercial fishing or shipping vessel will require navigational and operational lighting, and therefore any vessels passing within the vicinity of Development activities within the DA has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the commercial fishing or shipping vessel has moved away from the Development activities within the DA. Due to their intermittent and transient nature of other commercial vessels, negligible cumulative impacts (i.e. Incidental [6]) from commercial vessels are expected. A similar assessment applies for vessel-based IMR from third-party petroleum activities. IMR activities are typically short durations (unless for major repairs). However, for installation projects (e.g. CAPL's J-IC, Woodside's proposed Goodwyn Infill Development) the potential for concurrent activities of longer duration is possible. Of these, the closest and potential longest duration of overlap is the J-IC installation. Based on current indicative schedules, it is possible that J-IC installation and the commencement of activities within the G&E field for the Development may occur at the same time. If activities occurred in proximity to each other (e.g. G&E tie-in to Jansz), cumulative impacts from light emissions may occur. However, as light intensity is inversely proportional to distance, any additive effect of overlapping light emissions substantially reduces the greater the distance between the vessels. As such, cumulative impacts between multiple installation campaigns are expected to be Incidental (6). Further, any spatial or temporal overlap in light emissions occurs over open ocean and does not intersect any offshore islands (i.e. does not intersect with any known habitat for birds or marine turtles). If a temporal overlap in drilling activities occurs between the Development and third-parties (e.g. CAPL's Wheatstone, Woodside's proposed Goodwyn Infill Development), any spatial overlap in light emissions is only likely to occur during concurrent flaring operations. However, as flaring is a contingency activity during well clean-ups for all drilling campaigns, this is considered an unlikely scenario; and if it did occur would be of short and intermittent duration only. As such,

Cumulative impact evaluation
negligible cumulative impacts (i.e. Incidental [6]) between multiple flaring operations during drilling campaigns are expected. Fixed sources of light emissions within the vicinity of the DA include the Wheatstone and Pluto platforms, and the John Brooke's and Wonnich WHPs (~36.2 km, ~34.7 km, ~15.6 km, and ~45.4 km from the DA respectively). For the purposes of this CIA, a ~12.6 km buffer (i.e. the same as the distance used for MODU operations) was applied around each of these platforms. Under routine operations, there would be no overlap between Development activities in the DA, and respective light emissions from each of these platforms. There is the potential that during Development flaring that these emissions may spatially overlap with platform emissions; however, this will be of short and intermittent durations, and is dependent on the location of flaring with the DA. As such, negligible cumulative impacts (i.e. Incidental [6]) between platforms and the Development are expected. Once installed and operational, CAPL's J-IC FCS, which is inside the Development's DA, will be a permanent source of lighting. The lighting is typically just at levels required for safe navigation of other marine users (the FCS is a normally unattended installation); additional task lighting may be required during maintenance campaigns. Any Development activities occurring within the immediate vicinity of the FCS has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the Development vessels move away from the FCS. As such, negligible cumulative impacts (i.e. Incidental [6]) between the FCS and the Development are expected. With the exception of the permanent light sources (platforms and FCS), ambient light conditions will return to natural levels immediately following cessation of vessel or MODU based Development and third-party activities. The worst-case consequence of any cumulative impacts to ambient light are not expected to have a consequence above that already assessed as the worst-credible impact to ambient light from any individual aspect of the Development (Incidental [6]).
Demonstration of acceptability
The evaluation of potential cumulative impacts ambient light from the Development and third-party activities indicates that potential cumulative impacts are no greater than those already assessed for the Development in isolation. The evaluation of cumulative impacts to ambient light demonstrates that: • cumulative impacts do not introduce additional sources or pathways which could contravene the principles of ESD • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts to ambient light has been received. Consequently, potential cumulative impacts to ambient light are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to benthic habitats and associated communities.

9.2.6 ambient underwater sound

Table 9-5 provides the CIA and demonstration of acceptability for ambient underwater sound.

Table 9-5: CIA and demonstration of acceptability—ambient underwater sound

Cumulative impact evaluation
Cumulative impact from the Development and third-party activities
Third party activities in the region, when combined with the Development's activities, may result in cumulative impacts to ambient underwater sound. These third parties include (refer to Table 9-1 for scoping):

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- Vessel operations – commercial fishing and commercial shipping vessels.
- Petroleum activities which could result in changes to ambient underwater sound:
  - CAPL – GFP (vessel operations during IMR; operation of subsea hydrocarbon system)
  - CAPL – GFP J-IC installation (vessel operations during installation and pre-commissioning)
  - CAPL – GFP J-IC operations (vessel operations during IMR; operation of subsea compression station)
  - CAPL – Wheatstone Project (vessel operations during IMR; MODU operations during drilling or well intervention)
  - CAPL – Legacy wellhead decommissioning (vessel operations)
  - Woodside – proposed Goodwyn Infill Development (vessel or MODU operations)
  - Woodside – Julimar Development Project (vessel operations during IMR)
  - Woodside – JDP3 commissioning and start-up (vessel operations)
  - Woodside – Pluto LNG Project (vessel operations during IMR)
  - Woodside – Julimar wellhead decommissioning (vessel operations)
  - Santos – Varanus Hub operations (vessel operations during IMR).

Underwater sound emissions generated by the Development will result in local ensonified areas—based on maximum horizontal distance to behavioural effect criteria for marine mammals from non-impulsive sound, this was estimated at up to ~12.1 km for drilling, ~18.3 km for pipelay, ~17.3 km for subsea installation, and ~3.76 km for an IMR vessel (Section 8.5.3.3.3). Vessel and MODU presence from the Development will peak during drilling, installation and commissioning, and decommissioning phases. During operations, vessel presence will be low (and intermittent) for IMR activities.

Note: Maximum horizontal distance to behavioural effect criteria for marine mammals from impulsive sound sources from Development activities was estimated at up to 2.37 km (Section 8.5.4.2). Given these smaller ensonified areas and that they would only be present for short and intermittent durations (VSP operations may not be used for each well, however, where they are, VSP operations may take up to ~24 hours), cumulative impacts from impulsive sound with third-party activities is not expected and is not discussed further in this assessment.

Commercial fishing within the DA is relatively low (Section 6.4.1). One of the NWS shipping fairways does intersect with the DA (Figure 6-45). Any commercial fishing or shipping vessel will generate non-impulsive sound (e.g. from engines, DP, equipment, etc.), and therefore any vessels passing within the vicinity of Development activities within the DA has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the commercial fishing or shipping vessel has moved away from the Development activities within the DA. Due to their intermittent and transient nature of other commercial vessels, negligible cumulative impacts (i.e. Incidental [6]) from commercial vessels are expected.

A similar assessment applies for vessel-based IMR from third-party petroleum activities. IMR activities are typically short durations (unless for major repairs). However, for installation projects (e.g. CAPL's J-IC, Woodside's proposed Goodwyn Infill Development) the potential for concurrent activities of longer duration is possible. Of these, the closest and potential longest duration of overlap is the J-IC installation. Based on current indicative schedules, it is possible that J-IC installation and the commencement of activities within the G&E field for the Development may occur at the same time. If activities occurred in proximity to each other (e.g. G&E tie-in to Jansz or J-IC FCS), cumulative impacts from sound emissions may occur. Concurrent activities may generate multiple ensonified areas, or if the vessels are in close proximity, then a larger merged ensonified area may occur. If concurrent drilling activities occurs between the Development and third-parties (e.g. CAPL's Wheatstone, Woodside's proposed Goodwyn Infill Development), multiple ensonified areas are likely to be generated (rather than merged areas) given the distances between respective drilling locations. As such, cumulative impacts between multiple installation campaigns are expected to be Minor (5).

As described in Section 8.5.2.4, non-impulsive sound emissions from the operation of subsea hydrocarbon systems are typically minor and likely not detectable beyond the immediate vicinity (e.g. tens to hundreds of metres) from a source. As such, negligible cumulative impacts from the operation existing GFP (or other third-party systems located further away) subsea hydrocarbon systems with the Development's system are expected and are not discussed further in this assessment.

Once installed and operational, CAPL's J-IC subsea compression station (SCSt), which is inside the Development's DA, will be a long-term subsea source of non-impulsive sound. Given the

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location of the SCSt in deep water (~1,345 m), the deep ocean sound channel (centre estimated at ~800–1,000 m water depth at J-IC location) has the most significant effect on propagation of subsea sound emissions from the SCSt. Upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 14). Acoustic modelling of the predicted ensonified area above the behavioural effect criteria for marine mammals indicates a maximum horizontal distance from the subsea compression station of ~1.1 km, extending vertically ~950 m from the seabed to ~400 m from the sea surface (Ref. 10). Interaction between this ensonified area and any Development activities may occur from vessel-based operations within the immediate vicinity (e.g. tie-ins to the Jansz field for G&E and Chandon, or IMR during operations) which are all of relatively short duration. As such, cumulative impacts between the Development and the J-IC subsea compression station are expected to be Incidental (6). Operational platforms within the vicinity of the DA include the Wheatstone and Pluto platforms, and the John Brooke's and Wonnich WHPs (~36.2 km, ~34.7 km, ~15.6 km, and ~45.4 km from the DA respectively). Gales (Ref. 693) describes non-impulsive underwater sound from platform operations as ~110–142 dB re 1 µPa @ 100 m. The resultant sound field is expected to be limited (up to ~1.37 km under conservative detection), and similar to typical ambient underwater sound levels. Therefore, no cumulative impacts between the Development and operation of adjacent platforms is expected and are not discussed further in this assessment. With the exception of the permanent third-party sound sources (J-IC subsea compression, existing subsea hydrocarbon systems), ambient underwater sound conditions will return to natural levels immediately following cessation of vessel or MODU based Development and third-party activity. The worst-case consequence of any cumulative impacts to ambient underwater sound are not expected to have a consequence above that already assessed as the worst-credible impact to ambient underwater sound from any individual aspect of the Development (Minor [5]).
Demonstration of acceptability
The evaluation of potential cumulative impacts to ambient underwater sound from the Development and third-party activities indicates that potential cumulative impacts are no greater than those already assessed for the Development in isolation. The evaluation of cumulative impacts to ambient underwater sound demonstrates that: • cumulative impacts do not introduce additional sources or pathways which could contravene the principles of ESD • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts to ambient underwater sound has been received. Consequently, potential cumulative impacts to ambient underwater sound are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to benthic habitats and associated communities.

9.2.7 benthic habitats and associated communities

Table 9-6 provides the CIA and demonstration of acceptability for benthic habitats and associated communities.

Table 9-6: CIA and demonstration of acceptability—benthic habitats and associated communities

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in alteration of benthic habitat and/or the risk of injury and mortality to benthic communities: • seabed disturbance (evaluated in Section 8.1) • planned discharges–drilling (evaluated in Section 8.8). The impact of alteration of benthic habitat for each aspect was evaluated individually and the highest impact consequence ranking assigned was Moderate (4). These rankings were assigned given BCH affected by the Development are mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment, (i.e. soft sediment habitats) along with isolated areas of high structural complexity. Limited number of benthic infauna were found (Ref. 104; appendix a). These findings are consistent with previous seabed surveys in the NWS region (Ref. 115; Ref. 109; Ref. 114; Ref. 539; Ref. 104; appendix a). The DA overlaps three KEFs, of which two are associated with benthic values (Exmouth Plateau and ancient coastline at 125 m depth contour KEF) (Section 6.3.6.1). A benthic survey of the DA found that the benthic environment is characteristic of the North Carnarvon Basin and the NWS region (Ref. 104; appendix a). Cumulative impacts pathways to benthic habitats and associated communities from the Development include the combination of seabed disturbance and drilling discharges affecting the same small area of benthic habitat or associated species, and these same effects on multiple small areas of benthic habitat and associated species across multiple small areas as a result of the Development activities (e.g. multiple drill centres). Any potential cumulative impacts to soft sediment benthic habitat and risks to related to associated benthic infauna, from the Development are restricted to the DA, where benthic survey results show that there is a mixture of flat bare substrates, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 109; Ref. 111; Ref. 104; appendix a). The benthic habitat identified limited number of benthic infauna and did not identify epifaunal communities around the DCs (Ref. 104; appendix a). An EPBC PMST report (Ref. 122; appendix b) did not identify any epifaunal of infaunal threatened or migratory species, or any TECs within the DA. Following decommissioning of the Development, and given soft sediment benthic habitats, the benthic communities impacted in the DA are expected to recover within <1 year (Ref. 260). The above listed aspects of the Development may present a localised cumulative impact and risk to benthic habitats and associated communities that have are highly represented in the region. Given this, and that following decommissioning, soft sediment benthic habitats and associated communities impacts are expected to recover, the effect on benthic habitats and associated communities of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative impact assessment is ranked as Moderate (4).
Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risk to benthic habitats and associated communities. These third parties (and potential aspects) include (refer to Table 9-1 for scoping): • Commercial fisheries – trawling activity could result in alteration of benthic habitats and injury or mortality of benthic communities. • Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities): – CAPL – GFP J-IC installation – CAPL – Wheatstone Project – Woodside – proposed Goodwyn Infill Development. Third-party generated aspects are evaluated to be of a similar nature and scale impact / risk to those predicted from the Development, and in isolation are therefore evaluated as Incidental (6) / Low (8) respectively. However, commercial Commonwealth fisheries, specifically fisheries which use trawling gear such as the NWSTF introduce an additional impact pathway.

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The BCH within the DA are mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment, (i.e. soft sediment habitats) along with isolated areas of high structural complexity with presence of biota (sponges, echinoderms, cnidarians). Limited benthic infauna and epifauna were observed during ground truthing. These types of habitats and communities have been previously disturbed by the placement of seabed infrastructure by prior petroleum activities (refer to Table 9-1 for project specific details), and ongoing trawling activities by commercial fisheries.

The Development and other third-party activities will lead to an increase in the alteration of these bare soft sediment benthic habitats. However, this is still considered a localised impact given the NWMR, which covers ~1.07 million km^2, is dominated by soft sediment benthic habitats and associated communities (Ref. 102; Ref. 103). The isolated high structural complexity habitat includes scarps and reef mosaics with presence of biota, and discrete patches of depressions over bare substrate. The biota identified are expected to tolerate or adapt turbidity from seabed disturbance activities (Ref. 263; Ref. 661; Ref. 662; Ref. 734).

Given the benthic habitat and associated communities represented in the DA and relevant third-party project area:

- are well represented in the NWMR
- are mainly characterised by soft sediment habitats
- biota identified are expected to tolerate or adapt to turbid conditions
- high structural complexity habitats are predicted to occur in isolated sections and are typically sparse and patchy in distribution
- have underlying conditions that support recolonisation and recovery.

The consequence of further alteration of benthic habitat and injury or mortality to benthic communities from the Development and third-party activities is considered a limited environmental impact and therefore an Incidental (6) consequence.

Given the BCH predicted in the DA and, as they are highly represented throughout the NWMR the likelihood that the Development and third-party activities will result in the loss of benthic habitats and associated communities was assessed as Occasional (2).

Recognising the Incidental (6) consequence of further minor and localised alteration and loss of benthic habitats and associated communities and the Occasional (2) likelihood that the consequence may occur during the Development and third-party activities; potential cumulative risks to benthic habitats and associated communities does not materially change the worst-case level of risk (i.e. cumulative risk of Low (7) compared to worst-case individual aspect risk of Low (8)), if evaluated considering the Development and third-party activities.

Demonstration of acceptability

The evaluation of potential cumulative impacts and risks to benthic habitats and associated communities from the Development and third-party activities indicates that potential cumulative impacts or risks are no greater than those already assessed for the Development in isolation.

The evaluation of cumulative impacts and risks to benthic habitats and associated communities demonstrates that:

- cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD
- no additional legislative or other requirements have been identified, other than those presented in Section 8
- no additional CAPL procedures have been identified, other than those presented in Section 8
- no stakeholder feedback related to cumulative impacts or risks to benthic habitats and associated communities has been received.

Consequently, potential cumulative impacts and risks to benthic habitats and associated communities are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.

Are identified EPO/s and adopted control measures appropriate?

CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to benthic habitats and associated communities.

9.2.8 seabirds and shorebirds

Table 9-7 provides the CIA and demonstration of acceptability for seabirds and shorebirds.

Table 9-7: CIA and demonstration of acceptability—Seabirds and shorebirds

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to seabirds and shorebirds: • change to behaviour, from – light emissions (evaluated in Section 8.4) • change in predator/prey dynamics, from – planned discharges–MODU and Vessels (evaluated in Section 8.6) The relevant values and sensitivities identified for seabirds and shorebirds in the DA is the wedge-tailed shearwater BIA (breeding) (Section 6.3.3.4). As discussed in Sections 8.4 and 8.6, minor changes to normal foraging behaviours for seabirds and shorebirds as a result of both light emissions and planned discharges from the MODU and vessels will be limited to the DA and affect only individuals. Assessment of the change in predator / prey dynamics resulting from planned discharges from the MODU and vessels concludes that changes in primary production will be localised and temporary, and subsequent indirect impacts to other marine fauna are not expected (Section 8.6). The risk of each aspect to seabirds and shorebirds was evaluated individually and the highest risk ranking assigned was Very Low (10). This evaluation is based on the temporary nature of the risks, the absence of overlap with breeding islands, and that the DA and surrounds provides open water habitat for seabirds and shorebirds that are highly represented throughout the NWS region (Sections 8.4.2 and 8.6.2). Cumulative impact pathways to seabirds and shorebirds from the Development may occur if there is: • an intersection of impact/risk footprints from multiple aspects, and/ or • a concurrent occurrence of multiple impacts/risks on the same footprint. When considered in combination, risks from the Development may result in changes in predatory / prey dynamics whilst also potentially causing disruption of critical behaviours i.e. to the wedge-tailed shearwater. Wedge-tailed shearwater are known to breed on islands off Barrow Island (Mushroom, Double and Boodie islands) and the Montebello Islands. Since there are no roosting or nesting habitats within the DA as it is located entirely offshore, foraging is the only critical behaviour likely to occur in the marine waters, particularly where adjacent to breeding locations, such as waters close to Barrow Island. Known to use a bimodal foraging strategy during nesting, the wedge-tailed shearwater may forage both relatively close to breeding islands and over the larger area (from the Cape Range Canyon to the Indonesian Archipelago), depending on prey availability (Ref. 172). Procellariiformes (i.e. shearwaters) may also forage at night on bioluminescent prey, and therefore are attracted to light of any kind (Ref. 292; Ref. 291). As evaluated in Section 8.4.2, minor changes to normal foraging behaviours for seabirds and shorebirds is expected to be spatially restricted to the immediate vicinity of the DA and affect only individuals (rather than populations) due to the absence of seabird aggregation areas in the spatial extents. While planned discharges of sewage and macerated wastes from vessels and the MODU may attract foraging seabirds and shorebirds, effects on environmental receptors along the food chain are not expected beyond the immediate vicinity of the temporary discharges (Ref. 356) (Section 8.6). While the Development may lead to minor, temporary and localised cumulative impacts to foraging seabirds and shorebirds, the effect on seabirds and shorebirds of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of risk. Consequently, the overall cumulative risk assessment is ranked as Very Low (10).
Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts to seabirds and shorebirds. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):

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- Vessel operations – commercial fishing vessels, commercial shipping, and petroleum industry vessels will result in comparable sources of light emissions to those assessed in Section 8.4 and comparable source of planned marine discharges as assessed in Section 8.6.
- Petroleum activities which will result in light emissions:
  - Woodside – proposed Goodwyn Infill Development
  - Woodside – JDP3 commissioning and start-up
  - Woodside – Pluto Offshore Facility
  - CAPL – Wheatstone Project
  - CAPL – GFP J-IC installation and operations.

As described in Table 9-4, commercial fishing or shipping vessel will require navigational and operational lighting, and therefore any vessels passing within the vicinity of Development activities within the DA has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the commercial fishing or shipping vessel has moved away from the Development activities within the DA. Due to their intermittent and transient nature of other commercial vessels, negligible cumulative impacts (i.e. Incidental [6]) from commercial vessels and Development activities on seabirds and shorebirds are expected.

Similarly, for vessel-based IMR from third-party petroleum activities (e.g. Pluto Offshore Facility, Wheatstone Project and J-IC Operations) given these are generally short-term campaigns using one vessel, negligible cumulative impacts (i.e. Incidental [6]) from third-party IMR activities and Development activities on seabirds and shorebirds are expected.

However, for installation projects (e.g. CAPL's J-IC, Woodside's proposed Goodwyn Infill Development) the potential for concurrent activities of longer duration is possible. Of these, the closest is CAPL's J-IC installation activities. Based on the indicative schedule, for the Development G&E drilling may commence from late-2026 and G&E installation and commission from mid-2027 (Table 4-2). The indicative schedule for J-IC installation and pre-commissioning has activities occurring between late-2024 to mid-2027 (Ref. 15). Therefore, there may be some temporal overlap (i.e. late-2026 to mid-2027) between G&E drilling activities and the J-IC installation and pre-commissioning activities.

Of the specific J-IC activity scopes (see Table 3-2 of Ref. 15) that may occur during this potential overlap with G&E drilling activities, the highest use of vessels in-field is associated with:

- FCS installation (~75 days with 6 vessels)
- installation of seabed spools associated with the SCSt (~25 days, with 3 vessels)
- HVSC installation and hook-up (~233 days with 1 vessel)

That is, there may be a short period where up to 10 vessels are undertaking J-IC activities. The remaining scopes for the FCS and SCSt installation are typically based on 1 vessel (i.e.~3 vessels in field is likely the more common activity during the temporal overlap).

The Goodwyn Area Infill Development has an indicative schedule of drilling and subsea installation commencing during 2027; however, the OPP does not indicate which of the reservoir developments will be targeted during Phase 1 of the development (Ref. 576). As the Goodwyn Project Area is ~37 km from the Development's DA and Wilcox Prospect is the only associated field with potential overlap, cumulative impacts are expected to be limited and therefore, negligible cumulative impacts (i.e. Incidental [6]) from third-party Goodwyn Area Infill Development and Development activities on seabirds and shorebirds are expected.

Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Very Low (10). Several of the petroleum activities identified (Wheatstone Project, Pluto Offshore Facility) undertake intermittent or continuous flaring, which will generate light emissions over a larger spatial extent compared to routine operations. Note the flaring rates will affect the resulting light intensity; flaring associated with well clean ups would be expected to be of a higher intensity but shorted duration compared to routine platform operations with lower intensity but continual flaring. Therefore, third-party activities will not introduce any new risk or impact pathways to seabirds or shorebirds within the DA, however the number of sources of risk will increase.

Under existing conditions, seabirds and shorebirds are expected to be attracted to vessels servicing the commercial fishing, shipping, and petroleum industries. While foraging opportunities outside of bright moonlit nights may be increased due to the temporal presence of artificial light (Ref. 751), the potential changes to foraging behaviour are expected to be limited (Section 8.4.3). In addition, the DA and project areas for third-party activities do not overlap nesting habitats for seabirds or shorebirds (Section 8.4). Consequently, the cumulative risk of further attracting

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seabirds and shorebirds as a result of the Development and third-party activities is not considered a disruption of behaviours.

For migratory birds, nocturnal migratory behaviour may be influenced by artificial light, particularly during low-visibility conditions such as fog, cloud cover, bad weather (Ref. 742). However, foggy conditions are rarely encountered on the NWS. As previously mentioned, although light intensity (i.e. very bright light) may attract birds, the peak spectral emissions are not expected to fall within the range most sensitive to seabird night vision (scotopic vision). Changes in migratory behaviour of birds would be limited to <5 km from the sources. Consequently, potential impacts are expected to be spatially restricted. Under existing conditions, seabirds and shorebirds are expected to be attracted to vessels servicing the commercial fishing, shipping, and petroleum industries. As a result, third-party activities will not introduce any new risk or impact pathways to seabirds or shorebirds within the DA, however the number of sources of risk will increase.

The cumulative risks to seabirds and shorebirds are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction behaviours). The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to seabirds and shorebirds is considered Incidental (6) owing to the following characteristics of the DA and third-party project areas:

- absence of aggregation areas
- absence of seabirds and shorebirds nesting habitats within the 42.4 km spatial extent adopted for flaring.

The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts/ risks is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to seabirds and shorebirds from the Development and third-party activities is considered Remote (5) given:

- existing transient and intermittent presence of vessel operations in the region from commercial shipping and fishing industries
- the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the DA will not be continuous, and will vary per phase
- for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the DA such that illuminated areas, ensonified areas and discharge plumes in the DA are limited to a single vessel (i.e. source).
- there are minimal non-CAPL petroleum activities within the DA itself (i.e. some of the Woodside Julimar wells and infrastructure) with most occurring at a greater distance (e.g. ongoing operations at existing facilities or the proposed Goodwyn Infill Development).

Given the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to seabirds and shorebirds and the Remote (5) likelihood that the consequence may occur during simultaneous Development and third-party activities; the potential cumulative impacts to seabirds and shorebirds does not materially change the worst-case level of risk (Very Low (10)) assessed for any individual aspect.

Demonstration of acceptability

The evaluation of potential cumulative risks to seabirds and shorebirds from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation.

The evaluation of cumulative risks to seabirds and shorebirds determines that:

- cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD
- significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur. Areas of importance, such as onshore nesting habitats will not be impacted
- the potential impact and risk to seabirds and shorebirds is inherently acceptable with the highest residual risk ranking of Very Low (10)
- no additional legislative or other requirements have been identified, other than those presented in Section 8
- no additional CAPL procedures have been identified, other than those presented in Section 8

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• no stakeholder feedback related to cumulative impacts or risks to seabirds and shorebirds has been received. Consequently, potential cumulative impacts and risks to seabirds and shorebirds are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for seabirds and shorebirds.

9.2.9 fishes, including sharks and rays

Table 9-8 provides the CIA and demonstration of acceptability for fishes.

Table 9-8: CIA and demonstration of acceptability—Fishes, including sharks and rays

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to fishes (including sharks and rays): • change to behaviour, from: – seabed disturbance (evaluated in Section 8.1) – light emissions (evaluated in Section 8.4) – underwater sound (evaluated in Section 8.5) • change in predator/prey dynamics, from: – planned discharges–MODU and vessels (evaluated in Section 8.6) • injury or mortality of marine fauna, from: – – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The relevant values and sensitivities for fishes, including sharks and rays, in the DA and surrounds includes: • whale shark BIA (foraging) • fish communities (associated with the various KEFs). The risk of each aspect to fishes, including sharks and rays, was evaluated individually and the highest risk ranking assigned was Low (7). These evaluations (Section 8) are based on the risk footprint being limited to the DA, where fishes are likely to be highly mobile and transient, and no biological cost to populations due to the localised nature of any consequences. Cumulative impact pathways to fishes from the Development may occur if there is: • an intersection of impact/ risk footprints from multiple aspects, and/ or • a concurrent occurrence of multiple impacts/ risks on the same footprint. Transient and highly-mobile fishes may display cumulative behavioural changes by being attracted to illuminated areas and/or avoiding multiple ensonified areas and discharge plumes. Multiple sources of illuminated areas, ensonified areas and discharge plumes may be present in the DA during the temporary drilling, installation, and commissioning phases. During the operations phase, all infrastructure will be subsea and the source of illuminated areas, ensonified areas and discharge plumes is reduced to the low frequency, short-term presence of an IMR vessel. Noise from the operation of subsea infrastructure is expected to be negligible as outlined in Section 8.5.1. The localised and temporary nature of the aspects may lead to temporary and localised cumulative impacts to transient and highly-mobile fishes, including sharks and rays. Given this, the effect on fishes, including sharks and rays, of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative risk assessment is ranked as Low (7).

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Cumulative impact from the Development and third-party activities

Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to fishes, including sharks and rays. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):

- Vessel operations – commercial fishing vessels, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (noise).
- Petroleum activities undertaking construction or drilling, which could result in seabed disturbance and planned discharges-subsea or drilling (and subsequent impacts to fishes):
  - CAPL – GFP
  - CAPL – GFP J-IC installation and operations
  - CAPL – Wheatstone Project
  - Woodside – proposed Goodwyn Infill Development
  - Woodside – Julimar Development
  - Woodside – JDP3 commissioning and start-up.

With the exception of J-IC operations, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). There are no additional impact pathways.

Under existing conditions, transient and highly-mobile fishes are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping and petroleum industries. The Development and third-party activities will introduce additional sources of aspects, which in turn adds additional illuminated areas attracting prey and subsequently feeding fishes, and ensonified areas and discharge plumes that may elicit active avoidance behaviours in fishes.

The cumulative risks of change in predator/prey dynamics to transient and highly-mobile fishes is considered an incidental consequence that will not result in population level impacts. Population level consequences is only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 37).

The cumulative risks to fishes, including sharks and rays, are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours. The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to fishes, including sharks and rays is considered Incidental (6) owing to the following characteristics of the DA and third-party project areas:

- absence of aggregation areas
- presence of transient and highly-mobile pelagic and benthopelagic fishes
- absence of suitable fish habitat for high-site fidelity.

The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviour to fishes, including sharks and rays from the Development and third-party activities is considered Occasional (2) given:

- existing transient and intermittent presence of vessel operations in the region from commercial shipping and fishing industries.
- the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the DA will not be continuous and will vary per phase.
- for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the DA such that illuminated areas, ensonified areas and discharge plumes in the DA is limited to a single vessel (i.e. source).
- there are minimal non-CAPL petroleum activities within the DA itself (i.e. some of the Woodside Julimar wells and infrastructure) with most occurring at a greater distance (e.g. ongoing operations at existing facilities or the proposed Goodwyn Infill Development).

Recognising the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to fishes, including sharks and rays and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities; the potential cumulative impacts to fishes, including sharks and rays does

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not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect, if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative risks to fishes, including sharks and rays, from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to fishes, including sharks and rays, determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur • the potential impact and risk to fishes, including sharks and rays, is inherently acceptable with the highest residual risk ranking of Low (7) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to fishes, including sharks and rays, has been received. Subsequently, potential cumulative impacts and risks to fishes, including sharks and rays, are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for fishes, including sharks and rays.

9.2.10 marine reptiles

Table 9-9 provides the CIA and demonstration of acceptability for marine reptiles.

Table 9-9:CIA and demonstration of acceptability—Marine reptiles

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to marine reptiles: • change to behaviour, from: – light emissions (evaluated in Section 8.4) – underwater sound (evaluated in Section 8.5) • change in predator/prey dynamics, from: – light emissions (evaluated in Section 8.4) – planned discharges–MODU and vessels (evaluated in Section 8.6) • injury or mortality of marine fauna, from: – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The relevant values and sensitivities identified for marine reptiles in the DA and surrounds (42.4 km spatial extent adopted for flaring) are: • flatback turtle BIA (internesting buffer) and HCTS • loggerhead turtle BIA (internesting buffer) and HCTS • green turtle BIAs (foraging, internesting buffer) and HCTS. The risk of each aspect to marine reptiles was evaluated individually and the highest risk ranking assigned was Low (7). This evaluation is based on the DA and surrounds being located in remote offshore waters with increasing water depths and marine turtles prefer habitats in proximity to the coast with relatively shallow depths (Ref. 24; Ref. 146). As such it would be very unlikely that

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turtles would be aggregating within the area and only a small number of transient marine turtles are expected to be present.

Cumulative impacts pathways to marine reptiles from the Development may occur if there is:

- an intersection of impact/ risk footprints from multiple aspects, and/ or
- a concurrent occurrence of multiple impacts/ risks on the same footprint.

Individual risk evaluations are all based on the localised nature of any consequences, concluding that the risk footprint is limited to the DA, where marine reptiles are likely to be highly mobile and transient. The only risk footprint which extends beyond the DA is light emissions from flaring (42.4 km spatial extent).

The cumulative risk of injury or mortality to marine reptiles is limited to the exposure of a small number of transient marine turtles to planned subsea discharge and drilling discharge plumes. Due to rapid mixing and dispersal in the open ocean environment, these plumes are only likely to result in localised, low concentrations of toxicants (e.g. chemical additives such as biocide). Toxicity impacts to marine reptiles have only been observed from long-term exposure to persistent pollutants resistant to environmental degradation (Ref. 483). The presence of discharges from subsea and drilling operations in the marine environment are expected to be localised and temporary, where rapid dilution and low bioaccumulation potential of these discharges are expected based on dispersion predictions. As a result, it would be highly unlikely for marine reptiles to be adversely affected by the temporary exposure of toxicants due to the short-term exposure and dispersion. Discharge plumes will only cause cumulative risk of injury or mortality if the plume acts as a barrier to critical foraging and breeding habitats essential for life-cycle requirements (Ref. 37), which is not predicted. Although the DA overlaps the spatial extent of HCTS of Flatback Turtles, due to the distance offshore and increasing water depths within the Development (~100–1,400 m) only on rare occurrences would flatback turtles be undertaking internesting behaviours within the DA.

Multiple sources of illuminated areas and ensonified areas will be present during the temporary drilling, installation and commissioning phases and will reduce to a single source during routine operations phase. The cumulative risk of disruption of behaviours to marine reptiles is expected to be limited to incidental attraction or avoidance behaviours from light emissions and underwater sound. The cumulative risk of attracting or repelling marine reptiles from the DA is unlikely to disrupt marine turtle critical behaviours, given the conservative 42.4 km spatial extent of the light emissions adopted for flaring does not overlap marine turtle nesting habitats and only a small number of transient marine turtles are likely to display cumulative behavioural changes by being attracted to or avoiding multiple illuminated areas and/or avoiding multiple ensonified areas.

Recognising the above listed aspects may be present simultaneously and temporarily in the DA over the course of the Development, this may lead to temporary and localised cumulative impacts to a small number of marine reptiles. CAPL has determined that the effect on marine reptiles of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative risk assessment is ranked as Low (7).

Cumulative impact from the Development and third-party activities

Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative impacts to marine reptiles. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):

- Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (sound).
- Petroleum activities undertaking construction or drilling, which could result in planned discharges-subsea or drilling (and subsequent impacts to marine turtles):
  - CAPL – GFP
  - CAPL – GFP J-IC installation and operations
  - CAPL – Wheatstone Project
  - Woodside – proposed Goodwyn Infill Development
  - Woodside – Julimar Development
  - Woodside – JDP3 commissioning and start-up.

As described in Table 9-4, commercial fishing or shipping vessel will require navigational and operational lighting, and therefore any vessels passing within the vicinity of Development activities

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within the DA has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the commercial fishing or shipping vessel has moved away from the Development activities within the DA. Due to their intermittent and transient nature of other commercial vessels, negligible cumulative impacts (i.e. Incidental [6]) from commercial vessels and Development activities on marine reptiles are expected.

Similarly, for vessel-based IMR from third-party petroleum activities (e.g. GFP, J-IC operations, and Wheatstone Project) given these are generally short-term campaigns using one vessel, negligible cumulative impacts (i.e. Incidental [6]) from third-party IMR activities and Development activities on marine turtles are expected.

However, for installation projects (e.g. CAPL's J-IC, Woodside's proposed Goodwyn Infill Development) the potential for concurrent activities of longer duration is possible. Of these, the closest is CAPL's J-IC installation activities. Based on the indicative schedule for the Development G&E drilling may commence from late-2026 and G&E installation and commission from mid-2027 (Table 4-2). The indicative schedule for J-IC installation and pre-commissioning has activities occurring between late-2024 to mid-2027 (Ref. 15). Therefore, there may be some temporal overlap (i.e. late-2026 to mid-2027) between G&E drilling activities and the J-IC installation and pre-commissioning activities.

Of the specific J-IC activity scopes (see Table 3-2 of Ref. 15) that may occur during this potential overlap with G&E drilling activities, the highest use of vessels in-field is associated with:

- FCS installation (~75 days with 6 vessels)
- installation of seabed spools associated with the SCSt (~25 days, with 3 vessels)
- HVSC installation and hook-up (~233 days with 1 vessel)

That is, there may be a short period where up to 10 vessels are undertaking J-IC activities. The remaining scopes for the FCS and SCSt installation are typically based on 1 vessel (i.e.~3 vessels in field is likely the more common activity during the temporal overlap).

The Goodwyn Area Infill Development has an indicative schedule of drilling and subsea installation commencing during 2027; however, the OPP does not indicate which of the reservoir developments will be targeted during Phase 1 of the development (Ref. 576). As the Goodwyn Project Area is ~37 km from the Development's DA, and Wilcox Prospect is the only associated field with potential overlap, cumulative impacts are expected to be limited and therefore, negligible cumulative impacts (i.e. Incidental [6]) from third-party Goodwyn Area Infill Development and Development activities on marine reptiles are expected.

Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. As outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 14). With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities.

Taking the above into consideration third-party generated aspects are evaluated as Low (7). There are no additional impact pathways.

The J-IC installation and pre-commissioning activities (Ref. 15) identified that change in ambient light is predicted to be within ~1.8 km. Given the distance between the G&E drilling and the J-IC installation activities, light exposure areas will not overlap and light sources will be perceived as distinct. Due to the offshore location of the G&E drilling activities and the J-IC installation and pre-commissioning activities, dispersing hatchlings are not expected to be attracted to light sources from these activities (i.e. frenzy period would have concluded prior to entering the area). Similarly, given the offshore location of the G&E drilling activities and the J-IC installation and pre-commissioning activities relative to habitats more frequently used by turtles, no overlap of any marine turtle nesting habitats, HCTS or BIAs, and the seasonal and transitory nature of the marine turtles, the concurrent impact of multiple light exposure areas is not expected to affect these biological behaviours. With the exception of CAPL's J-IC FCS, light level conditions will return to ambient levels immediately following cessation of Development and third-party activities.

Under existing conditions, a small number of transient marine turtles are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping, and petroleum industries. The Development and third-party activities will introduce additional sources for the aspects listed, which in turn adds additional illuminated areas attracting marine turtles, and ensonified areas and discharge plumes that may elicit active avoidance behaviours in marine reptiles. The cumulative risk of attracting or repelling marine reptiles as a result of the Development and third-party

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activities is not considered a disruption of critical behaviours, given the DA and project areas for third-party activities do not overlap marine turtle nesting habitats (Section 8).

The cumulative risk of minor, localised, and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction and avoidance behaviours) to a small number of transient marine turtles is considered an incidental consequence that will not result in population level impacts. Population level consequences are only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 37). Relevant values and sensitivities to marine reptiles in the DA and 42.4 km spatial extent adopted for flaring are limited to offshore inter-nesting behaviours for marine turtles and does not include marine turtle nesting habitats.

The cumulative risks to marine reptiles are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction and avoidance behaviours). The consequence of further minor, localised and temporary changes in behaviours to marine reptiles is considered Incidental (6) owing to the following characteristics of the DA and third-party project areas:

- absence of aggregation areas
- presence of a small number of transient marine turtles
- absence of marine turtle nesting habitats within the 42.4 km spatial extent adopted for flaring.

The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to marine reptiles from the Development and third-party activities is considered Occasional (2) given:

- existing transient and intermittent presence of vessel operations in the region from commercial shipping and fishing industries.
- the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the DA will not be continuous and will vary per phase.
- for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the DA such that illuminated areas, ensonified areas and discharge plumes in the DA is limited to a single vessel (i.e. source).
- there are minimal non-CAPL petroleum activities within the DA itself (i.e. some of the Woodside Julimar wells and infrastructure) with most occurring at a greater distance (e.g. ongoing operations at existing facilities or the proposed Goodwyn Infill Development).
- acoustic modelling for the J-IC SCSt predicted the maximum horizontal distance to AUD INJ and TTS onset effect criteria were <10 m and ~10 m respectively (Ref. 10). Noting that these effect criteria are for accumulated SEL24h exposure, and given the depth of the J-IC SCSt, auditory impairment or injury to marine turtles is not considered credible.

Given the Incidental (6) consequence of causing further minor, localised and temporary changes in behaviours of marine reptiles and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities, potential cumulative impacts to marine reptiles does not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect.

Demonstration of acceptability

The evaluation of potential cumulative risks to marine reptiles from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation.

The evaluation of cumulative risks to marine reptiles determines that:

- cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD
- significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur. Areas of importance, such as onshore nesting habitats will not be impacted
- the potential impact and risk to marine reptiles is inherently acceptable with the highest residual risk ranking of Low (7)
- no additional legislative or other requirements have been identified, other than those presented in Section 8

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• no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to marine reptiles has been received. Consequently, potential cumulative impacts and risks to marine reptiles are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for marine reptiles.

9.2.11 marine mammals

Table 9-10 provides the CIA and demonstration of acceptability for marine mammals.

Table 9-10: CIA and demonstration of acceptability—Marine mammals

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to marine mammals: • change to behaviours, from: – underwater sound (evaluated in Section 8.5) • change in predator/prey dynamics, from: – planned discharges–MODU and vessels (evaluated in Section 8.6) • injury or mortality of marine fauna, from: – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The risk of each aspect was evaluated individually against marine mammals, with the highest residual risk ranking of Low (7). The individual Low (7) risk rankings were generally assigned given the DA and surrounds (i.e. modelled ensonified areas and discharge plumes) provides open water habitat for migrating humpback and pygmy blue whales (Sections 8.5; 0; 8.7 and 8.8). The relevant values and sensitivities for marine mammals in the DA and surrounds includes: • humpback whale BIA (migration) • pygmy blue whale BIA (migration). The presence of humpback and pygmy blue whale migration BIAs in the DA and surrounds infers the potential for the presence of these whales during peak migration periods (Section 6.3.3.1). There currently is no evidence of high-site fidelity for other marine mammals within the DA and surrounds (i.e. ensonified areas and discharge plumes do not contain known marine mammal breeding, calving and foraging grounds). As a result, other marine mammals are expected to be highly-mobile and transit within the DA (Section 6.3.3.1). Cumulative impact pathways to marine mammals from the Development include overlap in impact footprint from each risk due to multiple aspects, and from overlap of multiple risks on the same footprint. Individual risk evaluations are all based on the localised nature of any consequences, where humpback and pygmy blue whales may be seasonally present within the DA; and other marine mammals are expected to be transient. The cumulative risk of injury or mortality to marine mammals is limited to the exposure of transient and highly-mobile individuals to toxicants (chemical additives such as biocide) in discharge plumes resulting from planned subsea discharges and drilling discharges. Marine mammals breathe air and would be able to swim past the discharge plume and not be adversely affected by the temporary exposure of toxicants due to their thick epidermal layer (Ref. 484; Ref. 485). Discharge plumes will only cause cumulative risk of injury or mortality if the plume acts as a barrier to known marine mammal breeding, calving and significant foraging grounds. Population level consequences such as changes in growth, reproduction and survival of marine mammals have only been observed when marine mammals abandon and avoid foraging and breeding critical habitats (Ref. 486; Ref. 128). Within ~50 km of the Development, relevant values and

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sensitivities for marine mammals are limited to known migration and inferred foraging behaviours and does not include critical foraging and breeding habitats essential for life-cycle requirements. Marine mammals are expected to swim through discharge plumes to avoid the area, with no cumulative risk of injury or mortality.

Planned MODU and vessel discharges may temporarily increase primary productivity, and the presence of prey may attract marine mammals into the DA, resulting in the cumulative risk of change in predatory/prey dynamics. Routine vessel discharge plumes will dissipate rapidly in open water environments represented in the DA; however it is recognized that the Development will introduce multiple sources of routine vessel discharges over a long period of time. The number of vessels working concurrently across a field or co-developed field within the DA is estimated to range between ~2 and ~10 vessels. This may occur when different phases or activities are occurring concurrently, but will typically be intermittent and would occur for a small proportion of the overall duration. Following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea and the source of the above listed aspects will be from the low frequency, short-term presence of an IMR vessel in the DA during the operations phase. Therefore, discharge plumes in the DA during operations phase is limited to a single vessel (i.e. source). The presence of vessels in the DA during the Development may introduce another temporary feeding area for passing marine mammals, which is not considered outside of normal behaviour given migrating marine mammals are known to opportunistically feed along their migration routes (Ref. 126; Ref. 487).

Migrating marine mammals may elicit behavioural responses such as actively avoiding multiple sources of planned discharges and underwater sound; however, it is not expected that this would result in displacement from their migratory corridor. Discharge plumes may alter normal marine mammal behaviours, but these minor movements will be too small to be meaningfully measured or detected (NOAA 2023). Marine mammals are expected to swim through discharge plumes to avoid the area, rather than change direction in swimming.

Conversely, marine mammals are known to actively avoid ensonified areas generated by vessels, such that marine mammals may increase swim speed and dive frequency to avoid the underwater sound source (Ref. 330; Ref. 332; Section 8.5). Multiple sources of ensonified areas and discharge plumes will be present in the DA during the temporary drilling, installation and commissioning phases and will reduce to a single source during routine operations phase. Review of modelling predictions for low frequency cetaceans found the conservative area for behavioural response to low frequency cetaceans to be 18.26 km from the source (i.e. maximum horizontal distance predicted for pipelay operations with multiple vessels). Within the 18.26 km radius around the expected position of subsea infrastructure, where these activities will occur, migration BIAs were identified for the pygmy blue and humpback whales and inferred foraging areas for the pygmy blue whale. No other BIAs and associated important behaviours for low frequency cetaceans were identified (refer to Section 6.3.3.1). The potential energetic cost of avoiding activities associated with the Development is likely to be small in the context of the greater migratory movements of humpback and pygmy blue whales migrating through the area.

Recognising the above listed aspects may be present simultaneously and temporarily in the DA over the course of the Development, this may lead to temporary and localised cumulative impacts to transient and highly-mobile marine mammals. The effect on marine mammals of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of impact or risk. Subsequently, the overall cumulative risk assessment is ranked as Low (7).

Cumulative impact from the Development and third-party activities

Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to marine mammals. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):

- Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable sound emissions to those discussed in Section 8.5 .
- Petroleum activities undertaking operations, construction, or drilling, which could result in planned discharges-subsea or drilling or underwater sound emissions (and subsequent impacts to marine mammals):
  - CAPL – GFP
  - CAPL – GFP J-IC installation and operations
  - CAPL – Wheatstone Project

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- CAPL – Legacy wellhead decommissioning
- Woodside – proposed Goodwyn Infill Development
- Woodside – Julimar Development
- Woodside – JDP3 commissioning and start-up
- Woodside – Pluto LNG Project
- Woodside – Julimar wellhead decommissioning
- Santos – Varanus Hub operations.

As described in Table 9-5, while commercial fishing or shipping vessel will generate non-impulsive sound (e.g. from engines, DP, equipment, etc.), and therefore any vessels passing within the vicinity of Development activities within the DA has the potential to result in cumulative impacts. However, these impacts will be temporary, ceasing once the commercial fishing or shipping vessel has moved away from the Development activities within the DA. Due to their intermittent and transient nature of other commercial vessels, negligible cumulative impacts (i.e. Incidental [6]) from commercial vessels and Development activities on marine mammals are expected.

Similarly, for vessel-based IMR from third-party petroleum activities (e.g. CAPL's GFP and Wheatstone Projects, Woodside's Julimar Development and Pluto Project, and Santos Varanus Hub operations), commissioning and start-up (e.g. Woodside's JDP3) or decommissioning (e.g. CAPL's and Woodside's wellhead activities) given these are generally short-term campaigns using one vessel, negligible cumulative impacts (i.e. Incidental [6]) from third-party IMR activities and Development activities on marine mammals are expected.

However, for installation projects (e.g. CAPL's J-IC, Woodside's proposed Goodwyn Infill Development) the potential for concurrent activities of longer duration and/or using a greater number of vessels is possible. Of these, the closest is CAPL's J-IC installation activities. Based on the indicative schedule for the Development G&E drilling may commence from late-2026 and G&E installation and commission from mid-2027 (Table 4-2). The indicative schedule for J-IC installation and pre-commissioning has activities occurring between late-2024 to mid-2027 (Ref. 15). Therefore, there may be some temporal overlap (i.e. late-2026 to mid-2027) between G&E drilling activities and the J-IC installation and pre-commissioning activities. Of the specific J-IC activity scopes (see Table 3-2 of Ref. 15) that may occur during this potential overlap with G&E drilling activities, the highest use of vessels in-field is associated with:

- FCS installation (~75 days with 6 vessels)
- installation of seabed spools associated with the SCSt (~25 days, with 3 vessels)
- HVSC installation and hook-up (~233 days with 1 vessel)

That is, there may be a short period where up to 10 vessels are undertaking J-IC activities. The remaining scopes for the FCS and SCSt installation are typically based on 1 vessel (i.e.~3 vessels in field are likely to be the more common activity during the temporal overlap).

Based on a similar approach to that presented for concurrent Development scenarios in Section 8.5.3.4, a qualitative analysis of areas ensonified above the behavioural and TTS onset effect criteria has been undertaken for J-IC installation and G&E drilling activities.

The largest width of the pygmy blue whale migration BIA that would be exposed above the marine mammal behavioural effect criteria is ~58.7 km (this is based only the J-IC scenario for combined FCS and SCSt activities and G&E drilling; Figure 9-1). This represents ~54% (43–62%) of the width of the migration BIA (Figure 9-1). The largest length of ensonified area above the marine mammal behavioural effect criteria is ~52.9 km (this is based the J-IC scenario for combined FCS and SCSt (Figure 9-1) plus J-IC cable lay). During northern and southern migrations this may result in ~22 hours and ~11–13 hours respectively of exposure to sound above the behavioural effect criteria (assuming no avoidance behaviours). Therefore, underwater sound associated with the Development and J-IC activities may result in migrating pygmy blue whales to make some spatial deviations. However, the energetic cost of avoiding the ensonified areas from the Development and J-IC activities (e.g. tens of kilometres) is likely to be small in the context of the greater migratory movements (e.g. several thousands of kilometres) of pygmy blue whales migrating between Southern Ocean and Indonesian waters (Section 6.3.3.1.2). Therefore, this level of behavioural avoidance within the pygmy blue whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales. As such the cumulative impacts from Development and third-party installation activities are considered similar to previous Development risk assessments; i.e. the potential risk of a change to behaviour in marine mammals from non-impulsive underwater sound is Moderate (6).

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Similarly, the largest length of ensonified area above the TTS onset effect criteria for low frequency cetaceans is ~21.7 km (this is based the J-IC scenario for combined FCS and SCSt plus J-IC cable lay). During northern and southern migrations this may result in an accumulated duration of exposure of above the SEL_{24h} effect criteria of ~9 hours and ~4–5 hours respectively; i.e. substantially less than the 24 hours exposure at this received sound level required for TTS onset to occur. However, the onset of TTS effects may also be reached by shorter durations of exposure at higher received sound levels. Given that behavioural responses for cetaceans are predicted at distances much larger than those for auditory impairments or injury, and that it is unlikely that cetaceans will remain within the immediate proximity of a non-impulsive sound source for extended durations, the risk of TTS or PTS onset is further reduced. As such the cumulative impacts from Development and third-party installation activities are considered similar to previous Development risk assessments; i.e. the potential risk of accumulated sound exposure causing auditory impairment (TTS) or injury (AUD-INJ including PTS) from non-impulsive underwater sound is Low (7).

The Goodwyn Area Infill Development has an indicative schedule of drilling and subsea installation commencing during 2027; however, the OPP does not indicate which of the reservoir developments will be targeted during Phase 1 of the development (Ref. 576). As the Goodwyn Project Area is ~37 km from the Development's DA, if Phase 1 (or subsequent phases) does occur at the same time as any Development activities, the ensonified areas are expected to remain separate. The Goodwyn Project Area is also situated between (i.e. doesn't intersect) with the pygmy blue or humpback whale BIA. As such, negligible cumulative impacts from Goodwyn and Development activities on marine mammals are expected.

The operation of the J-IC SCSt provides a subsea sound source (i.e. a different potential interaction pathway compared to vessel-based construction/installation activities). However, as outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column). Acoustic modelling of the predicted ensonified area above the behavioural effect criteria for marine mammals indicates a maximum horizontal distance from the J-IC SCSt of ~1.1 km, extending vertically ~950 m from the seabed to ~400 m from the sea surface (Ref. 10). Interaction between this ensonified area and any Development activities may occur from vessel-based operations within the immediate vicinity (e.g. tie-ins to the Jansz field for G&E and Chandon, or IMR during operations) which are all of relatively short duration. Taking the above into consideration, the subsea operation of the J-IC SCSt and the predominantly surface noise-based activities of the Development activities are unlikely to introduce significant cumulative impacts.

With the exception of J-IC SCSt and other ongoing subsea petroleum operations, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party vessel-based activities. Taking the above into consideration, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Moderate (6).

It is possible that cumulative risks to marine mammals from the Development and third-party activities may occur if these activities coincide with peak migration periods for migrating humpback and pygmy blue whales across the DA and surrounds (Section 6.3.3.1).

Review of the Listing Advice for the humpback whale (Ref. 125) and Conservation Management Plan for the Blue Whale (Ref. 20) identifies noise interference (underwater sound) and habitat modification from acute and chronic chemical discharges (planned discharges) as threats to humpback and pygmy blue whale populations. The following assessment will focus on migrating humpback and pygmy blue whales to evaluate worst-case potential cumulative risk to marine mammals, given migration BIAs for these species overlap the DA and third-party project areas. It is noted that other marine mammal species may be present in the DA, however with no known high-fidelity habitats in the DA (i.e. BIAs or habitats critical to the survival of the species), other marine mammals in the DA are expected to be highly-mobile and transient (Section 6.3.3.1).

Under pre-existing conditions, transient and highly-mobile marine mammals are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping and petroleum industries (Ref. 330; Ref. 332; Sections 8.5; 8.6; 8.7 and 8.8). The Development and third-party activities will introduce additional sources for the aspects listed, which in turn adds additional ensonified areas and discharge plumes that may prompt active avoidance behaviours to marine mammals, at no significant change to pre-existing levels.

The cumulative risk of minor, localised, and temporary changes to predator/prey dynamics and behaviours (i.e. temporary avoidance behaviours) to transient and highly-mobile marine mammals is considered an incidental consequence that will not result in population level impacts. Population

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level consequences are only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 37).

The cumulative risks to marine mammals are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviour (i.e. opportunistic feeding during migration and avoidance behaviours). The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to marine mammals is based on the following characteristics of the DA and surrounds:

- absence of aggregating marine mammals outside of peak migration periods
- absence of geomorphic or oceanographic features generally associated with higher primary productivity
- absence of sufficient prey biomass to represent a consistent and reliable feeding area
- absence of breeding habitats
- the population of migrating humpback whales has continued to increase in recent years.

The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to marine mammals from the Development and third-party activities is considered Occasional (2) given:

- existing transient and intermittent presence of vessel operations in the region from commercial shipping and fishing industries.
- the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the DA will not be continuous and will vary per phase.
- for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea and the source of the above listed aspects is reduced to the low frequency, short-term presence of an IMR vessel in the DA for the operations phase. Therefore, illuminated areas, ensonified areas and discharge plumes in the DA are limited to a single vessel (i.e. source).
- there are minimal non-CAPL petroleum activities within the DA itself (i.e. some of the Woodside Julimar wells and infrastructure) with most occurring at a greater distance (e.g. ongoing operations at existing facilities or the proposed Goodwyn Infill Development).
- acoustic modelling for the J-IC SCSt predicted the maximum horizontal distance to AUD INJ onset criteria was ~30 m, ~10m, and ~60 m for low, high, and very high frequency cetaceans respectively (Ref. 10). The modelling also indicated the maximum horizontal distance to TTS onset criteria was ~400 m, ~150 m, and ~680 m for low, high, and very high frequency cetaceans respectively (Ref. 10). Noting that these effect criteria are for accumulated SEL_{24h} exposure, and given the transient nature of cetaceans within the DA, the risk of auditory impairment or injury to cetaceans from the J-IC SCSt is not considered credible.
- acoustic modelling for the J-IC SCSt predicted the maximum horizontal distance to behavioural effect criteria for marine mammals was ~1.1 km, extending vertically ~950 m from the seabed to ~400 m from the sea surface (Ref. 10). For species with shallow water migrating and feeding preferences, including the pygmy blue whale in the Jansz region (Section 6.3.3.1.2), the ensonified area from the J-IC SCSt is unlikely to result in a behavioural response that would affect migratory or foraging behaviours (Ref. 10).

Recognising the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to marine mammals and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities; potential cumulative impacts to marine mammals does not materially change the worst-case level of risk (Moderate (6) assessed for any individual aspect, if evaluated considering the Development and third-party activities.

Recognising the incidental consequence of increase in avoidance behaviours to marine mammals and the occasional likelihood that a marine mammal would be exposed to the short-term presence of any of the above listed aspects from multiple third-party activities, the cumulative risk of the Development and third-party activities is considered Moderate (6).

Demonstration of acceptability

The evaluation of potential cumulative risks to marine mammals from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation.

The evaluation of cumulative risks to marine mammals determines that:

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• cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur • impacts to marine mammals from the Development and third-party activities are not inconsistent with the relevant objectives of any recovery or conservation management plan, conservation advice, or bioregional plan • the potential impact and risk to marine mammals is inherently acceptable with the highest residual risk ranking of Low (7) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to marine mammals has been received. Consequently, potential cumulative impacts and risks to marine mammals are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for marine mammals.

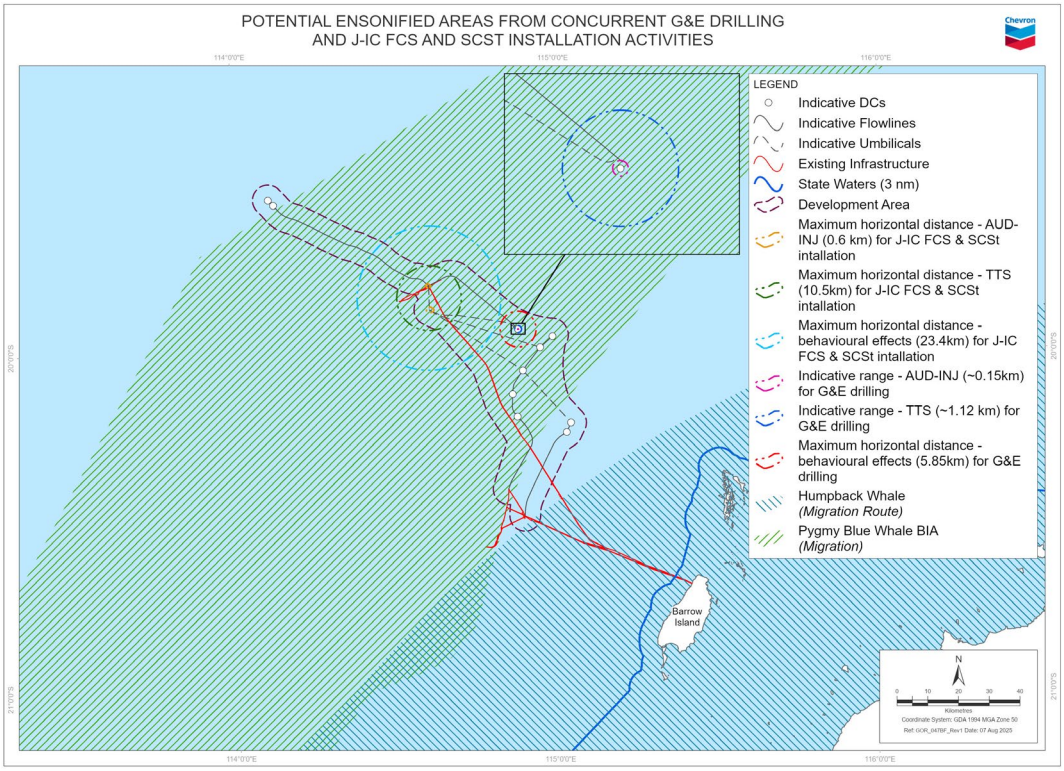


Figure 9-1: Potential concurrent activities—G&E drilling with J-IC FCS and SCSt installation

9.2.12 cultural heritage values

Table 9-11 provides the CIA and demonstration of acceptability for cultural heritage value: Traditional Owners.

Table 9-11: CIA and demonstration of acceptability–Cultural heritage value: Traditional Owners

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in changes to Traditional Owner cultural heritage values: • seabed disturbance (evaluated in Section 8.1) • light emissions (evaluated in Section 8.4) • underwater sound (evaluated in Section 8.5) • planned discharges–subsea operations (evaluated in Section 8.7) • planned discharges–drilling (evaluated in Section 8.8). The risk of change to cultural heritage values for each aspect was evaluated individually and the highest risk ranking assigned was Low (7) based on: • the DA and surrounds not containing known artefacts or specific sites of cultural value associated with the seabed (Section 6.5.2), and • potential risks being limited to indirect impacts to intangible Traditional Owner heritage i.e. obligations for the protection of Sea Country including marine fauna and benthic habitats and associated communities. The assigned ranking considering indirect impacts to intangible Traditional Owner heritage was Low (7) given: – potential disruption of behaviours for marine mega fauna will be localised and temporary – potential injury and death to epibenthic and infaunal invertebrates will be localised – alteration of benthic habitats and associated communities will be localised. – no threatened or migratory epifaunal or infaunal species, or TECs were identified within the DA – benthic survey results predicted a mixture of soft sediment habitat and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 109; Ref. 111; Ref. 104; appendix a) Given the above, the cumulative risk these aspects may present to cultural heritage values for Traditional Owners is localised. Consequently, Consequently, exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk and the overall cumulative risk assessment is ranked as Low (7).
Cumulative impact from the Development and third-party activities
Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative risks to cultural heritage values for Traditional Owners. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable sources of light emissions (Section 8.4), underwater sound (Section 8.5) and planned marine discharges (Section 8.6). • Commercial fisheries – trawling activity could result in alteration of benthic habitats and associated communities. • Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities), generate light emissions, underwater sound, planned subsea and drilling discharges: – CAPL – GFP – CAPL – GFP J-IC installation and operations – CAPL – Wheatstone Project – Woodside – proposed Goodwyn Infill Development – Woodside – Julimar Development – Woodside – JDP3 commissioning and start-up. Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). However commercial Commonwealth fisheries, specifically from fisheries which use trawling gear such as the NWSTF, introduces an additional impact pathway for alteration of benthic habitats and associated communities.

Cumulative impact evaluation
The BCH within the DA are mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment, (i.e. soft sediment) along with isolated areas of high structural complexity with presence of biota (sponges, echinoderms, cnidarians). Limited benthic infauna and epifauna were observed during ground truthing. These types of habitats and communities have been previously disturbed by the placement of seabed infrastructure by prior petroleum activities (refer to Table 9-1 for project specific details) and ongoing trawling activities by commercial fisheries. The Development and other third-party activities will lead to an increase in the alteration of these bare soft sediment benthic habitats. However, this contribution is still considered a localised impact given the NWMR which covers ~1.07 million km^2 is dominated by soft sediment benthic habitats and associated communities (Ref. 102, Ref. 103). The isolated high structural complexity habitat includes scarps and reef mosaics with presence of biota, and discrete patches of depressions over bare substrate. The biota identified are expected to tolerate or adapt to turbid conditions (Ref. 263; Ref. 661; Ref. 662; Ref. 734).The consequence of further alteration of benthic habitats and associated communities from the Development and third-party activities is considered a limited environmental impact, and therefore an Incidental (6) consequence of change to cultural heritage values for Traditional Owners. Given the BCH predicted in the DA and, as they are highly represented throughout the NWMR the likelihood that the Development and third-party activities will result in alteration of benthic habitats and associated communities and therefore change to cultural heritage values for Traditional Owners was assessed as Occasional (2). Recognising the Incidental (6) consequence of further minor and localised change to cultural heritage values for Traditional Owners and the Occasional (2) likelihood that the consequence may occur during the Development and third-party activities, potential cumulative risk of change to cultural heritage values for Traditional Owners does not materially change the worst-case level of risk (i.e. Low (7)), if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative risks to cultural heritage values for Traditional Owners from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to change to cultural heritage values for Traditional Owners demonstrates that: • cumulative risks do not introduce additional sources or pathways which could contravene the principles of ESD • risks to cultural heritage values for Traditional Owners from the Development and third-party activities are not inconsistent with the relevant objectives of any bioregional plan • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no further feedback was received in relation to seabed disturbance from Phase 1 stakeholder consultation. Consequently, potential cumulative risks to cultural heritage values for Traditional Owners are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to cultural heritage values for Traditional Owners.

9.2.13 KEFs

Table 9-12 provides the CIA and demonstration of acceptability for KEFs.

Table 9-12: CIA and demonstration of acceptability–KEFs

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to KEFs: • Changes to values and sensitivities, from: – seabed disturbance (evaluated in Section 8.1) – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The relevant values and sensitivities for KEFs in the DA and surrounds are: • Benthic habitat values; the ancient coastline at 125 m depth contour KEF (Ancient coastline KEF) and the Exmouth Plateau KEF. • Demersal fish assemblage values; continental slope demersal fish communities KEF The impact of alteration of benthic habitat for each aspect was evaluated individually and the highest impact consequence ranking assigned was Moderate (4). The risk of injury and mortality to benthic communities for each aspect was also evaluated individually and the highest risk ranking assigned was Low (8). These rankings were assigned given the localised nature of consequences and because benthic habitats and associated communities affected by the Development are highly represented through the NWS region. In addition, following decommissioning of the Development, benthic communities impacted in the DA are expected to recover, given soft sediment benthic habitats have underlying conditions that support recolonisation and recovery (Ref. 260). Sections with complex BCH within the proposed infrastructure is typically sparse and patchy in distribution. As such, ecosystem function or habitat connectivity is not expected to be affected. Furthermore, biota identified within these sections are expected to tolerate or adapt to turbid conditions (Ref. 263; Ref. 661; Ref. 662; Ref. 734). Cumulative impacts pathways to KEFs with benthic habitat values from the Development may occur if there is: • an intersection of impact/risk footprints from multiple aspects, and/ or • a concurrent occurrence of multiple impacts/risks on the same footprint. Despite the DA overlapping three KEFs, the benthic survey (Ref. 104; appendix a) results predicted that within the DA the most dominant BCH were predicted as relatively uniform and dominated by smooth and irregular seabed with bioturbation or bare substrate, and isolated areas of higher structural complexity, typical of the Northern Carnarvon Basin (Ref. 109; Ref. 111; Ref. 104; appendix a). Endemic values associated with these KEFs were not detected within the DA benthic survey (Ref. 104; appendix a). The extent of any potential impact is relatively localised, with the DA only covering from between 0.02–1% of these three KEFs. The cumulative risk of injury and mortality to benthic communities will be restricted to mortality within the subsea infrastructure footprint and the potential for injury to a minor area from planned discharges–drilling. The sparsely distributed, epibenthic and infaunal invertebrates in the DA are well represented in the region and there are no epifaunal or infaunal threatened or migratory species, or TECs within the DA (Ref. 122; appendix b). Consequently, the area of benthic communities affected by both seabed disturbance and planned discharges–drilling is representative of a negligible impact on a regional scale. The continental slope demersal fish communities KEF has values relating to fish that live and feed near the seabed. The continental slope demersal fish communities KEF will overlap with the DA at the C&D flowline, C&D DC-3, WTR umbilical and one of the Gorgon tie-in points. According to the fish assemblage survey undertaken as part of the benthic survey, fish assemblages were strongly influenced by water depth and water masses (Section 6.3.3.3; Ref. 104; appendix a). Pelagic fishes accounted for 99% of individuals observed and were significantly more abundant in the shallower water KEFs, including the continental slope demersal fish communities KEF. Consequently, demersal fish species are expected to be limited. Where the DA crosses with the continental slope demersal fish communities KEF, BCH identified in the habitat mapping mostly comprises irregular and smooth seabed with bare substrates and discrete depressions of bare substrates (Ref. 104; appendix a). Topographically complex habitat, in varying percent cover (from low [<10%] to high cover [>80%]) of epibenthic invertebrate were predicted to be present traversing through the DA within this KEF (Ref. 104; appendix a). Demersal fishes may frequent these areas to shelter from currents and reduce energetic demands but will roam more widely for foraging (Ref. 748). If a particular patch becomes temporarily unavailable, deep-water demersal species are likely to move to other areas. Once the

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seabed disturbance from Development activities ceases, these species are likely to move back and utilise these areas again. Only limited displacement of individuals is expected. The cumulative risk of injury and mortality to fish taxa affected by both seabed disturbance and planned discharges–drilling will not pose a significant risk to demersal fish assemblage values due to the localised (potential DA overlap of 0.02–1% of these three KEFs) and temporary extent of potential impact as well as the highly mobile and transient nature of the demersal species. The potential cumulative impacts or risks to KEFs, with values that are highly represented in the region, from the above listed aspects will be localised, and following decommissioning soft sediment benthic habitats and associated communities impacts are expected to recover. Therefore, the effect on KEFs of exposure to multiple aspects at the same time during the development does not materially change the worst-case impact or risk level of Moderate (4) / Low (8) respectively.
Cumulative impact from the Development and third-party activities
Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to KEFs. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping): • Commercial fisheries – trawling activity could result in alteration of benthic habitats and injury or mortality of benthic communities. • Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities) – CAPL – GFP J-IC installation – CAPL – Wheatstone Project – Woodside – proposed Goodwyn Infill Development. – Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Incidental (6) / Low (8) respectively. However commercial Commonwealth fisheries, specifically from fisheries which use trawling gear such as the NWSTF, introduces an additional impact pathway. The BCH within the DA are mostly comprised of a mixture of flat sediment terrain with bioturbation or bare sediment (i.e. soft sediment habitats) along with isolated areas of high structural complexity with presence of biota (sponges, echinoderms, cnidarians). Limited benthic infauna and epifauna were observed during ground truthing. These habitats have been previously disturbed by the placement of seabed infrastructure from previous petroleum activities (refer to Table 9-1 for project specific details) and trawling activities from commercial fisheries. The Development and other third-party activities may contribute to the existing loss of these soft sediment benthic habitats. However, this is still considered a localised impact given the NWMR which covers ~1.07 million km^2 is dominated by soft sediment benthic habitats and associated communities (Ref. 102; Ref. 103). The isolated high structural complexity habitat includes scarps and reef mosaics with presence of biota, and discrete patches of depressions over bare substrate. The biota identified are expected to tolerate or adapt to turbid conditions (Ref. 263; Ref. 661; Ref. 662; Ref. 734). The consequence of further alteration of benthic habitat and injury or mortality to benthic communities from the Development and third-party activities is considered a limited environmental impact, and therefore an Incidental (6) consequence owing to the following characteristics of benthic habitat and associated communities represented in the DA and relevant third-party project area: • values associated with the Ancient coastline KEF and Exmouth Plateau KEF were not detected within the DA benthic survey (Ref. 104; appendix a) • values associated with the continental slope demersal fish communities KEF detected in the DA are typical deep-sea benthic biota • epibenthic and infaunal invertebrates located in soft sediment benthic habitats in the DA are well represented in the NWS region • soft sediment benthic habitats have underlying conditions that support recolonisation and recovery (Ref. 260). The sparse distribution of benthic communities found in the DA and throughout the NWS region gives the Occasional (2) likelihood that the Development and third-party activities will result in the injury or mortality of benthic communities.

Cumulative impact evaluation
Recognising the Incidental (6) consequence of further minor and localised alteration and loss of benthic habitats and associated communities and the Occasional (2) likelihood that the consequence may occur during the Development and third-party activities, potential cumulative risks to KEFs does not materially change the worst-case level of risk (i.e. Low (7)), if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative impacts and risks to KEFs from the Development and third-party activities indicates that potential cumulative impacts or risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative impacts and risks to KEFs determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • impacts and risks to KEFs from the Development and third-party activities are not inconsistent with the relevant objectives of any bioregional plan • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to KEFs has been received. Subsequently, potential cumulative impacts and risks to KEFs are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to KEFs.

9.2.14 commercial fisheries

Table 9-13 provides the CIA and demonstration of acceptability for commercial fisheries.

Table 9-13: CIA and demonstration of acceptability—Commercial fisheries

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in a change to the functions, interests and activities of other marine users: • planned discharges-subsea (evaluated in Section 8.7) • physical presence—other marine users (evaluated in Section 8.9) The risk of each aspect to commercial fisheries was evaluated individually and the highest risk ranking assigned was Low (8). This evaluation is based on the low level of commercial fishing within the DA and the small and temporary nature of the risk footprint. Cumulative impact pathways to commercial fisheries from the Development may occur if there is overlap of multiple impacts / risks on the same footprint. Given the localised and temporary nature of the discharges impacts on fish populations are not expected to manifest at a fish population level, and therefore the risks of changes in fish stocks to fisheries are assessed as Very Low (9) (Section 9.2.1). The cumulative effect of a small exclusion area during the Development, combined with a very low risk of changes to fish stocks impacting catch rates, does not materially increase the worst-case level of risk determined for the Development. Consequently, the overall cumulative risk assessment is ranked as Low (8).
Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risk to commercial fisheries. These third parties (and potential aspects) include (refer to Table 9-1 for scoping):

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- Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (noise).
- Petroleum activities that will implement exclusion zones comparable to those assessed in Section 8.9 (physical presence – other marine users) and are undertaking construction or drilling, which could result in seabed disturbance and planned discharges-subsea or drilling (and subsequent impacts to commercial fishes):
  - CAPL – GFP
  - CAPL – GFP J-IC operations
  - CAPL – Wheatstone Project
  - Woodside – proposed Goodwyn Infill Development
  - Woodside – Julimar Development
  - Woodside – JDP3 commissioning and start-up.

Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. As outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 14). With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities. Taking the above into consideration, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). The interaction of the Development and third-party activities may introduce:

- additional illuminated areas attracting prey and subsequently feeding fishes
- exclusion zones for other marine users
- ensonified areas
- discharge plumes that may elicit active attraction or avoidance behaviours in commercial fishes.

The cumulative risk of attracting or repelling commercial fishes, and restricted access at exclusion zones is considered an Incidental (6) consequence to commercial fishers owing to the following characteristics of the DA and third-party project areas:

- loss of fishing grounds will be temporary and limited to SNAs, a small area of typically a 500 m radius around specific vessels and MODUs during certain activities
- exclusion will be temporary and short-term, affecting a limited proportion of a large fishery management area where fishing effort is currently low
- although third-party activities in combination with the Development will result in an overall increase in the total exclusion area, there will be no overlap in spatial extent of exclusion areas and limited temporal overlap
- presence of transient and highly-mobile pelagic and demersal fishes.

The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of unplanned interactions resulting in change to the functions, interests and activities of other marine users including commercial fisheries from the Development and third-party activities is considered Unlikely (4) given:

- the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the DA will not be continuous.
- no incidences of commercial fishing activities interacting with the infrastructure or with support activities has been communicated to CAPL since GFP construction began in 2010.
- for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In operations phase, the source of the above listed aspects is reduced to the low frequency, short-term presence of an IMR vessel in the DA such that illuminated areas, ensonified areas and discharge plumes in the DA is limited to a single vessel (i.e. source).
- there are minimal non-CAPL petroleum activities within the DA itself (i.e. some of the Woodside Julimar wells and infrastructure) with most occurring at a greater distance

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(e.g. ongoing operations at existing facilities or the proposed Goodwyn Infill Development). These are discrete campaigns that are not continuous. • operation of the J-IC SCSt introduces ensonified fields in the lower parts of the water column surrounding J-IC SCSt, compared to ensonified fields in the upper water column generated by other third-party vessels. Given the consequence of change to the functions, interests and activities of other marine users including commercial fisheries is ranked as Incidental (6) and the likelihood that the consequence may occur during simultaneous Development and third-party activities is Unlikely (4) ; the potential cumulative impacts to commercial fisheries does not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect.
Demonstration of acceptability
The evaluation of potential cumulative risks to commercial fisheries from the Development indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to commercial fisheries determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD. • no additional legislative or other requirements have been identified, other than those presented in Section 8. • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to commercial fisheries has been received. Consequently, potential cumulative impacts and risks to commercial fisheries are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to commercial fisheries.

10 implementation strategy

CAPL will carry out the Development in accordance with this OPP and all subsequent related EPs. The implementation strategy identifies the systems, practices, and procedures used to ensure this occurs, with particular focus on managing the environmental impacts and risks of the Development. The implementation strategy will help achieve the EPOs (detailed in Section 8).

10.1 operational excellence management system

CAPL's operations are managed in accordance with Chevron Corporation's Operational Excellence Management System (OEMS), which is a comprehensive management framework that supports the corporate commitment to protect the safety and health of people and the environment. The OEMS aligns with ISO 14001:2015 Environmental Management Systems – Requirements with Guidance for Use (Ref. 488) and meets the requirements of the OPGGS(E)R.

OE systematically manages workforce safety and health, process safety, reliability, and integrity, environment, efficiency, security, and stakeholders to meet the OE objectives and ensure safe operations of CAPL facilities and projects. The OEMS comprises these key components (Figure 10-1):

- **leadership and OE culture**—through the OEMS, CAPL leaders engage employees and contractors to build and sustain the OE culture and deliver OE performance
- **management system cycle**—by applying this cycle, CAPL leaders make risk-based and data-driven decisions, prioritise activities, and direct improvements
- **focus areas and OE expectations** (including common expectations)
  - focus areas are categories of OE risks and include workforce safety and health, process safety, reliability and integrity, environment, efficiency, security, and stakeholder engagement
  - OE expectations guide the design, management, and assurance of the presence and effectiveness of safeguards.

The OEMS outlines the process for identifying, establishing, and maintaining safeguards and assures that they are in place, functioning as intended, and are in accordance with legal and OE requirements. The risk management process (Figure 10-1) assesses and identifies safeguards (hardware and human actions designed to directly prevent or mitigate an incident or impact associated with the project), personnel, and the environment. The assurance process (Figure 10-1) verifies and validates that the safeguards are in place and functioning as intended.

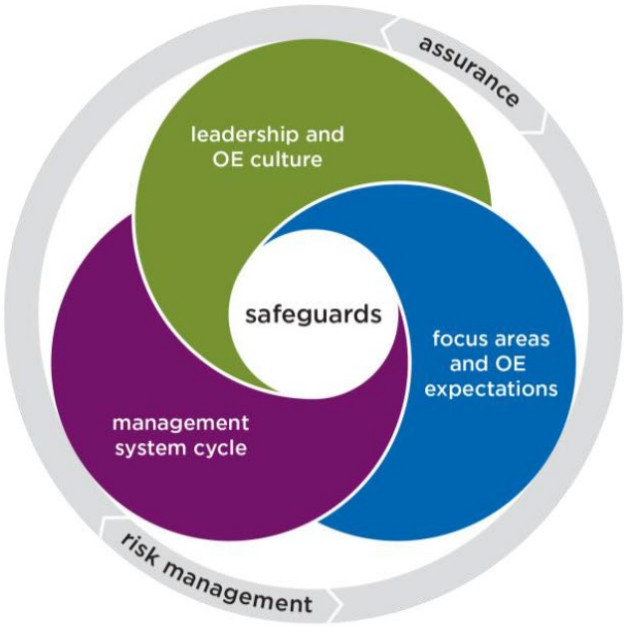


Figure 10-1: Overview of Chevron Corporation's OEMS

10.2 leadership and OE culture

CAPL leaders demonstrate and are accountable for the consistent and rigorous application of the OEMS to drive performance and manage risks. The actions and visibility of leaders reinforce CAPL's commitment to place the highest priority on the safety and health of its workforce, and on protecting communities, the environment, and the integrity and reliability of its assets.

10.2.1 roles and accountability

CAPL leaders have overall accountability for implementing the OEMS.

10.2.1.1 training and competency

Personnel who hold responsibilities relating to implementing this OPP or subsequent EPs are hired by CAPL based on their particular qualifications, experience, and competency.

All external contractor personnel involved with the Development will hold qualifications or training certification relevant to their role, which will be confirmed through the contractor selection process, audits and review processes.

All personnel (including contractors) working on or in connection with the Development are required to attend inductions, relevant to their role, where they will be made aware of their responsibilities.

10.3 focus areas and OE expectations

The OE expectations are organised into six focus areas (Figure 10-2), which provide guidance to design, operate, maintain, improve, and assure the presence and effectiveness of safeguards. Common expectations also apply—these support the OE expectations and focus areas (Figure 10-2).



Figure 10-2: Focus areas and common expectations

Table 10-1 lists the focus areas and common expectations, and related key processes relevant to this Development. Each focus area and common expectation is described in further detail in the following subsections.

Table 10-1: Relevant focus areas and common expectations

Focus area / common expectation	Key processes
Focus area	
Workplace safety and health	• ABU Operations Process: Control of Work Manual (Ref. 507) • Chevron Shipping's Marine Standard Non Tankers: Corporate OE Standard (Ref. 265) • ABU Hazardous Materials Management Procedure: ABU Standardised OE Procedure (Ref. 368)
Process safety, reliability and integrity	• OE Information Management: ABU Standardised OE Process (Ref. 489) • ABU Management of Change for Facilities and Operations: ABU Standardised OE Process (Ref. 490) • ABU Surface Equipment Reliability & Integrity Process (SERIP) Base Business Standardised OE Process (Ref. 491)
Environment	• Environment Risk Management Process (Ref. 492) • Environment Risk Assessment and Management Procedure (Ref. 493) • Quarantine Procedure Marine Vessels. ABU Standardised OE Process (Ref. 74)
Stakeholders	• Stakeholder Engagement and Issues Management: ABU Standardised OE Process (Ref. 81)
Common expectation	
Risk management	• ABU OE Risk Management Process (Ref. 257)
Assurance	• ABU OE Assurance Corporate Process (Ref. 494) • OE Data Reporting Standard (Ref. 496)
Incident investigation and reporting	• OE Corporate Standard Incident Investigation (Ref. 497) • Incident Investigation and Reporting (II&R) Execution Manual: Chevron Australia Incident Investigation and Reporting (Ref. 498)
Emergency management	• Emergency Management: OE Execution Manual (Ref. 499)

10.3.1 workplace safety and health

10.3.1.1 control of work

The CoW expectation is to assess workplace safety and health hazards and manage the risks associated with carrying out and controlling work performed by CAPL employees and their business partners. The CoW process (Ref. 507) and supporting work authorisation, ensures activities are assessed and undertaken in a safe and consistent manner.

10.3.1.2 marine

The Chevron Shipping Marine Standard Non Tankers (Ref. 265) identifies the requirements and activities necessary to deliver safe, reliable, and efficient third-party marine operations. This process describes key roles and responsibilities for managing marine safety and establishes measurement and verification activities designed to promote a process of continual improvement.

The Chevron Shipping Marine Standard Non Tankers applies to all marine vessels, emergency response, and all other (non-bulk petroleum) vessels chartered, owned, or operated by CAPL. The process also applies to vessels contracted by an affiliate or contractor that provide marine support or marine services to CAPL.

10.3.1.3 hazardous materials

CAPL's Hazardous Materials Management Procedure (Ref. 368) outlines the process for HSE assessment and approval of hazardous materials. Hazardous materials include those classified as hazardous substances or dangerous goods.

The Hazardous Materials Management Procedure is designed to:

- assess hazardous materials requested for procurement for their HSE risks
- ensure that appropriate controls are identified for using procured hazardous materials and that these controls are communicated to the requestors of the materials and end users at locations within CAPL's operations
- ensure no product includes CAPL-prohibited ingredients
- ensure substitutes were considered if a product contains CAPL-restricted ingredients.

10.3.2 process safety, reliability and integrity

10.3.2.1 OE information management

Under the OEMS, compliance records to demonstrate environmental performance will be retained.

The OE Information Management Process (Ref. 489) explains how critical information related to environment, workforce safety and health, process safety, reliability and integrity, efficiency, and security is to be identified, developed, assessed, and maintained so that the workforce has access to, and is using, the most current OE information.

10.3.2.2 management of change

Management of change expectations are to manage proposed changes to design, equipment, operations and products before they are implemented. In conjunction

with the Risk Management Process (Section 10.3.5), the Management of Change for Facilities and Operations Process (Ref. 490) is followed to document and assess the impact of changes to activities described in this OPP.

These changes will be addressed to determine if there is potential for any new or increased environmental impact or risk not already provided for in this OPP. In the EP phase, the trigger for resubmission of an EP will be evaluated against the requirements of regulation 39 of the OPGGS(E)R.

10.3.2.3 surface equipment reliability & integrity process

The ABU Surface Equipment Reliability & Integrity Process (SERIP) (Ref. 491) sets the expectations for CAPL's Asset Integrity Program to verify that equipment, components, and systems perform their required functions across their full asset lifecycle and provides guidance in alignment with Chevron Corporation's Tenets of Operation and the company's commitment to OE to achieve integrity and reliability excellence in our operations.

This process includes principles of continuous improvement with the intent of assisting operating facilities in achieving best-in-class performance within the industry over time. SERIP supports the following OEMS OE Objectives:

- eliminate fatalities, serious injuries, and illnesses
- eliminate high-consequence process safety incidents
- operate with industry-leading reliability.

At the time of writing this OPP, CAPL had begun the process to transition from SERIP to Facilities Integrity and Reliability Management.

10.3.3 environment

The environment focus area provides a framework for CAPL to protect the environment using a risk-based approach that addresses potential environmental impacts.

10.3.3.1 environment risk management process

The Environment Risk Management Process (Ref. 492) provides a framework for CAPL to identify, assess, mitigate, and manage environmental risks, including environment-related community health and social risks, across the life cycle of CAPL assets.

The objectives of the process are to:

- establish standardised methodologies for the data-driven assessment and management of environmental risks
- identify environmental safeguards and mitigation measures, and support prioritisation of their verification
- support assurance activities for environmental safeguards and mitigation measures
- maintain environmental information associated with the evaluation of environmental risks
- utilise the Management System Cycle process to identify improvement opportunities for the Environment Risk Management Process.

10.3.3.2 quarantine

The Quarantine Procedure Marine Vessels (Ref. 74) defines the procedure for marine vessels intending to undertake activities in offshore title areas. It provides information about quarantine compliance, including biofouling and ballast water requirements, to CAPL, contractors, and others associated with marine vessels.

10.3.4 stakeholders

The Stakeholder Engagement and Issues Management Process (Ref. 81) details an integrated approach for engaging stakeholders and managing external stakeholder issues. This process describes key roles and responsibilities for stakeholder engagement, establishes measurement and verification activities designed to monitor the effectiveness of the stakeholder engagement process and to promote continual improvement. Section 3 describes the process undertaken for appropriate consultation with relevant authorities, interested persons or organisations. CAPL will continue to engage with relevant stakeholders as described in Section 3.

10.3.5 risk management

The Risk Management Process (Ref. 257) assesses and identifies safeguards (hardware and human actions designed to directly prevent or mitigate an incident or event). This process is designed to be consistent with the environmental risk management requirements of ISO 14001 Environmental Management System (Ref. 488) and ISO 31000:2018 Risk management – Principles and guidelines (Ref. 255).

10.3.6 assurance

Within the OEMS, assurance is a common expectation that supports the OE objective of each focus area. The Assurance Process (Ref. 494) enables CAPL to assure that safeguards are established and functioning; it details:

- a framework for managing verification activities that assure that CAPL complies with applicable legal and OEMS requirements
- a process to identify, report and resolve noncompliance
- the minimum qualifications and organisational capability to carry out this process.

The Assurance Plan (Ref. 495) documents CAPL's integrated assurance system and associated assurance activities by focus area. This plan is reviewed and approved annually and includes:

- a list of OE assurance priorities based on risk
- a schedule of assurance activities to evaluate safeguards and verifications (e.g. reviews, audits, and assurance programs)
- reference to project and asset assurance plans that outline asset-specific assurance activities and risk-based frequency (i.e. field inspection programs, audits, compliance reviews, performance reviews).

Assurance activities focus on infield activities and administrative processes (depending on the activities being undertaken), and assurance priorities (which are based on risk), demonstrate that EPOs have been met and the activity implemented in accordance with this implementation strategy. A record of all

assurance activities undertaken, and the outcomes, are maintained and actions are tracked until closure.

10.3.7 incident investigation and reporting

The II&R Execution Manual (Ref. 498) defines the requirements to report, classify, record, and investigate incidents and near misses, including but not limited to injury, occupational illness, environmental impact, reliability, business disruption, and community concern. This includes the reporting to applicable regulators.

Events that meet the required criteria are recorded in the CAPL incident management system (IMS), which also contains records of associated investigation results. The lessons learned from selected investigations are shared to reduce the likelihood of future comparable events.

Specific incident reporting requirements for this OPP are detailed in Section 10.5.2.

10.3.8 emergency management

The emergency management arrangements outline a systematic approach for preventing, planning, responding to, and recovering from emergency events and are intended to provide a standardised corporate management and response structure that details emergency management documentation, emergency response organisation (ERO), facilities and equipment, and training and exercises.

The ERO provides a standardised management and response structure for any emergency. Personnel filling roles within this structure may include full-time professionals, but most will be part-time volunteers drawn from across the workforce.

The system used to organise CAPL's emergency management teams is based on the Incident Command System and provides a standardised approach to the coordination of an emergency response across all hazards, including oil spill response. This program is compatible with the Australasian Inter-service Incident Management System and the National Plan for Maritime Environmental Emergencies (National Plan; Ref. 476) and is consistent with the core aspects presented in the IMO-equivalent courses.

Any subsequent EPs are required to include an Oil Pollution Emergency Plan (OPEP) as per regulation 22(8) of the OPGGS(E)R.

The Emergency Management OE Execution Manual (Ref. 499) is CAPL's system for managing emergencies. The process ensures CAPL is prepared to respond immediately and effectively to all emergencies involving contractor- or CAPL-owned or -operated assets as defined in their scope of work.

The emergency management process comprises these key elements.

- emergency scenarios, including worst-case, are identified; these scenarios are based on the findings from risk assessments of significant safety, health and environmental hazards and other sources (e.g. historical incidents)
- response plans are developed and maintained to address emergency scenarios
- a reliability program is in place for inspection, testing and preventive maintenance of critical emergency response equipment and systems supporting emergency response plans

- an IMS is in place that is capable of immediately and effectively managing all emergencies
- a training and exercise program, including minimum training and exercise requirements, is developed to establish and maintain emergency response capability
- a crisis management plan is developed to address potential crisis or significant event
- business continuity plans are developed in conformance with the Business Continuity Planning Corporate OE Process (Ref. 500).

The emergency management process and the OPEP prioritise the safety of all personnel and subsequently the protection of the environment and property. All employees, contractors and visitors are required to comply with the emergency management process and OPEP throughout the life of the Development.

10.4 adaptive management framework for pygmy blue whales exposed to underwater sound emissions from the Development

10.4.1 purpose

This adaptive management framework is designed to ensure the control measures developed and implemented during the Development's petroleum activities are effective in managing the potential risks of underwater sound emissions on pygmy blue whales such that the residual risk is consistent with the relevant acceptable levels and EPOs established for the Development. This framework for pygmy blue whales works in conjunction with the broader **CM-20** and **CM-21** for marine fauna (Table 8-57).

In relation to underwater sound emissions and the potential risks to pygmy blue whales, the relevant acceptable levels (Table 7-6) and EPOs (Table 8-57) that have been developed to manage the Development's petroleum activities such that they are not inconsistent with the Conservation Management Plan for the Blue Whale (Ref. 20) are:

- **AL-12**: Impacts from the Development will not interfere with the recovery of the population of an EPBC Act listed threatened species
- **AL-13**: Impacts from the Development will not be inconsistent with the requirements of threatened species recovery plans made or adopted under the EPBC Act
- **EPO-17**: Sound emissions from planned Development activities will be managed such that EPBC Act listed species continue undertaking biological important behaviours[193]

[193] Where biologically important behaviours are defined as behaviour associated with critical life functions (e.g. reproduction, foraging, migration, and resting) (Ref. 719).

- **EPO-19**: Any blue whale continues to utilise the biologically important area without injury[194], and is not displaced from a foraging area[195,196]
- **EPO-23**: Implement an adaptive management approach (**CM-20**, **CM-21**) for underwater sound emissions from the Development such that it can be demonstrated that risks have been reduced to as low as reasonably practicable and can be managed to meet acceptable levels. The outcomes of this adaptive management approach will be incorporated into Environment Plans for the petroleum activities associated with this Development.

10.4.2 key sensitivities and considerations

Based on information available at the time of writing this OPP, key sensitivities and considerations for evaluating potential risk to pygmy blue whales within the vicinity of the DA include:

- the DA overlaps with the migration BIA
  - studies indicate that the migration corridor used during the northern migration is broader than the migration BIA
  - presence within the north-bound migration corridor in the vicinity of the DA is not evenly distributed—with higher presence detected along the inshore edge of the BIA (at the continental shelf edge) and further offshore beyond the BIA, compared to the central area of the BIA
  - studies indicate that the southern migration predominantly occurs further offshore than the BIA
- presence of pygmy blue whales in the vicinity of the DA has been observed
  - late-March to mid-September (peak late-May to June) during northern migration
  - early-October to late-January (peak late-November to early-December) during southern migration
  - however, this presence of migratory whales varies temporally and spatially each year
- the DA and surrounding area are not considered to represent a Foraging Area, but may provide opportunistic foraging if the environmental conditions provide for the aggregation of prey at sufficient quantities at the time a pygmy blue migrates through the area
  - if opportunistic foraging does occur, this is likely to occur within surface waters (e.g. photic zone).

[194] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'injury to blue whales' is considered both PTS and TTS and any other form of physical harm arising from anthropogenic sources of underwater sound (Ref. 369).

[195] For the purpose of Action A.2.3 from the Conservation Management Plan for the Blue Whale (Ref. 20) 'displaced from a foraging area' applies in relation to BIAs (Ref. 369); and these BIAs correspond to 'Foraging Area', 'Possible Foraging Area', and 'Known Foraging Area' as illustrated in Figure 1 of the Conservation Management Plan for the Blue Whale (Ref. 20; Ref. 369). There are no Foraging Area BIAs within or adjacent to the DA.

[196] In accordance with Australian Government guidance, activities outside designated Foraging Areas should adopt adaptive management approaches in the event that indicators (e.g. aggregation in a particular area) of whale foraging are evident to ensure that impacts are not unacceptable (e.g. no injury or biologically significant disturbance) (Ref. 369). EPO-17 incorporates foraging as one of the biologically important behaviours of marine fauna, and EPO-23 applies adaptive management.

The above key sensitivities and consideration are sourced from the description of pygmy blue whales in Section 6.3.3.1.2; refer to this section for further details and scientific studies/literature sources.

10.4.3 risk-based approach

Consistent with the approach within Chevron Corporation's Environment Risk Management Process (Ref. 492; see also Section 10.3.3.1), this adaptive management framework for pygmy blue whales adopts a risk-based approach to managing environmental risks. That is, safeguards (control measures) are developed commensurate to the nature and scale of the risk (e.g. there may be greater risk reduction and/or different controls required during peak north-bound migration versus south-bound migration, or during concurrent petroleum activities versus an individual petroleum activity, etc.).

10.4.3.1 sources of uncertainty

At the time of writing this OPP, detailed information on the staging of field developments is not yet available (Section 4.1.4), but this will become available as the field developments progress through design stages. It was also noted in Section 8.5.3.1.1 that some of the analogue source levels for MODU/vessels used in the acoustic and animal behaviour modelling to inform the risk evaluation in the OPP are likely over-conservative, which would subsequently overestimate the predicted ensonified areas. This framework is intended to address these and other key areas of uncertainty in managing the risk of underwater sound emissions on pygmy blue whales, including:

- activity-specific schedules for the Development (and any overlap with other CAPL petroleum activities)
- predictions of ensonified areas (e.g. including estimation of the sound source level, effect-criteria, inputs into animal movement modelling, etc.)
- the behavioural response and physiological effects on pygmy blue whales from exposure to underwater sound
- the implications/consequences of these effects to pygmy blue whale individuals or populations
- detection methods for biologically important behaviours (e.g. foraging versus migrating) of pygmy blue whales within vicinity of the DA
- changes to and/or new regulatory requirements in relation to the management of underwater sound and pygmy blue whales.

New information related to these areas of uncertainty is likely to become available over the life of the Development. The implementation of an adaptive management framework allows CAPL to incorporate new information at the time of a specific petroleum activity and to develop safeguards commensurate to the environmental risk.

10.4.4 framework

The management of environmental risks from the Development's underwater sound emissions to pygmy blue whales follows these key steps:

- prediction of potential worst-case credible consequence
- application of the environmental mitigation hierarchy to guide the selection of safeguards such that the environmental risk can be demonstrated to be

  - reduced to ALARP
  - managed to a level consistent with the EPOs (and therefore equal to or better than the acceptable levels)
- implementation of monitoring and adaptive management commensurate to the nature and scale of the risk.

Given the staged field developments for the backfill fields, the framework can be applied at both the specific petroleum activity and broader Development level. An overview of the adaptive management framework is provided in Figure 10-3.

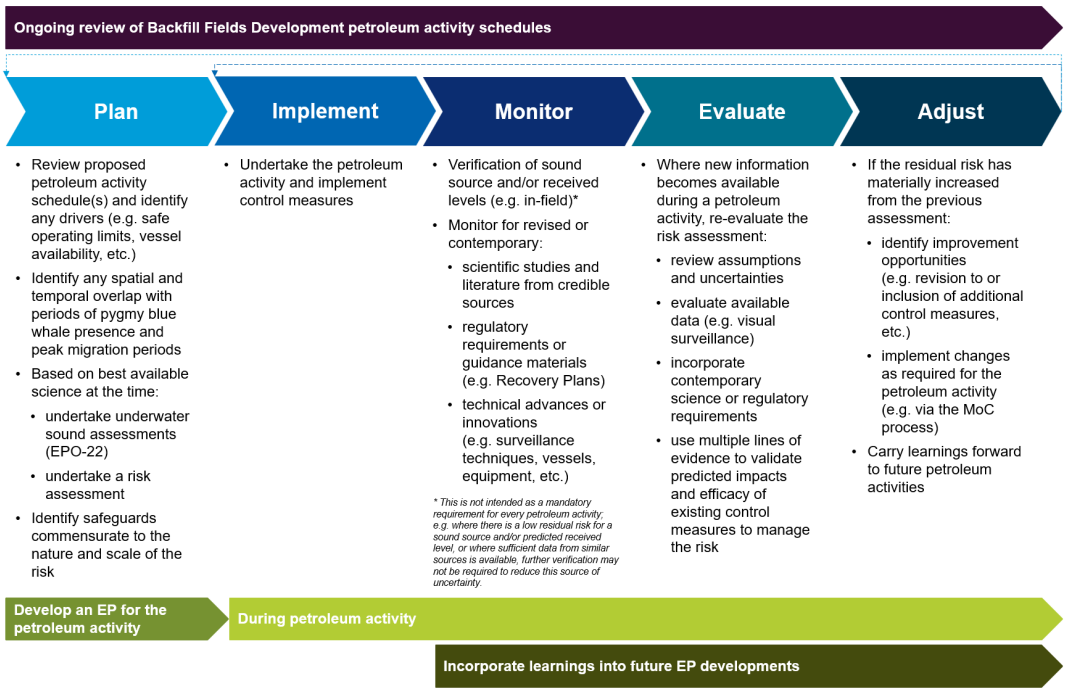


Figure 10-3: Overview of adaptive management framework

The Environment Risk Assessment and Management Procedure (Ref. 493) adopts an environmental mitigation hierarchy based on the IPIECA mitigation hierarchy (Ref. 765). The application of the environmental mitigation hierarchy identifies opportunities to limit potential negative impacts on environmental receptors of concern. The two preventative mitigation steps are:

- **avoid**—measures taken to anticipate and prevent potential negative impacts before actions or decisions are taken that could lead to such impacts
- **reduce**—measures taken to reduce the duration, intensity, significance and/or extent of potential impacts (including direct, indirect, and cumulative impacts, as appropriate) that cannot be completely avoided.

Under the Environment Risk Assessment and Management Procedure, application of the mitigation hierarchy is required for a potential consequence of Minor or above (see Table 7-4 for consequence descriptions from Chevron Corporation's Integrated Risk Prioritization Matrix).

Figure 10-4 provides an extended overview of the 'plan' stage of the framework, including undertaking a risk assessment and applying the environmental

mitigation hierarchy to ensure that the residual risk is consistent with the relevant acceptable levels and EPOs established for the Development.

To assist in the application of the environmental mitigation hierarchy a preliminary toolbox of potential safeguards has been collated in Table 10-2. The types of safeguards presented in the toolbox are based on CAPL's operational experience on the NWS and CAPL's involvement in national and international working groups related to the management of underwater sound. It is expected that this toolbox will be revised over time as new information and/or new technologies become available.

Table 10-2: Toolbox of example safeguards for managing the environmental risk from underwater sound to pygmy blue whales

Hierarchy	Example types of control measures that may be considered
Avoid	• Temporal avoidance (e.g. avoid activities during predicted peak periods of north-bound migration)
Reduce	• Reduce spatial exposure within migration BIA (e.g. adjust activity schedules[197], if operationally feasible and practicable, to reduce or remove concurrent activities) • Reduce temporal exposure during peak sensitivity periods (e.g. adjust activity schedules [as above] to reduce or remove concurrent activities; reduce activities to day-time operations during predicted peak periods of north-bound migration, etc.) • MODU/vessel selection • Position-holding selection (e.g. anchoring in place of DP) • Equipment (e.g. geophysical) selection • Separation distances (e.g. for vessels or helicopters under transit) • Speed limits (e.g. for vessels under transit) • Use of operating procedures, e.g. – ongoing visual surveillance within an observation zones[198] during the petroleum activity (e.g. by bridge-watch, dedicated Marine Fauna Observers, passive monitoring equipment, etc.) to advise of presence/behaviour of pygmy blue whales – adjust activity[199] (e.g. pause activity, reduce DP, change position, etc.) if pygmy blue whale foraging behaviour[200] is observed within action zone[198] – use of soft-starts and/or shut-down zones for impulsive (e.g. VSP) sound sources – activity re-start procedures

[197] The ability to adjust schedules is dependent on the type of activity and any schedule drivers (e.g. safe operating [metocean] conditions, vessel or equipment availability, integrity management for IMR, etc.).

[198] The development, spatial extent, and use of any management zones (e.g. observation, action, shut-down) will be commensurate with the sound source and risk being managed.

[199] These in-field decisions to adjust an activity are the responsibility of the Vessel Master (or equivalent), and would only be implemented where it is considered operationally safe and technically feasible.

[200] In-field observations of actual whale feeding are difficult to detect, so indicators of probable foraging (e.g. aggregating in a particular area) may be used as a proxy (Ref. 369). The type of indicator, or ability to detect actual feeding behaviours, may change over the life of the Development with advancement in science and technology.

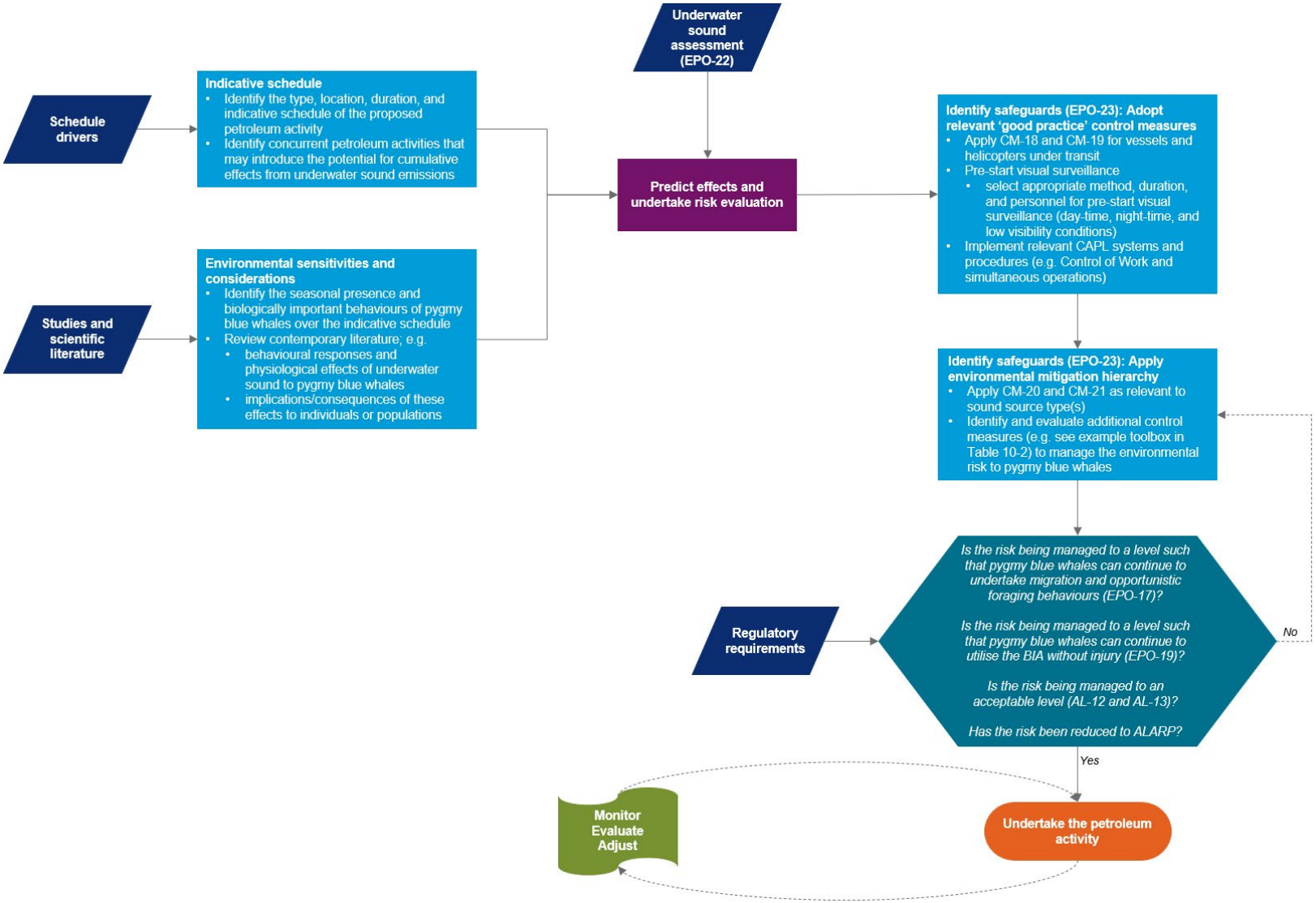


Figure 10-4: Expanded overview of 'plan' with application of the environmental mitigation hierarchy

10.4.5 implementation of the framework in EPs

It is intended that this adaptive management framework for pygmy blue whales is applied to the subsequent suite of EPs required for the Development. As each EP is developed, this framework may be refined and revised (e.g. to incorporate new science, technology, regulatory requirements, etc.), and changes will be described in the EPs.

10.5 environmental monitoring and reporting

10.5.1 environmental monitoring

Monitoring will be undertaken to demonstrate that CAPL complies with regulatory requirements specified in the OPP and subsequent EPs. The goals of monitoring activities are to:

- monitor discharges and emissions
- identify changes to the environment as a result of Development activities
- provide continuous review of procedures and activities.

Monitoring programs will be described in detail in subsequent EPs. The OSMP will be included with subsequent EPs and will describe a program of monitoring to determine the extent, severity, and persistence of environmental impacts from emergency conditions and emergency response activities undertaken by CAPL.

10.5.2 incident reporting

Part 5 of the OPGGS(E)R requires the reporting of incidents in subsequent EPs.

A reportable incident, as defined under the OPGGS(E)R 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 regulations 47, 48, and 49.

Environmental incident reporting requirements are covered in the II&R Execution Manual (Ref. 498) outlined in Section 10.3.7.

Other reporting requirements are shown in Table 10-3.

Table 10-3: Other incident reporting requirements

Reporting requirement	Reporting to	Timing
An oil/gas pollution incident that occurs within a marine park or is likely to impact on a marine park. The notification should include: • titleholder details • time and location of the incident (including name of marine park likely to be affected) • proposed response arrangements as per the OPEP (e.g. dispersant, containment, etc.)	DNP (24-hour) Marine Compliance Duty Officer • Phone: 0419 293 465. • Email: marine.compliance@environment.gov.au	As soon as practicable

Reporting requirement	Reporting to	Timing
• confirmation of providing access to relevant monitoring and evaluation reports when available • contact details for the response coordinator.		
Death or injury to individual(s) from an EPBC Act Listed Species as a result of the petroleum activities	Report injury to or mortality of EPBC Act listed threatened or migratory species to DCCEEW or equivalent: • Phone: +61 2 6274 1111 • Email: EPBC.Permits@environment.gov.au	Within 7 business days of observation
Vessel collision with marine megafauna	DCCEEW: • https://data.marinemammals.gov.au/report/shipstrike	As soon as practicable
Presence of any suspected IMP or disease	DPIRD: • Email: biosecurity@fish.wa.gov.au • Phone: FishWatch 24-hour hotline: 1800 815 507	Within 24 hours of confirmation

10.5.3 routine environmental reporting

Regulation 51 of the OPGGS(E)R requires environmental performance reporting for activities described in subsequent EPs, including recordable incidents. These are summarised in Table 10-4.

Table 10-4: Routine external reporting requirements

Reporting requirement	Description	Reporting to	Timing
Environmental performance	A report detailing environmental performance of the activity detailed in an EP	NOPSEMA submissions@nopsema.gov.au Phone: 1300 674 472	Annually
Recordable incident	Report includes details of recordable incidents (if any) that have occurred during the petroleum activity for the previous month		Monthly

10.6 implementing requirements of the OPP in subsequent EPs

NOPSEMA's Offshore Project Proposal Content Requirements (Ref. 16) states that EPOs must be consistent with the principles of ESD and demonstrate that the environmental impacts and risks of the project will be managed to an acceptable level.

Control measures detail how EPOs will be achieved and are provided in subsequent EPs. EPs must have EPSs set with appropriate measurement criteria to monitor the performance of the control measures and determine whether the EPOs and EPSs have been met during the activity.

The impact and risk assessments in this OPP are based on conservative assumptions of Development activities, as understood at the time of writing. Evaluations in subsequent EPs will revalidate levels of impact and risk and acceptability, as needed.

This implementation strategy will have further detail added in subsequent EPs. The strategy will ensure control measures are effective in reducing the environmental impacts and risks of the activity to ALARP and acceptable levels, and that EPOs and EPSs are continually met.

11 acronyms, abbreviations and definitions

Table 11-1 defines the acronyms, abbreviations and terminology used in this document.

Table 11-1: Acronyms and abbreviations

Acronym / abbreviation	Definition
~	Approximately
″	Inch
<	Less / fewer than
>	Greater / more than
≥	Greater / more than or equal to
µg	Microgram
µm	Micrometre. 1 µm = 10^{-6} metre = 0.000001 metre or one millionth of a metre.
µPa	Micropascal
3D	Three-dimensional
AASM	Airgun Array Source Model
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABU	Australian Business Unit
ACAP	Agreement on the Conservation of Albatrosses and Petrels
ACCU	Australian carbon credit unit
ACHIS	Aboriginal Cultural Heritage Inquiry System
AFMA	Australian Fisheries Management Authority
AHO	Australian Hydrographic Office
AIMS	Australian Institute of Marine Science
ALARP	As low as reasonably practicable
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
API	American Petroleum Institute
APS	Announced Pledges Scenario
AR6	Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC)
AUV	Autonomous underwater vehicle
barg	Bar gauge
BC Act	Western Australian *Biodiversity Conservation Act 2016*
BCH	Benthic habitat and community
bcm	Billion cubic metres
BIA	Biologically important area
BOP	Blowout preventer
BRS	Commonwealth Bureau of Rural Sciences

Acronym / abbreviation	Definition
BTEX	Benzene, toluene, ethylbenzene, and xylene
C&D	Chrysaor and Dionysus
CALM Act	Western Australian *Conservation and Land Management Act 1984*
CAMBA	China Australia Migratory Birds Agreement
CAPEX	Capital expenditure
CAPL	Chevron Australia Pty Ltd
CCS	Carbon capture and storage
CDU	Controls Distribution Unit. For the distribution of hydraulics, electrical power, chemicals and communications; refers to new units in the backfill fields that will be termination points for the umbilicals from the FCS or existing subsea infrastructure and where the umbilicals split to link components such as production manifolds.
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (UK)
CER	Clean Energy Regulator
CH_4	Methane
CIA	Cumulative impact assessment
cm	Centimetre
CM	Control measure
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CoW	Control of Work
cP	Centipoise
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cth	Commonwealth of Australia (Australian Government)
DA	Development area
DAFF	Department of Agriculture, Fisheries and Forestry
DAWE	Former Commonwealth Department of Agriculture, Water and the Environment (now DCCEEW)
dB	decibel
DBCA	Department of Biodiversity, Conservation and Attractions (WA)
DC	Drill Centre. Refers to a central location from which several subsea wells are drilled. Some fields have more than one DC.
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEMIRS	Western Australian Department of Energy, Mines, Industry Regulation and Safety
DGV	Default guideline value
DISER	Department of Industry, Science, Energy and Resources (Cth) (now DISR)
DISR	Department of Industry, Science and Resources (Cth)
DNP	Director of National Parks

Acronym / abbreviation	Definition
DoT	Department of Transport (WA)
DP	Dynamic positioning
DPIRD	Department of Primary Industries and Regional Development (WA)
DWER	Department of Water and Environmental Regulation (WA)
e.g.	For example
EEZ	Exclusive economic zone
EFL	Electrical flying lead
EIS	Environmental Impact Statement
EMBA	Environment that may be affected
EP	Environment Plan
EP Act	Western Australian *Environmental Protection Act 1986*
EPBC 2003/1294	Gorgon Gas Development/Barrow Island
EPBC 2005/2184	Jansz Feed Gas Pipeline
EPBC 2008/4178	Gorgon Gas Development Revised
EPBC 2011/5942	Gorgon Fourth Train Expansion
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPO	Environmental performance outcome
EPRS	Emergency pipeline repair system
EPS	Environmental performance standard
ERMP	Environmental Review and Management Programme
ERO	Emergency Response Organisation
ESD	Ecologically sustainable development
FCGT	Flood, clean, gauge and testing
FCS	Field control station
Feed Gas Pipeline	Pipeline system from the Gorgon and Jansz–Io gas wells to the Gas Treatment Plant
FPSO	Floating production storage and offloading
G&E	Geryon and Eurytion
g/m^2	Grams per square metre
GEC	Global Energy and Climate
GES	Greater East Spar
GFP	Gorgon Foundation Project
GHG	Greenhouse gas
GHGMP	Greenhouse Gas Management Plan
GS2	Gorgon Stage 2
Gt	Gigatonne
GTP	Gas treatment plant
GWL	Global warming level

Acronym / abbreviation	Definition
ha	Hectare
HFL	Hydraulic flying lead
Hg	Mercury
HGs(s)	Mercury (II) sulfide
HSE	Health, safety, and environment
HWM	High water mark
HWU	Hydraulic workover unit
Hz	Hertz
i.e.	That is
IChEMS	Industrial Chemicals Environmental Management Standard
IEA	International Energy Agency
II&R	Incident investigation and reporting
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMO	International Maritime Organization
IMP	Invasive marine pest
IMR	Inspection, maintenance and repair
IMS	Incident management system
in	inch
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Birds Agreement
J-IC	Jansz–Io Compression
KEF	Key ecological feature
kg	Kilogram
kHz	Kilohertz
km	Kilometre
kV	Kilovolt
L	Litre
LC_{50}	Lethal concentration with the potential to result in a 50% mortality of a sample population
LGM	Last glacial maximum
LNG	Liquefied natural gas
LOC	Loss of containment
LOWC	Loss of well control
lux	A standard for measuring light; equal to the amount of visible light per square metre incident on a surface. 1 lux = 1 lumen/square metre
m	Metre
m^3	For liquids: Cubic metres

Acronym / abbreviation	Definition
	For gases: Standard cubic metres (Sm^3) measured at 0 barg
MARPOL	The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978; also known as MARPOL 73/78.
MASS	Marine Autonomous Surface Ship
MBES	Multibeam echo sounder
MDO	Marine diesel oil
MEG	Monoethylene glycol
MFE	Mass flow excavation
mg	Milligram
MGO	Marine gas oil
mm	Millimetre
MM	Million
MMscf/d	Million standard cubic feet per day (of gas). 1 MMscf/d = 1180 Sm^3/h (standard cubic metres per hour)
MNES	Matters of national environmental significance
MODU	Mobile offshore drilling unit
MOPU	Mobile operational production unit
MoU	Memorandum of Understanding
MPTS	Midline pipeline termination structure
MS 1002	Ministerial Statement 1002 – Gorgon Gas Development Fourth Train Expansion Proposal
MS 1198	Ministerial Statement 1198 – Gorgon Gas Development Revised and Expanded Proposal
MS 748	Ministerial Statement 748 –Gorgon Gas Development Barrow Island Nature Reserve
MS 1136	Ministerial Statement 1136 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 769	Ministerial Statement 769 – Jansz Feed Gas Pipeline – Barrow Island Nature Reserve
MS 800	Ministerial Statement 800 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 865	Ministerial Statement 865 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 965	Ministerial Statement 965 – Gorgon Gas Development – Barrow Island
Mt	Million tonnes
Mtpa	Million tonnes per annum
N/A	Not applicable
NADF	Nonaqueous drilling fluids
NCVA	National conservation values atlas
NDC	Nationally determined contribution
NEPM	National Environmental Protection Measure
NGER Act	Commonwealth *National Greenhouse and Energy Reporting Act 2007*

Acronym / abbreviation	Definition
NIS	Non-indigenous species
nm	Nautical mile
NMVOC	Non-methane volatile organic compound
NNM	Not normally manned
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOPSEMA	National Offshore Petroleum Safety and Environment Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NORM	Naturally occurring radioactive material
NO_x	Nitrous oxides
NTGAC	Nganhurra Thanardi Garrbu Aboriginal Corporation
NWMR	North-west Marine Region
NWS	North West Shelf (of Western Australia)
NWSTF	North West Slope Trawl Fishery
NZE	Net Zero Emissions by 2050 Scenario
NZS	New Zealand Standard
O_3	Ozone
OCNS	Offshore Chemical Notification Scheme
OCV	Offshore construction vessel
ODS	Ozone-depleting substance
OE	Operational Excellence
OEMS	Operational Excellence Management System
OHS	Occupational health and safety
OPEP	Oil Pollution Emergency Plan
OPGGS Act	Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPGGS(E)R	Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009*
OPP	Offshore Project Proposal
OSMP	Operational and Scientific Monitoring Plan
OSV	Offshore support vessel
P&A	Plug and abandonment
PAH	Polycyclic aromatic hydrocarbon
PCPT	Piezocone penetration test
PER	Public environmental review
Pipeline termination structure	For the commingling of production fluids; may refer to existing GFP infrastructure or a new pipeline termination structure in the backfill fields
PLEM	Pipeline end manifold
PLET	Pipeline end termination

Acronym / abbreviation	Definition
PLONOR	Pose little or no risk
PLV	Pipelay vessel
PM	Particulate matter
$PM_{2.5}$	Particulate matter with a diameter of 2.5 micrometres or less
PNEC	Predicted no-effect concentration
POB	Personnel on board
ppb	Parts per billion
ppm	Parts per million
Production pipeline	For the transport of production fluids; refers to the existing Jansz and Gorgon Feed Gas Pipelines associated with the GFP.
PSU	Practical Salinity Units
PSZ	Petroleum safety zone
PTS	Permanent threshold shift
RNTBC	Registered Native Title Body Corporate
ROKAMBA	Republic of Korea Migratory Birds Agreement
ROV	Remotely operated vehicle
RTM	Response Time Model
SBP	Sub-bottom profiler
SCSt	Subsea compression station
SIMAP	Spill Impact Mapping and Analysis Program
SMC	Safeguard Mechanism credit
SNA	Safe navigation area
SO	Sulfur monoxide
SO_2	Sulfur oxides
SO_3	Sulfur trioxide
SoE	State of the Environment
SOLAS	International Convention for the Safety of Life at Sea 1974
SOPEP	Ship Oil Pollution Emergency Plan
SPL	Sound pressure levels
SSPLR	Subsea pig launcher receiver
SSS	Side-scan sonar
STEPS	Stated Policies Scenario
STFL	Steel tube flying lead
t	Tonne
TEC	Threatened ecological community
TJ	Terajoules
TLP	Tension-leg platform
TSS	Total suspended solids

Acronym / abbreviation	Definition
TTS	Temporary threshold shift
UCH	Underwater cultural heritage
UCH Act	*Underwater Cultural Heritage Act 2018* (Cth)
Umbilical	For the transfer of electricity; electrohydraulic umbilicals incorporate hydraulic power, electric power and a fibre-optic control link.
UN SDG	United Nations Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change
UXO	Unexploded ordnance
VSP	Vertical seismic profiling
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council Inc
WBF	Water-based fluid
WDTF	Western Deep Trawl Fishery
WEO	World Energy Outlook
WHP	Wellhead platform
WOMP	Well operations management plan
WTBF	Western Tuna and Billfish Fishery
WTR	West Tryal Rocks

12 references

Table 12-1 lists documentation directly referenced in this document or recommended as a source of background information.

Table 12-1: References

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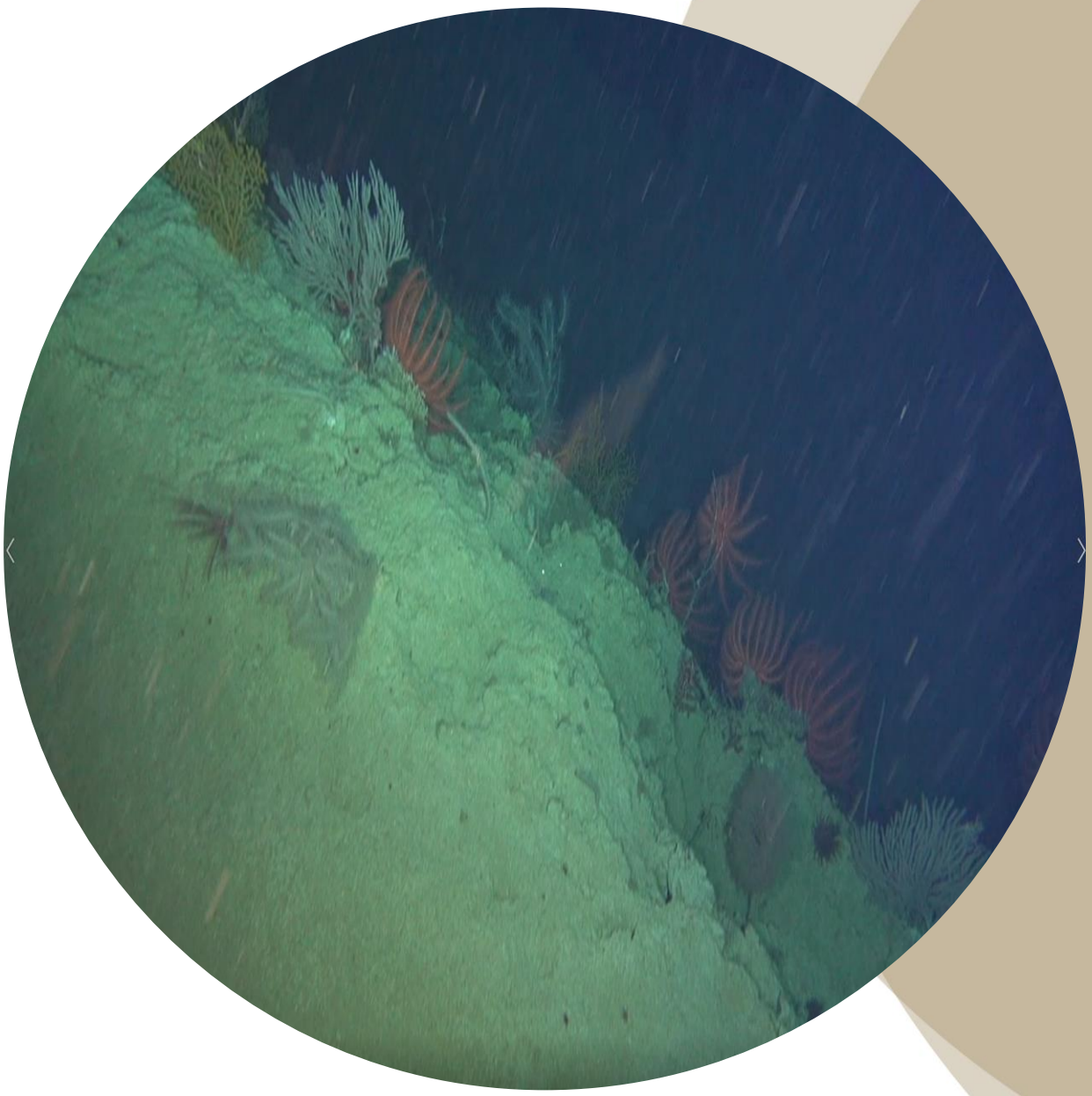
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appendix a gorgon backfill fields benthic survey 2022



Gorgon Backfill Fields Benthic Survey 2022

Survey Report

Chevron Australia Pty Ltd

August 2025

411012-00488

Advisian
Worley Group

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PROJECT 411012-00488: Gorgon Backfill Fields Benthic Survey 2022 - Survey Report

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5	Final	ES	MW	MW	22/07/25		
6	Final	KS	MW	MW	1/08/25		

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Executive Summary

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area (collectively known as Gorgon Gas Development: Backfill Fields; GBF) which will include the installation of multiple subsea facilities such as flowlines, umbilicals, and drill centres/well infrastructure sites. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd to characterise the marine benthic environment within the GBF project area, which is defined as a 5 km buffer around all indicative subsea infrastructure. The final flowlines and umbilical routes have not been identified yet by CAPL however, survey sites are focused on indicative flowline and umbilical routes, tie-in locations and proposed drill centres. The scope of works included: 1) the development of a preliminary benthic habitat map to identify areas of significance (such as Key Ecological Features; KEFs) and notable benthic features and identify survey sites for field verification; and 2) to undertake an environmental survey of benthic habitat, sediment, benthic infauna, marine water, and fish assemblages within the GBF project area.

Prior to the field survey, a preliminary benthic habitat map spanning 500 m from all potential benthic disturbance footprints was generated using all available geophysical data provided by CAPL, which included multibeam echo sounder, backscatter, sidescan sonar, 3D seismic, and geotechnical sediment data. Images were processed and enhanced where possible to identify geomorphic habitat types. The map identified eight broad habitats within the GBF project area, and identified three KEFs (elements of the Commonwealth marine environment that are considered to be of regional importance; DCCEEW, 2022) that intersect with some of the GBF project area: 'Exmouth Plateau', 'Continental Slope Demersal Fish Communities', and 'Ancient Coastline at 125 m depth contour' (hereafter 'Ancient Coastline'). From this map, sampling sites were identified for ground-truthing based on the geomorphic attributes, the presence of benthic features within these KEFs, and areas with data deficiency and other points of interest. Following the completion of in field ground-truthing, the project operational area was expanded from 500 m to a 5 km radius around all potential subsea facilities, and was further mapped using all available desktop resources. No ground truthing of benthic habitats was undertaken within the expanded operational area footprint.

The field survey was completed between the 26th April and 11th May 2022 on board Skandi Singapore (DOF Subsea Pty Ltd). Benthic habitat and fish survey data were collected along transects using a remotely operated vehicle (ROV). The ROV had a forward-facing high definition (HD) camera to collect video footage for habitat mapping and fish assemblages, and a downward-facing HD camera that captured still images and video footage for benthic cover. The vessel position and ROV were tracked using survey grade positioning equipment. The ROV was also used to deploy all sampling equipment to the seafloor including push corers for the collection of sediments and benthic infauna, Niskin bottles for water sampling above the seabed, and a water quality probe to measure conductivity, temperature, and depth throughout the water column. Surface water samples were also collected from the vessel. All sediment samples were analysed for hydrocarbons, total metals/metalloids, particle size distribution, total organic carbon (TOC) and moisture content. All water samples were analysed for hydrocarbons, dissolved and total metals, dissolved organic carbon (DOC), TOC, total dissolved solids (TDS) and nutrients.

Benthic habitat mapping following ground-truthing confirmed that a mixture of habitat types were present within the proposed GBF project area. Where the GBF project area intersects with the Exmouth

Plateau KEF, the benthic habitat is dominated by irregular seabed with bioturbation, irregular and smooth seabed floor with bare substrates, and mounds on the seafloor of bare substrate. In the Exmouth Plateau KEF that lies within the GBF project area, two large discrete scarps with 3-dimensional hard structure (i.e., rock) cross through the indicative flowline from east to west, likely providing biota with suitable habitat. Where the GBF project area crosses with the Continental Slope Demersal Fish Communities KEF, irregular and smooth seabed with bare substrates and discrete depressions of bare substrate, and scarps with bare substrate were the most dominant benthic features. Topographically complex rock reefs and scarps were also present traversing through the GBF project area between ~400–800 m depths that were colonised by cnidarians, echinoderms, sponges, and a mixture of these biotic groups. Mapping of the GBF project area that lies within the Ancient Coastline KEF shows that the benthic habitat consisted of smooth seabed with bioturbation and appeared devoid of non-cryptic biota.

Benthic habitat mapping of low slope areas (defined as areas within the GBF project area containing proposed infrastructure located outside of KEFs in the lower slope and Kangaroo Syncline areas) showed a mixture of low structural habitats present within the Chandon DC-1 to JMT corridor. The benthic habitat within the Jansz to Geryon and Eurytion corridors comprised smooth seabed with bioturbation and irregular seabed with bare substrate, with intermittent mounds with bare substrate and scattered patches of depressions over bare substrate. The benthic habitats within the Chrysaor and Dionysus to Gorgon corridor are predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation.

Benthic habitat mapping around proposed drill centres and tie in locations that are located outside a KEF and not in a low slope area, which include Jansz DC2, G & E DC-1, Semele DC-1, Semele DC-2, BCH40 and WTR DC-1, were of low structural complexity and dominated by smooth seabed with bioturbation. Ground truthing transects at each of these locations did not reveal any epifaunal communities.

The benthic cover at 14 proposed drill centres and tie-in locations showed that bare sediment with no biota was the dominant benthic category. Gorgon M1 was the only site with bioturbation and very low cover of cnidarians[1].

For fish assemblages, Ancient Coastline KEF recorded a total of 18,011 individuals from 13 fish taxa compared to the Exmouth Plateau (165 individuals from 14 taxa), Continental Slope Demersal Fish Communities (165 individuals from 14 taxa) and out of KEF area (11,800 individuals belonging to 28 taxa). The fish assemblage across most KEFs were by dominated trevallies such as *Seriola dumerili* (Carangidae), *Carcharhinus* sp1 (Carcharhinidae), an unidentified anguilliform fish, and an unidentified baitfish species. The crustacean assemblage was greatest in the Exmouth Plateau KEF and outside of KEF areas, comprising of 228 individuals from seven taxa and 236 total individual crustaceans from seven taxa, respectively. Prawns were the most dominant crustacean taxa found across all KEFs.

[1] Note: this revision (Rev 6) of the Gorgon Backfill Fields Benthic Survey Report has been updated to correct a transcription error presented in the previous revisions of this Report. The correction resulted in the reassignment of one abiotic category from low relief sand/mud with boulders (rocks >255 mm), to the same category without boulders for the affected transects in Section 4.2. This revision has been updated to correct a classification error resulting in the reassignment of one abiotic category from <1% cover low relief sand/mud with boulders at Chandon DC-1 T2 to the same category without boulders and with bioturbation. Note that the occasional presence of boulders in low relief sand/mud have minimal role in habitat provision for biotic assemblages.

Of the four geomorphic features (plateau slope, trench/trough slope, slope, and deep/hole/valley slope), the slope geomorphic features had the largest number of individual fish species (30,033) belonging to 37 taxa followed by the deep/hole/valley slope with 187 individuals from 16 fish taxa. Between 110 and 236 individual crustaceans were recorded across all geomorphic features with the exception for slope which only recorded five individuals.

A total of 922 invertebrate individuals from 26 taxa were recorded across all sites. The invertebrate assemblage included feather stars, jellyfish, sea cucumbers, sea stars, sea urchins and squids.

For sediment samples located within proposed drill centres and tie in locations, concentrations of all hydrocarbons were below the laboratory limit of reporting (LOR). Concentrations of all metals and metalloids were all below their relevant ANZG (2018) default guideline values (DGVs), with the exception of nickel. TOC concentrations were relatively low across all samples. Sediments primarily consisted of well-sorted clays and silts that were odourless and contained the occasional small shell fragments. A total of five individual benthic infauna belonging to three families were collected across four sites.

No hydrocarbons were detected in water samples collected from the surface and near the seabed across the GBF project area. Concentrations of all dissolved and total metals in water samples met the relevant DGVs except for dissolved cobalt and copper. Measurable levels of DOC, TOC, TDS, and nutrients were detected in the water samples. Water profiles were consistent across the sites and showed a gradual decrease in temperature and conductivity with increasing depth while salinity was relatively consistent with depth. At the deeper sites, three water masses were identified in the water column: low salinity surface waters (upper ~180 m), higher salinity mid-waters (~185–250 m) and low salinity bottom waters (~250–1310 m depth).

Overall, the benthic environment is characteristic of the North Carnarvon Basin and the North West Shelf region and is typical of an undisturbed tropical offshore environment (Heyward et al., 2001; Falkner et al., 2009; Williams et al., 2010). This survey did not find any benthic communities and habitats of regional significance.

Acronyms and Abbreviations

Acronym/abbreviation	Definition
°C	Degrees Celsius
2D	Two dimensional
3D	Three dimensional
AAIW	Antarctic Intermediate Water
ANZG	Australian and New Zealand Guidelines
BCH	Benthic communities and habitats
BS	Backscatter
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CATAMI	Collaborative and Automated Tools for Analysis of Marine Imagery
CoC	Chain of custody
CTD	Conductivity, temperature, and depth
C & D	Chryasor and Dionysus
DC	Drill centre
DGV	Default guideline value
DEM	Digital elevation model
DistLM	Distance-based linear modelling
DOC	Dissolved organic carbon
DPIRD	Department of Primary Industries and Regional Development
FCS	Field Control Station
fps	Frames per second
G & E	Geryon and Eurytion
GBF	Gorgon Backfill Fields
GIS	Geographic information system
GMT	Gorgon midline termination
GPS	Global positioning system
HD	High-definition
JMT	Jansz midline termination
KEF	Key Ecological Features

Acronym/abbreviation	Definition
km/h	Kilometre per hour
LOR	Limit of reporting
MBES	Multibeam echo sounder
mS/cm	MilliSiemens per centimetre
NATA	National Association of Testing Authorities
nMDS	Non-parametric multidimensional scaling
OPP	Offshore Project Proposal
PAH	Polycyclic aromatic hydrocarbons
PEP	Project Execution Plan
PERMANOVA	Parametric analysis of variance
PSD	Particle size distribution
PSU	Practical Salinity Unit
QA/QC	Quality assurance and quality control
ROV	Remotely operated vehicle
RPD	Relative percent difference
RSD	Relative standard deviation
SAGA GIS	System for Automated Geoscientific Analyses
SE	Standard error
SICW	Southern Indian Central Water
SSS	Sidescan sonar
TMS	Tether management system
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TPI	Topographic Position Index
TRH	Total recoverable hydrocarbons
TSW	Tropical Surface Water
WTR	West Tryal Rocks

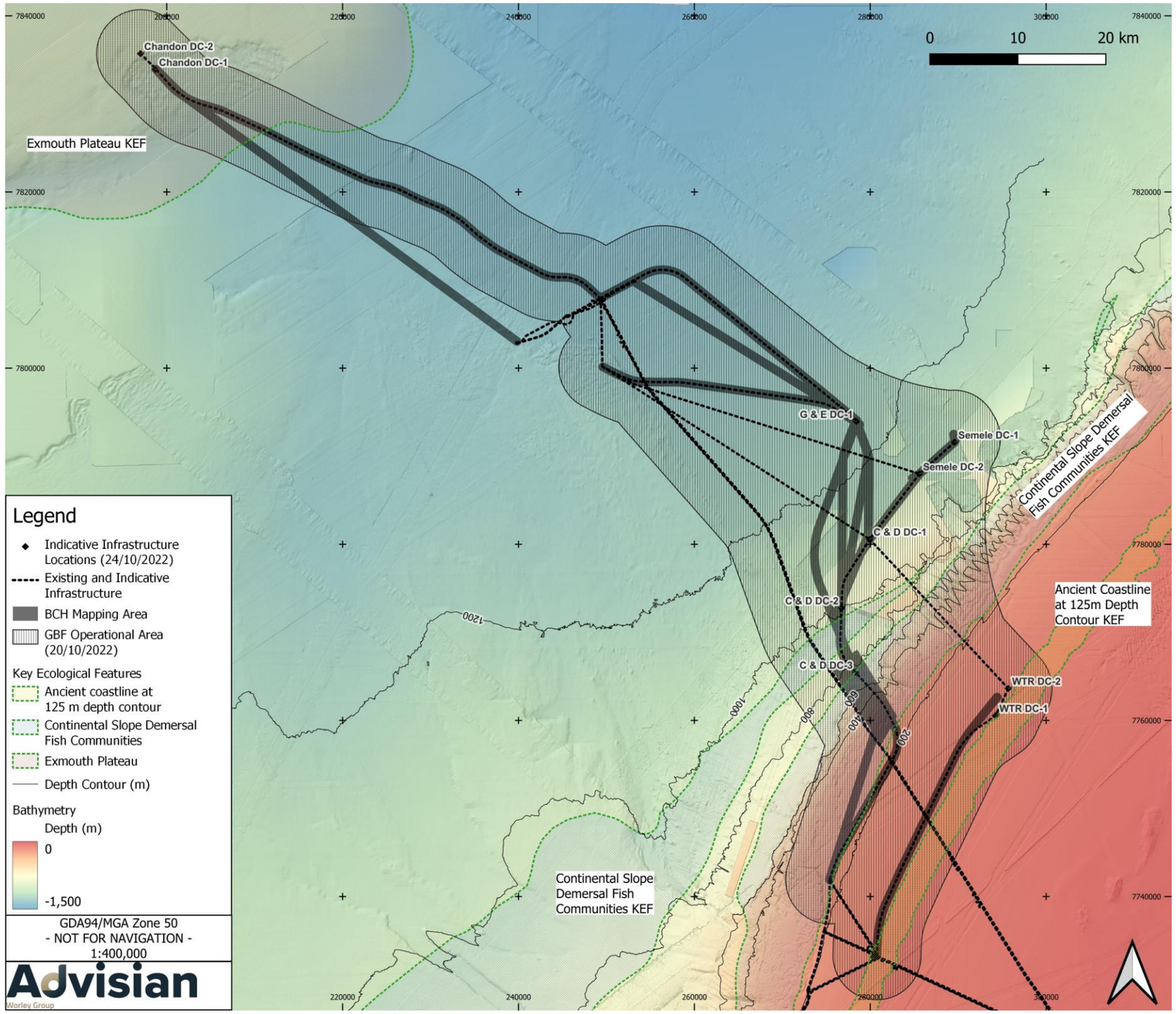
1 Introduction

1.1 Background

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area: Geryon, Eurytion, Chandon, Semele, Chrysaur, Dionysus and West Tryal Rocks (WTR) (hereafter; collectively known as Gorgon Gas Development: Backfill Fields, GBF; Figure 1-1). The fields are located between ~60–130 km north-west of Barrow Island, Western Australia, in water depths ranging from 150 m (WTR) to 1,300 m (Chandon). Multiple subsea facilities such as flowlines, umbilicals and drill centres/well infrastructure sites may be required for the development of each field. Although the final flowlines and umbilical routes have not been identified yet by CAPL, the study sites are focused on indicative flowline and umbilical routes, tie-in locations and indicative drill centres.

The GBF project area spans three Key Ecological Features[2] (KEF) of the Commonwealth marine environment; from the Exmouth Plateau in the west, to the Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour (hereafter Ancient Coastline) (Figure 1-1). These KEFs are likely to be relatively topographically complex and support a range of benthic habitats and organisms such as soft deep-sea coral, sea fans (gorgonians), sponges as well as regionally significant stocks of demersal fishes. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd (Advisian) to characterise the marine benthic environment within the GBF project area.

[2] Key Ecological Features 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 (DCCEEW, 2022).



Notes:
1. BCH = Benthic communities and habitat, GBF = Gorgon Backfill Fields, KEF = Key Ecological Feature, WTR = West Tryal Rocks
2. The GBF operational area has been expanded to a 5 km radius around the GBF project area post-field survey, as further discussed in Section 3.4

Figure 1-1 Overview of Gorgon Backfill Fields project area with conceptual subsea facilities in relation to Key Ecological Features of the area

1.2 Project Location and Geomorphology

To better understand the geomorphic characteristics of the GBF project area, which is defined as a 500 m radius around the proposed drill centres and tie-in locations, and a 500 m buffer around all associated subsea flowlines, CAPL and Advisian undertook a desktop study to develop a preliminary benthic habitat map. To develop this map, CAPL provided Advisian all available geophysical data to classify the habitat type based on discernible physical geomorphic or other notable benthic features. This map was then used to identify and inform targeted survey sites where information within the GBF project area may have been lacking. Refer to Section 2 for more details.

The primary geomorphic features in the GBF project area include the continental shelf, the upper, middle, and lower continental slope, the Kangaroo Syncline, and the Exmouth Plateau. The continental shelf is generally defined as extending from the nearshore environment to the shelf break at approximately 200 m water depth. The shelf features varied terrain including both modern sedimentary deposits and the remains of low sea level shoreline features (Geoscience Australia, 2022). The shallower continental slope deposits comprise mixed sediments, including both modern terrigenous (river derived) and carbonate (biogenic) materials, as well as the often-coarse preserved remains of ancient sediments [relict intraclasts] (James et al., 2004). The continental slope is characterised by complex and often steep submarine canyon systems, smooth sedimentary fans, and abrupt landslide scars.

The deep-water area separating Barrow Island from the Exmouth Plateau is known as the Kangaroo Syncline. This area includes mostly featureless seabed and the remains of older landslide deposits and sedimentary fans. The majority of the GBF project area is within this deeper area (800–1350 m) and is typically dominated by hemipelagic-pelagic sandy muds (high carbonate foraminiferal and nannofossil 'ooze'), which mantles all but the steepest of seabed features. Rates of sediment deposition and disturbance are low in these environments and even highly pronounced seabed features can be very old and may be draped with many metres of pelagic sediments (Hengesh et al., 2013).

The Exmouth Plateau is located in the Northwest Province and covers an area of approximately 49,310 km^2 (Heap and Harris, 2008). The plateau is an ancient, stranded section of continental crust that now resides in water depths typically greater than 1000 m. The plateau has associated lower continental slope features including landslide scars. The seascape is generally considered not unique in the regional context however it is believed that the expansive surface and large size may modify deep water flow and generate internal tides (Brewer et al., 2007). The Exmouth Plateau has been described as an area of low habitat heterogeneity, however, is considered to be an important area of biodiversity for offshore communities (DSEWPaC, 2012).

The GBF project area also intersects through three KEFs at different locations: proposed Chandon drill centre and associated flowline/umbilical corridors are located within the Exmouth Plateau KEF; flowlines in the Chrysaor and Dionysus fields are within Continental Slope Demersal Fish Communities KEF; and flowlines stemming from Gorgon GMT to WTR DC-1 in the WTR field are located within the Ancient Coastline KEF (Figure 1-1). The Exmouth Plateau KEF is recognised for its biodiversity values, with unique seafloor features ecological properties of regional significance, which apply to both the benthic and pelagic habitats within this KEF (DSEWPaC, 2012). The Continental Slope Demersal Fish Communities is an area on the Australian continental slope with a high diversity of demersal fish assemblages and high levels of endemism (DSEWPaC, 2012). This KEF has documented more than 500 fish species, 76 of which are endemic, making it the most diverse continental slope bioregion in Australia (Last et al., 2005). Demersal fish species occupy two distinct demersal community types, or

biomes, associated with the upper slope (water depth of 225–500 m) and the mid-slope (750–1000 m). The Ancient Coastline is an area of hard substrate (i.e., rock escarpments) that may be associated with enhanced species richness and higher diversity relative to surrounding areas of predominantly soft sediment. Likely fauna associated with the hard substrate of the ancient coastline include sponges, molluscs, echinoderms, corals, and crinoids (DSEWPaC, 2012).

1.3 Project Objective and Scope

The primary objective of this project was to describe the marine benthic environment (benthic habitats and communities; BCH) within the GBF project area. Secondary, we used the field mobilisation to broadly characterise other elements of the GBF project area, including marine water and sediment quality, demersal fish and benthic infaunal assemblages.

The scope of work included:

1. Development of a preliminary benthic habitat map based on assessment of geomorphic features to identify areas of significance (such as KEFs) and notable benthic features within the GBF project area and identify survey sites for field verification
2. Complete a visual benthic survey within identified survey sites to:
    a) verify the presence/absence of prominent and/or complex seabed features and other BCH across the GBF project area to further inform the preliminary habitat map
    b) describe and quantify BCH across a subset of representative sites
    c) opportunistically describe demersal fishes and identify fish and habitat associations within surveyed areas
3. Broadly characterise the water and sediment quality and composition within the GBF project area.
4. Describe the benthic infaunal assemblages within a subset of representative sites

This report presents the results of the field survey and includes both preliminary and refined benthic habitat assessment and mapping.

2 Preliminary Benthic Habitat Mapping Methods and Results

2.1 Data Acquisition

A preliminary benthic habitat map within the GBF project area was developed prior to the field survey to classify key benthic and geomorphic features of the seabed, and identify areas with insufficient information to describe the existing environment. To support the development of this map, all available geophysical data was provided by CAPL (Table 2-1), which included data collected from shipborne and underwater vehicles:

- Multibeam echo sounder (MBES) data, which provided a medium to high resolution 3-dimensional (3D) bathymetric terrain model of the seabed, from which morphological features were identified. Bathymetric grids of 2 m, 3 m, 5 m, 10 m, and 20 m resolution were supplied.
- Backscatter (BS) data, which is a product derived from MBES outputs that represents the strength of the acoustic signal returning from the seabed. This allows an assessment of seabed textural qualities (e.g., hardness or roughness) which can help in identifying features not otherwise visible in the bathymetry data.
- Sidescan Sonar (SSS) data, which is similar to BS however, it typically has higher resolution, allowing identification of fine-scale objects and textures, but lower spatial accuracy.
- 3D Seismic data, which comprises an acoustic reflection that can be processed to create a bathymetric terrain model similar to MBES.
- Geotechnical sediment data, including the results of 349 sediment descriptions as well as qualitative sediment assessments from SSS data.

Table 2-1 Details of the available geophysical data within the Gorgon Backfill Fields project area

Data Type	Number of Files	Grid Cell Resolution (m)	Areas Covered
MBES data	31	2, 3, 5, 10, 20	Most of the study area
BS data	6	1, 2, 3, 5	Same area as MBES
SSS data	69	0.2, 0.3, 0.5	Various narrow track lines covering less than 50% of the study area
3D Seismic data	3	10, 20, 25	Most of the study area

Note:
1. BS = Backscatter, MBES = multibeam echo sounder, SSS = sidescan sonar

2.2 Image Processing

MBES imagery was processed into a number of derivative products, to delineate seabed features at a variety of scales. Quantitative bathymetric analysis techniques were used to split the project area into multiple polygons for final interpretation. Bathymetric terrain derivatives were calculated using the powerful software tool SAGA GIS (System for Automated Geoscientific Analyses). These included:

- Shaded relief bathymetry: a 'sun shading' software rendering process was applied to the bathymetry dataset, which enhances textural features that are large enough to be captured by the mapping and processing equipment used (Yokoyama et al., 2002).
- Topographic roughness: roughness was computed by subtracting the minimum depth from the maximum depth value in a defined-neighbourhood around a central pixel. The neighbourhood is defined as the 8 nearest cells to a central pixel. Roughness is equal to the maximum depth displacement in a 3 by 3 grid of digital elevation model (DEM) cells around a central point. Given how roughness is calculated, it is always given as a value greater than or equal to zero. Values of zero or those close to zero indicate flat areas, whereas larger roughness values indicate increasingly steep or complex terrain (Riley et al., 1999).
- Topographic Position Index (TPI): the TPI algorithm compares a DEM cell value to the mean value of its neighbours. The mean value is calculated based on the shape selected by the user. Positive values represent features typically higher than surrounding features, negative values represent lower features, and values near zero are either flat or areas of constant slope (Watkins, 2020).
- Quantitative Seabed Slope (°): slope was defined as the ratio of rise to run over the defined-neighbourhood area. In geospatial data, slope is defined as the steepness of a surface or its inclination and is always positive. It should be noted that slope cannot differentiate between a mound and a depression, or a ridge and a valley (Evans, 1979; Florinsky, 2009).
- BS/SSS: indicates the strength of the returning signal as received by the vessel-mounted MBES or SSS system. This can indicate much finer scale textural and hardness information relating to the seabed. Note that only a derived image of BS was provided, which limits the potential classification techniques which can be applied. Images were locally stretched in order to maximise the resolving capability. High BS (typically white) indicates a harder/rougher seabed, whereas low BS (typically black) typically indicates a softer/smoother seabed.

2.3 Data Coverage and Quality

Data reliability buffers were applied that represent the distribution of the source data. A combination of MBES and SSS imagery with a resolution ranging from 0.2–10 m were considered more reliable, spatially accurate and of higher confidence, whereas 3D seismic/MBES combination with a resolution range of 10–25 m was considered of moderate (adequate) confidence.

2.4 Classification of Habitat

Due to the high spatial variability and availability of data types, no fully automated classification techniques could be implemented. However, using the derived terrain and textural feature layers, physical seabed features could be recognized and manually interpreted according to the following documented techniques:

- Morphological features (Dove et al., 2020)
- Terrain feature segmentation (Watkins, 2020)
- Sedimentary bedforms (Ashley, 1990)
- Shelf and slope classification (Butler et al., 2017, James et al., 2004)
- Submarine landslide interpretation (Hengesh et al., 2013)
- Debris fans (Posamentier and Walker, 2006)

- Habitat mapping surrogacy assumptions (McArthur et al., 2010)
- Habitat mapping assumptions (EPA, 2016)
- Submarine canyons (Huang et al., 2014, 2018)
- Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) classification scheme (Althaus et al., 2015).

Using the shaded relief, slope, TPI, roughness and backscatter information, seabed features were visually assessed for any discernible physical geomorphic or other notable benthic features. Assessments were made for potential sediment type, presence of rock or subsurface rock, relief, slope and sedimentary bedforms according to the CATAMI classification scheme (Althaus et al., 2015; Table 2-2). These features were nested within common boundaries in order to allow geographic information system (GIS) polygon attribution. Additionally, a morphological descriptor nested with the CATAMI scheme was also provided (Table 2-3). On-screen delineation of polygon boundaries was undertaken at a scale of 1:5000 using a desktop GIS software package.

Table 2-2 Collaborative and Automated Tools for Analysis of Marine Imagery classification scheme with feature descriptors

CATAMI	Feature Descriptors
Substrate Type 1 (S1)	Consolidated/ Hard (CAAB 82 001001) Unconsolidated/ Soft (CAAB 82 001005)
Substrate Type 2 (S2)	Fine sand/ mud (CAAB 82001015 + 82001016 Undifferentiated) Coarse sand (CAAB 82 001014) Pebble/ Gravel (CAAB 82001006)
Substrate Type 3 (S3)	Veneer Rock (CAAB 82 001002)
Relief Type 1 (R1)	Flat (CAAB 82 003001), Roughness <0.05 Low / Moderate (CAAB 82 003002) High (CAAB 82 003005), Roughness >0.1
Relief Type 2 (R2)	Low <1 m (CAAB 82 003003) Moderate 1-3 m (CAAB 82 003004) High >3 m (CAAB 82 003006) Wall (CAAB 82 003007) Other
Bedform Type 1 (B1)	None (CAAB 82 002001) 2D (CAAB 82 002002) 3D (CAAB 82 002006) Other
Bedform Type 2 (B2)	Ripples <10 cm (CAAB 82 002003) Waves >10 cm (CAAB 82 002004)

CATAMI	Feature Descriptors
	Large waves >0.75 m Very large waves >5 m Irregular
Bedform Type 3 (B3)	Small <10 m Medium 10–50 m Large 50–100 m Very large >100 m

Table 2-3 Attribute table (final substrate descriptor relating to Collaborative and Automated Tools for Analysis of Marine Imagery classification)

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
Bare seabed	Featureless sedimentary terrain	Smooth, no identifiable features, fine or coarse sediment	Typically, less than 2°, no topographic features	Low, no discernible feature	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: FLAT R2: N/A B1-3: N/A
Mostly bare seabed	Mostly flat sediment terrain with very minor features	Smooth with rare identifiable but unmappable regular bedforms or mounds. Fine or coarse sediment	Typically, less than 2°, very minor topographic features	Low, rare, and small discernible features	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: FLAT R2: N/A B1-3: N/A
Irregular Seabed	Mostly flat sediment terrain with minor features which may be derived from underlying geology	Smooth with identifiable, regular but small bedforms or mounds. Fine or coarse sediment	Typically, less than 2°, minor topographic features	Low, rare, and small discernible features	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: LOW-MOD R2: LOW B1: OTHER B2: IRREGULAR B3: N/A

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
Rock Veneer	Area of buried bedrock/rocks or cemented sediments with very low sediment input (Starved). Also known as low profile reef	Uneven, rugged, and irregular features, often angular or linear. Fine or coarse sediment	Typically, less than 2°, highly variable but low-profile topographic features. Signs of subsurface structure must be apparent	Varied, mostly high	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER R1: LOW-MODERATE R2: LOW or MODERATE B1: OTHER B2: IRREGULAR B3: N/A
Mound	Locally elevated Sediment or Rock Veneer feature which comprising rubble, geological or biological in origin	Bathymetric features measurable in profile. Isolated, smooth-edged feature. No structure indicating active sand wave or dune	Varied but smooth slope. TPI index high	Varies depending on incidence angle, typically very high	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Rock Reef	Bedrock or other consolidated material outcrop	Rough bathymetric features measurable in profile	Varied complex slope. TPI index high	High/variable	S1: CONSOLIDATED S2: N/A S3: ROCK R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: OTHER

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
					B2: IRREGULAR B3: N/A
Depression / Scour	Local depression which may be geological or biological in origin (Linear Scour or Pockmark)	Bathymetric features measurable in profile (low)	Varied slope. TPI index low	Varies depending on incidence angle	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER or N/A R1: LOW-MODERATE or HIGH R2: LOW or MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Scarp	Bedrock or other consolidated material outcrop, subject to landslide erosion	Rough bathymetric features measurable in profile	Typically, greater than 15°, may have steep sides	Varies depending on incidence angle	S1: CONSOLIDATED S2: N/A S3: ROCK R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Bedforms/Ripples/ Ribbons (Small, Medium 2 or 3 dimensional, Irregular)	Active or once active sediment bedforms indicating wave or current action on the seabed	May be visible bathymetric features or may only occur in backscatter if small	Varied, wavelength and amplitude measured in profile (Ashley, 1990)	Varies depending on incidence angle. Typically, low	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: LOW-MODERATE or HIGH

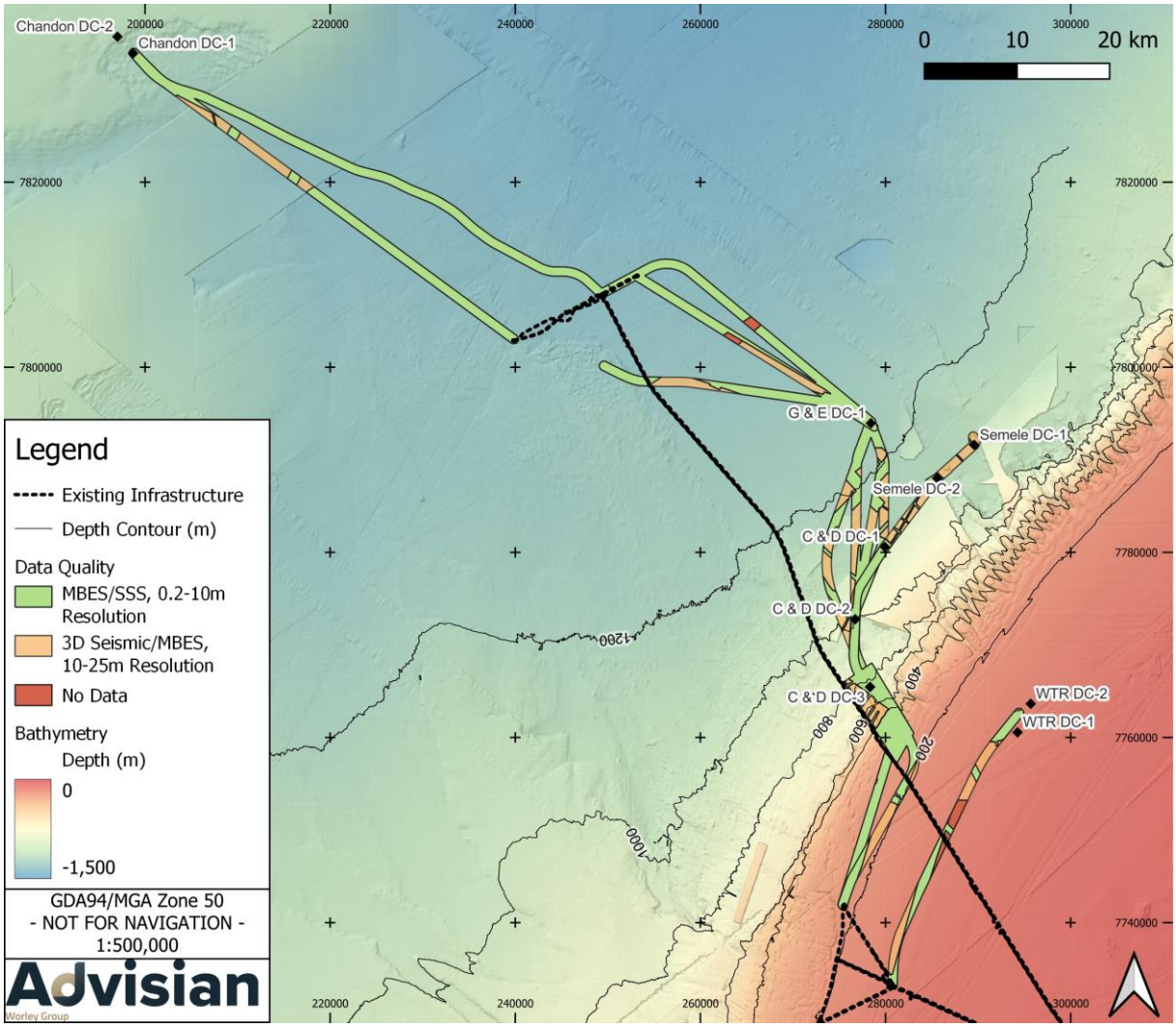
Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
					R2: MODERATE or HIGH B1: 2D or 3D B2: ANY B3: ANY

Note:
1. N/A = not applicable

2.5 Results

2.5.1 Mapping Confidence

A total of 31,053 hectares (ha) of benthic habitat was initially mapped within the GBF project area, which spanned 500 m from all preliminary indicative subsea infrastructure. Of this, 23,600 ha was mapped with high confidence based on the MBES and SSS imagery classification, and 6,721 ha was mapped with moderate confidence using 3D seismic/MBES imagery (Figure 2-1). The remaining 733 ha was classified as low confidence as there were no data available (Figure 2-1). Areas with no data included small sections along the proposed Geryon and Eurytion (G & E) to Jansz corridors, and sections along the proposed WTR corridor (Figure 2-1).



Note:

1. C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, MBES = multibeam echo sounder, SSS = sidescan sonar, WTR = West Tryal Rocks

Figure 2-1 Mapping confidence within the Gorgon Backfill Fields project area

2.5.2 Preliminary Habitat Mapping

Preliminary mapping of seabed geomorphology identified a total of eight broad geomorphic feature types, including mostly bare sediments, bedforms, irregular seabed, mounds, depression/scours, rock veneer, rock reef and scarp (Figure 2-2). Areas mapped with no polygons reflect data gaps where mapping could not be completed (Figure 2-2). The GBF project area is dominated by bare and irregular bare seabed, which comprised over 75% of the mapped area. Rock reef or areas that potentially feature exposed bedrock comprised ~10%.

Most of the GBF project area is dominated by recent or ancient landslide features. These features include incipient failure ridges and depressions on the shelf edge, a series of very steep escarpments (head scarps), signs of large translational and rotational mass movements, chaotic debris accumulations, isolated blocks, and distal debris fans with associated soft sediment 'crevasse' structures. Many areas have their morphology determined by rocky outcrops or rock debris. However, as pelagic marine sediment is known to cover most of the area, it is likely that all but the steepest areas may comprise a mosaic of outcrop or sediment cover.

The edge of the Exmouth Plateau KEF was mapped, showing sediment covered landslide features. Geomorphic habitats intersected with the Continental Slope Demersal Fish Communities KEF, forming highly complex and sometimes steep terrain. No Ancient Coastline KEF features were detected within the GBF project area. The Ancient Coastline KEF is known to exist in shallower water, particularly from the 60–80 m depth range (DSEWPaC, 2012).

No canyon features were observed in the GBF project area; however, these are known to occur close to the area in the Continental Shelf transition zone. Coarse sediment could not be detected with the available data, however, patches of high SSS anomaly on the shelf edge may indicate the presence of coarse material. Furthermore, the available SSS and high resolution MBES data was highly variable, meaning that the quality varied making interpretation harder in some cases, and fine scale features will have been missed in many areas.

The preliminary habitat map was reviewed by Advisian and CAPL marine environmental specialists to determine field survey sampling sites for further ground-truthing, which were based on the spatial representation of all geomorphic attributes throughout the GBF project area, the presence of benthic features within KEFs, and areas with data deficiency and other points of interest.

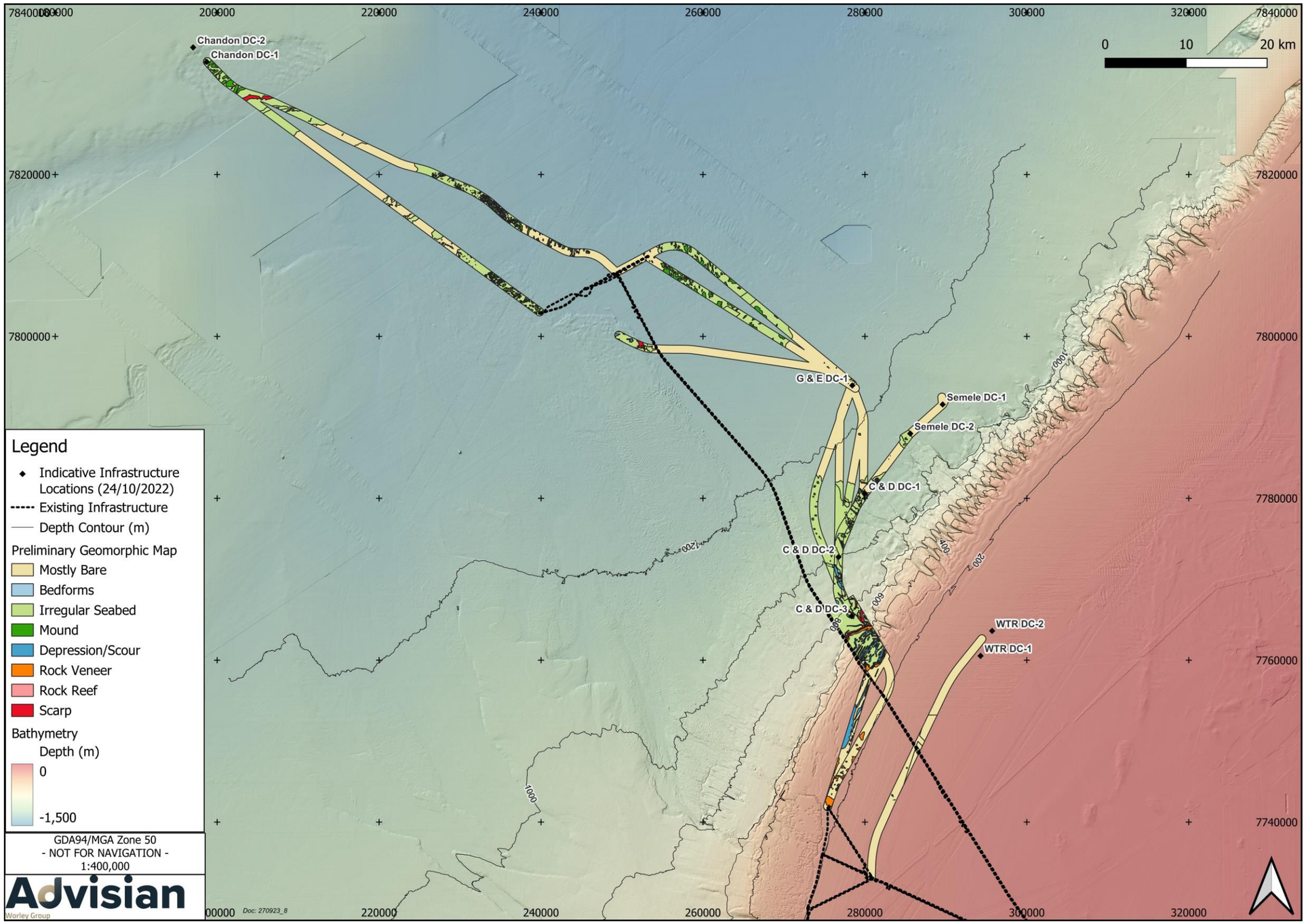


Figure 2-2 Preliminary benthic habitat maps based on assessment of geomorphic features within the Gorgon Backfill Fields project area

3 Field Survey Methods

3.1 Field Survey Scope

The main objective of this field survey was to investigate the physical and biological characteristics of the seabed features in the identified survey sites. Advisian delivered this scope in partnership with DOF Subsea under CAPL. Advisian led the scientific scope and DOF Subsea provided the vessel Skandi Singapore, the marine survey equipment for positioning of the vessel, and the remotely operated vehicle (ROV). DOF Subsea and CAPL were responsible for communicating with Barrow Island central control room to coordinate and approve permits (e.g., Permit to Work) to operate and undertake the field sampling program in GBF.

The primary field survey components and environmental monitoring parameters are summarised in Table 3-1.

Table 3-1 Summary of field survey monitoring parameters

Field Survey Component	Monitoring Parameters
Habitat Mapping	• Qualitative description of benthic habitats across a large project scale
Marine Benthic Survey	• Quantitative description of benthic cover and type at a subset of GBF project area
Fish Assemblage Survey	• Abundance, composition and size of fish assemblages and their association with key habitat types and other environmental variables • Description of mobile invertebrates and epifauna
Sediment Quality	• Hydrocarbons, metals, particle size distribution (PSD), total organic carbon (TOC) and moisture content
Benthic Infauna	• Benthic infauna composition
Water Quality	• Hydrocarbons, metals, TOC, dissolved organic carbon (DOC), total dissolved solids (TDS), nutrients • Water column profiling to describe physical water quality parameters (temperature, salinity, conductivity, and depth)

3.2 Permits

In order to collect sediment infauna, Advisian applied for an Instrument of Exemption from the Department of Primary Industries and Regional Development (DPIRD) in line with the Fish Resources Management Act 1994 and Regulations, Section 7, and Regulation 6. Advisian were granted this permit by DPIRD on 26 April 2022 (Appendix A).

3.3 Survey Schedule

The field survey was completed between the 26th April and 11th May 2022. Table 3-2 details the field schedule for high level activities completed during the GBF field survey. Further details on field survey timing can be found in the Field Survey Summary Report (Advisian, 2022a).

Table 3-2 Field survey schedule

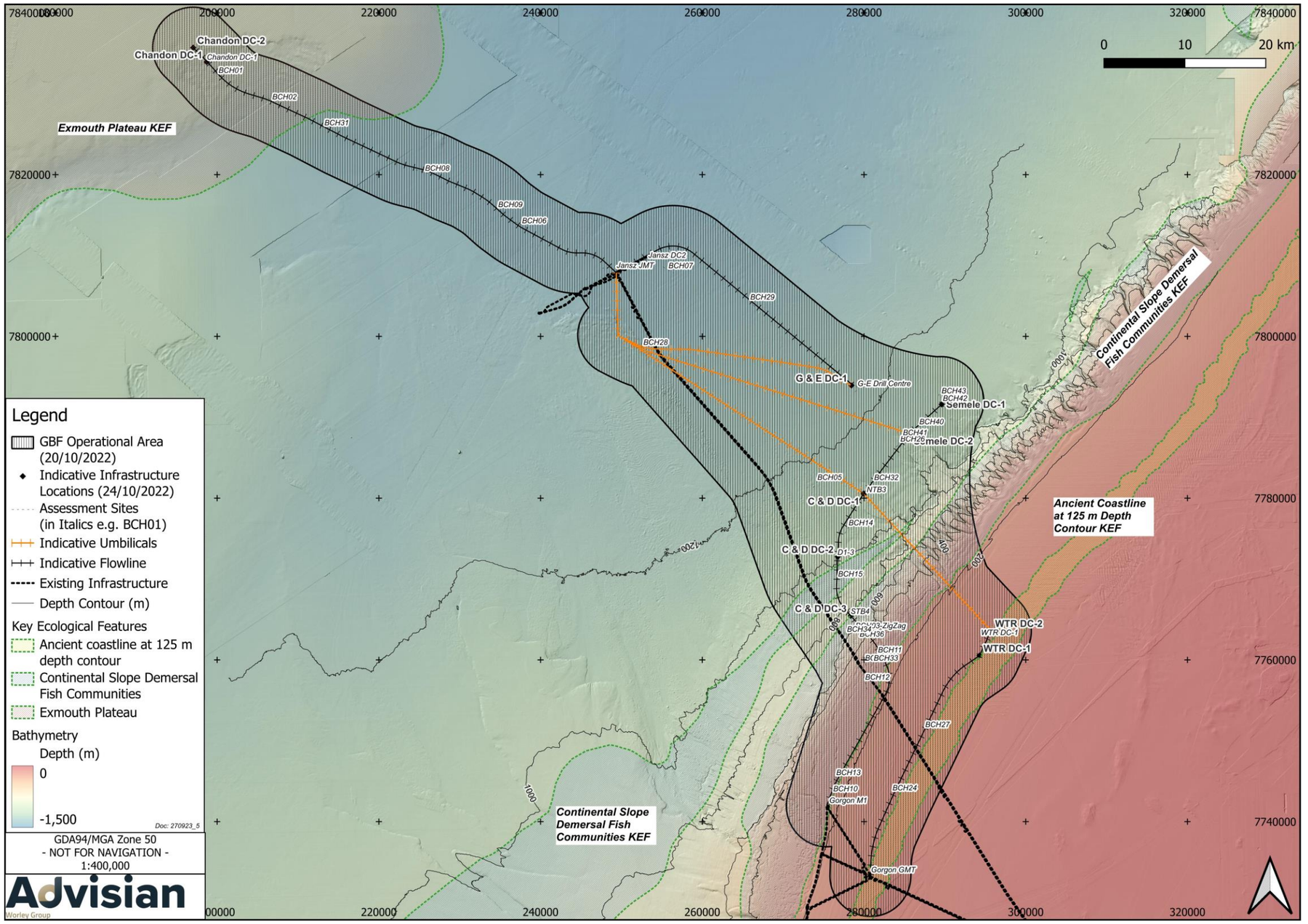
Date	Activity
26 April 2022	Mobilised to Dampier and boarded the Skandi Singapore vessel Transit to survey sites
27 April 2022	ROV test dives and calibrations
28 April – 3 May 2022	Complete benthic habitat survey at sites BCH16, BCH19, BCH17, Gorgon M1, BCH10, BCH13, BCH21, BCH23, BCH30, BCH18, BCH22, BCH25, BCH12, BCH04, BCH11, BCH03 and C&D DC3 (and water and sediment quality samples)
4 May 2022	Complete benthic habitat survey and water and sediment quality sites (where applicable) for sites BCH15, C & D DC-2, BCH14, NTB3 and BCH05 Freight chemical samples
5 –10 May 2022	Complete benthic habitat survey and water and sediment quality sites (where applicable) for sites G & E DC-1, BCH29, BCH18, BCH07, Jansz DC2, Jansz JMT, BCH28, BCH06, BCH09, BCH08, BCH02, BCH01, Chandon DC-1, BCH31, Semele DC-2, Semele DC-1, BCH42, BCH40, BCH43, BCH41, BCH32, WTR DC-1, BCH27, BCH33, BCH34, BCH35, BCH36, BCH24, Gorgon BMT
10 May 2022	Scope completed
11 May 2022	Pack equipment, freight samples Demobilise from Dampier

3.4 Survey Locations

Following the development of a preliminary benthic habitat map (Section 2.5), survey sites (Figure 3-1) for benthic habitat mapping, sediment and water quality sampling were selected based on:

- the spatial representation of all geomorphic attributes throughout the GBF project area (drill centres and associated well infrastructure, and flowlines/umbilical corridors)
- the presence of benthic features within KEFs
- areas with data deficiency and other points of interest
- to understand the composition of sediment at potential drill centres and tie-in locations
- to understand background concentrations of marine water quality near proposed infrastructure locations.

In response to an increase in project operational area post-field survey, the originally proposed 500 m radius around proposed manifold and tie-in locations and associated flowlines has been expanded to a 5 km radius around the GBF project area (as per Figure 1-1). Classification and mapping procedures for benthic habitats that fall within the 5 km operational buffer area is described in Section 3.6.5, and the distribution of benthic habitats within the 5 km operational buffer area are presented in Sections 4.1.1 and 4.1.2.



Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, GBF = Gorgon Backfill Fields, KEF = Key Ecological Features, WTR = West Tryal Rocks

Figure 3-1 Gorgon Backfill Fields project area with survey sites for benthic habitat mapping, sediment, and water quality sampling

3.5 Project Equipment

3.5.1 Remotely Operated Vehicle

A work class ROV (TRITON XLX) was provided and operated by DOF Subsea and used to deploy all sampling equipment to the seafloor (habitat and fish survey cameras, water quality profiler, sediment, and infauna corers, and Niskin bottles) (Figure 3-2). The ROV was deployed while connected to a tether management system (TMS). Once the ROV was near the seabed, the ROV was detached from the TMS and was flown at approximately 1.5 m above the seabed at approximately 0.7 knots (1.3 km/h) while recording video footage of benthic habitat and fish assemblages. This speed ensured adequate image quality was captured.

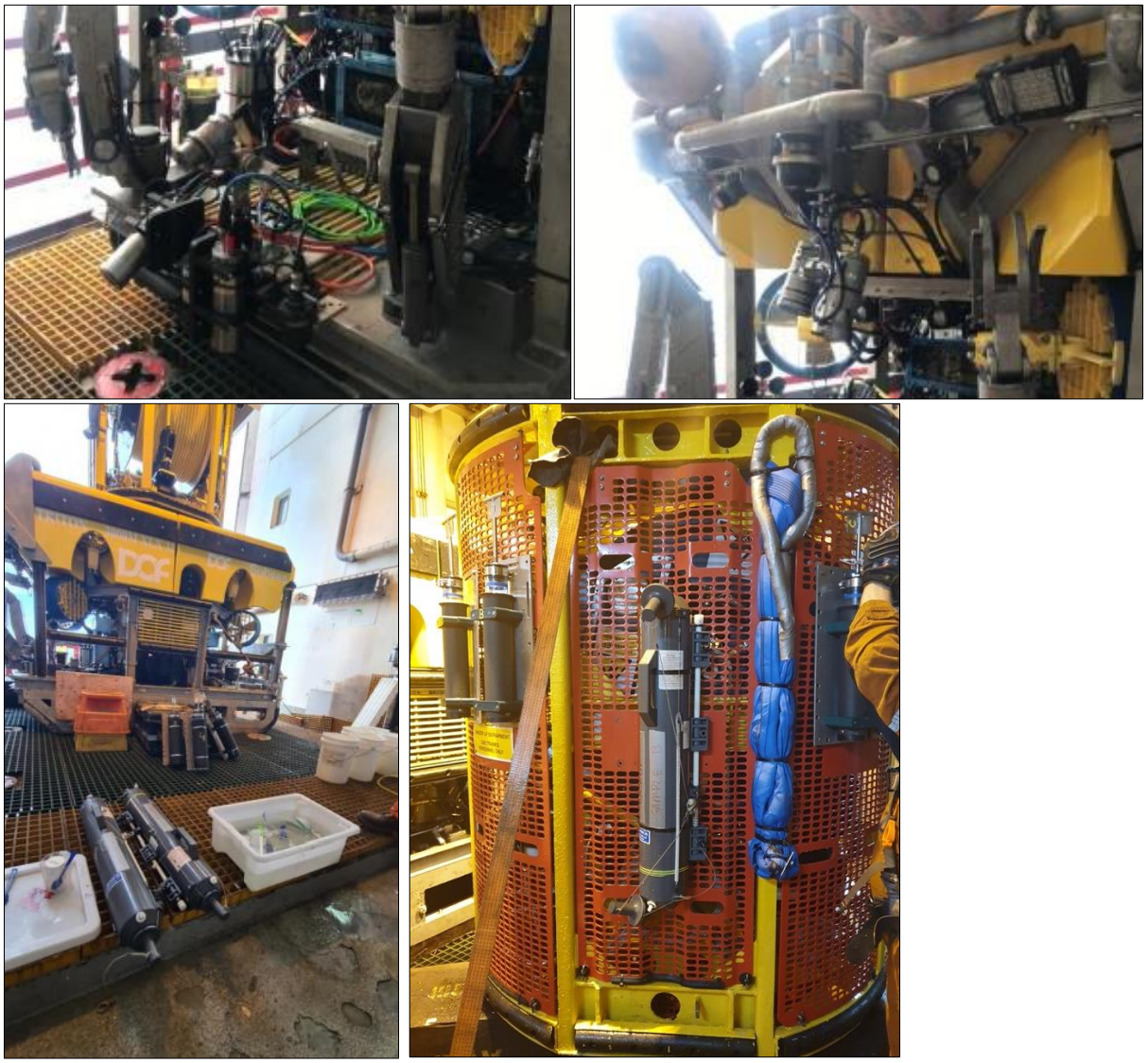


Figure 3-2 Remotely operated vehicle and tether management system with cameras, sediment corers and Niskin bottles attached

3.5.2 Habitat Mapping and Fish Survey Cameras

The ROV utilised the forward-facing high-definition (HD) camera (30° angle) for the collection of video footage for habitat mapping and demersal fish assemblages, and a downward facing camera (90° angle) for collection of marine benthic survey data (Table 3-3). The ROV pan and tilt HD camera captured suitable additional footage and provided a backup in the event of failure of the primary forward-facing camera. Two sets of cameras were also included as redundancy in case of equipment failure. All camera systems were controlled from the surface with a live feed ensuring correct operating and capture of the required data. All cameras were powered from the surface through the ROV tether.

Table 3-3 Camera systems mounted on the remotely operated vehicle

Camera	Tasks
1 x forward-facing camera (~30º)	• Capture benthic habitat and demersal fish data • Subsea HD wide angle camera Kongsberg/Imenco OE14-504 (1080i/720p 50 frames per second; fps) • External lighting system –Imenco SeaLED 300 (15,000 lumens) was added to the ROV for illumination (camera pan/tilt/zoom/altitude and set to forward and approximately 30° tilt)
1 x downward facing camera (~90º)	• Capture 'still' images of benthic habitat for percent cover • 1CAM Mk5 camera (stills/4K/1080p 60 fps) • Lighting system – Aquorea Mk2 LED/strobe mounted away from camera • Laser scale
ROV Pan & Tilt (HD video)	• General ROV navigation

Note:
1. HD = High definition, ROV = remotely operated vehicle

3.5.3 Sediment Sampling Push Corers

Raytech push corers were used for the collection of marine sediments. Each push corer was comprised of a Perspex core tube with T-bar handle, a one-way valve, and the corer housing (Table 3-4).

Sets of push cores were attached to the ROV TMS and transported to the seabed. Using the ROV manipulator arm, a core was removed from its holster style housing and pushed into the sediment while holding on to the T-bar handle (Figure 3-3). The one-way valve at the top of the chamber allowed water to escape during the capture of sediment. The sample was retained in the corer by suction as the corer was withdrawn from the sediment. The core containing sediment sample was then returned to the housing, which has a tapered, rubber plug at the base of the housing to retain the sample in the corer. Once the ROV surfaced, the T-bar and valve were removed and the core with its rubber plug was removed from the housing with.

Cores of two different internal diameters were used: 60 and 100 mm. Specifications of the push corers are provided in Table 3-4.

Table 3-4 Push corer specifications

Corer internal diameter (mm)	Total length (mm)	Insertion into sediment (mm)	Maximum volume of sediment retrieved (ml)	~Weight of wet sediment (kg)	Weight of corer empty (kg)	Weight of holster and mount (kg)	Weight of corer full (kg) in holster
60	575	355	1,003	1.73	1.5	2	5.23
100	575	355	2,788	4.8	2	3	9.8



Figure 3-3 Raytech push corer and attachment plate (left) and milk crate style carrier (right)

3.5.4 Niskin Bottles

Niskin bottles were used for the collection of surface and near-bottom water samples (Figure 3-4). For the collection of water at depth, one 10 L externally sprung Niskin bottle was attached vertically to the TMS (Figure 3-2) and activated by the ROV manipulator arm to secure containment of the sample at the target location. A second 10 L Niskin bottle was attached to the ROV to provide redundancy in case of failure to collect a water sample from the primary unit mounted to the TMS. All near-bottom water sampling was undertaken prior to sediment sampling to ensure the seabed was not disturbed and a clean water sample was collected.

Surface waters were sampled at each location using a 10 L Niskin bottle deployed over the side of the vessel using a davit arm. Once the Niskin bottle settled approximately 1 m below the surface, the activating weight was dropped to release the springs and close the bottle.

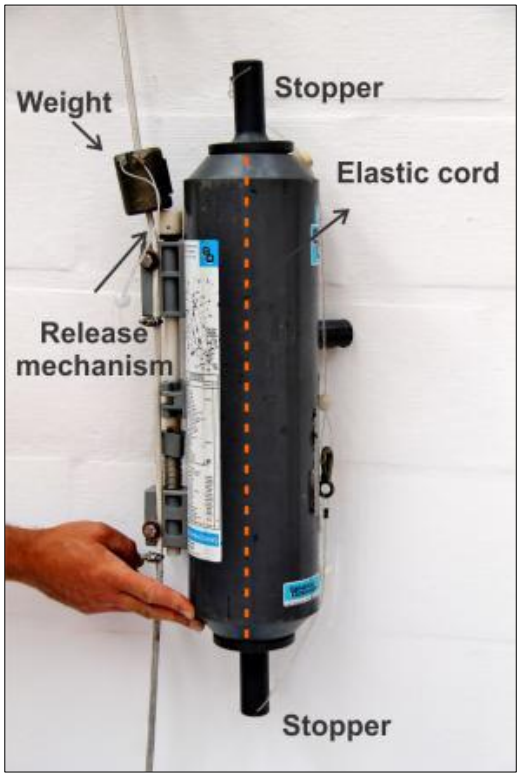


Figure 3-4 Niskin bottle (VLIZ 2022)

3.5.5 Water Quality Profiler

A calibrated Valeport Midas SVX2 water quality probe was used to collect physico-chemical profiles of the water column, specifically conductivity (MilliSiemens per centimetre; mS/cm), temperature (°C), depth (meters; m, below sea level) (CTD), and salinity (Practical Salinity Unit; PSU) (Figure 3-5). The probe was attached to the ROV and logged data on the downcast (surface to seabed) and upcast (seabed to surface) for each dive, in addition to transects along the bottom (just above the seabed). Specifications of the probe are provided in the PEP (Advisian, 2022b).



Figure 3-5 Valeport water quality probe for physico-chemical sampling parameters

3.5.6 Subsea Positioning

The vessel was equipped with a differential global positioning system, and an ultra-short baseline acoustic positioning system was placed on the ROV to track its position during sampling operations. A

hand-held global positioning system (GPS) was used as a secondary GPS in verification of vessel location in relation to each sampling site.

3.6 Benthic Habitat Survey

3.6.1 Survey Sites

Benthic habitat transects were positioned across predicted geomorphic transition zones (i.e., an area where a shift in geomorphic features is apparent) to capture highly variable environments, which are typically attributed with diverse benthic habitats and epifaunal communities. This approach also enabled the validation of predicted benthic habitat boundaries. Seabed imagery for benthic habitat mapping was collected at a total of 39 sites within the originally proposed GBF project area (500 m radius around proposed drill centres, tie-in locations and associated subsea flowlines) (Figure 3-1; Table 3-5), as this smaller footprint represented areas of most-likely benthic disturbance at the time of field mobilisation. At each benthic survey site, video footage was collected along ~2 km-long transects using the ROV, capturing a total of approximately 45.4 km of benthic imagery across the Project area.

Of these 39 sites, 14 sites were identified within more discrete disturbance areas (i.e., proposed drill centres and tie-in locations will be subject to localized disturbance through drilling installation activities; Table 3-5). Within each of the 14 survey sites, five haphazard transects of variable length (ranging from 102–570 m) were surveyed to allow quantitative assessment of benthic cover (%) at these sites. These data were also used to inform habitat mapping objectives. Haphazard transects were positioned by applying a random point generator across the spatial extent of each site that had been adjusted to existing seabed infrastructure (Figure 3-6).

Table 3-5 Benthic habitat mapping and benthic cover survey sites

Field	Site Name	Survey Date	Facility / BCH Transect	Easting	Northings	Depth Range (m)	Habitat Mapping Site	Benthic Cover Site[1]
Chandon	Chandon DC-1	7/05/2022	Proposed Drill Centre	198899	7833791	1,100–1,200	✓	✓
	BCH01	7/05/2022	BCH Transect	200918	7832022	1,200–1,300	✓	
	BCH02	6/05/2022	BCH Transect	207775	7828300	1,200–1,300	✓	
	BCH31	7/05/2022	BCH Transect	212359	7826383	1,300–1,400	✓	
	BCH08	6/05/2022	BCH Transect	226558	7819703	1,300–1,400	✓	
	BCH09	6/05/2022	BCH Transect	235129	7815472	1,300–1,400	✓	
	BCH06	6/05/2022	BCH Transect	238540	7813367	1,300–1,400	✓	
	Jansz JMT	5/05/2022	Tie in	249098	7807831	1,300–1,400	✓	✓
Geryon and Eurytion (G & E)	Jansz DC2	5/05/2022	Tie in	253210	7809856	1,300–1,400	✓	✓
	BCH07	5/05/2022	BCH Transect	256861	7807601	1,300–1,400	✓	
	BCH28	6/05/2022	BCH Transect	253595	7798894	1,200–1,300	✓	
	BCH29	5/05/2022	BCH Transect	266573	7803572	1,300–1,400	✓	
	G & E DC-1	5/05/2022	Proposed Drill Centre	278876	7793169	1,200–1,300	✓	✓
Chrysaor and Dionysus (C & D)	BCH05	4/05/2022	BCH Transect	273569	7781327	1,100–1,200	✓	
	BCH14	4/05/2022	BCH Transect	277661	7775678	1,000–1,100	✓	
	C & D DC-2	4/05/2022	Proposed Drill Centre	276899	7772322	1,000–1,100	✓	✓
	BCH15	4/05/2022	BCH Transect	276638	7769400	900–1,000	✓	
	C & D DC-3	3/05/2022	Proposed Drill Centre	278747	7765155	700–800	✓	✓
	BCH03 – ZIGZAG	3/05/2022	BCH Transect	277706	7763557	500–600	✓	
	BCH34	9/05/2022	BCH Transect	277665	7763570	700–800	✓	

Field	Site Name	Survey Date	Facility / BCH Transect	Easting	Northings	Depth Range (m)	Habitat Mapping Site	Benthic Cover Site[1]
	BCH36	9/05/2022	BCH Transect	279285	7762860	200–300	✓	
	BCH11	3/05/2022	BCH Transect	281368	7761555	200–300	✓	
	BCH04	3/05/2022	BCH Transect	280271	7759126	200–400	✓	
	BCH33	9/05/2022	BCH Transect	281572	7758993	200–300	✓	
	BCH12	1/05/2022	BCH Transect	280344	7756362	200–300	✓	
	BCH13	29/04/2022	BCH Transect	275791	7744842	200–300	✓	
	BCH10	28/04/2022	BCH Transect	276682	7744321	200–300	✓	
	Gorgon M1	28/04/2022	Tie in	275354	7741583	200–300	✓	✓
Semele	BCH42	7/05/2022	Proposed Drill Centre	290128	7792145	1,100–1,200	✓	✓
	BCH43	8/05/2022	Proposed Drill Centre	289623	7792140	1,100–1,200	✓	✓
	BCH40	8/05/2022	BCH Transect	286880	7789035	1,100–1,200	✓	✓
	BCH41	8/05/2022	BCH Transect	285124	7787323	1,100–1,200	✓	✓
	BCH26	8/05/2022	BCH Transect	283944	7786339	1,100–1,200	✓	
	BCH32	8/05/2022	BCH Transect	281605	7782094	1,100–1,200	✓	
	NTB3	4/05/2022	Proposed Drill Centre	280281	7780314	1,100–1,200	✓	✓
WTR	WTR DC-1	9/05/2022	Proposed Drill Centre	294288	7762283	100–200	✓	✓
	BCH27	9/05/2022	BCH Transect	288135	7752668	100–200	✓	
	BCH24	10/05/2022	BCH Transect	283879	7744470	100–200	✓	
	Gorgon GMT	10/05/2022	Tie in	280989	7733571	100–200	✓	✓

Notes:
1. Within these sites, a set of 5 haphazard transects were collected to allow quantitative assessment of the BCH
2. BCH = Benthic communities and habitat, DC = drill centre, WTR = West Tryal Rocks

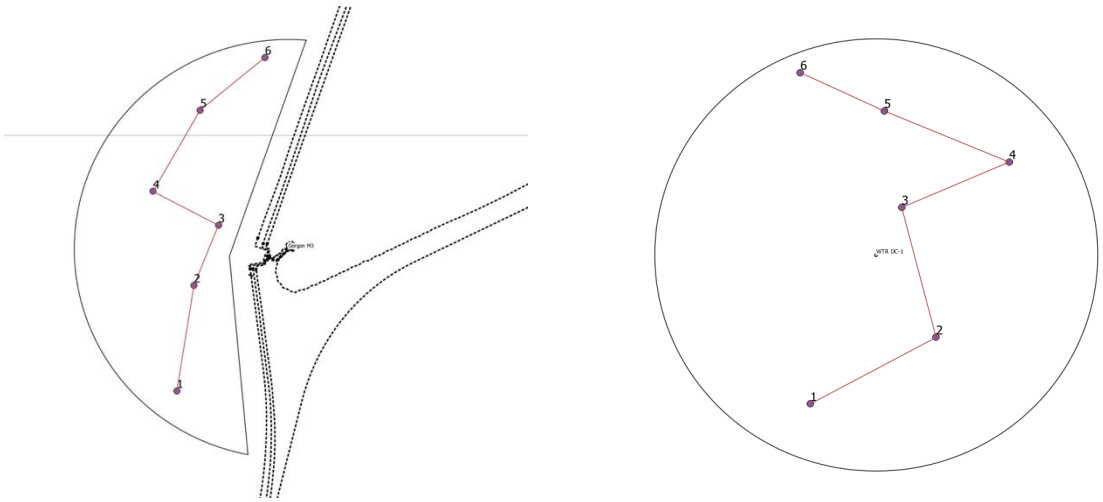


Figure 3-6 Nominal sampling layout for haphazard transects around tie-in locations (left) and proposed drill centres (right)

3.6.2 Benthic Habitat Data Collection

Video footage was collected along the transects outlined in Table 3-5. A video log was maintained throughout the recording. The video log was used to note the start and end times of each transect, as well as for scientific notes such as key physical and biological attributes, and biota (including semi-quantitative descriptions where appropriate). These video logs were used to aid the classification of data. All video footage was stored on external hard drives by the ROV operator and transferred daily to backup hard drives for transport back to Advisian.

3.6.3 Video Classification

Classification of benthic habitat (39 sites) and benthic cover (14 sites) was conducted according to a set of standardised classification categories based on the CATAMI classification scheme (Table 3-6; CATAMI, 2014; Althaus et al., 2015) developed with CAPL. Analysis and classification of video footage for benthic habitat was completed using TransectMeasure (SeaGIS, 2022a) by a marine scientist experienced in image classification. Following classification, the time and classification log were merged with the position and time log to provide a single file with a classification for every position where valid video footage was obtained. Example images of benthic habitat and biotic categories extracted from the video images are provided in Appendix B.

Analysis and classification of video footage (5 x 50 m transects) for benthic cover was also undertaken using TransectMeasure (SeaGIS, 2022a). TransectMeasure was set to randomly pause, enabling 20 images to be extracted per transect (n=100). Ten random points were generated on each image (n = 200/transect) and each point was classified based on the CATAMI classification scheme (Table 3-6).

Table 3-6 Habitat classification categories applied to image analysis for benthic habitat mapping and benthic cover

Habitat Categories	Biota Categories
Relief/Slope	**Biota**
Low (<1 m)	Sponges
Moderate (<3 m)	Cnidaria
High (>3 m)	Echinoderms
Wall	Sponges, Cnidaria
Substrate	Sponges, Echinoderms
Unconsolidated (soft)	Cnidaria, Echinoderms
Consolidate (hard)	Mixed biota (all 3)
Substrate size/appearance	
Sand/mud (<2 mm)	
Sand/mud (<2 mm) and occasional boulders	
Cobbles	
Boulders	
Rock (Outcropping bedrock)	
Modifier	
Bare	
Biota only	
Bioturbation and bare	
Bioturbation and occasional veneer only	
Bioturbation with biota and occasional veneer	
Ripples (<10 cm height) and bare	
Ripples (<10 cm height) with biota and sparse veneer with biota	
Veneer with biota	
Unknown	

3.6.4 Video Quality Assurance and Quality Control Assessment

Following completion of the video classification, a quality assurance and quality control (QA/QC) assessment was performed by Advisian personnel to determine confidence in video analysis

techniques. Each video analyser was assigned 5% of processed video transects to re-process and note errors. The video QA/QC assessment is detailed in Appendix C.

3.6.5 Classification and Mapping Procedures

To characterise the benthic habitat and potential occurrence of significant BCH in areas away from ground truthing transects (between 500 m and 5 km from the proposed subsea facilities), a predictive mapping approach known as supervised classification was adopted. Supervised classification techniques use an artificial intelligence algorithm to statistically compare specific attributes of multiple raster layers of known sites of interest. Supervised classification is a 'bottom up' approach (Brown et al., 2011) whereby the *in-situ* ground truthing transects are used to inform the organization and segmentation of the broad scale environmental data, and is applied at the same taxonomic level as the ground truthing data.

For this study, the video footage captured by the ROV is used to verify the distribution of epibenthic BCH of interest (e.g., bare seabed, cnidaria, sponges, or a combination of categories). The verified BCH is then spatially linked with characteristics of the seabed terrain derived from the 3D seismic data to build a predictive model of a large component of the mapping area.

3.6.5.1 Bathymetric Derivatives

A 25 m cell size bathymetric digital terrain model derived from 3D seismic data was available for a large proportion of the GBF project area (including the entire escarpment area) and was free of data artefacts. A series of 'derivative' terrain layers were created to extract additional information about the type of seabed terrain that most commonly support the observed BCH. The derivatives calculated for each cell included:

- Depth: depth in metres of the seabed for every cell, with implications for water pressure and light penetration.
- Roughness: derived from the bathymetric dataset by subtracting the minimum depth from the maximum depth value in a defined-neighbourhood around a central pixel (Riley et al., 1999). The neighbourhood is defined as the eight nearest cells to a central pixel (a 3 m x 3 m area). Values of zero or close to zero indicate flat areas, whereas larger roughness values indicate increasingly complex terrain. For this study, roughness was a good proxy for the complex terrain associated with rocky outcrops on the seabed. Smaller scale sediment ripples can also appear to have high seabed roughness values; however, ripples were not a common seabed characteristic in the GBF project area.
- Slope: slope is the ratio of rise to run over a defined neighbourhood area. For this study, the seabed away from the coastline was typically very flat, and slopes greater than five degrees were rare and often indicative of interesting features. Higher slopes are often associated with seabed features that are important for ecological habitats such as reef edges and drop offs.
- Aspect: the facing direction of the local neighbourhood area of seabed, defined as slope orientation in degrees clockwise from north, with implications for exposure to oceanic currents (Florinsky, 2016).
- Relative TPI (two scales): the TPI distinguishes topographic features such as a hilltops, valley bottoms, exposed ridges, flat plains, and slopes. It is calculated by comparing the elevation of each pixel above or below its surrounding neighbours. The number of neighbours compared (i.e., the scale of the neighbourhood) is of critical importance, therefore two scales were calculated and

incorporated. Smaller neighbourhood sizes are better at detecting small-scale features whereas larger neighbourhood sizes better detect large features (Guisan et al., 1999; Wilson and Gallant, 2000).

- Total Curvature: measured 3D curvature of the local topographic surface (Wilson, 2018).
- Morphometric Protection Index: analyses the immediate surrounding of each cell up to a given distance and evaluates how the relief protects it, describing canyon or pinnacle reef environments (Olaya, 2002).

These seabed terrain indices were calculated for the GBF project area, and merged in a desktop GIS software package to directly 'stack' all pixel values into an n-dimensional multiband raster image.

3.6.5.2 Criteria for likelihood of biota presence

Acoustic backscatter data, which is a product derived from MBES outputs, relates to seafloor micro-topography (or roughness) and volume heterogeneity (sediment grain-size and sediment composition). It has been used as a qualitative indicator of the nature of the substrate, whereby high backscatter is received from hard and rough materials such as rocky reefs, whereas lower backscatter might be expected from smooth, soft, muddy bottoms.

All sediment habitats that appeared as flat and featureless soft sandy substrates (smooth and irregular seabed, bare substrate, mound, veneer of sand) lack the overt visual complexity of more ecologically enigmatic habitats such as coral reefs and seagrass meadows, and are likely to provide a less diverse and/or lower benthic assemblage than other habitat types. As such, these habitats are assigned a 'low' likelihood of biota presence.

Raised geomorphic features (depression/scour, reef mosaic, rock reef, scarp) typically offer structural complexity (e.g., fissures, holes, caves and overhangs) with a hard surface to an otherwise flat bare substrate for marine life to attach to, potentially supporting extensive communities and providing refuge to epibenthic and encrusting biota. Therefore, these structures are primarily assigned a 'high' likelihood of biota presence. However, due to the varying degree of soft sediment coverage and other environmental factors within raised or otherwise apparent consolidated geomorphic features, these locations may also be represented to have a 'low' likelihood of biota presence and/or classified as a bare substrate.

3.6.6 Model Training

The ground truthing habitat layer was compiled into a GIS for integration with the supervised classification algorithm. For each training dataset point, a single consistent and unified class was attributed, which included:

- Bare seabed (including areas that support mobile echinoderms)
- Cnidaria
- Sponges
- Sponges and Cnidaria.

Using spatial analysis techniques, the 'training' dataset was linked to the corresponding terrain characteristics. This dataset was used to train the random forest classifier for habitat prediction.

A random forest classifier known as an ensemble machine learning method, was employed to predict the distribution of habitats across the GBF project area. The classifier was trained on the small dataset of biota types and their locations using the derivative terrain layers as predictor variables. The random forest approach was chosen for its ability to handle complex and non-linear relationships, robustness to noise, and resistance to overfitting. This technique was only applied to the 'slope break' component of the GBF project area as this was the only region with available high quality bathymetry dataset. Areas in deeper waters (the 1200 m contour that defined the outer limit) with no biota recorded in the ground truthing survey were not included. Supervised data classification was undertaken in a Python-based software implementation Dzetsaka (Karasiak, 2016). Once imported, the seven composite bands (the derivative terrain layers outlined in Section 3.6.5.1) were overlain with the habitat-attributed training dataset, and were analysed to determine the spectral statistics relevant to each habitat layer. The classification was then run on the entire dataset, allowing the program to assess the band spectral values for each pixel cell. For the dominant habitat classification, the algorithm assigns one of the four main habitat types to each cell: bare seabed, cnidaria, sponges, and sponges and cnidaria. For the presence-absence assessment, the cells are attributed to either 1 (unknown), 2 (known to be absent) or 3 (known to be present).

For validation and error assessment, a 'bootstrap' subset of data was withheld from the training dataset; 90% of original data pixels were used to train the model, and the remaining 10% dataset was used by the model to evaluate its own performance.

3.6.6.1 Results of the Model Training

The results show that the BCH are likely to be found along areas with very steep escarpments (Figure 3-7), which coincides with the observational data. The overall accuracy of the self-assessment model, which is a comparison of the 10% training pixels withheld from the classification with classified pixels in the same location, was 92% (Kappa statistic of 98.7%), suggesting a strong correlation, and a Cohens Kappa value of 0.48, indicating a moderate correlation between the datasets and a low probability of the influence of random chance (de Raadt, A et al., 2021).

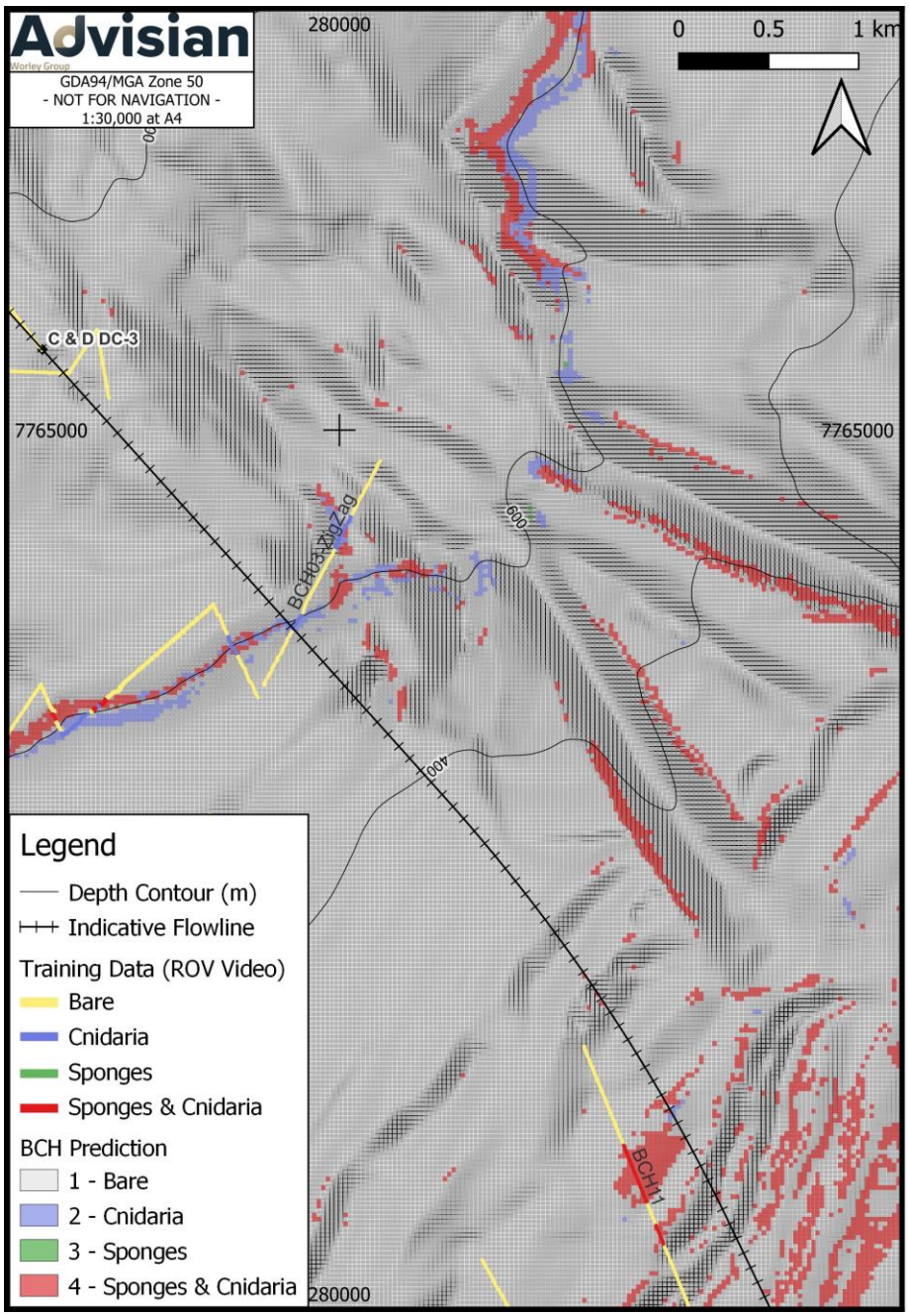


Figure 3-7 Example of a supervised classification map of the East Scarp-Tryal area within the Gorgon Backfill Fields project area

3.7 Fish Assemblage Surveys

3.7.1 Survey Sites

A total of 11 sites were examined to describe and compare the fish and crustacean assemblages (Table 3-7). Of these sites, two sites were located within the Exmouth Plateau KEF, four sites were within the Continental Slope Demersal Fish Communities KEF, and one site was located within the Ancient

Coastline KEF, while the remaining four sites were located outside any KEFs (Table 3-7). The sites also covered four geomorphic features (Heap & Harris, 2008) including plateau slope, deep/hole/valley slope, trench/tough slope, and slope (Table 3-7).

Table 3-7 Fish survey sites

Field	Site Name	Key Ecological Feature	Geomorphic Feature	Survey Date	Easting	Northings	Depth Range (m)
Chandon	BCH01	Exmouth Plateau	Plateau slope	7/05/2022	198899	7833791	1,100–1,200
	BCH02	Exmouth Plateau	Plateau slope	7/05/2022	200918	7832022	1,200–1,300
Chrysaor and Dionysus (C & D)	C &D DC-3	Outside of any KEF	Trench/ tough slope	3/05/2022	278747	7765155	700–800
	BCH04	Continental Slope Demersal Fish Communities	Slope	3/05/2022	280271	7759126	200–400
	BCH11	Continental Slope Demersal Fish Communities	Slope	3/05/2022	281368	7761555	200–300
	BCH12	Continental Slope Demersal Fish Communities	Slope	1/05/2022	280344	7756362	200–300
	BCH33	Continental Slope Demersal Fish Communities	Slope	9/05/2022	281572	7758993	200–300
Semele	NTB3	Outside of any KEF	Deep/hole/ valley slope	4/05/2022	280281	7780314	1,100–1,200
WTR	WTR DC-1	Outside of any KEF	Slope	9/05/2022	294288	7762283	100–200
	BCH24	Outside of any KEF	Slope	10/05/2022	283879	7744470	100–200
	Gorgon GMT	Ancient Coastline	Slope	10/05/2022	280989	7733571	100–200

Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, KEF = Key Ecological Feature, WTR = West Tryal Rocks

3.7.2 Fish Assemblage Data Collection

Video footage was collected along the transects outlined in Table 3-7 using the forward-facing HD camera (30° angle) on the ROV (Section 3.5.2).

3.7.3 Fish Species Classification System

Classification of the video footage was completed using EventMeasure Stereo (SeaGIS, 2022b). Each fish, crustacean and other mobile invertebrate that was encountered along each transect was identified to the lowest taxonomic resolution possible and enumerated as outlined in Goetze et al. (2019). Any fish that re-entered the field of view was not re-counted.

3.7.4 Statistical Treatment and Analysis

Due to the varying transects lengths collected at each site, the length of all transects were standardised to 200 m to allow for a robust statistical analysis and is a similar length to other studies conducted in the North West Shelf (Saunders et al., 2021). For six transects along three sites (C & D DC-3, NTB3 and Gorgon GMT), transects lengths ranged from 112 and 198 m and as such, the entire transect was used for analyses. For transects greater than 200 m, the first 200 m section of the transect was selected for statistical analysis. Where transect lengths were greater than 400 m, the transect was split into multiple replicate 200 m lengths with a 10 m gap to separate the transects.

To determine whether there are any differences between the fish and crustacean assemblages among water masses, among KEFs, and among the geomorphic features, three different statistical designs were used, each comprising of a two-factor design:

Design one – Water mass

- Water mass = fixed factor with three levels: Tropical Surface Water (TSW), Southern Indian Central Water (SICW), Antarctic Intermediate Water (AAIW)
- Site = random factor nested within water mass, varying levels depending on replication

Design two – KEFs

- KEF = fixed factor with four levels: Exmouth Plateau, Continental Slope Demersal Fish Communities, Ancient Coastline, and Outside of any KEF
- Site = random factor nested within KEF, varying levels depending on replication

Design three – Geomorphic features

- Geomorphic feature = fixed factor with four levels: slope, trench/trough, deep/hole/valley, plateau
- Site = random factor nested within geomorphic feature, varying levels depending on replication.

All statistical analyses, including post-hoc tests on significant factors, were undertaken using non-parametric analysis of variance (PERMANOVA) in the software package PRIMER with PERMANOVA+ (Primer-E Ltd, Version 7.0.18; Anderson, 2008; Clarke & Gorley, 2015). Fish assemblage data were fourth root transformed and crustacean assemblage data were square root transformed prior to analysis to down-weigh the contribution of dominant species and allow rarer groups to play a part in the analyses. The Bray-Curtis dissimilarity measure was used on the multivariate dataset prior to analysis with PERMANOVA.

Results of multivariate analysis (fish and crustacean assemblages) were presented graphically using a non-parametric multidimensional scaling (nMDS) plot to visualise any patterns in two-dimensional space. Vectors were overlaid on the nMDS plot to illustrate the strength and direction of the Pearson's correlation (>0.5) of individual taxa to the dataset.

To investigate the effect of depth on the composition of the multivariate fish and crustacean assemblages, a distance-based linear modelling (DistLM) was completed. For this analysis, depth was the explanatory variable, and the fish or crustacean assemblages were the dependent variables.

Data were not transformed prior to univariate analyses of number of fish and crustaceans, and number of fish taxa and crustacean taxa. Euclidean distance was used as a dissimilarity measure for univariate

analyses. Results were presented using bar graphs of means and standard errors (SE) to illustrate patterns among the factors of interest.

Refer to Appendix D for more details on the methodology of fish assemblages.

3.8 Sediment Sampling

Sediment sampling comprised of two separate assessments: sediment characterisation (chemistry and composition) and benthic infauna. Sample collection for both types of assessments were completed simultaneously using ROV-operated push corers.

3.8.1 Sediment Sample Collection

Sediment quality sampling sites were selected to understand the chemistry and composition of sediment at potential drill centres and tie-in locations. These sites were sampled to characterise the sediment quality prior to any disturbance or potential contamination arising from development activities (e.g., drilling and cutting disposal), providing a broad-level baseline understanding of project area.

Sediment samples were collected using push corers operated by the ROV manipulator arm (Section 3.5.3). At each site (Table 3-8), three replicate sediment cores (of 100 mm internal diameter) were collected and analysed for sediment chemistry, and two replicate sediment cores (60 mm internal diameter) were collected for benthic infauna (Table 3-9). This approach was a reduction in effort compared with the PEP (Advisian, 2022a) due to time constraints encountered in the field. A total of 30 samples for chemistry (excluding QA/QC samples; Section 3.8.4) from ten sites (Table 3-8) were collected. For benthic infauna, a total of 28 samples (14 sites with two replicate samples collected from each site) were collected.

Table 3-8 Sediment sampling sites

Field	Site Name	Survey Date	Easting	Northings	Depth Range (m)
Chandon	Chandon DC-1	7/05/2022	198899	7833791	1,100–1,200
Chrysaor and Dionysus	C & D DC-3	3/05/2022	278747	7765155	700–800
	C & D DC-2	4/05/2022	276899	7772322	1,000–1,100
Geryon and Eurytion	G & E DC-1	5/05/2022	278876	7793169	1,200–1,300
Semele	NTB3	4/05/2022	280281	7780314	1,100–1,200
	Semele DC-1	7/05/2022	290128	7792145	1,100–1,200
	Semele DC-2	8/05/2022	289623	7792140	1,100–1,200
	Semele BCH1	8/05/2022	286880	7789035	1,100–1,200
	Semele BCH2	8/05/2022	285124	7787323	1,100–1,200
WTR	WTR DC-1	9/05/2022	294288	7762283	100–200

Note:
1. C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

Table 3-9 Sediment samples for each core size

Parameters	Corer Size	Core Sample Depth	Sample Sites per Location	Replicate Samples
Sediment chemistry and composition	100 mm	5 cm	1	3
Benthic infauna	60 mm	10 cm	1	2

3.8.2 Sediment Chemistry Sample Processing and Labelling

All sediment samples were processed and preserved according to Australian and New Zealand Standards (AS/NZS 5667.1:1998) and the requirements of the analytical laboratories. On the recovery of samples to the surface, each core was deposited into core trays, assessed for physical properties (e.g., odour, sediment grain size and the presence of organic matter, marine organisms, shells, and other relevant features), and photographed with the relevant site identification prior to sample processing. All sampling equipment including the push corers and core trays, were washed with laboratory grade decontamination solution (Decon 90), and rinsed thoroughly with clean seawater. Field personnel wore disposable sterile nitrile gloves at all times during the sampling process which were changed between sampling collections at each site.

For the analysis of sediment chemistry and composition (PSD), the top 5 cm of sediment sample from each of three replicate cores were extracted and homogenised in a glass bowl until the texture and colour was uniform. The sediment sample was then placed into laboratory supplied containers (Table 3-10) and labelled with the date and time of sampling, field location and site number (sample unique identifier). All samples were stored in a refrigerator and each sample was recorded on a field sheet.

Chain of custody (CoC) documentation was used for all stages of the sample processing and storage. Field sheets and data tracking sheets were used to ensure all sites were sampled and samples were properly stored, labelled, preserved, and delivered to the laboratories within the recommended holding times. However, due to the remote location of sampling sites, recommended holding times for the analyses of some analytes (TRH, BTEX and moisture content) were exceeded for sites WTR DC-1 and Semele 4. Such exceedances should be taken into consideration when interpreting the results. CoC tables are presented in Appendix E.

3.8.3 Sample Analysis

Sediment samples were analysed using standard laboratory methods at ALS Environmental (Perth), a National Association of Testing Authorities (NATA) accredited laboratory. Samples were analysed for hydrocarbons (total recoverable hydrocarbons [TRH], benzene, toluene, ethylbenzene and xylenes [BTEX], and polycyclic aromatic hydrocarbons [PAHs]), total metals/metalloids, PSD, TOC, and moisture content (Table 3-10). Sediment concentrations were compared to Australian and New Zealand Guidelines (ANZG; ANZG, 2018) default guideline values (DGVs), and upper guideline values (GV-High) if required.

Table 3-10 Chemical and physical analysis of sediment samples

Parameter	ALS Limit of Reporting (LOR) as per Quote EP/246/22 (mg/kg)[1]	Container, Preservation and Holding Time (as per ALS Methods)
TRH		
C_6–C_{10} fraction	10	*250 ml Soil Glass Jar – Unpreserved Chilled <6 degrees Celsius (°C) Holding Time: 14 days
>C_{10}–C_{16} fraction	50	
>C_{16}–C_{34} fraction	100	
>C_{34}–C_{40} fraction	100	
Total TRHs	–	
BTEX		
Benzene	0.2	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days
Toluene	0.5	
Ethylbenzene	0.5	
Xylenes (sum M&P and O)	0.5	
PAHs if TRH recorded		
Naphthalene	0.005	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days
Acenaphthylene	0.004	
Acenaphthene	0.004	
Fluorene	0.004	
Phenanthrene	0.004	
Anthracene	0.004	
Fluoranthene	0.004	
Pyrene	0.004	
Benz(a)anthracene	0.004	
Chrysene	0.004	
Benzo(b,k)fluoranthene	0.004	
Benzo(a)pyrene	0.004	
Indeno(1,2,3-cd)pyrene	0.004	
Dibenz(a,h)anthracene	0.004	
Benzo(g,h,i)perylene	0.004	
Total PAHs	0.004	

Parameter	ALS Limit of Reporting (LOR) as per Quote EP/246/22 (mg/kg)[1]	Container, Preservation and Holding Time (as per ALS Methods)
Metals (total only)		
Silver	0.1 (1.0, 4.0)	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 180 days
Aluminium	50	
Arsenic	1.0 (20, 70)	
Barium	10	
Cadmium	0.1 (1.5, 10)	
Cobalt	0.5	
Chromium	1.0 (80, 370)	
Copper	1.0 (65, 270)	
Iron	50	
Manganese	10	
Nickel	1.0 (21, 52)	
Lead	1.0 (50, 220)	
Zinc	1.0 (200, 410)	
Mercury	0.01 (0.15, 1.0)	
Others		
PSD (laser diffraction and wet sieving)	–	2 x 500 ml snap lock bag – PSD Bag Chilled <6°C Holding Time: 180 days
TOC (%)	0.02%	150ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 28 days
Moisture (%)		*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days

Notes:
1. Value in parentheses for total metals is the ANZG (2018) default guideline value (DGV), and guideline value high (GV-High)
2. Asterisks (*) denotes a shared laboratory container
3. BTEX = Benzene, toluene, ethylbenzene and xylenes, PAH = polycyclic aromatic hydrocarbons, PSD = particle size distribution, TOC = total organic carbon, TRH = total recoverable hydrocarbons

3.8.4 Quality Assurance and Quality Control Analysis

As part of the NATA requirements, the following QA/QC samples were collected in the field to ensure data integrity:

- Sediment field blanks were used to test for potential contamination of sediment samples during the sampling process. The blank sample consisted of acid washed and heated soil to remove organic content. The blank sample was processed using the same methods and equipment as the actual sediment samples and was analysed for hydrocarbons. A field blank was collected at sites G & E DC-1 and WTR DC-1.
- Duplicate sediment samples (two extra cores) were collected at sites Semele BCH2 and WTR DC-1 to test for inter-laboratory variability. Two independent samples (i.e., two separate grabs) were collected at the same location and were analysed by the secondary laboratory (ALS on the east coast of Australia) for metals and moisture content.
- Triplicate sediment samples were collected at site WTR DC-1 to test for intra-laboratory variability. Three independent samples (i.e., three separate grabs) were collected at the same location and were analysed by the primary laboratory for metals and moisture content.

The accuracy of sediment analyses was determined by quantifying the differences between the concentrations of analytes in the duplicate and triplicate samples. The relative percent difference (RPD) was calculated for duplicate samples and the relative standard deviation (RSD) was calculated for the triplicate sample using the methods outlined in the National Assessment Guidelines for Dredging (Commonwealth of Australia, 2009). The RPD and RSD calculations are determined as follows:

$$\text{RPD (\%)} = \frac{\text{(difference between replicates) x 100}}{\text{(average of the replicates)}}$$

$$\text{RSD (\%)} = \frac{\text{(standard deviation of replicates)x 100}}{\text{(average of replicates)}}$$

Values for RPD and RSD greater than 50% may signify that sediments are either heterogenous, or greatly differ in grain size. RPD/RSD calculations were not completed where one or more of the replicates were below the laboratory limit of reporting (LOR).

In addition to the field QA/QC samples, laboratory analyses included quality control testing of sediment samples to include:

- 5% method blanks (one analysed within each process lot of 20 samples)
- 10% laboratory duplicates (two analysed within each process lot of 20 samples)
- 5% laboratory control samples (one analysed within each process lot of 20 samples)
- 5% matrix spikes (one analysed within each process lot of 20 samples).

All QA/QC samples were analysed within laboratory holding times and in accordance with NATA quality control procedures (Appendix I). QA/QC samples were not required for benthic infauna samples.

3.8.5 Benthic Infauna Collection and Processing

Sediment samples for infauna were collected using methods similar to Hook et al. (2016) in which the top 10 cm of sediment sample from both cores were used. If the sample contained less than 10 cm, the depth of sample was noted on the field sheet and the whole sample was used. Samples were sieved on site to 1 mm, placed into a calico bag and were preserved in 100% ethanol before transporting to the laboratory. CoC documentation was used for all stages of the sample processing and storage.

Benthic infauna samples were processed by Benthic Australia. Laboratory processing of sediment samples for benthic infauna included:

- Sample sorting – the separation of biological material from sediment, shell-hash, and other non-living biological material retained by sieving. Rose Bengal may be added to stain the biological material and facilitate the sorting process.
- Species identification and enumeration – the accurate identification (using stereomicroscopy) of all invertebrates found in a sample to the lowest reliable taxonomic level and the counting of invertebrate numbers in each taxonomic category.

Invertebrates were identified to the lowest reliable taxonomic level using appropriate standard identification guides and keys for the taxonomic groups. After sorting, identification and counting, invertebrates were stored in 70% isopropyl alcohol.

3.9 Water Sampling

3.9.1 Water Sample Collection

Sampling sites for water quality were selected to ensure sufficient spatial representation across the GBF project area whilst still maintaining alignment with planned ROV benthic survey deployment locations. Sampling for water ensured a high-level baseline dataset was obtained prior to any disturbance or potential contamination arising from development activities (e.g., drilling and cutting disposal), and allows for valid comparisons in the unlikely event of a discharge or spill event(s).

Replicate water samples were collected from the surface and near the seabed at each site (n = 4 per site; Table 3-11) using a Niskin bottle (Section 3.5.4). Samples were collected from approximately 1 m below the surface using a Niskin bottle deployed over the side of the vessel, and from near the seabed (~5–10 m above) from ROV-activated Niskin bottles attached to the ROV TMS. At site Jansz JMT, the second Niskin bottle attached to the ROV was not loaded and only one of two water samples from near the seabed was collected. As such, a total of 31 samples (excluding QA/QC samples; Section 3.9.4) from eight sites (Table 3-11) were collected.

Table 3-11 Water quality sampling sites

Field	Site Name	Survey Date	Number of Surface Samples	Number of Near Seabed Samples	Facility / BCH Transect	Easting	Northings	Depth Range (m)
Chandon	Jansz JMT	5/05/2022	1	2	Tie in	249098	7807831	1,300–1,400
	Chandon DC-1	7/05/2022	2	2	Proposed Drill Centre	198899	7833791	1,100–1,200

Field	Site Name	Survey Date	Number of Surface Samples	Number of Near Seabed Samples	Facility / BCH Transect	Easting	Northings	Depth Range (m)
Chrysaor and Dionysus	C & D DC-3	3/05/2022	2	2	Proposed Drill Centre	278747	7765155	700–800
Geryon and Eurytion	G & E DC-1	5/05/2022	2	2	Proposed Drill Centre	278876	7793169	1,200–1,300
	BCH28	6/05/2022	2	2	BCH Transect	253595	7798894	1,200–1,300
Semele	NTB3	4/05/2022	2	2	Proposed Drill Centre	280281	7780314	1,100–1,200
WTR	WTR DC-1	9/05/2022	2	2	Proposed Drill Centre	294288	7762283	100–200
	Gorgon GMT	10/05/2022	2	2	Tie in	280989	7733571	100–200

Note:

1. BCH = Benthic communities and habitat, C & D Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

3.9.2 Water Chemistry Sample Processing and Labelling

All water samples were processed and preserved according to Australian and New Zealand Standards (AS/NZS 5667.1:1998) and the requirements of the analytical laboratories. For all samples, water from the Niskin bottle was emptied directly into the laboratory containers in order to decrease chance of contamination (Table 3-12). All sampling equipment including the Niskin bottles, were washed with Decon 90 and rinsed thoroughly with clean seawater. Field personnel wore disposable sterile nitrile gloves at all times during the sampling process which were changed between sampling collections at each site. Filtering of water samples was completed by the laboratory, where required. All sample containers were labelled with the date and time of sampling, field location and site number (sample unique identifier). All samples were stored in a refrigerator and each sample was recorded on a field sheet.

CoC documentation was used for all stages of the sample processing and storage (Appendix E). Field sheets and data tracking sheets were used to ensure all water sampling sites were sampled and samples were properly stored, labelled, preserved, and delivered to the laboratories within the recommended holding times. However, due to the remote location of sampling sites, recommended holding times for the analyses of some analytes were exceeded for some samples, including TRH and TDS for surface and seabed water samples at NTB3, and TDS for surface and seabed water samples at C & D DC-3. Such exceedances should be taken into consideration when interpreting the results.

3.9.3 Sample Analysis

Water samples were analysed using standard laboratory methods at ALS Environmental (Perth), a NATA-accredited laboratory. Samples were analysed for hydrocarbons (TRH, BTEX, PAHs), total and dissolved metals, DOC, TOC, TDS, total phosphorus (TP) and total nitrogen (TN) (Table 3-12). Concentrations were compared to ANZG (2018) DGVs for 99% species protection.

Table 3-12 Chemical analysis of water samples

Parameter	ALS LOR as per Quote EP/246/22 (µg/L)[1]	Container & Holding time (ALS Methods)
TRH		
C_6–C_{10} fraction	20	100 ml amber glass Chilled <6°C Holding Time: 7 days
>C_{10}–C_{16} fraction	100	
>C_{16}–C_{34} fraction	100	
>C_{34}–C_{40} fraction	100	
Total TRHs	-	
BTEX		
Benzene	1.0 (500)	2 x 40 ml volatile organic chemical vials, preserved Chilled <6°C Holding Time: 14 days
Toluene	2.0 (110)	
Ethylbenzene	2.0 (50)	
Xylenes (sum M&P and O)	2.0	
Total BTEX	1.0	
PAHs if TRH recorded		
Naphthalene	1.0 (50)	100 ml amber glass Chilled <6°C Holding Time: 7 days
Acenaphthylene	1.0	
Acenaphthene	1.0	
Fluorene	1.0	
Phenanthrene	1.0 (0.6)	
Anthracene	1.0 (0.01)	
Fluoranthene	1.0	
Pyrene	1.0	
Benz(a)anthracene	1.0	
Chrysene	1.0	
Benzo(b,k)fluoranthene	1.0	
Benzo(a)pyrene	0.5 (0.1)	
Indeno(1,2,3-cd) pyrene	1.0	
Dibenz(a,h)anthracene	1.0	
Benzo(g,h,i)perylene	1.0	

Parameter	ALS LOR as per Quote EP/246/22 (µg/L)[1]	Container & Holding time (ALS Methods)
Total PAHs	0.5	
Metals (total and dissolved)		
Silver	0.1 (0.8)	60 ml clear high-density polyethylene (U-T ORC) bottle – Unfiltered/filtered, laboratory acidified Chilled <6°C Holding Time: 180 days
Aluminium	5.0	
Arsenic	0.5	
Barium	1.0	
Cadmium	0.2 (0.7)	
Cobalt	0.05 (0.005)	
Copper	0.2 (0.3)	
Iron	5.0	
Manganese	0.5	
Nickel	0.5 (7.0)	
Lead	0.2 (2.2)	
Zinc	5.0 (7.0)	
Mercury	0.1 (0.1)	
Chromium III	0.001 (7.7)	60 ml clear plastic bottle – preserved with sodium hydroxide, filtered/unfiltered Chilled <6°C Holding Time: 28 days
Chromium VI	0.001 (0.14)	
Others		
DOC (mg/L)	1.0	40 ml amber bottle, filtered and preserved with sulfuric acid Chilled <6°C Holding Time: 28 days
TOC (mg/L)	1.0	40 ml amber vial, preserved with sulfuric acid Chilled <6°C Holding Time: 28 days
TDS (mg/L)	10	500 ml clear plastic bottle Chilled <6°C Holding Time: 7 days
TP (mg/L)	0.01	60 ml clear plastic bottle, preserved with sulfuric acid Chilled <6°C
TN (mg/L)	0.1	

Parameter	ALS LOR as per Quote EP/246/22 (µg/L)[1]	Container & Holding time (ALS Methods)
		Holding Time: 28 days

Notes:
1. Value in parentheses is the ANZG (2018) default guideline value (DGV) for 99% species protection
2. °C = Celsius degrees, BTEX = benzene, toluene, ethylbenzene and xylenes, DOC = dissolved organic carbon, LOR = limit of reporting, PAH = polycyclic aromatic hydrocarbons, TDS = total dissolved solids, TOC = total organic carbon, TN = total nitrogen, TP = total phosphorus, TRH = total recoverable hydrocarbons

3.9.4 Quality Assurance and Quality Control Analysis

As part of the NATA requirements, the following QA/QC samples were collected in the field to ensure data integrity:

- Duplicate water samples were collected to test for inter-laboratory variability. Two independent samples (i.e., two separate grabs) were collected at the same location and were analysed by the secondary laboratory (ALS on the east coast of Australia) for dissolved and total metals, TN, TP, DOC, TOC, and TDS. Duplicate samples were collected from near the seabed at G & E DC-1, near the seabed at Gorgon GMT, and surface sample at WTR DC-1.
- Equipment water blanks were processed while at site WTR DC-1 to test for potential contaminants in the sampling equipment. Water blank samples were used on the four Niskin bottles (one attached to the ROV and another to the TMS, and two on the surface) and were analysed by the primary laboratory for dissolved and total metals, hydrocarbons and TN, TP, DOC, TOC, and TDS.

Similar to sediment samples, laboratory analyses included quality control testing of water samples to include 5% method blanks, 10% laboratory duplicates, 5% laboratory control samples, and 5% matrix spikes. All QA/QC samples were analysed within laboratory holding times and in accordance with NATA quality control procedures (Appendix I).

3.10 Water Profiling

3.10.1 Data Acquisition and Presentation

Profiles of the water column were collected by the water quality profiler attached to the ROV (Section 3.5.5). CTD measurements were collected at 35 sites, as presented in Table 3-13. After all sites were completed, the water quality profiler was removed from the ROV, and data downloaded to a laptop. Salinity was calculated by the CTD processing software using EOS-80 (Practical Salinity) equations.

Table 3-13 Summary of CTD sampling sites, start/end times, depth, and up/down cast

Field	Site Name	Upcast (U)/ Downcast (D)	Survey Date	Start Time	End Time	Depth (m)
Chandon	Jansz JMT	U	6/5/2022	00:34	01:13	1,356
	BCH06	D	6/5/2022	08:47	09:28	1,364
	BCH09	U	6/5/2022	13:56	14:37	1,364
	BCH08	D	6/5/2022	16:10	16:51	1,361
	BCH02	D	6/5/2022	20:47	21:55	1,276
	BCH01	D	7/5/2022	01:24	02:08	1,206

Field	Site Name	Upcast (U)/ Downcast (D)	Survey Date	Start Time	End Time	Depth (m)
	Chandon DC-1	U	7/5/2022	06:14	08:27	1,206
	BCH31	D	7/5/2022	10:43	12:16	1,326
Chrysaor and Dionysus	Gorgon M1	D	28/4/2022	18:53	19:09	219
	BCH13	U	29/4/2022	02:25	02:39	226
	BCH12	D	1/5/2022	20:03	20:37	234
	BCH03 – ZIGZAG	U	3/5/2022	15:10	16:27	702
	C & D DC-3	D	3/5/2022	19:03	19:48	746
	BCH15	D	4/5/2022	01:21	01:55	929
	BCH14	D	4/5/2022	10:03	11:24	1,092
	BCH05	D	4/5/2022	20:30	21:01	1,165
	BCH33	D	9/5/2022	16:05	16:26	232
	BCH34	D	9/5/2022	19:24	19:49	752
	BCH36	U	9/5/2022	22:47	23:08	381
	C & D DC-2	U	4/5/2022	04:39	06:04	1,007
Geryon and Eurytion	G & E DC-1	D	5/5/2022	00:47	01:29	1,228
	BCH29	D	5/5/2022	08:01	08:46	1,319
	BCH07	D	5/5/2022	13:31	14:12	1,348
	BCH28	D	6/5/2022	03:03	03:44	1,317
Semele	NTB3	U	4/5/2022	17:20	19:08	1,130
	Semele DC-2	D	7/5/2022	20:11	20:54	1,143
	Semele DC-1	D	8/5/2022	01:06	01:48	1,142
	BCH40	D	8/5/2022	08:15	09:04	1,170
	BCH26	D	8/5/2022	14:52	15:43	1,160
	BCH41	D	8/5/2022	18:49	21:10	1,161
	BCH32	D	9/5/2022	22:35	23:15	1,172
WTR	BCH04	D	3/5/2022	04:01	04:18	256
	WTR DC-1	D	9/5/2022	03:27	03:39	139
	BCH27	D	9/5/2022	10:40	12:27	141
	Gorgon GMT	D	10/5/2022	05:17	05:26	136

Note:
1. BCH = Benthic communities and habitat, C & D Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

Data are presented as profiles of temperature, salinity, and conductivity against depth for each site. Additionally, temperature-salinity plots were presented for the deepest site at each field to evaluate localised water masses that may be present in the area. Outliers in the water column profiles were removed.

Depth profiles were also recorded by the ROV (recorded as altitude) during each deployment (transect) in the GBF project area.

4 Results

4.1 Benthic Habitat

The overall distribution of benthic habitats within the GBF project area (within the 5 km operational area buffer) is presented in Figure 4-1. The overall benthic habitat map is split into seven maps to show the fine scale seabed features with higher resolution. The seven maps include the 1) Exmouth Plateau area (Figure 4-2), 2) North Jansz area (Figure 4-3), 3) Jansz area (Figure 4-4), 4) North East Semele area (Figure 4-5), 5) North Gorgon area (Figure 4-6), 6) East Scarp-Tryal area (Figure 4-7) and Figure 4-8, and 7) South Gorgon area (Figure 4-9).

These maps presented have been developed using a supervised classification approach, whereby the ROV imagery has been used to verify the distribution of BCH and inform the organisation and segmentation of the broadscale geophysical environmental data. The mapped classification categories presented herein are derived from nested CATAMI scheme (see examples in Appendix B) and have been grouped to represent the appropriate taxonomic level for assessment across a broad scale project area.

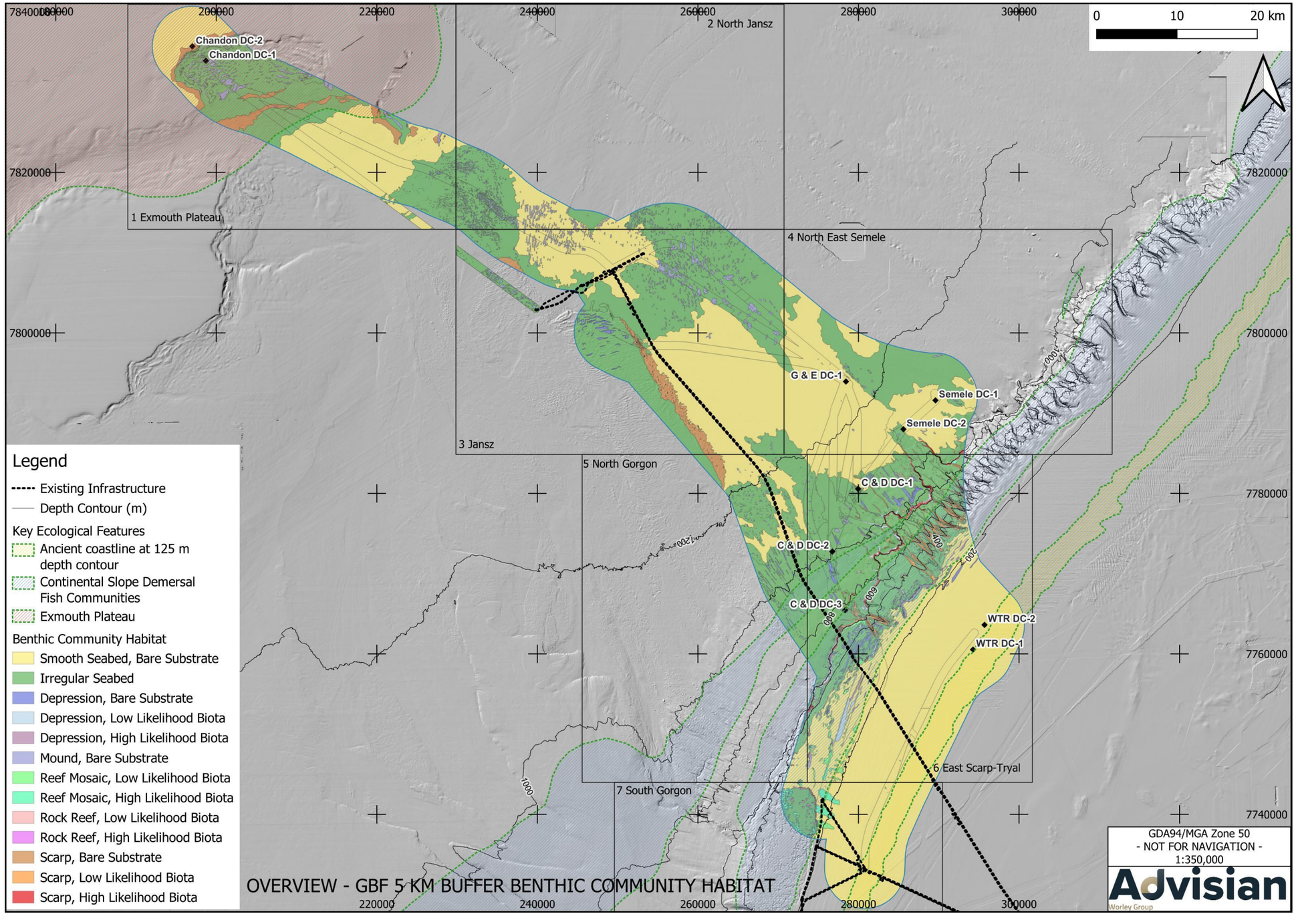


Figure 4-1 Overall distribution of benthic habitats within the Gorgon Backfill Fields project area, subdivided into seven broad areas (1 Exmouth Plateau, 2 North Jansz, 3 Jansz, 4 North East Semele, 5 North Gorgon, 6 East Scarp-Tryal, and 7 South Gorgon areas)

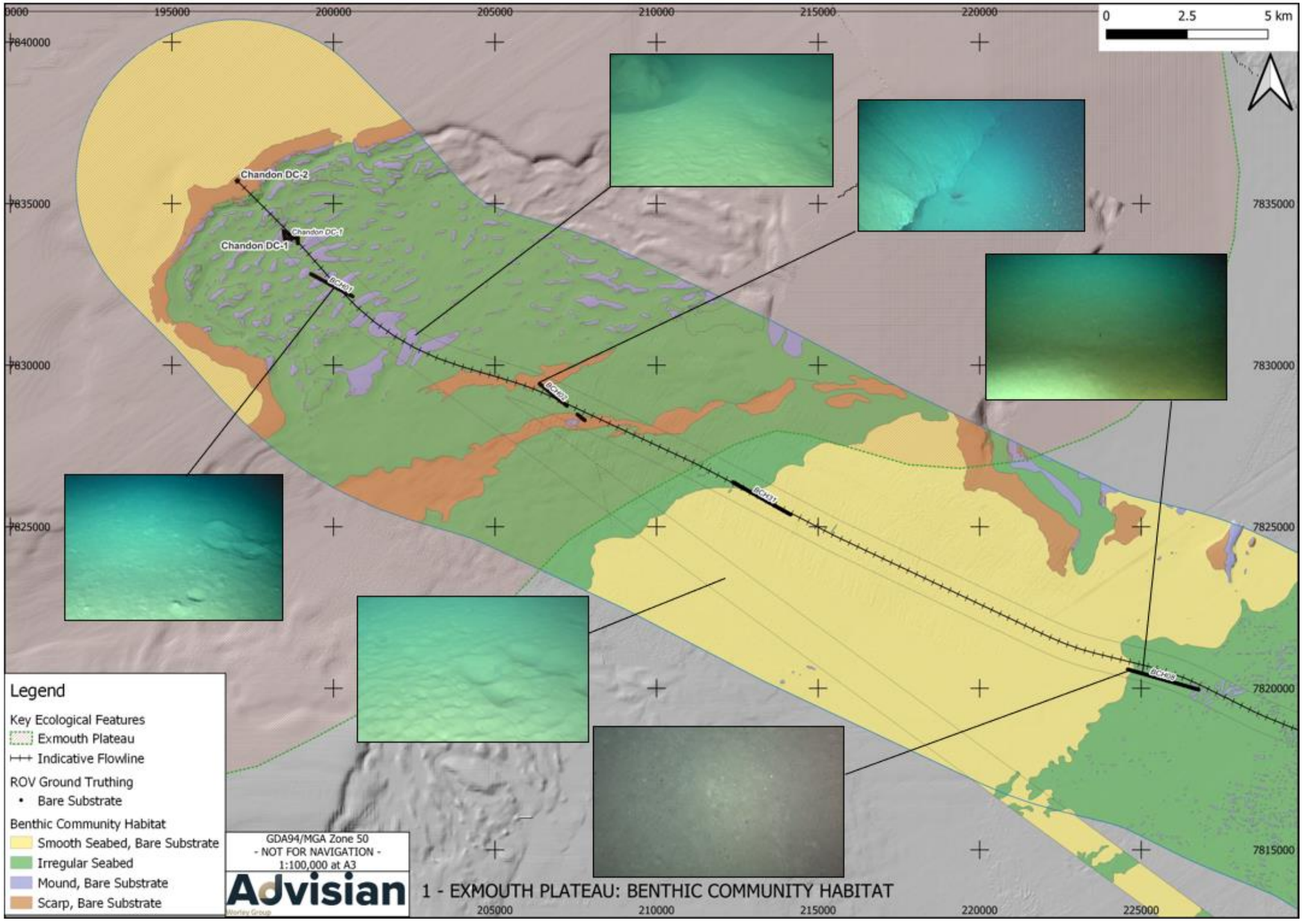


Figure 4-2 Distribution of benthic habitats within the Exmouth Plateau area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

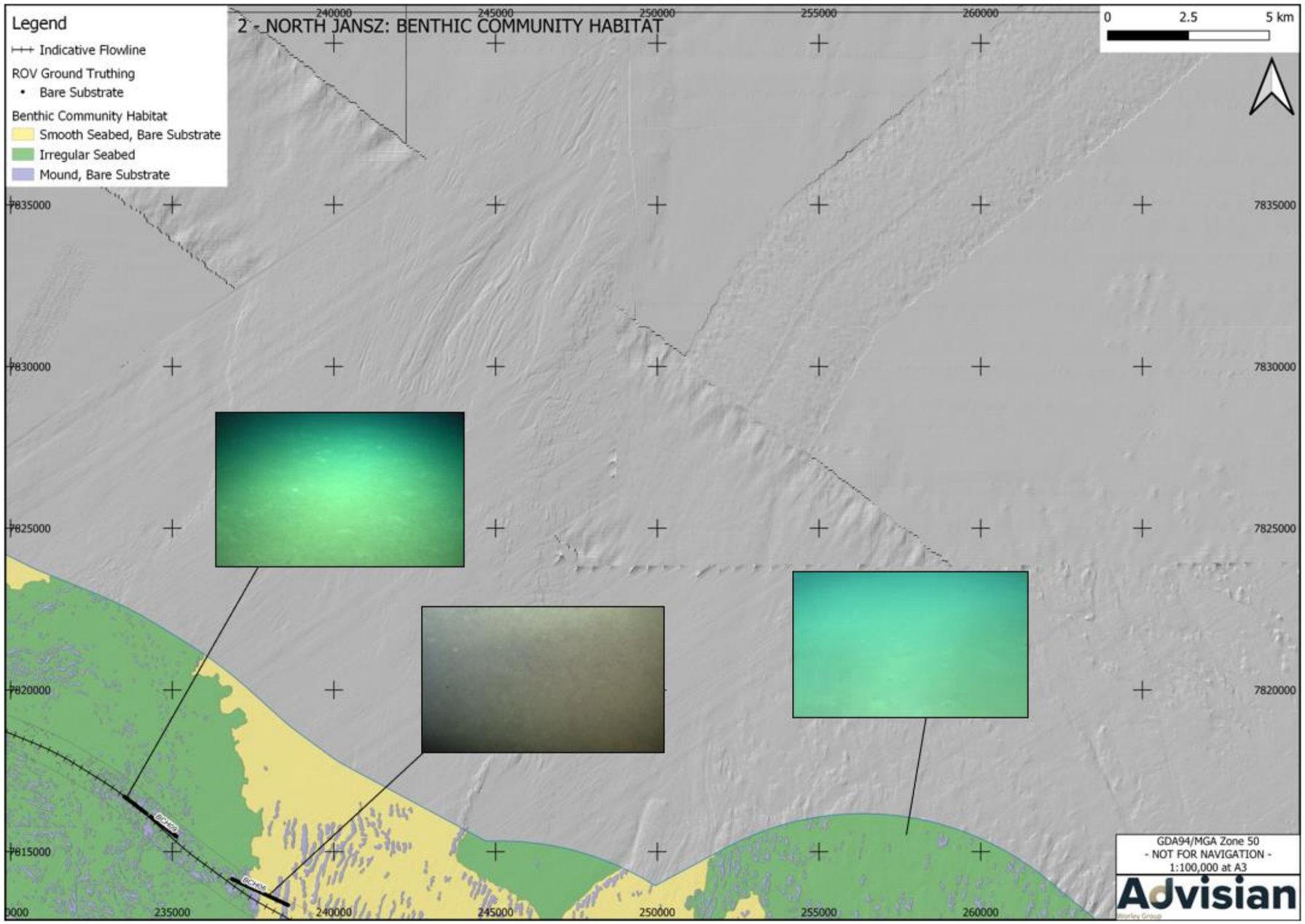


Figure 4-3 Distribution of benthic habitats within the North Jansz area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitat. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

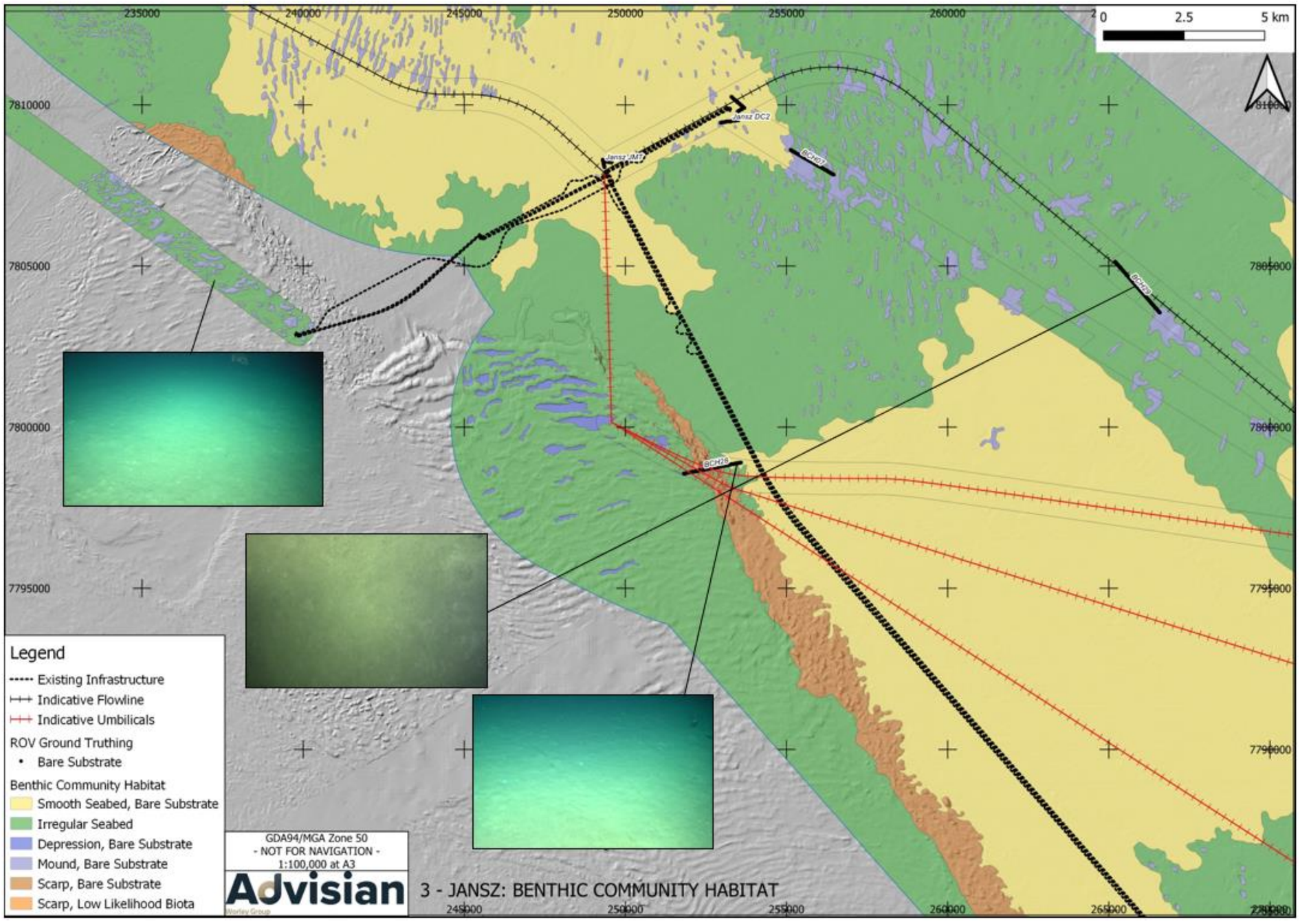


Figure 4-4 Distribution of benthic habitats within the Jansz area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

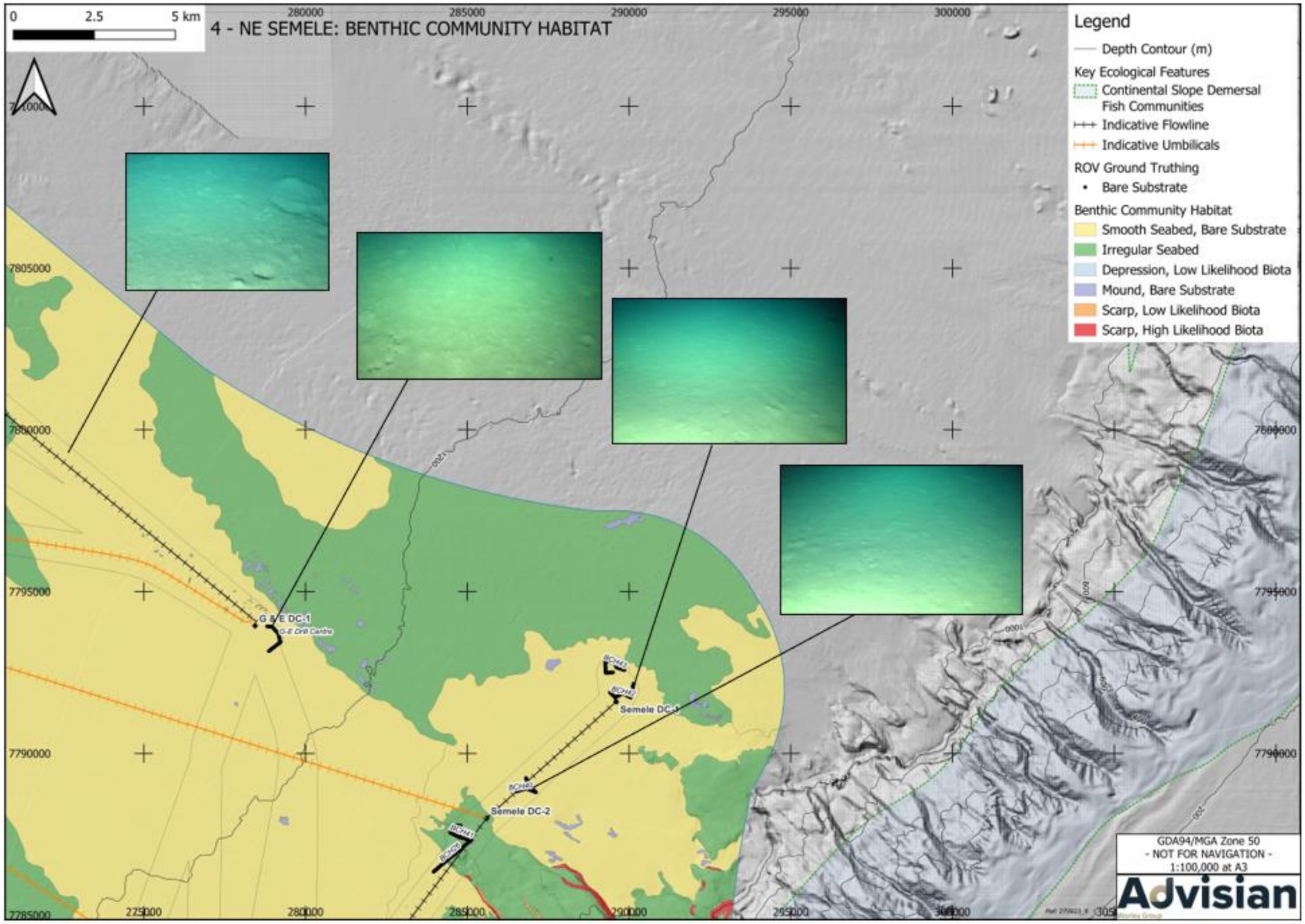


Figure 4-5 Distribution of benthic habitats within the North East Semele area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

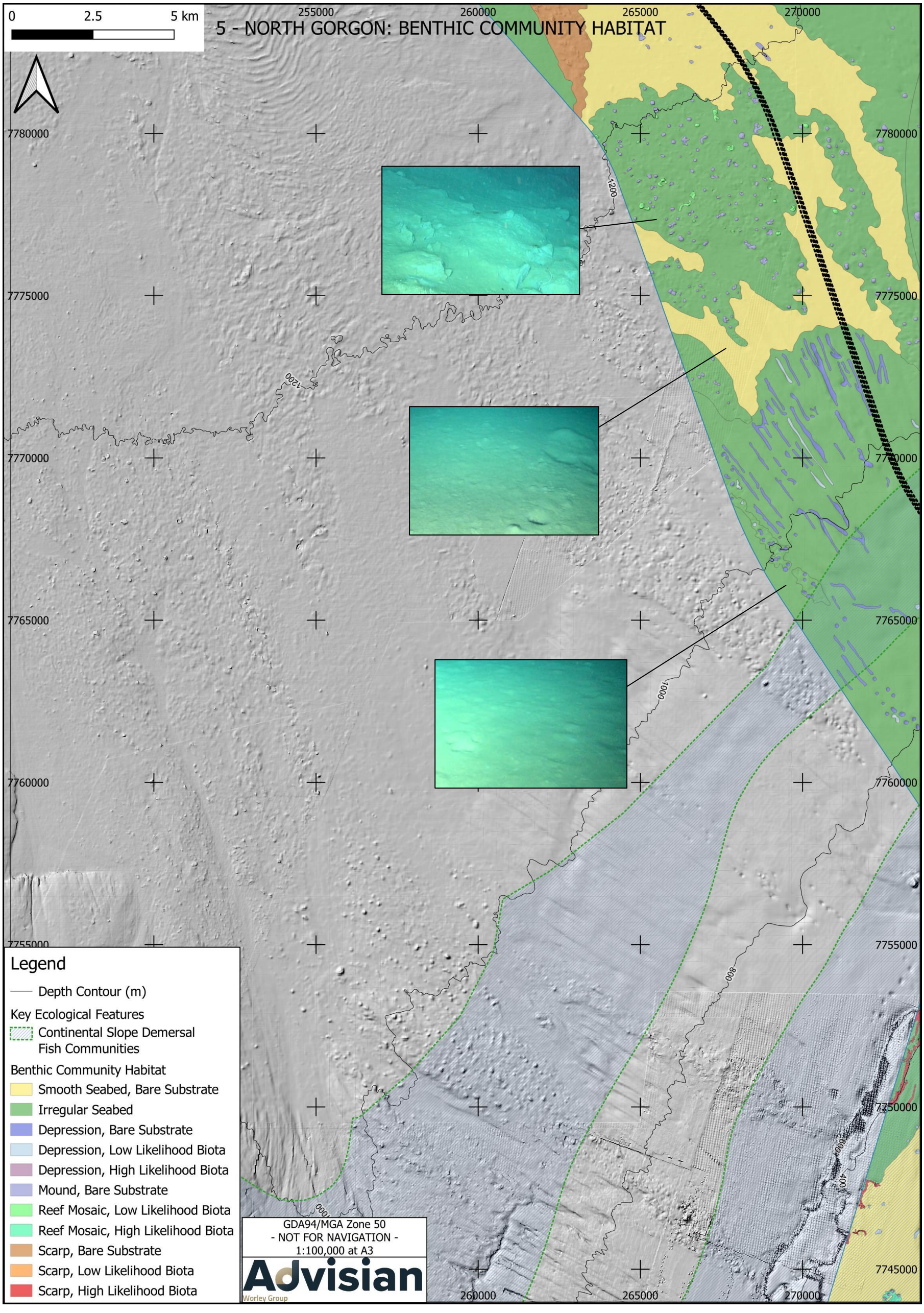


Figure 4-6 Distribution of benthic habitats within the North Gorgon area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

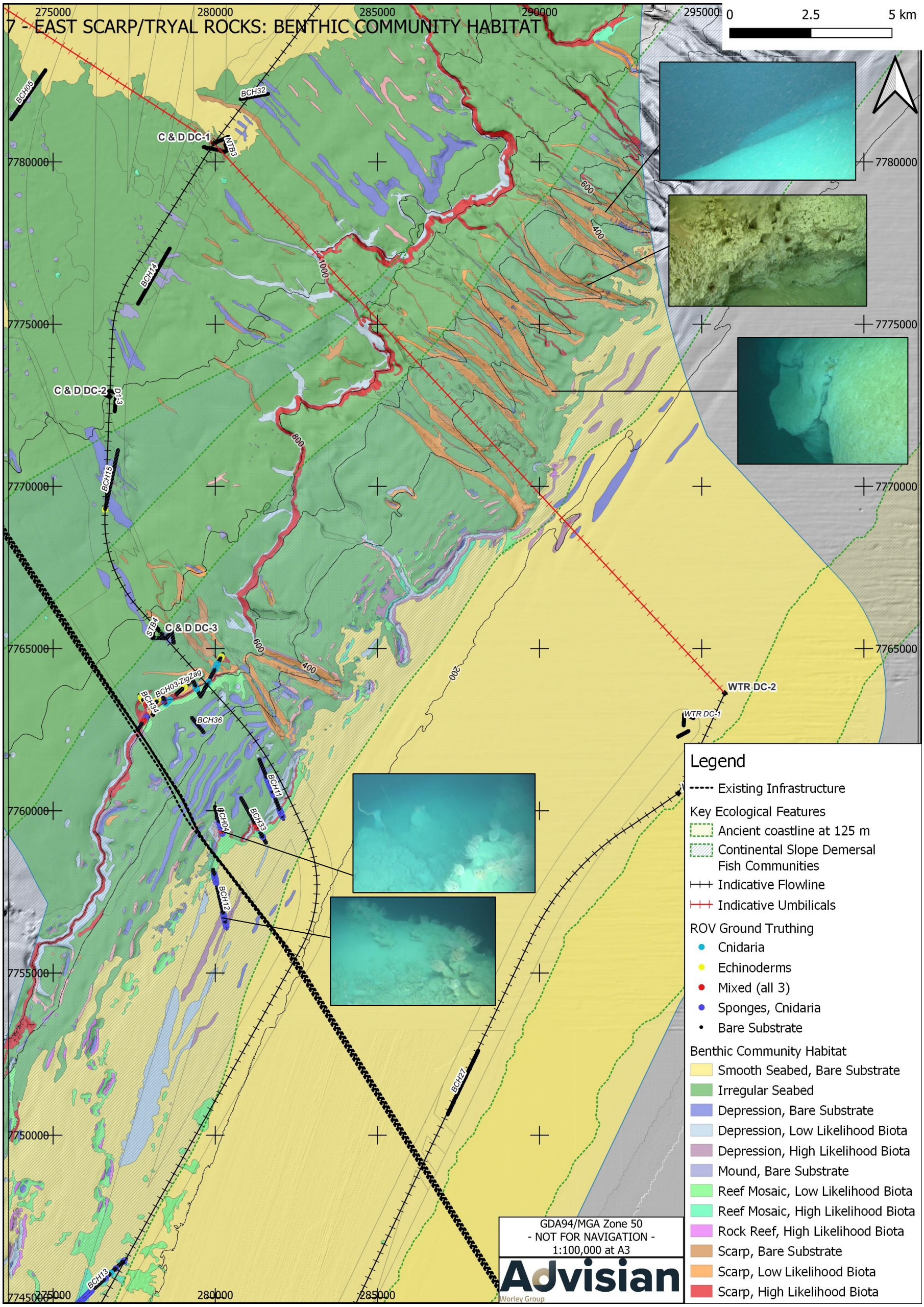


Figure 4-7 Distribution of benthic habitats within the East Scarp-Tryal area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

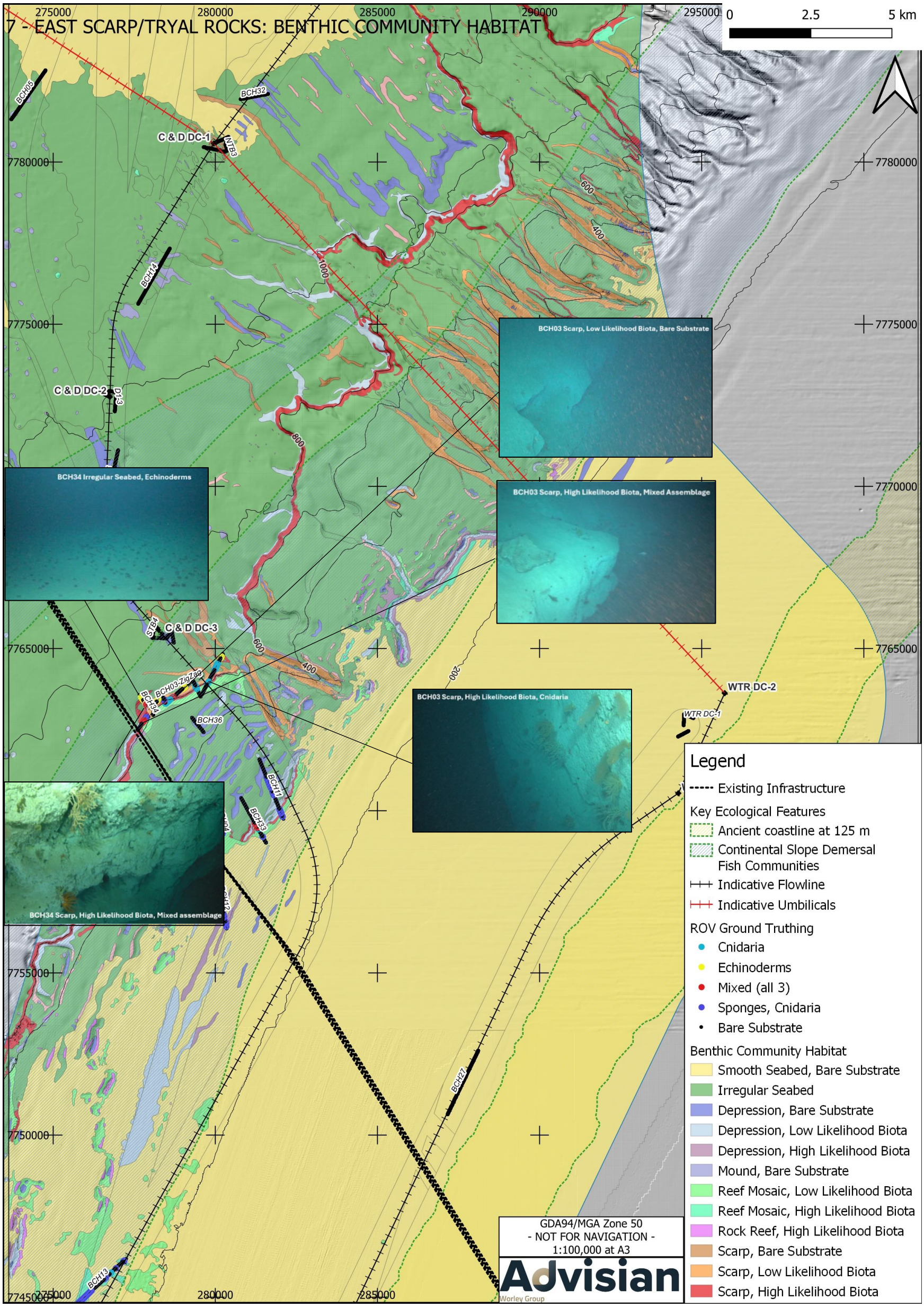


Figure 4-8 Distribution of benthic habitats within the East Scarp-Tryal area of Gorgon Backfill Fields project area, with ROV ground truthing images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

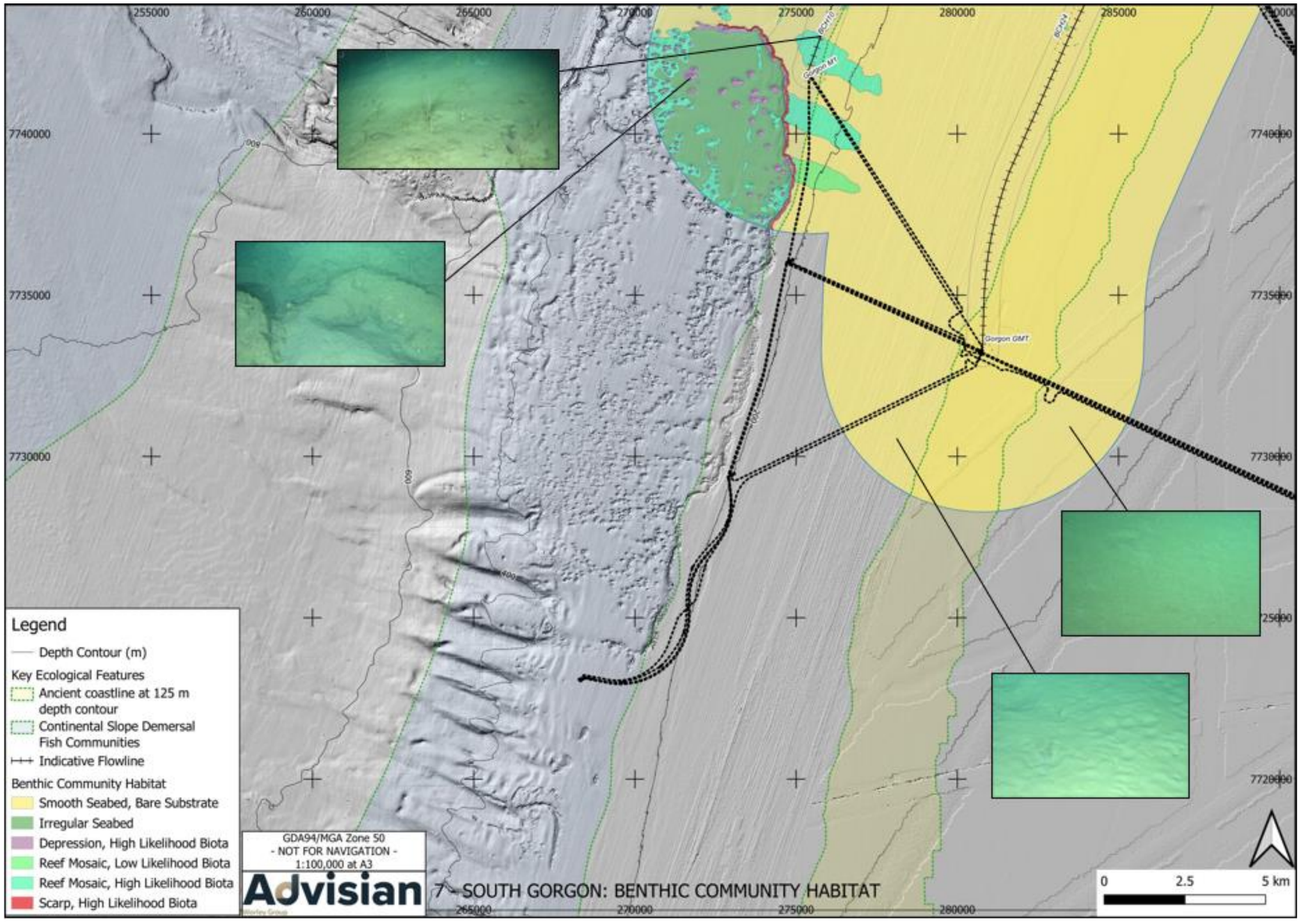


Figure 4-9 Distribution of benthic habitats within the South Gorgon area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats. Note – insert images of predictive mapped areas are taken from nearby ROV ground-truthing locations showing the same geomorphic characteristics

4.1.1 Benthic Communities and Habitats at Key Ecological Features

The distribution of benthic habitats in the Exmouth Plateau KEF is presented in Figure 4-2. Mapping shows the Exmouth Plateau KEF is dominated by mixed habitats comprising irregular seabed with bioturbation, irregular and smooth seabed floor with bare substrates, and mounds on the seafloor of bare substrate. The seabed immediately surrounding the proposed Chandon drill centre (Chandon DC-1), out to ~5 km east and west, and approximately 6 km along the proposed associated flowline comprise of bioturbated irregular seabed and large patches of depressions over bare substrate (as seen in BCH01). Little to no biota is predicted to occur in these bare substrates. In the Exmouth Plateau KEF that lies within the GBF project area, three large discrete scarps with bare substrate are present. Of these scarps, two scarps approximately 5.5 km and 2.5 km from the KEF border, cross through the indicative flowline from east to west, likely representing the edge of the Exmouth Plateau. The third scarp that runs from east to west and is ~500 m wide, is located ~1.4 km north of Chandon DC-1. Given that scarps or steep slopes may comprise of 3D hard structure (i.e., rock) and other structural features, the presence of biota is more likely, although not detected along the transect in this area (BCH02) due to the variable distribution across these habitats. The Exmouth Plateau is predominantly bare substrate, comprised of little to no biota. This is complemented by further ground-truthing in Figure 4-13. Aside from the mixture of sandy habitats with relatively low structural complexity, few ground-truthing transects were acquired along raised geomorphic features including scarps to validate the preliminary benthic habitat map in the Exmouth Plateau KEF. Therefore, the mapping product outlining scarps with bare substrate should be interpreted with a moderate level of certainty.

Mixed benthic habitats comprising irregular and smooth seabed of bare substrates, discrete depressions over bare substrate and scarps with bare substrate are the most dominant benthic features in the Continental Slope Demersal Fish Communities KEF (Figure 4-6, Figure 4-7 and Figure 4-9). A mixture of habitats is present along the proposed flowline route from benthic transect BCH15 to the proposed C & D DC-3 drill centre, including irregular seabed with bioturbation and bare substrate, depressions with bioturbation, and patches of scarps with bare substrate. Larger scarps (in relation to the scarp adjacent to the proposed C & D DC-3 drill centre) are mostly evident north, south and east of C & D DC-3 within the GBF project area which appear to follow changes in depth contours (Figure 4-7). A mixture of habitats and benthic communities extend along the indicative flowline from the proposed C & D DC-3 drill centre to the Gorgon M1 tie in location (Figure 4-4), including the presence of a continuous south-west to north-east scarp with low and high likelihood of biota, discrete patches of depressions over bare substrate, and reef mosaic adjacent to the scarps with a low likelihood of biota. Sections of rock reef mosaic that cross through the indicative flowline is colonised by sponges and cnidarians as identified in benthic transects BCH03 – ZIGZAG and BCH11 within the KEF (Figure 4-7). Topographically complex scarps in a south-west to north-east orientation with low and high likelihood of biota are present traversing through the GBF project area within the Continental Slope Demersal Fish Communities KEF between ~400–800 m depths. Ground-truthing transects (BCH34, BCH03 – ZIGZAG, BCH04, BCH11 and BCH33) verified the presence of cnidarians, echinoderms, sponges, and a mixture of these biotic groups along these scarps (Figure 4-3 and Figure 4-8) in varying percent cover (from low [<10%] to high cover [>80%]). Patches of reef mosaic with a low likelihood of biota, and rock reef and depressions with a high likelihood of biota are present to the west of the C & D DC-3 to Gorgon M1 corridor, which are likely to support sponges and cnidarians, as verified by benthic habitat transects BCH13 and BCH10 (Figure 4-7 and Figure 4-9). A scarp orientated north to south with a high likelihood of biota is present ~650 m west of Gorgon M1 tie in location and runs parallel to existing subsea infrastructure (Figure 4-9). The extensive field observations (ground-truthing transects) collected at and adjacent to indicative infrastructure locations confirmed the habitat

complexity and topographical heterogeneity present in the Continental Slope Demersal Fish Communities KEF as identified in the preliminary benthic habitat map. As such, the mapping products of this KEF can be inferred with a high level of confidence.

Mapping of the GBF project area (proposed flowline/umbilical corridors) that lie within the Ancient Coastline KEF only captures the existing infrastructure and Gorgon GMT proposed tie-in location (Figure 4-9). The benthic habitat at Gorgon GMT and the GBF project area within this KEF only consists of smooth seabed with bioturbation and bare substrate and appears to be devoid of biota, as further evidenced by ground-truthing (Figure 4-7 and Figure 4-9). This is also supported by ground truthing in Figure 4-13. However, the BCH distribution maps of the GBF project area within the Ancient Coastline KEF should be considered with moderate confidence, due to the limited and varying (low to high resolution) geophysical data available for the KEF, and the relatively small number of ground-truthing transects collected within the GBF project area of this KEF.

4.1.2 Benthic Communities and Habitats at Low Slope Areas

Low slope areas are defined as areas within the GBF project area that contain the proposed flowlines and umbilical corridors situated outside of KEFs in the lower slope and Kangaroo Syncline areas, and are characterised by low structural complexity/rugosity and carbonate and clay muds. These include benthic habitat transects collected along BCH31 and BCH08 (Figure 4-2), BCH09 and BCH06 (Figure 4-3) within the Chandon DC-1 to JMT corridor, BCH07, BCH28 and BCH29 (Figure 4-4) in the Jansz to Geryon and Eurytion (G & E) corridors, and BCH26 (Figure 4-5) BCH05, BCH14, BCH32 and proposed NTB3 drill centre (Figure 4-7) within the Chrysaor and Dionysus (C & D) to Gorgon corridor.

A mixture of habitats was present along the Chandon to JMT corridor however all were of low structural complexity: irregular and/or smooth seabed either with bioturbation or bare substrate, and scattered patches of depression over bare substrate. No epifaunal communities were noted during ground-truthing transects across this area (Figure 4-2, Figure 4-3 and Figure 4-4). These habitats of low structural complexity extend out to the boundary of the GBF project area, with the exception of scarps with bare substrate which are present between benthic habitat transects BCH31 and BCH08, and approximately 1.8 km north from the proposed flowline (Figure 4-2).

Benthic habitats along the proposed flowline and umbilical routes from Jansz DC2 to G & E DC-1 comprises smooth seabed with bioturbation and irregular seabed with bare substrate with intermittent mounds with bare substrate, and scattered patches of depressions over bare substrate (Figure 4-4). Geomorphic feature mapping identified a continuous scarp with bare substrate near the Jansz Field Control Station (FCS), orientated north to south and parallel to existing subsea infrastructure (Figure 4-4). Small patches along the scarp are identified as areas with low likelihood of biota (Figure 4-4). Despite this, the ground-truthing transect of this area (benthic transect BCH28) did not identify the presence of epifauna due to a thick coverage of sediment. Scarps are often located in or adjacent to deep-sea currents, which are exposed to increased bottom stress and significant sediment movement, resulting in a thin or thick veneer of sand over consolidated substrate that could compromise reef growth and the presence of epifauna. This showcases the dynamic nature of biotic and abiotic habitats. Therefore, there are some uncertainties in the BCH distribution maps around scarps of this area as a result of natural and localised sediment transport processes.

The benthic habitats within the low slope area of the C & D to Gorgon corridor are predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation. Along the Semele to C & D corridor, scarps orientated north to south are located ~500 m south of the proposed

flowline near benthic habitat transect BCH26, with a low and high likelihood of biota (Figure 4-5). Seabed areas of depressions with bare substrate and high likelihood of biota are present along BCH05, BCH14 and BCH32 that extend further out within the GBF project area (Figure 4-7). The acquisition of several ground-truthing transects, particularly along indicative flowline locations, have validated the presence of benthic biota and therefore, the BCH maps for this area can be interpreted with a high level of confidence.

Scarps orientated south-west to north-east with bare substrate are situated ~60 m north and ~1 km south of the proposed NTB3 drill centre that crosses through the indicative flowlines (Figure 4-7). As verified with ground-truthing, no epifauna were identified on the scarps with bare substrate (Figure 4-7). The scarp located north of the proposed NTB3 drill centre extends further out within the GBF project area in a south-easterly direction (Figure 4-5). The benthic habitat surrounding the proposed C & D drill centre (C & D DC-2), which is situated outside of the Continental Slope Demersal Fish Communities KEF on the northern border, consists primarily of irregular seabed with bare substrate.

4.1.3 Benthic Communities and Habitats at Proposed Drill Centres

The type of BCH present in proposed drill centres that are located within a KEF (Chandon DC-1 in the Exmouth Plateau KEF; and C & D DC-2 and C & D DC-3 within the Continental Slope Demersal Fish Communities KEF) are described in Section 4.1.1 Similarly, benthic habitat mapping of the proposed NTB3 drill centre that is situated in a low slope area, is described in Section 4.1.2

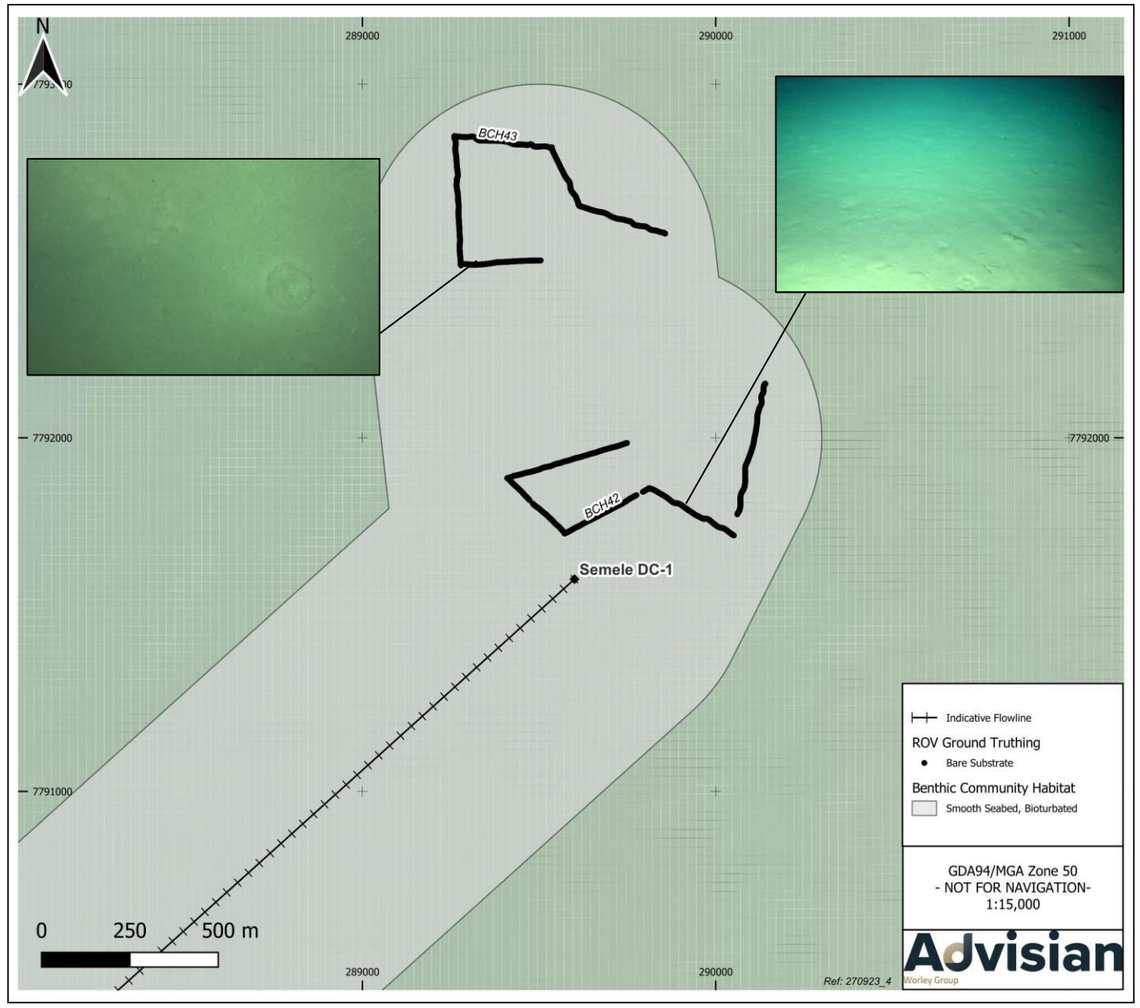
The benthic habitats immediately surrounding the Jansz DC2 tie-in (Figure 4-10) is characterised as low structural complexity, with smooth seabed with bioturbation and isolated patches of mounds with bioturbation. Similarly, the G & E DC-1 is primarily comprised of smooth seabed with bioturbation and scattered patches of bedforms with bare substrate to the north and north-east of the proposed drill centre (Figure 4-10). Ground truthing transects at each of these locations did not reveal any notable epifaunal communities.

The benthic habitat around the proposed drill centres Semele DC-1 and Semele DC-2, and benthic habitat transect BCH40 (Figure 4-11) and associated flowlines is of low structural complexity and dominated by smooth seabed with bioturbation. Irregular seabed with bioturbation and a mound with bare substrate is present around BCH41 (Figure 4-5). Ground truthing transects at each of these locations did not reveal any epifaunal communities.

Similarly to the proposed Semele drill centre sites, low structural complexity is present at WTR DC-1 and comprises only of smooth seabed with bioturbation (Figure 4-12) and no presence of biota. The ground-truthing transects collected around the proposed drill centres confirm the lack of complex seafloor structures as identified in the preliminary habitat map, and therefore, the BCH maps at the proposed drill centres can be interpreted with a high level of confidence.



Figure 4-10 Distribution of benthic habitats within Jansz DC2 tie in location (left) and Geryon and Eurytion drill centre (G & E DC-1) (right) with representative images of the benthic communities and habitats observed within the ROV transects



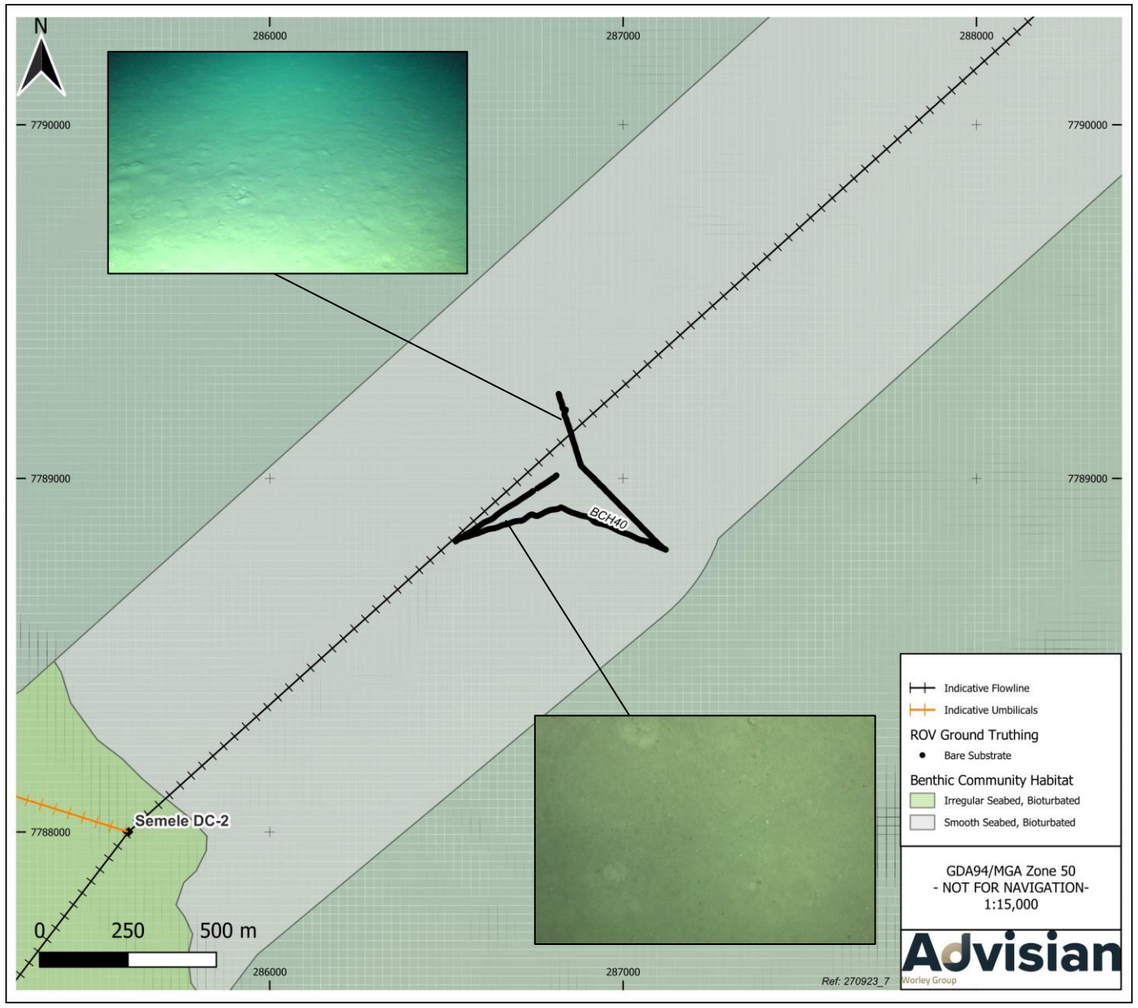


Figure 4-11 Distribution of benthic habitats within BCH42 and BCH43 (left) and BCH40 (right) with representative images of the benthic communities and habitats observed within the ROV transects

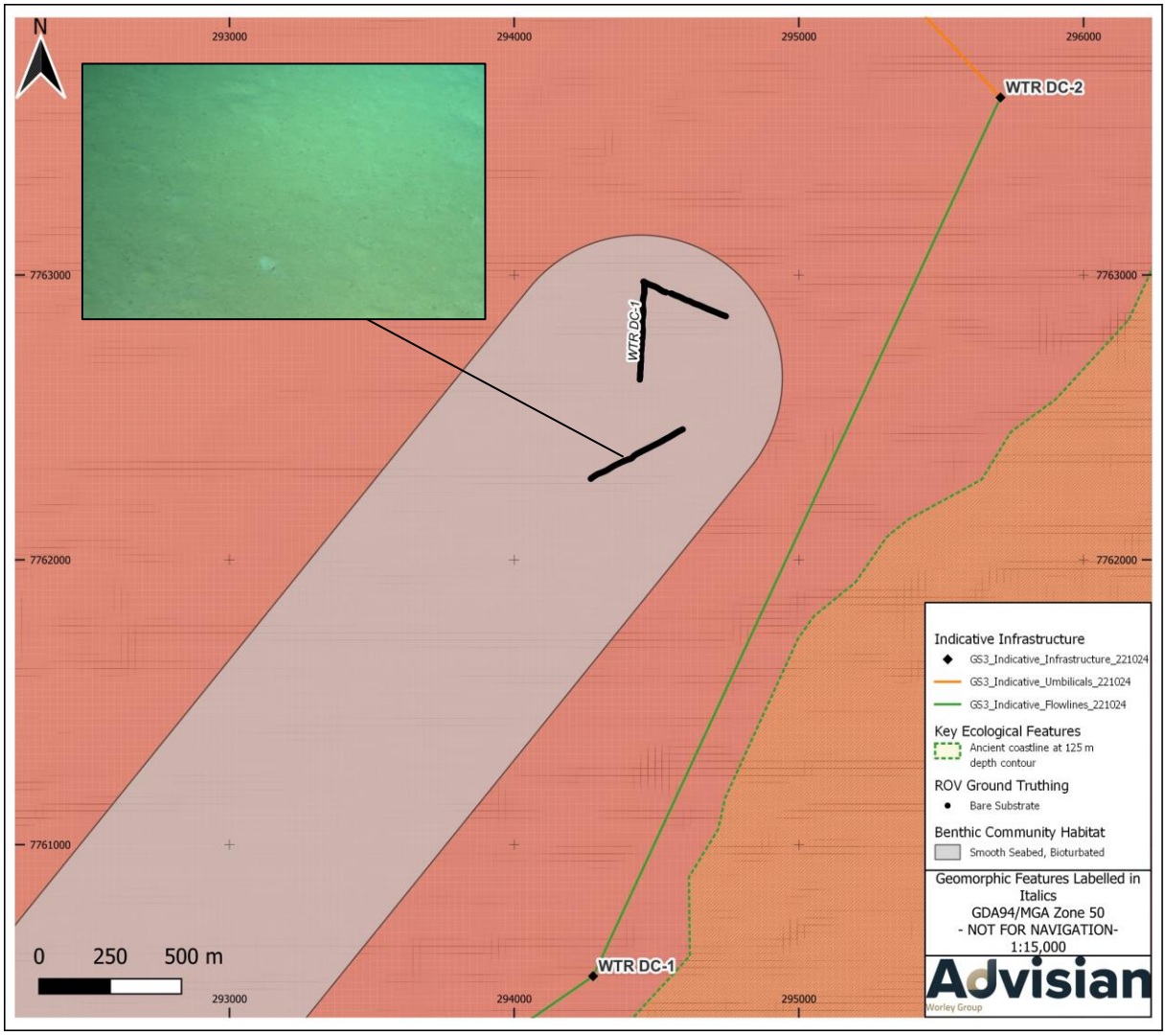


Figure 4-12 Distribution of benthic habitats within WTR DC-1 with a representative image of the benthic communities and habitats observed within the ROV transects

4.2 Benthic Cover

Across the 12 sites that are proposed drill centres and tie-in locations, and 2 benthic habitat transect sites, bare sediment (soft unconsolidated sand/mud <2 mm) with no biota was the dominant benthic category. Along one or more transects at sites Chandon DC-1, Semele DC-1, BCH42 and BCH43, bioturbation in bare sediment was observed in small quantities (with a range of 0.5–39% cover; (Figure 4-13). Bioturbation with cnidarians was only observed at site Gorgon M1 where they contributed to 1% of the overall cover (Figure 4-13). Overall, the proposed drill centre & tie-in locations are considered to be relatively devoid of epifauna.

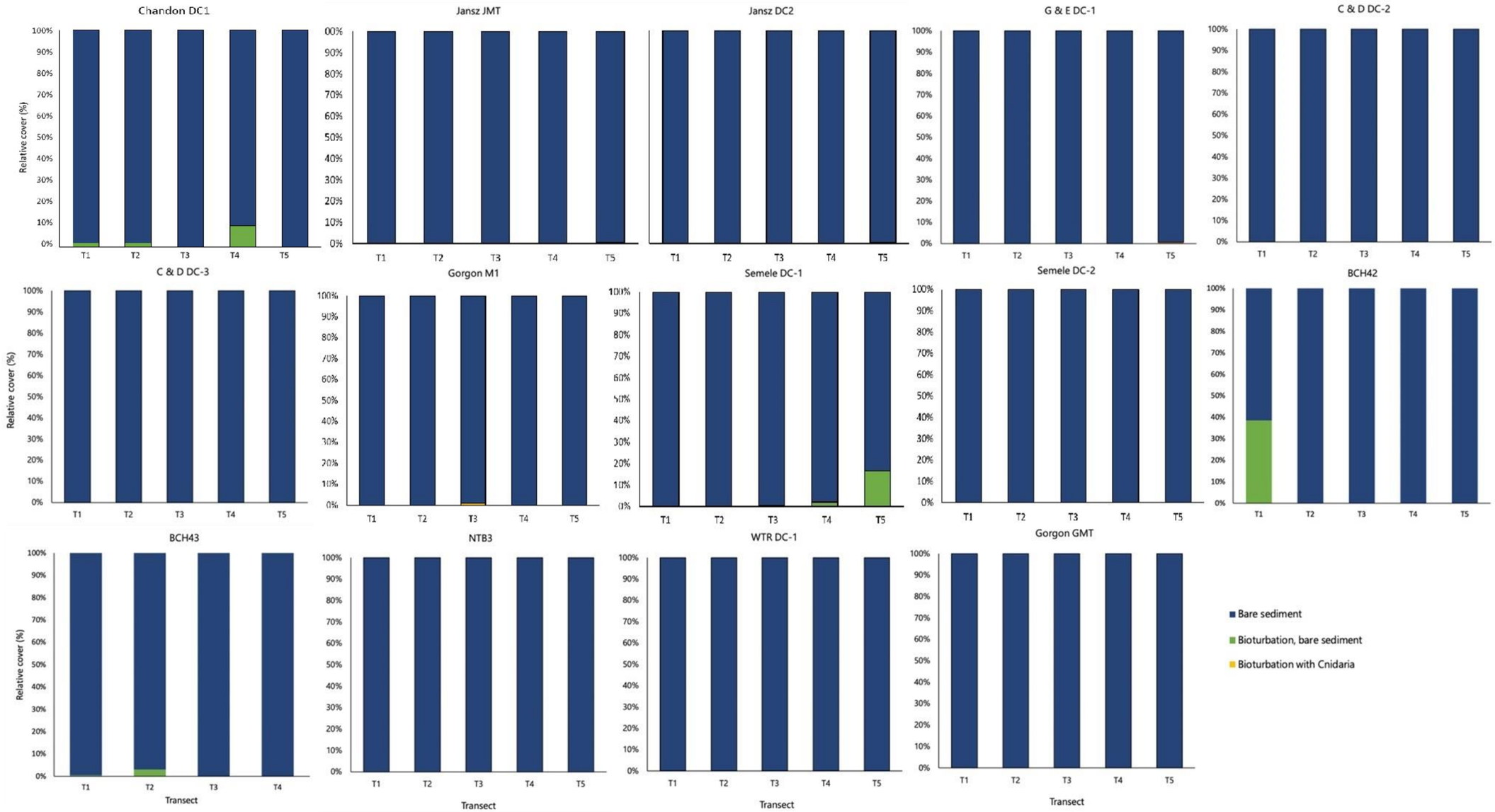


Figure 4-13 Benthic cover (%) along transects

4.3 Fish Assemblage

Refer to the Fish Report presented in Appendix D for more details on the results.

4.3.1 General Description of Fish and Crustacean Assemblages at Key Ecological Features

In the Exmouth Plateau KEF, a total of 165 individual fish from 14 taxa were identified. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois* sp1 (family Ipnopidae), together representing over 65% of the total number of individual fish recorded. Other abundant taxa included *Aldrovandia* sp1 and *Aldrovandia* sp2 (Halosauridae), and *Macrouridae* sp2 (Macrouridae, rat tails). The crustacean assemblage in the Exmouth Plateau KEF consisted of 228 individuals from seven taxa. A species of red prawn was the most dominant crustacean taxa representing over 81% of the total number of individuals, followed by a pink prawn and an orange prawn.

Within the Continental Slope Demersal Fish Communities KEF, a total of 468 fish belonging to 25 taxa were recorded. The fish assemblage was dominated by Trevallies (Carangidae) with four species from three genera accounting for 256 of the individuals observed. The five most abundant fish taxa were *Decapterus kurroides*, *Decapterus* sp1 and *Seriola dumerili* (Carangidae), an unidentified bait fish, and *Synodontidae* sp2 (Synodontidae). Only one site (BCH04) in this KEF recorded crustaceans. At this site, a total of three crustaceans from three taxa (two from infraorder Anomura, and one from infraorder Achelata) were recorded.

The Ancient Coastline KEF recorded a total of 18,011 individuals from 13 fish taxa. The fish assemblage was dominated by Trevallies (Carangidae) with three species representing 14,231 of the total individuals. The most abundant fish taxa were *Carangoides* sp1 and *Seriola dumerili* (Carangidae), an unidentified baitfish, *Carcharhinus* sp1 (Carcharhinidae), and *Rachycentron canadum* (Rachycentridae). Only one crustacean (unidentified prawn species) was recorded at Gorgon GMT.

At the four sites (C & D DC-3, NTB3, WTR DC-1 and BCH24) outside of KEF areas, a total of 11,800 individual fish belonging to 28 taxa were identified. The five most abundant taxa were *Trachurus novaezelandiae* and *Seriola dumerili* (Carangidae), an unidentified baitfish species, an unidentified anguilliform fish species, and *Carcharhinus* sp1 (Carcharhinidae). 11,007 of the total individual fish were recorded at site BCH24, which was dominated by *Trachurus novaezelandiae* (78% of total individuals) and an unidentified baitfish species (21% of total individuals). There were 236 total individual crustaceans recorded from seven taxa, with all sites dominated by a red prawn species. The red prawn species accounted for 66 of the 107 total individuals observed in site NTB3, whereas only one unidentified prawn species identified at site WTR DC-1

4.3.2 General Description of Fish and Crustacean Assemblages at Geomorphic Features

The fish and crustacean assemblages at the plateau slope, which contains the same two sites as the Exmouth Plateau KEF (BCH01 and BCH02), is described in Section 4.3.1.

The trench/trough slope contained 59 individual fish from 14 taxa. The fish assemblage was distinguished by Macrouridae species, Halosauridae species, and an unidentified anguilliform species (eel-like fish), which accounted for 82% of the total recorded individuals. The four most abundant taxa

were the unidentified anguilliform species (28 individuals), *Macrouridae* sp4 (eight individuals) and *Macrouridae* sp2 (Macrouridae; four individuals), and *Synaphobranchus* sp1 (Synaphobranchidae; four individuals). The crustacean assemblage in the trench/trough slope geomorphic feature consisted of 128 individuals belonging to five taxa. The assemblage was dominated by a red prawn species, which made up 80% of the total individuals and was also the most abundant taxa for each transect in site C & D DC-3. The other abundant crustacean species included a dark prawn species, a second red prawn species, and an orange prawn species.

The slope geomorphic feature comprised of seven sites (BCH04, BCH11, BCH12, BCH33, WTR DC-1, BCH24 and Gorgon GMT), where a total of 30,033 individual fish species belonging to 37 taxa were recorded. The fish assemblage was dominated by Trevallies (Carangidae) with 23,208 individuals from seven taxa. The five most abundant species were *Carangoides* sp1, *Trachurus novaezelandiae* and *Seriola dumerili* (Carangidae), an unidentified baitfish species, and Carcharhinus sp1 (Carcharhinidae), which together accounted for 98% of the total individuals. Only three sites in this geomorphic feature contained crustaceans: WTR DC-1, BCH04 and Gorgon GMT. The crustacean assemblage consisted of five total individuals recorded from four taxa.

In the deep/hole/valley slope geomorphic feature, there were 16 fish taxa and a total of 187 individuals recorded. The fish assemblage was dominated by an unidentified anguilliform fish species, representing 54% of the individuals observed, followed by *Aldrovandia* sp1, *Aldrovandia* sp2, and *Aldrovandia affinis* (Halosauridae), and *Macrouridae* sp1 (Macrouridae). The crustacean assemblage consisted of 110 total individuals recorded from four taxa. The assemblage was dominated by a red prawn species which accounted for 70% of the total individuals across the NTB3 site.

4.3.3 General Description of Invertebrate Assemblage

A total of 922 invertebrate individuals from 26 taxa were recorded across all sites. The invertebrate assemblage included one feather star (Cormatulida) species, four jellyfish (Scyphozoa) species, seven sea cucumber (Holothuroidea) species, seven sea star (Asteroidea) species, six sea urchin (Echinoidea) species and one squid (Cephlapod) species. The assemblage was dominated by a brown jellyfish species which accounted for 69% of the total number of individuals and were mostly recorded at site BCH24.

4.3.4 Comparison of Fish and Crustacean Assemblages Between Water Masses

The deeper water fish assemblages of the AAIW mass were significantly different ($p<0.001$) to the shallower water fish assemblages in both the SICW and the TSW water masses (Figure 4-14). The AAIW were characterised by species including two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of unidentified anguilliform fish, and a Bathypterois species (Ipnopidae) (Figure 4-14). A greater abundance of *Trachurus novaezelandiae* (Carangidae), an unidentified bait fish, and whaler shark *Carcharhinus* sp1 were observed at the TSW, whereas the SICW water mass was characterised by a high abundance of *Seriola dumerilii* (Carangidae) and *Carcharhinus plumbeus* (Figure 4-14).

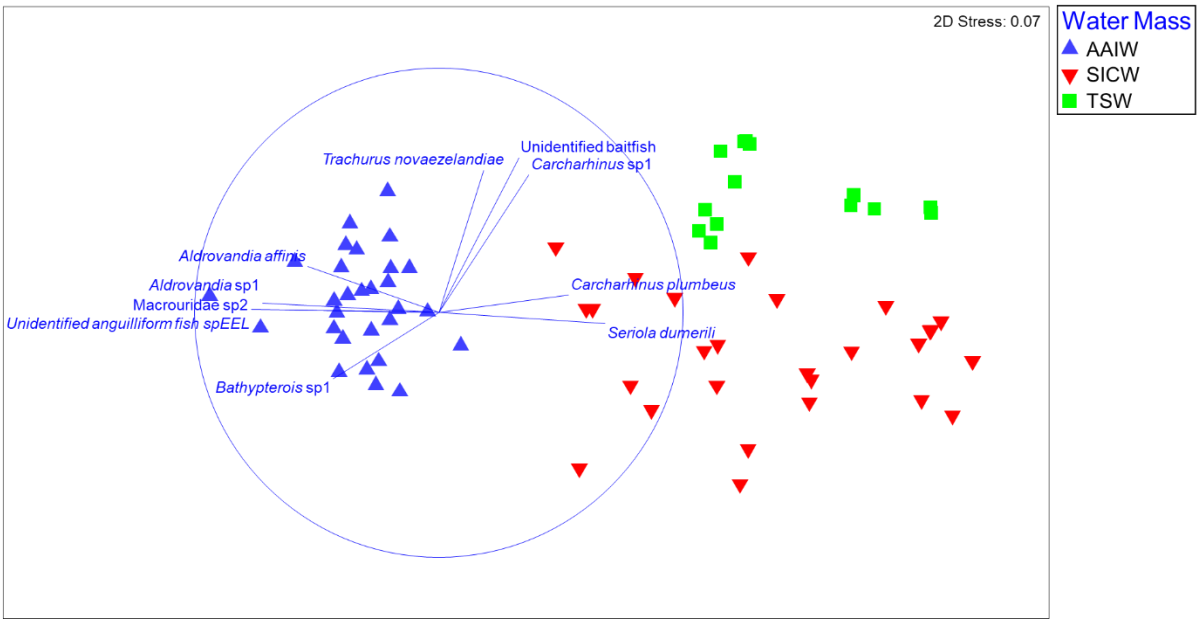


Figure 4-14 Non-metric multidimensional scaling plot illustrating the differences in fish assemblages among the Antarctic Intermediate Water (AAIW), Southern Indian Central Water (SICW) and Tropical Surface Water (TSW) masses

A greater mean number of fish per transect were identified in the TSW mass (1684 ± 358 no. fish) compared to SICW and AAIW (118 ± 38 and 16 ± 2 no. fish, respectively). There was no significant difference ($p>0.05$) in the mean number of fish taxa per transect between water masses. On average each transect had ~four and six fish taxa.

The crustacean assemblages of the deeper AAIW mass were significantly different ($p<0.001$) to the shallower assemblages in the SICW and the TSW water masses. The most strongly correlated taxa to the AAIW mass were all prawns.

The mean number of crustaceans and mean number of taxa were both significantly greater in the AAIW (27 ± 3 no. crustaceans; 3 ± 0.2 no. taxa) than SICW (0.1 ± 0.1 no. crustaceans; 0.1 ± 0.1 no. taxa) and TSW (0.1 ± 0.1 no. crustaceans; 0.1 ± 0.1 no. taxa).

4.3.5 Comparison of Fish and Crustacean Assemblages Among Key Ecological Features

The fish assemblages of the Continental Slope Demersal Fish Communities KEF were significantly different to the fish assemblages at the Exmouth Plateau KEF and outside any KEFs ($p<0.05$; Figure 4-15a). This difference was primarily driven by two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, an unidentified anguilliform fish, and a Bathypterois (Ipnopidae) species (Figure 4-15a).

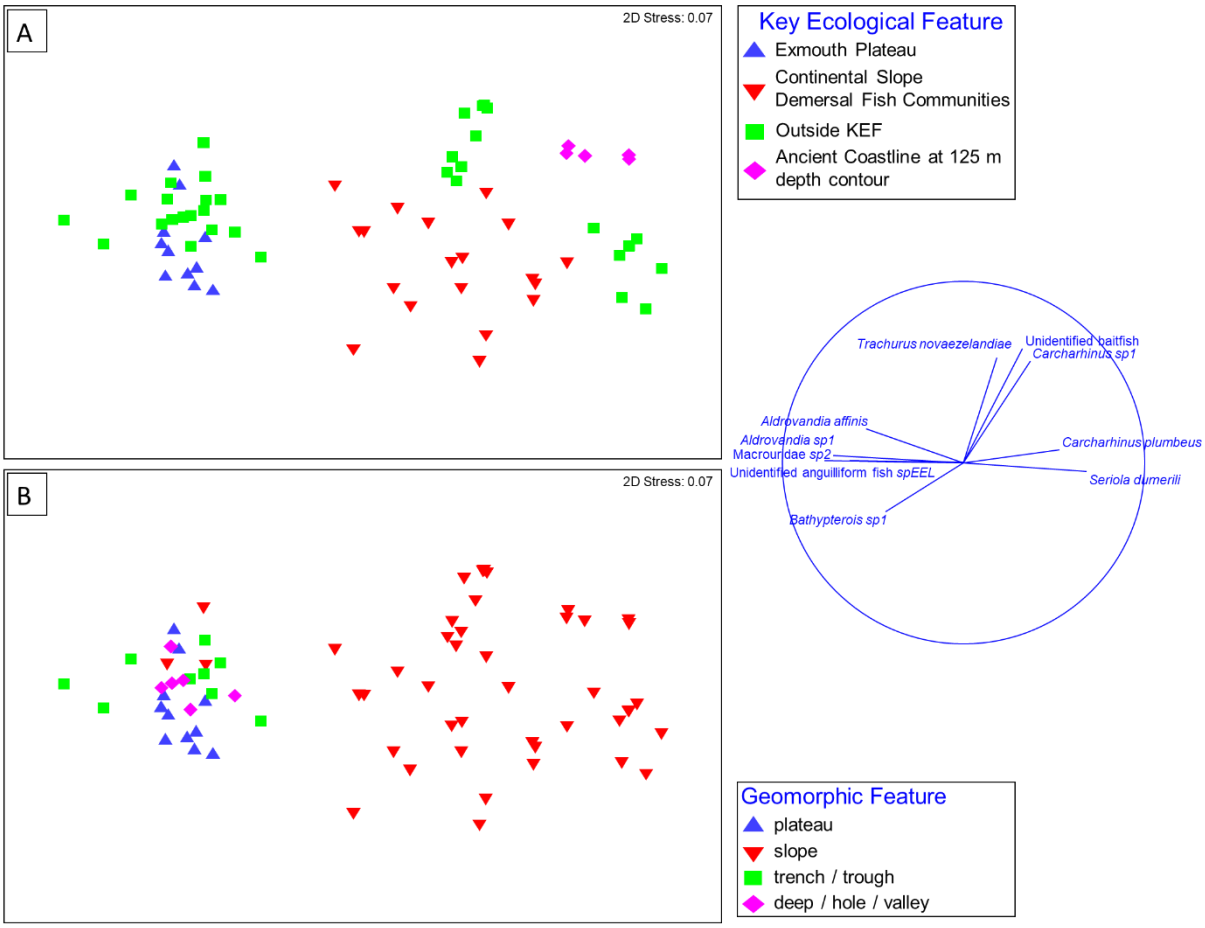


Figure 4-15 Non-metric multidimensional scaling plot illustrating the differences in fish assemblages among a) Key Ecological Features, and b) geomorphic features

The Ancient Coastline KEF had a greater mean number of fish per transect (3021 ± 150 no. fish) compared to Continental Slope Demersal Fish Communities KEF (25 ± 5 no. fish), Exmouth Plateau (13 ± 1 no. fish) and outside of KEF (322 ± 108 no. fish). There was no significant difference in the mean number of fish taxa between KEFs. Between five and nine fish taxa were recorded at each KEF.

The crustacean assemblage of the Exmouth Plateau KEF was significantly different ($p = 0.05$) to that of the Continental Slope Demersal Fish Communities KEF and the Ancient Coastline KEF. The crustacean assemblage of the Continental Slope Demersal Fish Communities KEF was also different to the crustacean assemblage at areas outside any KEF. Both the Exmouth Plateau and outside any KEF, which are located in deeper waters, were primarily driven by all prawn taxa.

The mean number of crustaceans and mean number of taxa were statistically greater in the Exmouth Plateau (17 ± 2 no. crustaceans; 3 ± 0.4 no. taxa) and outside any KEF (16 ± 4 no. crustaceans; 2 ± 0.3 no. taxa) compared to Ancient Coastline (0.2 ± 0.2 no. crustaceans; 0.2 ± 0.2 no. taxa) and Continental Slope Demersal Fish Communities KEFs (0.2 ± 0.1 no. crustaceans; 0.2 ± 0.1 no. taxa).

4.3.6 Comparison of Fish and Crustacean Assemblages Among Geomorphic Features

The fish assemblage of the slope geomorphic feature was significantly different ($p<0.05$) to the plateau, trench/trough, and deep/hole/valley slope, and was driven by shallower fish species such as *Trachurus novaezelandiae* (Carangidae), unidentified baitfish, *Carcharhinus* sp1, *Carcharhinus plumbeus* (Carcharhinidae), and *Seriola dumerili* (Carangidae; Figure 4-15b).

The mean number of fish was higher on the slope (598 ± 156 no. fish) than any other geomorphic features (plateau: 13 ± 1 no. fish; trench/trough: 12 ± 2 no. fish; deep/hole/valley: 27 ± 5 no. fish), however, there were large variations in the number of fish among samples. There was no significant difference in the mean number of fish taxa between geomorphic features. Between five and seven fish taxa were recorded at each geomorphic feature.

The crustacean assemblage of the shallower water slope geomorphic feature was significantly different ($p = 0.001$) compared to the other deeper water geomorphic features, in which deeper waters was the primary driven by the crustacean taxa.

Although not statistically significant, the mean number of crustaceans was lower in the slope geomorphic feature (3 ± 2 no. crustaceans) and highest at the trench/trough (41 ± 6 no. crustaceans), while deep/hole/valley and plateau were similar (15 ± 2 and 17 ± 2 no. crustaceans). The mean number of crustacean taxa was significantly lower in the slope (0.4 ± 0.2 no. taxa) compared to the deep/hole/valley (3 ± 0.3 no. taxa), plateau (3 ± 0.4 no. taxa), and trench/trough (3 ± 0.3 no. taxa) geomorphic features.

4.3.7 Composition of Fish and Crustacean Assemblages

For both fish and crustacean assemblages, water depth was an important predictor of the multivariate composition of assemblages. The DistLM analysis for fish assemblages showed that depth alone explained 27% of the variation in the fish assemblage composition ($R^2 = 0.27177$, pseudo $F_{(1,69)} = 25.751$, $p<0.001$). for the crustacean assemblages, water depth explained 73% of the variation in the assemblage composition ($R^2 = 0.72716$, pseudo-$F_{(1,69)} = 183.9$, $p<0.001$).

4.4 Sediment Chemistry

Laboratory reports for sediment samples are presented in Appendix F. Photos of the sediment cores are provided in Appendix G.

4.4.1 Hydrocarbons

Concentrations of hydrocarbons (TRH, BTEX and PAHs) in all sediment samples were below the laboratory LOR.

4.4.2 Metals and Metalloids

Concentrations of all metals and metalloids in sediment samples located within proposed drill centres and tie-in locations all met their relevant ANZG (2018) DGVs[3], with the exception of nickel (Table 4-1,

[3] There are no ANZG (2018) DGVs for aluminium, barium, cobalt, iron, and manganese.

Figure 4-16). Total nickel in all three replicate samples collected from Chandon DC-1 exceeded the ANZG (2018) DGV of 21 mg/kg however, were below the GV-High values (Table 4-1, Figure 4-16). Nickel concentrations across the remaining sites were slightly below the ANZG (2018) DGV (Table 4-1, Figure 4-16).

Concentrations of other total metals (aluminium, arsenic, barium, cobalt, copper, iron, manganese, lead, zinc and mercury) in sediments at Chandon DC-1 were slightly higher compared to the other sites (Table 4-1, Figure 4-16). Slightly higher metal concentrations at Chandon DC-1 may be linked to the higher content of clay-sized fraction sediments (see Section 4.4.3). It is also possible that these higher concentrations of metals are linked to sample contamination during the collection of or sub-sampling of cores (see Section 4.4.5), as the sample location is far beyond any industrial infrastructure and operational areas. Site WTR DC-1 also had notably and consistently lower concentrations for all metals (Table 4-1, Figure 4-16).

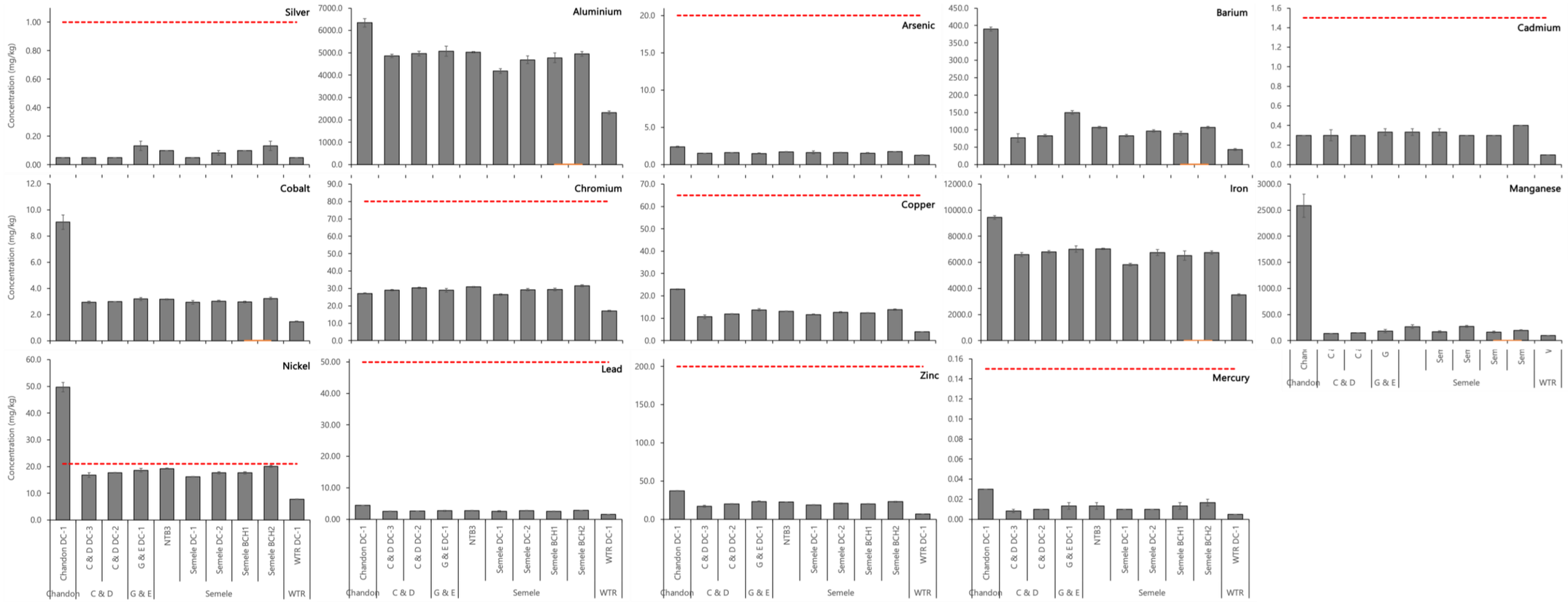
Concentrations of mercury were not detected in any replicate sediment samples collected at C & D DC-3, WTR DC-1, and WTR DC-2. Concentrations of silver were also absent in replicate sediment samples collected at Chandon DC-1, C & D DC-3, C & D DC-2, Semele DC-1 and WTR DC-1 (Table 4-1, Figure 4-16).

With the exception of elevated concentrations of some metals in sediments at Chandon DC-1 and the consistently lower concentrations of all metals at WTR DC-1 likely attributed to the particle size distributions found in each survey site (see Section 4.4.3), there were no other discernible trends in for metal concentrations across the sites.

Table 4-1 Total metal concentrations (mean ± SE) in sediment samples

Field and Site Name	Parameter (mg/kg)	Silver	Aluminium	Arsenic	Barium	Cadmium	Cobalt	Chromium	Copper	Iron	Manganese	Nickel	Lead	Zinc	Mercury
	LOR	0.1	50	1.0	10	0.1	0.5	1.0	1.0	50	10	1.0	1.0	1.0	0.01
	DGV[1]	1	–	20	–	1.5	–	80	65	–	–	21	50	200	0.15
	GV-High[1]	4	–	70	–	10	–	370	270	–	–	52	220	410	1.0
Chandon	Chandon DC-1	<0.1 ± 0.00	6346.7 ± 186.7	2.39 ± 0.08	390 ± 5.77	0.30 ± 0.00	9.07 ± 0.55	27.2 ± 0.27	23.0 ± 0.26	9440 ± 134.5	2586.7 ± 220.6	**49.7 ± 1.80**	4.40 ± 0.00	37.1 ± 0.49	0.03 ± 0.00
Chrysaor and Dionysus	C & D DC-3	<0.1 ± 0.00	4863.3 ± 79.7	1.53 ± 0.01	76.7 ± 12.0	0.30 ± 0.06	2.93 ± 0.09	29.0 ± 0.34	10.6 ± 0.79	6596.7 ± 143.1	134.0 ± 4.51	16.8 ± 0.92	2.57 ± 0.03	17.1 ± 1.35	0.01 ± 0.00
	C & D DC-2	<0.1 ± 0.00	4963.3 ± 104.0	1.60 ± 0.02	83.3 ± 3.33	0.30 ± 0.00	3.00 ± 0.00	30.3 ± 0.50	11.9 ± 0.10	6810 ± 100.2	148.0 ± 4.58	17.7 ± 0.10	2.60 ± 0.00	20.0 ± 0.33	0.01 ± 0.00
Geryon and Eurytion	G & E DC-1	0.13 ± 0.03	5073.3 ± 230.7	1.49 ± 0.07	150 ± 5.77	0.33 ± 0.03	3.20 ± 0.12	29.0 ± 1.05	13.8 ± 0.52	7020 ± 244.4	181.3 ± 32.6	18.6 ± 0.73	2.70 ± 0.15	23.3 ± 0.84	0.01 ± 0.00
Semele	NTB3	0.10 ± 0.00	5033.3 ± 29.6	1.71 ± 0.03	106.7 ± 3.33	0.33 ± 0.03	3.17 ± 0.03	30.9 ± 0.26	13.1 ± 0.09	7033.3 ± 48.4	267.7 ± 36.1	19.2 ± 0.19	2.77 ± 0.09	22.5 ± 0.21	0.01 ± 0.00
	Semele DC-1	<0.1 ± 0.00	4183.3 ± 105.9	1.64 ± 0.19	83.3 ± 3.33	0.33 ± 0.03	2.93 ± 0.13	26.5 ± 0.45	11.7 ± 0.22	5833.3 ± 104.8	171.3 ± 18.8	16.2 ± 0.09	2.53 ± 0.19	18.9 ± 0.37	0.01 ± 0.00
	Semele DC-2	0.08 ± 0.02	4686.7 ± 170.5	1.62 ± 0.06	96.7 ± 3.33	0.30 ± 0.00	3.03 ± 0.07	29.2 ± 0.69	12.6 ± 0.35	6753.3 ± 240.3	272.3 ± 19.9	17.6 ± 0.44	2.73 ± 0.07	20.9 ± 0.64	0.01 ± 0.00
	Semele BCH1	0.10 ± 0.00	4773.3 ± 218.4	1.55 ± 0.06	90.0 ± 5.77	0.30 ± 0.00	2.97 ± 0.07	29.4 ± 0.74	12.3 ± 0.15	6506.7 ± 359.6	160.7 ± 19.3	17.7 ± 0.42	2.53 ± 0.13	20.2 ± 0.40	0.01 ± 0.00
	Semele BCH2	0.13 ± 0.03	4953.3 ± 109.7	1.74 ± 0.01	106.7 ± 3.33	0.40 ± 0.00	3.23 ± 0.09	31.6 ± 0.54	13.9 ± 0.32	6746.7 ± 122.5	197.7 ± 11.7	20.0 ± 0.38	2.83 ± 0.03	23.0 ± 0.50	0.02 ± 0.00
WTR	WTR DC-1	<0.1 ± 0.00	2326.7 ± 76.9	1.28 ± 0.01	43.3 ± 3.33	0.10 ± 0.00	1.47 ± 0.03	17.0 ± 0.33	3.9 ± 0.06	3506.7 ± 69.4	98.3 ± 31.76	7.8 ± 0.18	1.57 ± 0.03	6.8 ± 0.06	<0.01 ± 0.00

Notes:
1. DGV and GV-High values derived from ANZG (2018)
2. For ease of identification, concentrations above the DVG (ANZG, 2018) are shown in **bold**
3. All metal data are the average of three replicate sediment samples
4. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, G & E = Geryon and Eurytion, GV-High = guideline value high, LOR = limit of reporting, WTR = West Tryal Rocks



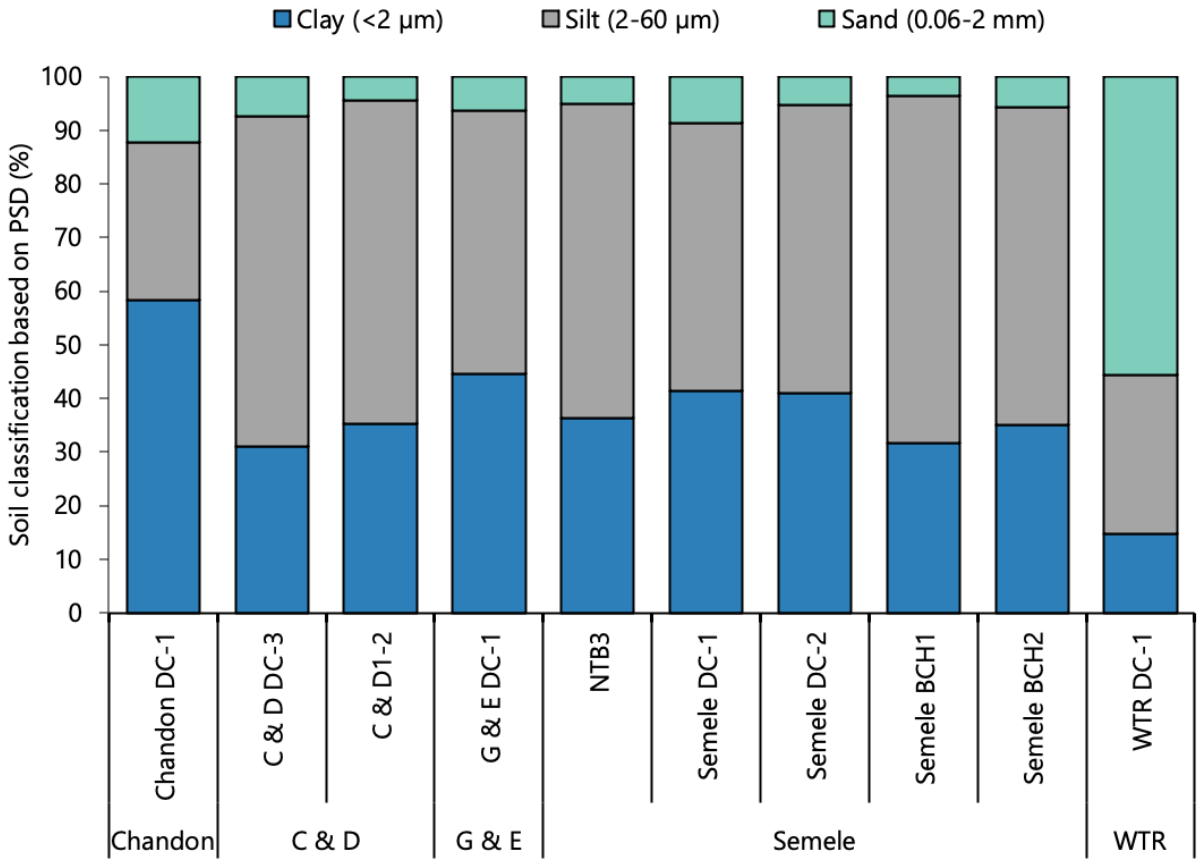
Notes:
1. If results were below the LOR, half the LOR was used for graphing purposes
2. Red dashed line denotes the ANZG (2018) DGV value; no ANZG (2018) DGV value exists for aluminium, barium, cobalt, iron, and manganese
3. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, WTR = West Tryal Rocks

Figure 4-16 Total metal concentrations (mean ± SE) in sediment samples

4.4.3 Particle Size Distribution

Sediment samples were comprised of well-sorted silts and clay, brown in colour, odourless and with occasional small (>2 mm) shell fragments. No anoxic layer was present in any of the samples. There was no visible biota or vegetation recovered from these samples.

All samples were predominantly comprised of clays (<2 µm), silts (2–60 µm) and sands (0.06–2 mm) (Figure 4-17). All sites with the exception of WTR DC-1 and Chandon DC-1, were dominated by silt fraction ranging from 29 to 65%, while clay-sized fractions ranged from 31 to 58% (Figure 4-17). Sediments at WTR DC-1 were dominated by sand (56%) and clay (58%) was the dominant sediment fraction at Chandon DC-1, whereas all other sites comprised of <13% sand (Figure 4-17).



Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, PSD = particle size distribution, WTR = West Tryal Rocks

Figure 4-17 Sediment particle size distribution across the Gorgon Backfill Fields project sites

4.4.4 Other Parameters

There is no ANZG (2018) guideline value for TOC in sediments. TOC concentrations were low, ranging from 0.51 to 1.36% (Table 4-2). Higher TOC concentrations were detected at C & D DC-2, G & E DC-1, and sites within the Semele field, while sediments at WTR DC-1 had lower TOC content (Table 4-2).

Lower TOC concentrations in sediments at WTR DC-1 may be attributed to the higher sand content (refer to Section 4.4.3).

Moisture content of sediment samples was generally consistent across the sites, ranging from 40.5 to 61.3% (Table 4-2).

Table 4-2 Sediment total organic carbon and moisture content across the Gorgon Backfill Fields project sites

Field and Site Name	Parameter (mg/kg)	TOC (%)	Moisture (%)
	LOR	–	–
	DGV	–	–
	GV-High	–	–
Chandon	Chandon DC-1	0.81 ± 0.08	61.3 ± 0.52
Chrysaor and Dionysus	C & D DC-3	1.10 ± 0.01	55.4 ± 1.03
	C & D DC-2	1.36 ± 0.20	56.3 ± 0.69
Geryon and Eurytion	G & E DC-1	1.24 ± 0.05	57.5 ± 1.18
Semele	NTB3	1.26 ± 0.03	58.7 ± 0.32
	Semele DC-1	1.30 ± 0.08	58.0 ± 1.05
	Semele DC-2	1.27 ± 0.08	59.0 ± 0.20
	Semele BCH1	1.34 ± 0.05	57.7 ± 0.57
	Semele BCH2	1.23 ± 0.04	61.1 ± 0.25
WTR	WTR DC-1	0.51 ± 0.01	40.5 ± 0.84

Notes:
1. DGV = Default guideline value, GV-High = guideline value high, LOR = limit of reporting, TOC = total organic carbon
2. C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, WTR = West Tryal Rocks

4.4.5 Quality Assurance and Quality Control Assessment

Intra-laboratory duplicates analysed for metals and moisture content were within acceptable limits of their assigned RPD (30%), indicating that the sediment samples were relatively homogeneous and/or small to no differences in laboratory methods for sample preparation and analysis. Intra-laboratory triplicates analysed for metals were within their RSD with the exception of cadmium that exceeded its assigned RSD. Variability between triplicate samples may be caused by heterogeneity between samples and/or differences in laboratory methods for sample preparation and analysis. The concentrations of cadmium in sediments should be noted as uncertain rather than precise measurements. A breakdown of the QA/QC assessment for sediment samples is provided in Appendix I.

Concentrations of hydrocarbons (TRH and BTEX) in the sediment field blanks were below the laboratory LOR suggesting there was no contamination during the sediment sampling process.

The results of laboratory quality control testing of sediment samples (method blanks, laboratory duplicates, laboratory control samples, and matrix spikes) are presented in Appendix F.

4.5 Benthic Infauna

A total of five individual benthic infauna belonging to three families across three phyla (Sipuncula, Annelida, and Mollusca) were collected from all the sediment sites (Table 3-8). Semele DC-1 and Semele DC-2 had one and two individual Sipunculids or marine worms, respectively, while Semele BCH1 had one individual mollusc (Aplacophora family). One polychaete worm (Annelida) was identified in WTR DC-1.

The benthic infauna laboratory results provided by Benthic Australia are included in Appendix J.

4.6 Water Chemistry

Laboratory reports for water samples are presented in Appendix H.

4.6.1 Hydrocarbons

Concentrations of hydrocarbons (TRH, BTEX and PAHs) in all water samples were all below the laboratory LOR.

4.6.2 Metals

Concentrations of all dissolved metals in water samples met their relevant ANZG (2018) DGVs for 99% species protection[4], with the exception of copper and cobalt (Table 4-3, Figure 4-18). Dissolved copper was at the 99% DGV of 0.3 µg/L for either one or both replicate samples from the surface at BCH38 and WTR DC-1 and from near the seabed at NTB3, whereas dissolved copper exceeded the DGV in both replicate samples collected from the surface at Chandon DC-1 and Gorgon GMT (Table 4-3). All samples were below the 95% species protection guideline value of 1.3 µg/L. It is possible that there may have been a copper source from the vessel during the sampling process that led to the contamination of the samples, particularly those collected from surface waters.

Dissolved cobalt concentrations in one replicate water sample near the seabed at Gorgon GMT exceeded the 99% DGV of 0.05 µg/L (Table 4-3). Furthermore, one surface sample at Gorgon GMT had higher total lead concentrations than other sites; however, these exceedances may be due to contamination during the sampling process, as the remaining samples at these sites have low or below laboratory LOR concentrations.

Concentrations for dissolved and/or total aluminium, arsenic, barium, iron, manganese, nickel, lead, and zinc were detected in either surface and/or near seabed water samples (Figure 4-19), while cadmium, silver and chromium VI concentrations in surface and seabed water samples were all below laboratory LOR.

Dissolved and total barium concentrations were notably higher in water samples near the seabed at all of the deeper sites (all sites with the exception of WTR DC-1 and Gorgon GMT; see Table 3-5 for depths). There were no other discernible trends observed for dissolved nor total metal concentrations across the sites.

[4] There are no ANZG (2018) 99% default guideline values for aluminium, arsenic, barium, iron, and manganese.

Table 4-3 Dissolved and total mean concentrations in water samples

Field and Site Name		Parameter (µg/L)	Silver	Aluminium	Arsenic	Barium	Cadmium	Cobalt	Copper	Iron	Manganese	Nickel	Lead	Zinc	Chromium III	Chromium VI
		LOR	0.1	5.0	0.5	1.0	0.2	0.05	0.2	5.0	0.5	0.5	0.2	5.0	0.001	0.001
		DGV 99%	0.8	–	–	–	0.7	0.05	0.3	–	–	7.0	2.2	7.0	7.7	0.14
Chandon	Jansz JMT	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.65 (1.75)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.25 (0.35)	5.3 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed*	<0.1 (<0.1)	<5.0 (<5.0)	1.70 (1.90)	13.0 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (0.3)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	Chandon DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.65 (1.80)	5.0 (6.0)	<0.2 (<0.2)	<0.05 (<0.05)	**0.95** (0.85)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (5.75)	1.80 (1.80)	13.0 (12.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.15 (0.2)	<5.0 (<5.0)	0.48 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Chrysaor and Dionysus	C & D DC-3	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.80 (1.90)	4.0 (6.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (<0.5)	1.58 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (4.8)	2.00 (1.90)	9.0 (14.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (10.3)	<0.5 (<0.5)	0.68 (0.88)	<0.2 (0.25)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Geryon and Eurytion	G & E DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.70 (1.70)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.2 (0.3)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.80 (1.80)	12.5 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.15 (0.15)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	0.3 (0.3)	4.25 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	BCH28	Surface	<0.1 (<0.1)	<5.0 (4.3)	1.55 (1.65)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.25)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (4.3)	1.70 (1.85)	13.0 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	0.15 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Semele	NTB3	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.75 (1.70)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.25 (0.2)	4.8 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.80)	12.0 (12.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.15)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (0.48)	0.35 (0.15)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
WTR	WTR DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.85)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.5)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.85 (1.85)	5.0 (4.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (4.8)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (0.15)	3.75 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	Gorgon GMT	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.90)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	**1.0** (0.75)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (3.75)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.95 (1.90)	4.0 (4.5)	<0.2 (<0.2)	**0.0625** (0.0625)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (1.00)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)

Notes:
1. Results indicated are the dissolved and (total) values
2. DGV for 99% species protection values derived from ANZG (2018)
3. For ease of identification, concentrations for dissolved metals above the DGV 99% species protection are shown in **bold**
4. All data are the average of two replicate samples
5. Asterisk (*) denotes that only one water sample near seabed was collected
6. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, G & E = Geryon and Eurytion, LOR = limit of reporting, WTR = West Tryal Rocks

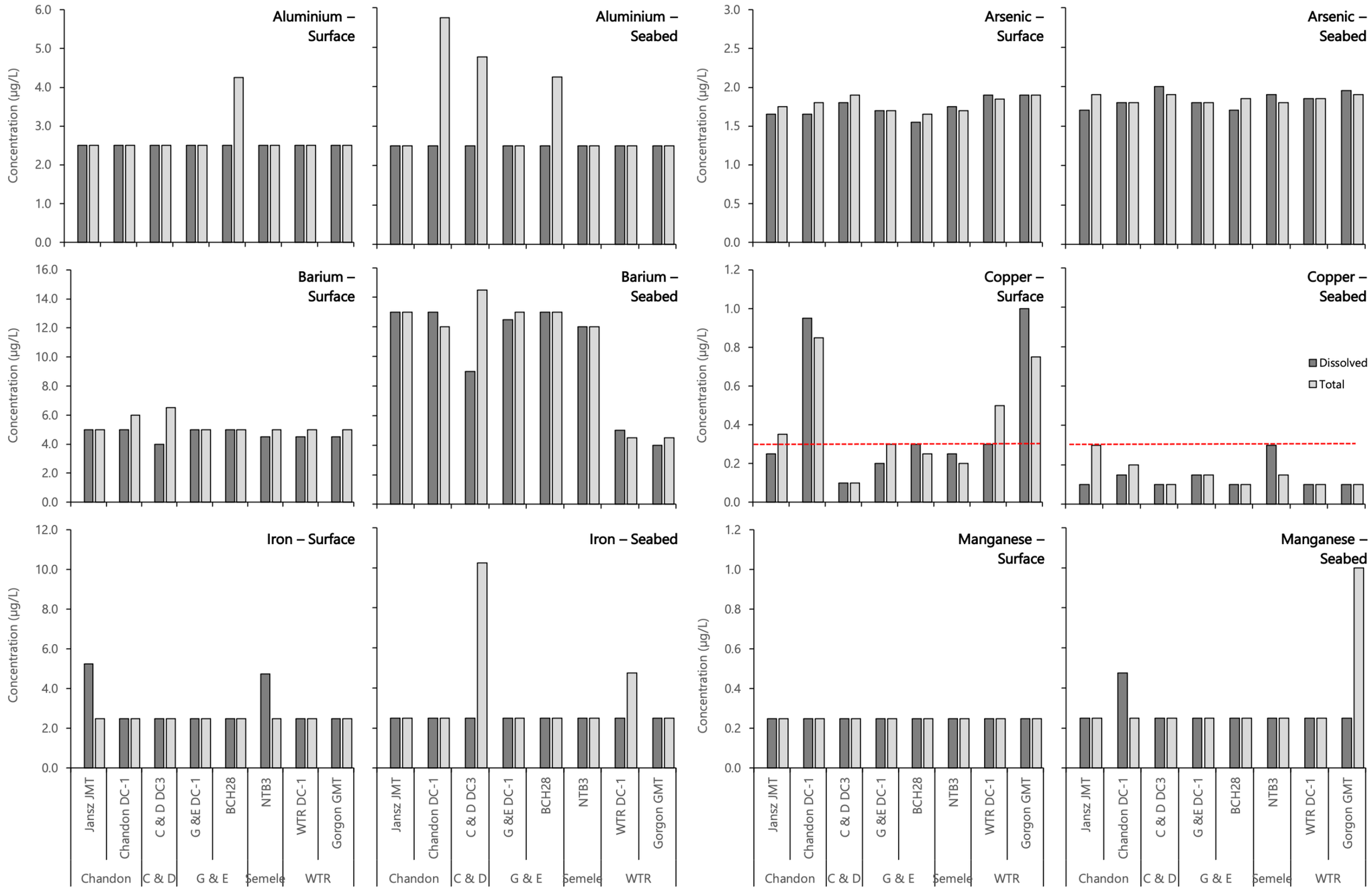


Figure 4-18 Dissolved (dark grey) and total (light grey) metal concentrations in water samples across the Gorgon Backfill Fields project sites. Red dashed line denotes the ANZG (2018) default guideline values 99% species protection

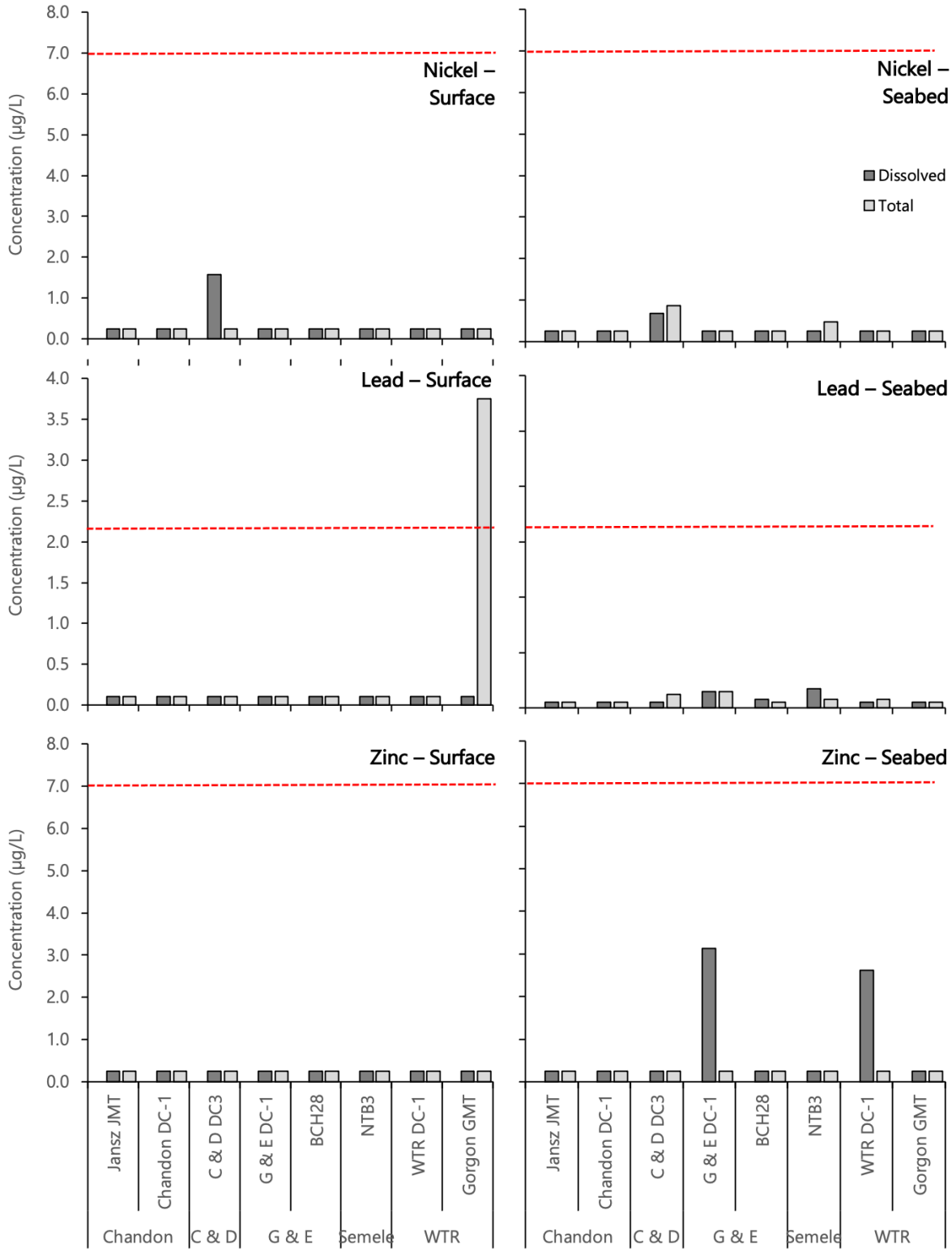


Figure 4-19 Dissolved (dark grey) and total (light grey) metal concentrations in water samples across the Gorgon Backfill Fields project sites. Red dashed line denotes the ANZG (2018) default guideline values 99% species protection

4.6.3 Other Parameters

Average DOC and TOC concentrations ranged from 0.5 to 2.0 mg/L and 0.5 to 2.0 mg/L, respectively. Average DOC concentrations were between 1.5 and 2.5-fold higher in surface waters compared to water samples collected from near the seabed at Jansz JMT, Chandon DC-1, C & D DC-3 and NTB3. Concentrations of TOC were on average higher in surface waters than near the seabed at Chandon DC-1 and C & D DC-3, whereas TOC concentrations were higher near the seabed at shallower sites WTR DC-1 and Gorgon GMT (100–200 m depth).

TDS ranged from 37,000 to 39,900 mg/L from surface and seabed samples across all sampling sites (Table 4-4). Across most sites (with the exception of Jansz JMT, Chandon DC-1 and Gorgon GMT), average TDS concentration were slightly higher in surface waters. TP and TN in surface and seabed water samples ranged 0.01 to 0.12 mg/kg, and 0.10 to 0.75 mg/kg, respectively (Table 4-4). At all sites, water samples near the seabed had higher mean TP concentrations (between 1.2 to 10-fold) compared to surface samples. A similar trend to TP concentration was observed for mean TN concentrations, whereby TN concentration were between 2 to 3-fold higher in water samples near the seabed compared to surface samples at all sites except for sites within the WTR field.

Table 4-4 Other parameter concentrations in water samples

Field and Site Name		Parameter (mg/L)	DOC	TOC	TDS	TP	TN
		LOR	–	–	–	–	–
		DGV 99%	–	–	–	–	–
Chandon	Jansz JMT	Surface	1.50	0.50	38,500	0.06	0.25
		Seabed*	0.50	0.50	38,700	0.10	0.70
	Chandon DC-1	Surface	1.50	1.00	38,000	0.01	0.25
		Seabed	0.50	0.75	38,600	0.11	0.75
Chrysaor and Dionysus	C & D DC-3	Surface	2.00	2.00	39,150	0.03	0.35
		Seabed	0.75	1.00	39,100	0.09	0.70
Geryon and Eurytion	G & E DC-1	Surface	0.50	0.50	38,350	0.02	0.25
		Seabed	0.50	0.50	38,050	0.09	0.70
	BCH28	Surface	1.00	0.50	39,050	0.01	0.25
		Seabed	1.00	0.50	38,850	0.09	0.70
Semele	NTB3	Surface	0.75	0.50	38,300	0.02	0.20
		Seabed	0.50	0.50	37,000	0.12	0.70
WTR	WTR DC-1	Surface	1.50	1.00	39,650	0.04	0.30
		Seabed	2.00	2.00	39,200	0.05	0.25
	Gorgon GMT	Surface	1.50	1.50	38,750	0.01	0.25

Field and Site Name		Parameter (mg/L)	DOC	TOC	TDS	TP	TN
		LOR	–	–	–	–	–
		DGV 99%	–	–	–	–	–
		Seabed	1.50	2.00	39,900	0.03	0.10

Notes:
1. All data are the average of two replicate samples
2. Asterisk (*) denotes that only one water sample near seabed was collected
3. C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, DOC = dissolved organic carbon, G & E = Geryon and Eurytion, LOR = limit of reporting, TDS = total dissolved solids, TN = total nitrogen, TOC = total organic carbon, TP = total phosphorus, WTR = West Tryal Rocks

4.6.4 Quality Assurance and Quality Control Assessment

Intra-laboratory duplicates analysed for metals and moisture content were within their assigned RPD of 30% for all samples with the exception of total manganese in Gorgon GMT near the seabed that exceeded its RPD (31.5%). Variability between duplicates can be caused by heterogeneity between splits and/or differences in laboratory methods for sample preparation and analysis. As such, the concentrations for manganese in seabed water samples should be recognised as uncertain rather than precise measurements. A breakdown of the QAQC assessment for samples is provided in Appendix I.

Blank water samples collected from the Niskin bottles contained measurable concentrations of TDS, dissolved barium, copper, manganese and zinc, total aluminium, barium, copper, iron, manganese, lead and zinc, DOC, TOC, TRHs (all fractions) and BTEX (except for benzene and ethylbenzene). The concentrations of these parameters suggest the likelihood of contamination during the water sampling process and as such, these parameters at site WTR DC-1 should be recognised as uncertain rather than precise measurements.

The results of laboratory quality control testing of water samples (method blanks, laboratory duplicates, laboratory control samples, and matrix spikes) are presented in Appendix H.

4.7 Water Quality Profiles

Depth profiles of each transect site recorded by the ROV are presented in Appendix K.

Warmer temperatures were seen in the top 50 m of water across all sampling sites, ranging from 27.7°C to 29.2°C, and gradually decreased in temperature with increasing depth (Figure 4-20). Water temperatures dropped to minimum of ~3.9–4.2°C in depths ~1,350 m (Figure 4-20).

Salinity was relatively consistent with depth, ranging from 32.3 to 36.3 PSU (Figure 4-20). Conductivity showed a similar trend to temperature, in which conductivity ranged from 52.9 to 57.4 mS/cm between the surface and 50 m, and gradually declined with depth, reaching a minimum of ~33.1 mS/cm at ~1,350 m (Figure 4-20).

For the temperature-salinity plots, the water quality profiles for the deepest site at each field indicated that the ocean environment around the sampling sites are relatively consistent across the GBF project area and are typical for the region. Across the five fields (Chandon, C & D, G & E, Semele and WTR), three separate water masses can be identified in Figure 4-21:

- Low salinity surface water ranging from 34.6–35.3 PSU with a temperature range of ~18–28°C; upper ~180 m of water column
- Higher salinity mid-waters with a salinity and temperature range of 35.4–36 PSU and 15–20°C, respectively; centred between 185 and 250 m depth
- Lower salinity bottom waters with a salinity and temperature range of 34.7–35.4 PSU ~3.5–15°C, respectively; between 250 to ~1,310 m depth.

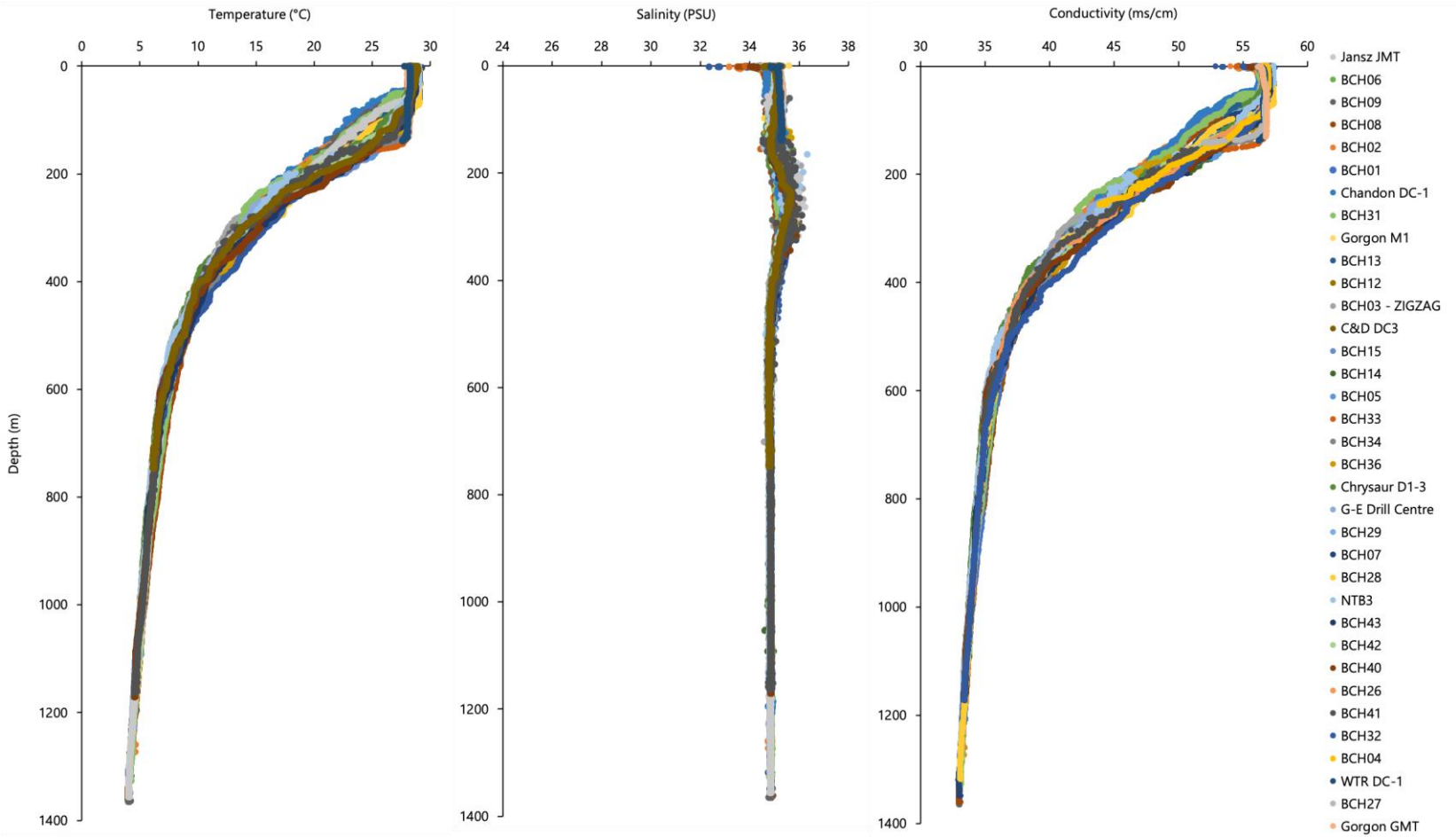
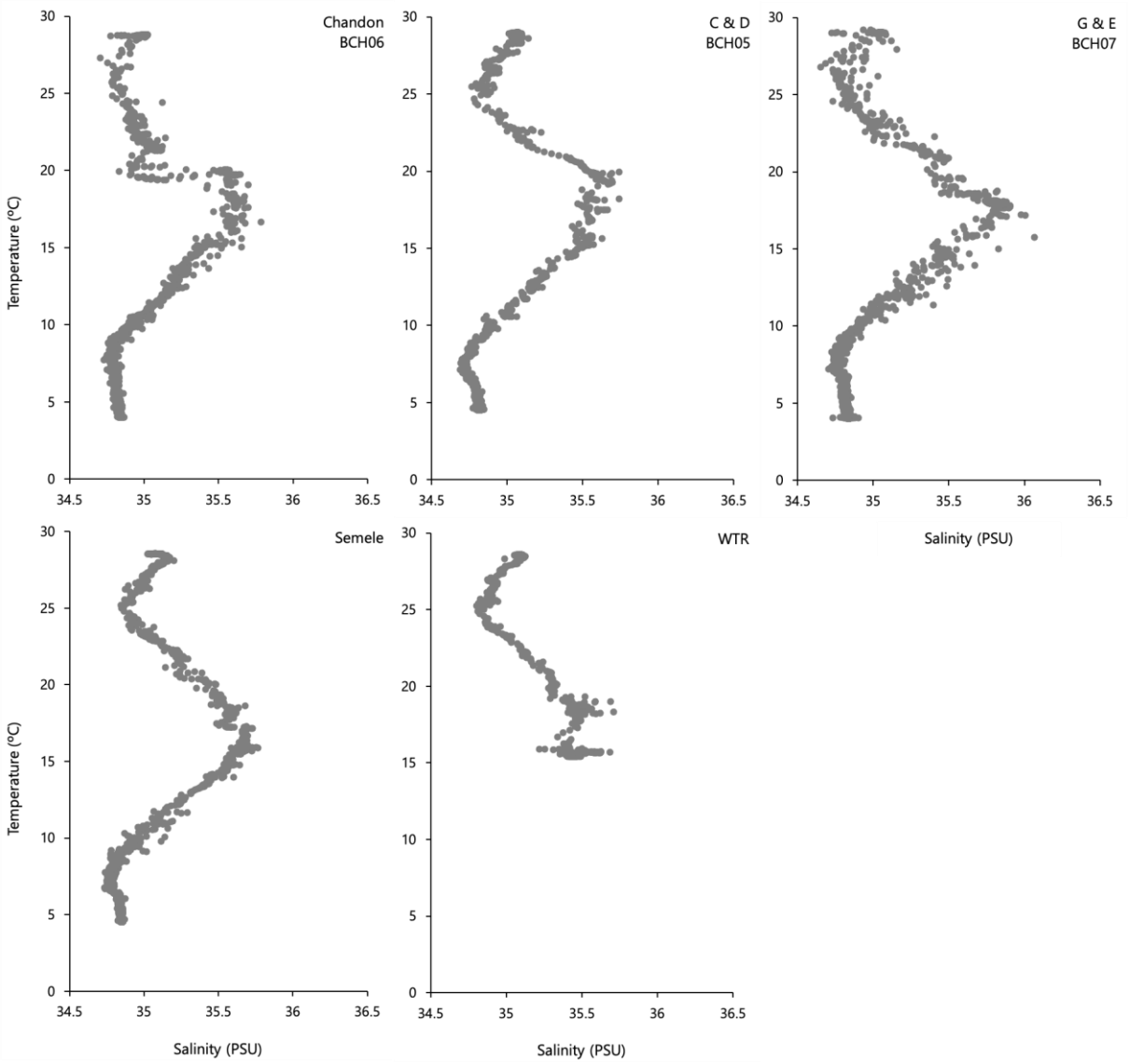


Figure 4-20 Water quality profiles at all sampling sites within the Gorgon Backfill Fields project area



Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, G & E = Geryon and Eurytion, PSU = practical salinity unit, WTR = West Tryal Rocks

Figure 4-21 Temperature-salinity measured at the deepest sites at each field (Chandon, Chrysaor and Dionysus, Geryon and Eurytion, Semele, and WTR)

5 Discussion and Conclusion

To inform the OPP and support future environmental approvals for the development of several new fields in the GBF, Advisian were commissioned by CAPL to characterise the marine benthic environment within the GBF project area. Specifically, the objectives of this study were to develop a validated benthic habitat map of the project area based on assessment of geomorphic features and BCH, describe the demersal fish assemblages associated with areas of interest, and to broadly characterise the water and sediment quality of the GBF project area.

5.1 Benthic Habitat Mapping

There was a strong positive correlation between the preliminary and final benthic habitat maps following the ground-truthing survey, meaning that the available geophysical data (SSS, MBES and 3D seismic) allowed for a good interpretation of the key benthic and geomorphic features of the seabed across the wider area without further ground-truthing effort.

The GBF project area, which is a 5 km radius from proposed or indicative subsea infrastructure, sits along the continental slope located between the continental shelf and the abyssal plain/deep ocean floor in the Exmouth Plateau in water depths ranging from 100 to 1,300 m (Heap et al., 2005; Falkner et al., 2009). Overall, the distribution of benthic habitat within the GBF project area comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Falkner et al., 2009; Geoscience Australia, 2022). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed.

The benthic habitat in shallower waters (<200 m) within and surrounding Gorgon GMT consisted of mostly smooth seabed with bioturbation and no epibenthic biota observed. Located within the Ancient Coastline KEF, the region is identified as having unique seafloor features comprising areas of hard substrate that may provide areas for higher diversity and enrich species richness compared to soft sediment areas (DSEWPaC, 2012; DCCEEW, 2022). However, at the Gorgon GMT survey site, minimal topographic seabed features (e.g., consolidated substrate) were observed (Puotinen and Currey-Randall, 2020; Currey-Randall et al., 2021), which may indicate a layer of soft substrate over consolidated hard substrate that is unlikely to provide significant habitat to biota. Furthermore, the positioning of existing Gorgon GMT facilities on which this survey site boundary was based, would have likely targeted seabed areas of low structural complexity.

Between 200 m and 1000 m depths within the Continental Slope Demersal Fish Communities KEF, a diversity of benthic habitats were present along the seabed, including irregular and smooth seabed, depressions, reef mosaics and discrete fault scarps. The topographically complex scarps that traverse through the GBF project area are indicative of extensive canyon systems (Geoconsult, 2005; Advisian, 2019) formed by the gradual erosion of the continental slope. These scarps which are adjacent to the proposed C & D DC-3 drill centre and sections along its associated flowline routes to Gorgon M1, hosts typical deep-sea benthic biota. These biota were sparsely distributed and limited to isolated individual biota including sponges, echinoderms, and cnidarians, which resemble benthic compositions previously found along continental slope seabed habitats at depths of 700–1,000 m (Heyward et al., 2001; Williams et al., 2010; Advisian, 2019).

The benthic habitat along the Chandon to JMT and Jansz DC2 to G & E DC-1 corridors, which are situated between 1,000 m and 1,400 m in low slope areas, consisted primarily of relatively flat terrain.

Isolated fault scarps with bare substrates are present around the proposed NTB3 drill centre and its associated flowline routes heading north (to benthic transects near Semele and G & E DC-1). It is probable that these scarps are steep and affect deep sea currents, transport of marine propagules and water temperatures, which in turn determine the composition of marine biotic assemblages present. Unlike the scarps within the Continental Slope Demersal Fish Communities KEF which have shown to provide high structural complexity in shallower (200–1000 m) waters, scarps in deeper waters may not provide suitable habitat for marine biota including invertebrates.

In deeper waters (1,200–1,300 m) within the Exmouth Plateau KEF, two large fault scarps ~7 km and ~11 km from Chandon DC-1 are positioned west to east and cross through the indicative flowline route. These scarps however, are devoid of epibenthic fauna as observed in the ground-truthing videos. The remaining benthic habitats were relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota with significant habitat. Similar to the low slope areas, deep water areas of complex bathymetry appear to support sparse to no biota (Advisian, 2019). It is probable that the spatial distribution of benthic biota across different benthic habitats depends on several factors such as water temperature, sediment characteristics, food availability, depth, and the nature of the underlying substrate. Furthermore, the seabed sediments are likely to host benthic infauna such as polychaetes, however, larger sediment grab samples instead of cores are required to verify their presence (e.g., Gardline, 2009; Section 5.5) given that no benthic infauna were collected within the Exmouth Plateau KEF during this survey.

5.2 Benthic Cover

Based on the distribution of benthic habitats mapped and the percent cover of benthic habitats in each proposed drill centre and tie-in locations and 2 benthic habitat transects, bare sediment (soft unconsolidated sand/mud) with no biota was the dominant benthic category with greatest benthic cover. These results are comparable to previous studies of the Exmouth Plateau (Falkner et al., 2009), Continental Slope Demersal Fish Communities (DSEWPaC, 2012) and Ancient Coastline (Currey-Randall et al., 2021) that identified soft sediments (sand and mud/silt) as the dominant substrate type in deeper waters with less than 15% benthos cover.

Of the 12 sites examined that consists of proposed drill centres and tie-in locations and 2 benthic habitat transects, the only biota present were cnidarians (over bioturbated sediments) that were detected at Gorgon M1, albeit at a very low percent cover. The presence of biota may suggest that unconsolidated soft sand/mud may only be present as a veneer over the top of consolidated hard substrate. Although higher or rougher topographic features were not identified in any of the captured still images, habitat mapping of C & D DC-3 and NTB3 proposed drill centres suggests that consolidated and steep scarps are present and may support benthic communities.

5.3 Fish Assemblage

Distinct fish and crustacean assemblages were found across the GBF project area which were strongly influenced by water depth. Shallower and warmer sites located in the TSW mass within the Ancient Coastline KEF had a greater number of fish recorded than other sites, with a mean of 3000 fish per transect in the Ancient Coastline KEF and 1700 fish per transect across all sites in the TSW mass. These shallower sites were characterised by sharks and Carangidae such as *Trachurus novaezelandiae* (yellowtail scad). The fish assemblages of the deeper continental slope were mostly dominated by Carangidae, Macrouridae (rat tails), Halosauridae (halosaurs) and unidentified anguilliform (eel-like) fishes. This zone was characterised by the SICW mass and included the slope geomorphic feature and

the Continental Slope Demersal Fish Communities KEF. Although there were large differences in the number of fish observed across the GBF project area among water masses, KEFs and geomorphic features, the average diversity of fishes remained consistent across the sites. Furthermore, while the deeper sites had lower numbers of fishes, the number of fish taxa was the same as the shallower sites.

The patterns of assemblage composition, abundance and number of taxa identified in both the fish and crustaceans sampled support that there is a different fauna associated with the deeper waters of greater than 800 m depth and the AAIW mass. A similar pattern was suggested by Saunders et al. (2021) and has previously been reported (Last et al., 2009). This change in fauna is likely linked to the AAIW, as the cold deep-water and lower saline current has a strong influence on the distribution of fish communities as seen in the south-west region between the Great Australian Bight and north of the Ningaloo Reef where its core fluctuates with depth from 875 m at 27.50°S to 520 m around 21.50°S (Williams et al., 1996; 2001; Woo & Pattiaratchi, 2008). A recent survey in a similar area covered water depths between 360 and 870 m and identified that a similar faunal break occurred between 700 and 800 m water depth (Saunders et al., 2021). A break between mid-slope and shelf-break fish assemblages at water depths of between 700 and 900 m was also reported by Williams et al. (2001) in the North West Cape.

5.4 Sediment Chemistry

The quality of sediments at proposed drill centre and tie-in locations met the ANZG (2018) environmental guidelines at all sites and for all parameters tested, except for nickel which only exceeded at Chandon DC-1. All other sediment sampling sites also contained detectable concentrations of nickel just below ANZG (2018) DGV. Given that this was a baseline study, and no previous activities have occurred in the proposed drill centres and tie-in locations, the detection of nickel across a range of depths (from 100 m at WTR DC-1 to 1300 m at G & E DC-1) is indicative of naturally occurring nickel in sediments.

The presence of nickel may be linked to the sediments' composition (PSD) and organic matter content (Munksgaard and Parry, 2002). The sediments at all sites were mainly composed of clays and silts with TOC concentrations below 1%, suggesting that there has been no enrichment of organic matter in these sediments. However, the high binding capacity of finer-sized particles (clays and silt fractions) will likely result in higher concentrations of naturally occurring nickel in sediments. This is evident in all sediment samples except for sediments in WTR DC-1 which is dominated by sand-size fractions.

The sediments in the Exmouth Plateau are of lithogenic origin consisting of high carbonate content (>55%; McLoughlin and Young, 1985) and largely comprise of sandy mud and muddy sand while larger-size sediment fractions are common in shallower depths along the Northern Carnarvon Basin (Baker et al., 2008). In summary, sediments are generally in a pristine condition, as expected given the absence of anthropogenic activities.

5.5 Benthic Infauna

Despite the limited number of individuals collected, the benthic infauna found were primarily in both deep-sea sediments (1100–1200 m) around proposed drill centres Semele DC-1, Semele DC-2, and Semele BCH1, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected in this study, which included marine worms, a mollusc and polychaete worm, is similar to previous seabed surveys in the north-west shelf region (Heyward et al., 2001; Falkner et al., 2009; Advisian, 2019) whereby polychaetes and crustaceans are the dominant epibenthic and infaunal invertebrates of soft

sediment habitats. Although few individuals were collected in this study, other surveys in the North West Shelf region have also recorded a sparse distribution of epifaunal and infaunal benthic biota, with abundances ranging from one to 47 individuals (Heyward et al., 2001; Advisian, 2019).

The sediments around the proposed drill centres were free of hydrocarbons, had low concentrations of metals and TOC content, indicating that these sediments used by the infauna are free of contaminants and there was no evidence of enrichment of organic matter. The quantity and distribution of infauna found in this survey suggests that other factors such as sediment type, depth, temperature, and food supply to the benthos (Basford et al., 1990; Künitzer et al., 1992; Levin and Gage, 1998) may be affecting the type and quantity of infauna inhabiting the area. Of the five individuals collected, four of the benthic infauna were found in sediments consisting of high silt and clay content, whereas one individual biota was collected in a shallower area with sediments dominated by sand. It is possible that homogeneous sediments provide less niches and support a lower diversity of benthic infauna than heterogeneous sediment (e.g., Gray, 1974). This survey did not find any endemic benthic infauna.

It is possible that the low number of benthic infauna collected in this survey may also be due to the sampling equipment. Compared to traditional box corers, push corers capture a smaller surface area of seabed that may have missed benthic infaunal communities of low density. Furthermore, it is possible that the standard sieve size of 1 mm (Hook et al., 2016) used may have lost smaller-sized individuals (<1 mm), particularly in deep-ocean sediments where lower organism densities and potentially smaller infauna sizes may occur (Gage et al., 2002).

5.6 Water Chemistry

A range of water quality parameters were collected across a range of sites within the GBF project area to understand background conditions. With the exception of dissolved copper and cobalt, metal and hydrocarbon concentrations in water samples were either below laboratory LORs, or below available 99% species protection DGVs, which is typical of an undisturbed tropical offshore environment.

Copper is a natural and essential trace element required by many marine organisms but in high concentrations is one of the most toxic trace metals in seawater (Mackey, 1984; ANZG, 2018). The natural presence of copper in surface water samples may vary in concentrations over time, in response to physical oceanographic effects such as tide and wind and/or seasonal differences (Wenziker et al., 2006). Copper is also released into the water column during physical and chemical weathering of the underlying geology (OzCoasts, 2013). However, the elevated levels of copper detected in some seawater samples may also suggest an alternative copper source such as wind-blown dust, fossil fuel burns, survey vessel discharges and antifouling paints may have contaminated the samples during the sampling process (Richon & Tagliabue, 2019). It is possible that some contamination occurred during sampling, with anomalous results for cobalt and lead being detected in some samples.

Nutrient concentrations across the GBF project area were consistently low across the sampling sites. Surface waters had lower concentrations of nutrients than bottom waters. These results are consistent with nutrient concentrations reported in previous studies in deep-water environments in the North West Shelf (Holloway et al., 1985; URS, 2007; Gardline, 2009), which are influenced by the Indonesian Throughflow. Given that slightly higher concentrations of nutrients were evident near the seafloor compared to the sea surface, it is likely that there are no physical processes such as upwelling (wave or current-induced) of deeper waters occurring in the region (Mackey, 1984).

5.7 Water Quality Profiles

Water quality profiles were consistent between sites, with a warm and low salinity surface layer (to ~180 m depth) overlying a broad thermocline/subsurface salinity maximum (between 185–250 m depth), followed by the colder, lower salinity waters of the deeper ocean (~250–1,350 m). The CTD data collected within the GBF project area allowed the identification of tropical surface waters corresponding with the southward-flowing Leeuwin Current and the deeper south Indian central water mass along with the subsurface Leeuwin Undercurrent which moves equator-ward along the Western Australian coast at deeper depths. Similar water mass structures have been identified in the Gascoyne region (Woo & Pattiaratchi, 2008; Pattiaratchi & Woo, 2009, BMT Oceanica, 2016). Oceanic processes such as currents in the water column can be used to understand the type and distribution of seabed habitat.

5.8 Conclusion

This survey report details the existing marine benthic environment and geomorphological seabed features within the GBF project area. In line with the scope of works, a preliminary benthic habitat map was developed based on assessment of geomorphic features derived from sonar and seismic survey data, and a visual benthic survey was completed to validate BCH. Further to this, we described the demersal fish and habitat associations across areas of interest, and broadly characterised the water and sediment quality and infaunal assemblages of the project area.

Overall, the benthic environment is characteristic of the North Carnarvon Basin and the North West Shelf region and is dominated by mixture of benthic habitats of low topographic features with few benthic biota. Sections of seabed between 200 m and 1000 m depths within the Continental Slope Demersal Fish Communities KEF and Exmouth Plateau KEF was comprised of topographically complex scarps with sparse benthic biota that are typically found in deeper waters (>200 m). Though these benthic habitats are well represented regionally, further consideration of the most suitable placement of subsea facilities may be warranted as the project matures to minimise potential impacts to the BCH within the GBF project area (i.e., along scarp and reef mosaic habitats with low and high likelihood of biota).

Water and sediment samples collected from within the GBF project area were free from contaminants and typical of an undisturbed tropical offshore environment. Although there were a few exceedances of some metal concentrations in water and sediment samples compared to ANZG (2018) guideline values, these concentrations could either be a result of contamination during the sampling process, or reflect natural background levels given the absence of anthropogenic activities in the area.

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Appendix A
Exemption from Fish Resources Management Act 1994 and Regulations, Section 7, and Regulation 6

Office use only
EXEMPTION NUMBER:

Fish Resources Management Act 1994
Section 7(2)(e)

INSTRUMENT OF EXEMPTION

I, Nathan Harrison, Director, Aquatic Resource Management, as delegate of the Minister for Fisheries pursuant to Section 7(2) (e) of the *Fish Resources Management Act 1994*, do HEREBY EXEMPT the persons specified in **Schedule 1** from the provisions of the *Fish Resources Management Act 1994* and associated subsidiary legislation which would otherwise prevent those persons from lawfully pursuing the activity specified in **Schedule 2**, using the methods specified in **Schedule 3**, for the area and period specified in **Schedule 4**, subject to the conditions specified in **Schedule 5**.

Schedule 1
Persons

Persons exempted	Exemption holder
Luca.Chiaroni +61 498 014 575 Luca.Chiaroni@Advisian.com And Employees of Worley Services Pty Ltd	Applicant: Worley Services Pty Ltd, trading as Advisian Address: Level 14, 240 St Georges Terrace, Perth, 6000 Telephone No: (08) 9485 3811

Schedule 2
Activity and Purpose

Marine Benthic Survey of the Greater Gorgon Area. This project performs habitat mapping and marine benthic surveys for seven new fields in the Greater Gorgon area on the Northwest Shelf.

Schedule 3
Fishing Methods

A key component of the baseline program is a sediment quality survey sampling and testing for metals, nutrients, and total organic carbon. Sediment samples will be collected via Push Cores to a depth of 40 cms.

Although some sediment infauna will be obtained through sediment push core samples, fish or other biota are an incidental catch. It is expected that the total biomass collected from the survey will be less than 10 kgs.

Schedule 4
Area and Period

Marine Benthic Survey Surveys will be conducted within the Greater Gorgon area located in the Northern Carnarvon Basin Surveys. The fields are located around 130 km northwest of Barrow Island, Western Australia (WA), in water depths ranging from 150 m to 1300 m. The study area covers an area of approximately

2000 square kilometres. Sediment samples will be conducted within these new fields indicated in Figure 1

From the date of signing until 10 October 2022.

Locations to be sampled

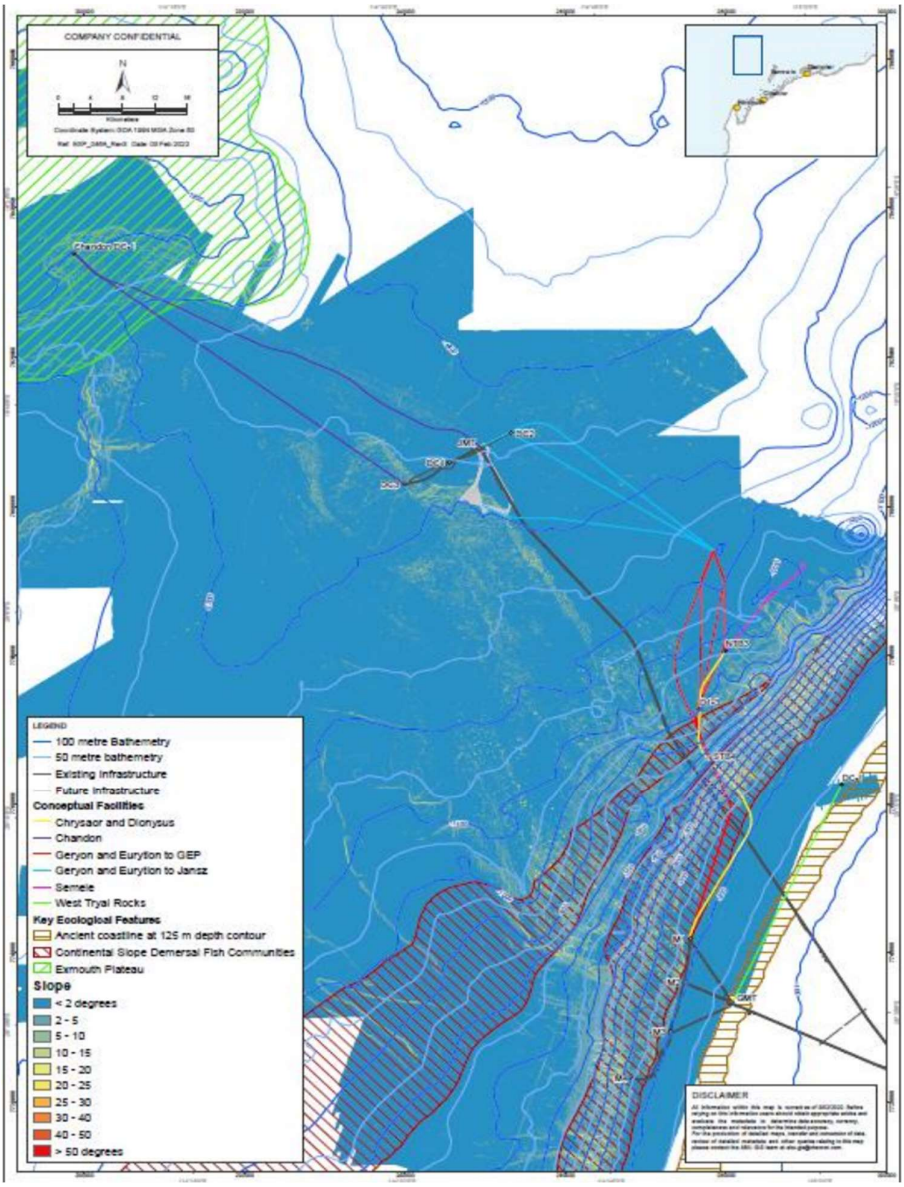


Figure 1: Overview of the greater Gorgon survey area

Schedule 5

Conditions

1. The exemption holder must advise the Department by calling FishWatch 1**800 815 507** at least 12 hours prior to commencing every sampling trip under the exemption, of:

    a) the Exemption holder's full name;
    b) the Exemption holder's contact numbers;
    c) the nearest Office of the Department;
    d) the location of the Exemption and the proposed place and time of landing of any fish retained under the authority of this Exemption;
    e) the Exemption number;
    f) the Exemption start date and time;
    g) the Exemption end date and time;
    h) the name and registration of any vessels/s and the registration of any vehicle/s used to transport any fish retained under the authority of this Exemption;
    i) the species and number of fish intended to be collected under the authority of this Exemption; and
    j) the Call date and time.

2. The exemption holder must ensure the Department is notified via FishWatch **1800 815 507** of any changes to the nomination information, including collection trip cancelations or variations to the date or time.

3. The person(s) exempt **(Schedule 1)** must carry a copy of this Exemption when they are carrying out the activities provided for by this Exemption or when transporting any species collected under this Exemption. The exemption holder must also retain the call reference number (provided by the call centre upon making the prior nomination to fish). A copy of the Exemption must be made available for inspection by a Fisheries and Marine Officer on request.

4. Where any vessel and / or vehicle is being used to take fish and / or samples pursuant to this exemption, the persons specified in **Schedule 1,** must ensure that these vehicles:

    a. be made visibly identifiable as belonging to the client or the persons specified in **Schedule 1;** and
    b. display a sign that is at least 600mm x 600mm, with a minimum character size of 50 mm, stating "Operating under Exemption No." along with the Exemption Number.

5. Where any fishing gear is being used to take fish and / or samples pursuant to this exemption, the persons specified in **Schedule 1,** must ensure that the fishing gear is visibly identifiable as belonging to those specified in **Schedule 1,** along with the Exemption Number, by attaching either marked surface floats or waterproof tags.

6. The persons specified in **Schedule 1,** must only use the sampling methods described in **Schedule 3** while operating under the authority of this Exemption.

7. No other fishing activities, other than those under the authority of this Exemption, are to be undertaken during any sampling trip.

8. The exemption holder must obtain any additional approvals or permissions to complete the activities specified under this Exemption should it be prohibited by other Western Australian or Commonwealth legislation.

9. The Director Aquatic Resource Management can at his discretion revoke this Exemption at any time.

10. If a fish or fish sample is removed from the collection site, it must be disposed of on land, in municipal waste, and not be returned to the marine environment or any water body.

11. Any person specified in **Schedule 1,** must not fish or collect samples, under the authority of this exemption, in any marine protected areas; including State Marine Nature Reserves, Marine Park Sanctuary Zones, Fish Habitat Protection Areas or Reef Observation Areas, without the specific written permission of the Department of Biodiversity, Conservation and Attractions Manager, Marine Science and the Department of Primary Industries and Regional Development's Director, Aquatic Resource Management or Director, Aquatic Science and Assessment.

12. All samples taken pursuant to this exemption, must only be transported in vessels or vehicles described as required under **Condition 1. (h).**

13. Any collected specimen or by-catch that are displaying invasive characteristics or are suspected or recognised invasive aquatic species identified in the Fish Resources Management Regulations 1995 (Schedule 5, Noxious Fish), and/or in the current version of the Western Australian Prevention List for Introduced Marine Pests, Department of Fisheries, found on the DPIRD website must not be returned to the water.

    http://www.fish.wa.qov.au/Documents/biosecurity/noxious fish list.pdf
    http://www.fish.wa.gov.au/Documents/biosecurity/epa introduced marine pests

    Noting these lists may be amended from time to time.

14. Any specimens retained in accordance with **Condition 13** must be humanely euthanized and kept in a sealed plastic bag or container, separate from any other fish and either kept on ice or refrigerated (but not frozen), until further advice is obtained from DPIRD.

15. The holder of the Exemption must report to the DPIRD via FISHWATCH (ph 1800 815 507) or by email at aquatic.biosecurity@dpird.wa.gov.au, within 24 hours following the:
    a) Initial detection of:
        a. a listed noxious fish

b. a suspected or recognised invasive aquatic species not previously known from the sampled waters; or
c. an introduced aquatic pest, or
d. a disease, and

b) Subsequent analysis and confirmation of fish/species identified in **Condition 13** above or by any other further investigation.



Nathan Harrison
DIRECTOR, AQUATIC RESOURCE MANAGEMENT
as delegate of Minister for Fisheries

26 April 2022

Appendix B
Benthic Habitat Categories and Example Images (Based on CATAMI Classifications)

Substrate descriptor

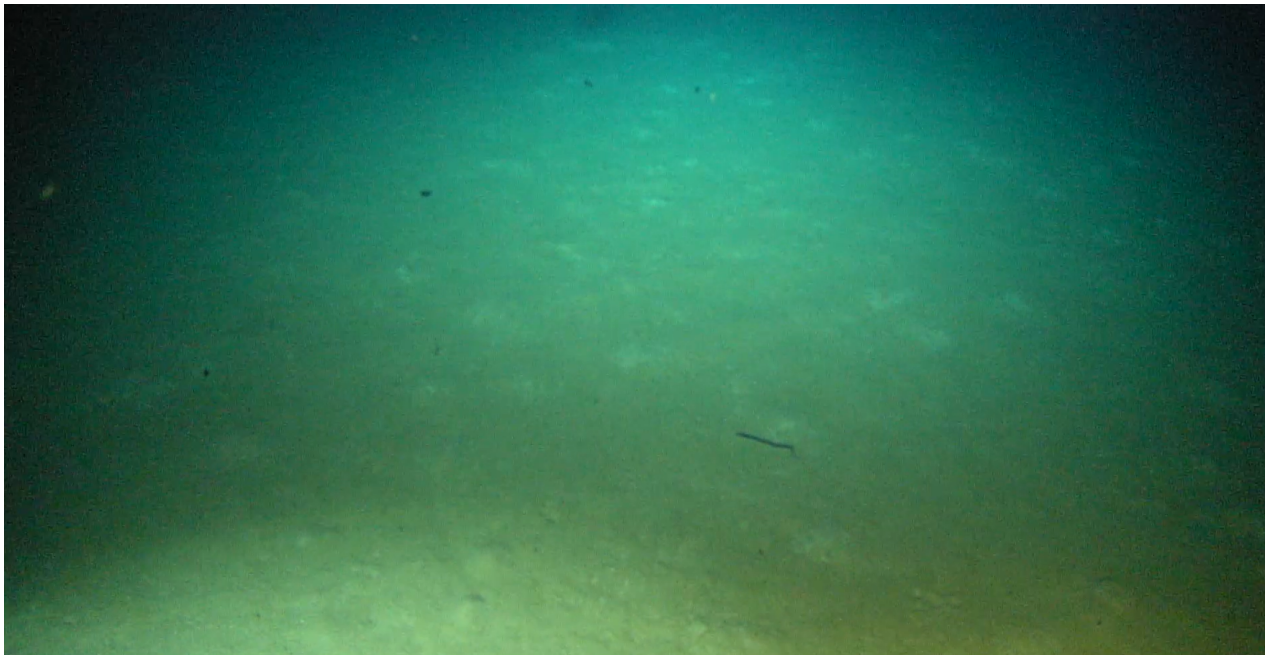
Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative Backscatter/ Sidescan
Bedforms	Active or once active sediment bedforms indicating wave or current action on the seabed.	May be visible bathymetric features, or may only occur in backscatter if small.	Varied, wavelength and amplitude measured in profile (Ashley 1990).	Varies depending on incidence angle. Typically, low.
Depression-Scour	Local depression which may be geological or biological in origin (Scour or Pockmark).	Bathymetric features measurable in profile (low).	Varied slope. TPI index low.	Varies depending on incidence angle.
Irregular Seabed	Mostly flat sediment terrain with minor features which may be derived from underlying geology.	Smooth with identifiable, regular but small bedforms or mounds. Fine or coarse sediment.	Typically, less than 2°, minor topographic features.	Low, rare, and small discernible features.
Mostly Bare	Mostly flat sediment terrain with very minor features.	Smooth with rare identifiable but unmappable regular bedforms or mounds. Fine or coarse sediment.	Typically, less than 2°, very minor topographic features.	Low, rare, and small discernible features.
Mound	Locally elevated Sediment or Rock Veneer feature which comprising rubble, geological or biological in origin.	Bathymetric features measurable in profile. Isolated, smooth edged feature. No structure indicating active sand wave or dune.	Varied but smooth slope. TPI index high.	Varies depending on incidence angle, typically very high.
Rock Reef	Bedrock or other consolidated material outcrop.	Rough bathymetric features measurable in profile.	Varied complex slope. TPI index high.	High/variable.
Rock Veneer	Area of buried bedrock/rocks or cemented sediments with very low sediment input (Starved). Also known as low profile reef.	Uneven, rugged, and irregular features, often angular or linear. Fine or coarse sediment.	Typically, less than 2°, highly variable low profile topographic features. Signs of subsurface structure must be apparent.	Varied, mostly high.
Scarp	Bedrock or other consolidated material outcrop, subject to landslide erosion.	Rough bathymetric features measurable in profile.	Typically, greater than 15°, may have steep sides	Varies depending on incidence angle.

The images below are classified according to the CATAMI scheme (table below) and are intended as representative examples of this habitat classification.

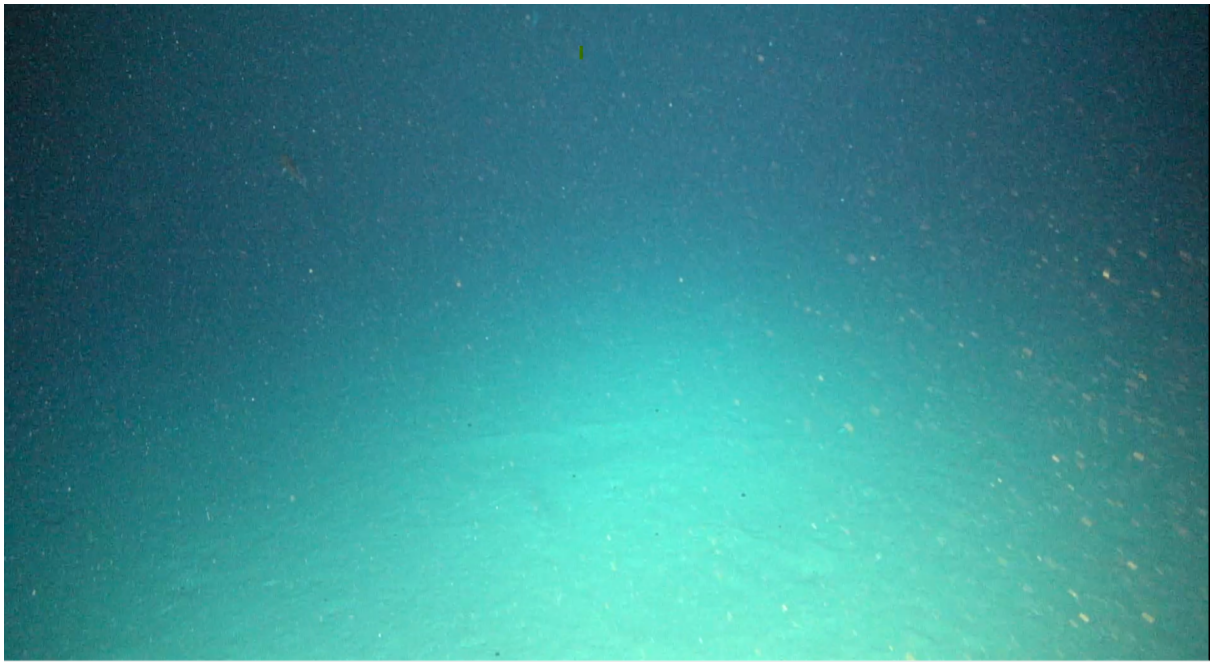
Habitat and Biota Categories

Habitat Categories	Biota Categories
Relief/Slope	**Biota**
Flat	Sponges
Low (<1 m)	Cnidaria
Moderate (<3 m)	Echinoderms
High (>3 m)	Sponges, Cnidaria
Wall	Sponges, Echinoderms
Substrate	Cnidaria, Echinoderms
Unconsolidated (soft)	Mixed biota (all 3)
Consolidate (hard)	
Substrate size/appearance	
Sand/mud (<2 mm)	
Sand/mud (<2 mm) and occasional boulders	
Cobbles	
Boulders	
Rock (Outcropping bedrock)	
Modifier	
Bare	
Biota only	
Bioturbation and bare	
Bioturbation and occasional veneer only	
Bioturbation with biota and occasional veneer	
Ripples (<10 cm height) and bare	
Ripples (<10 cm height) with biota and sparse veneer with biota	
Veneer with biota	
Unknown	

Flat > Unconsolidated (soft) > Sand/mud (<2 mm) >Bioturbation with bare sediment



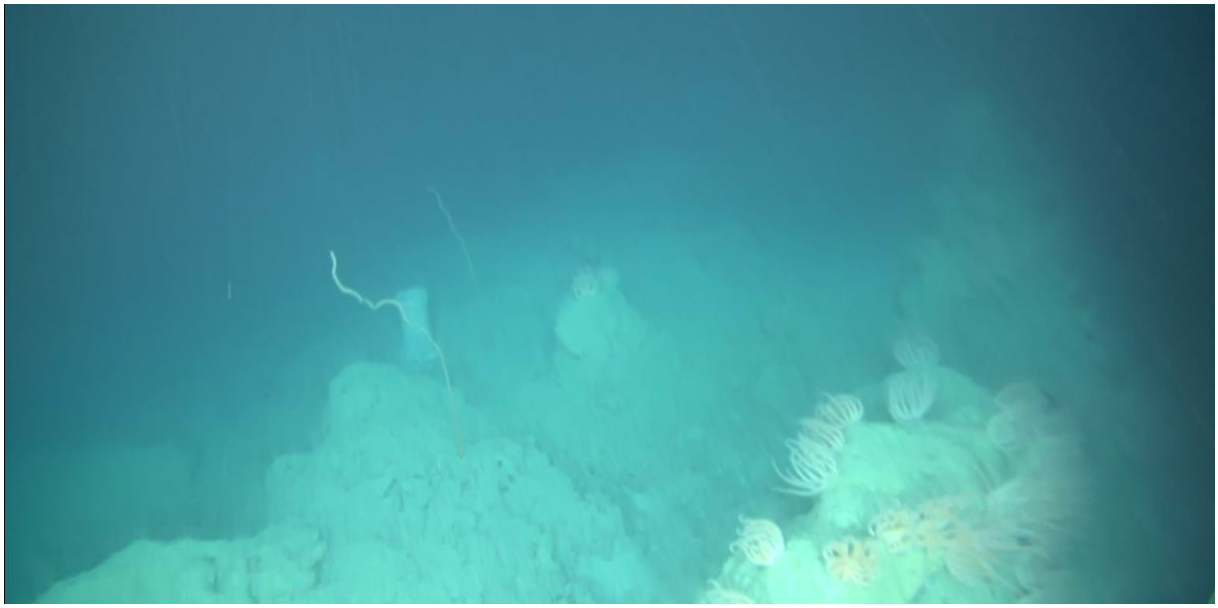
Flat > Unconsolidated (soft) > Sand/mud (<2 mm) >Bare sediment



High > Consolidated (hard) > Rock (Outcropping bedrock) >Bioturbation with occasional veneer only



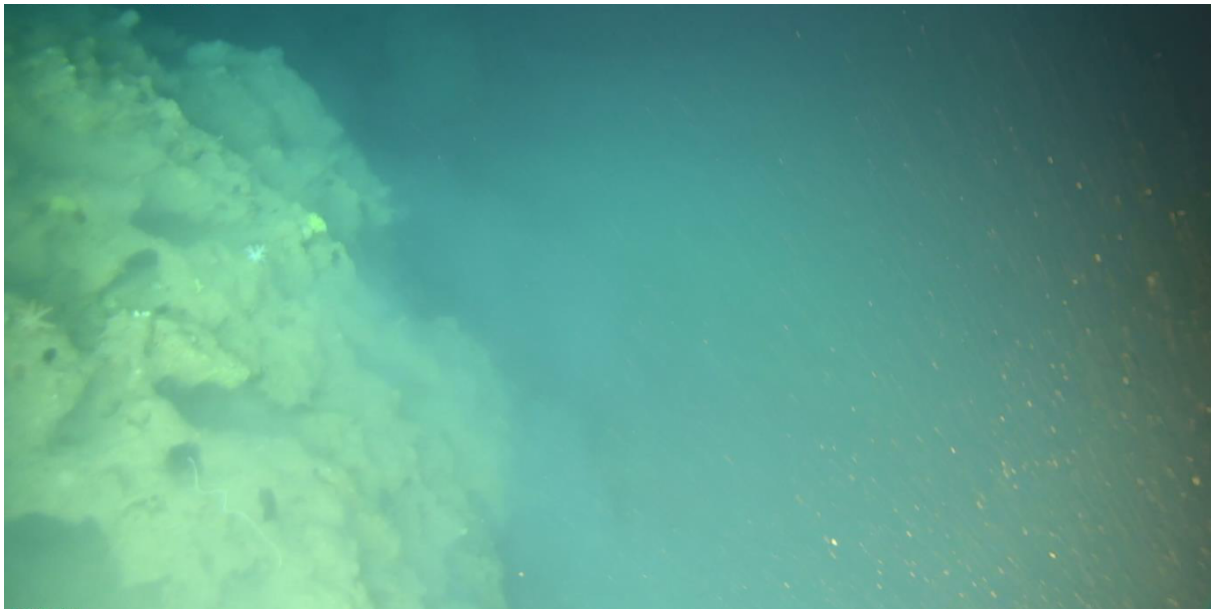
High > Consolidated (hard) > Rock (Outcropping bedrock) >Bioturbation with biota > Mixed biota



High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Cnidaria



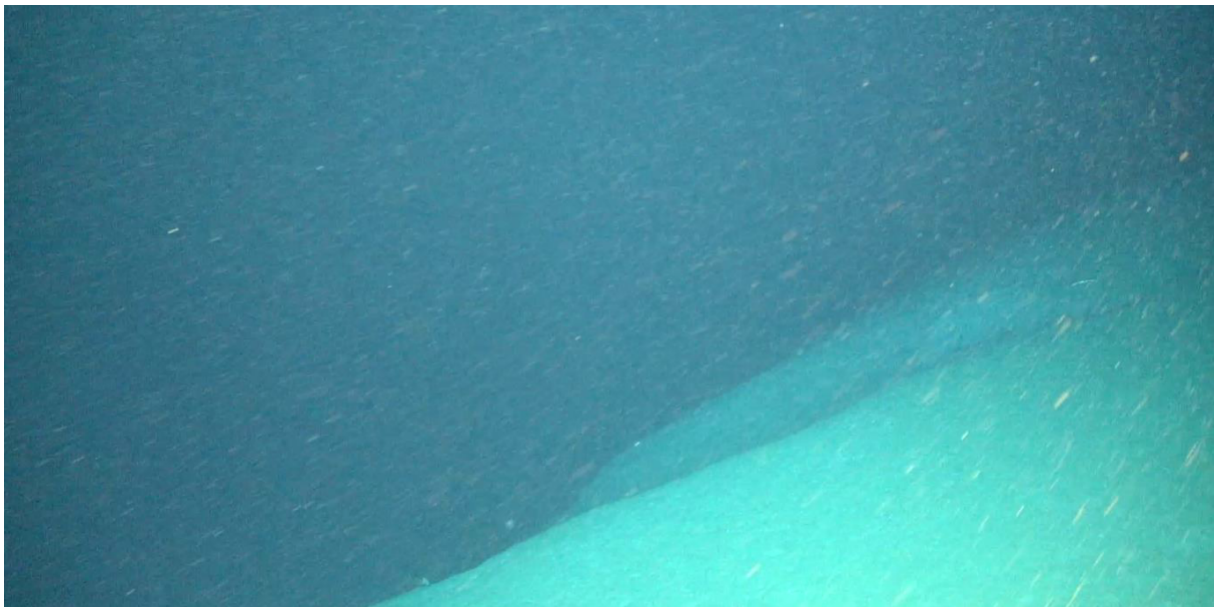
High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge and Cnidaria



High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Mixed biota

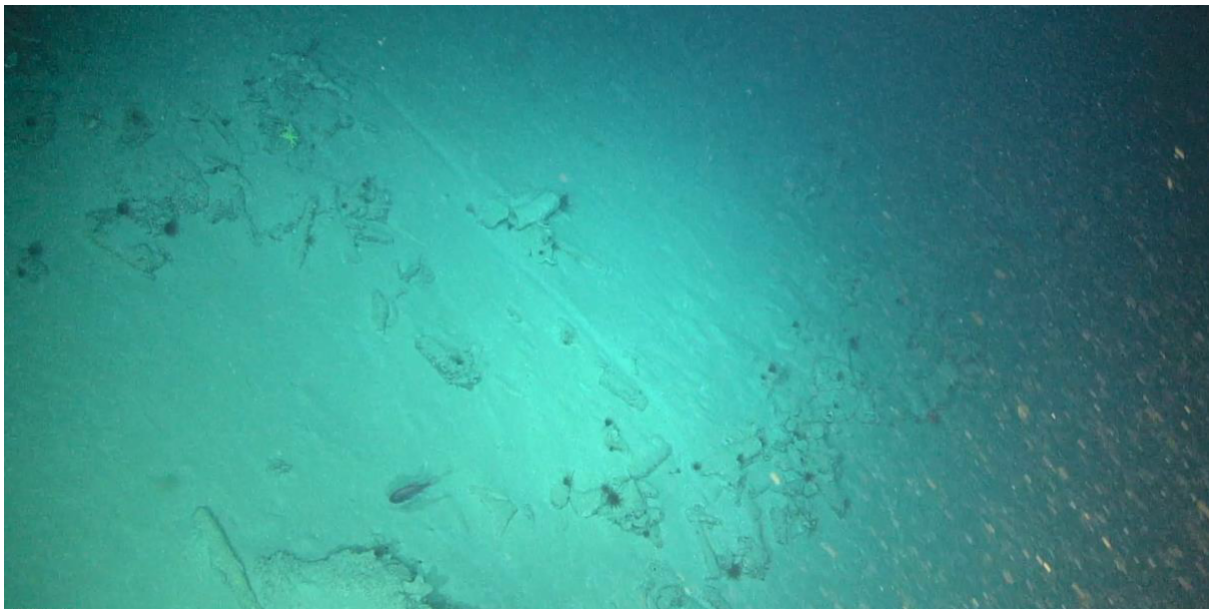


High > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment

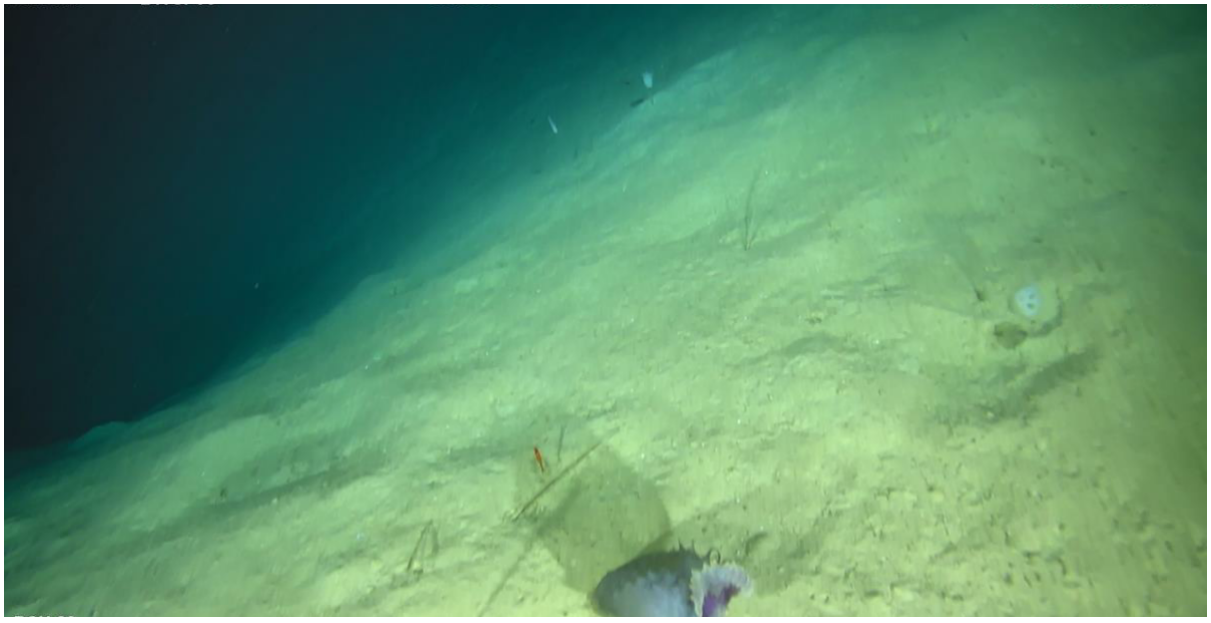




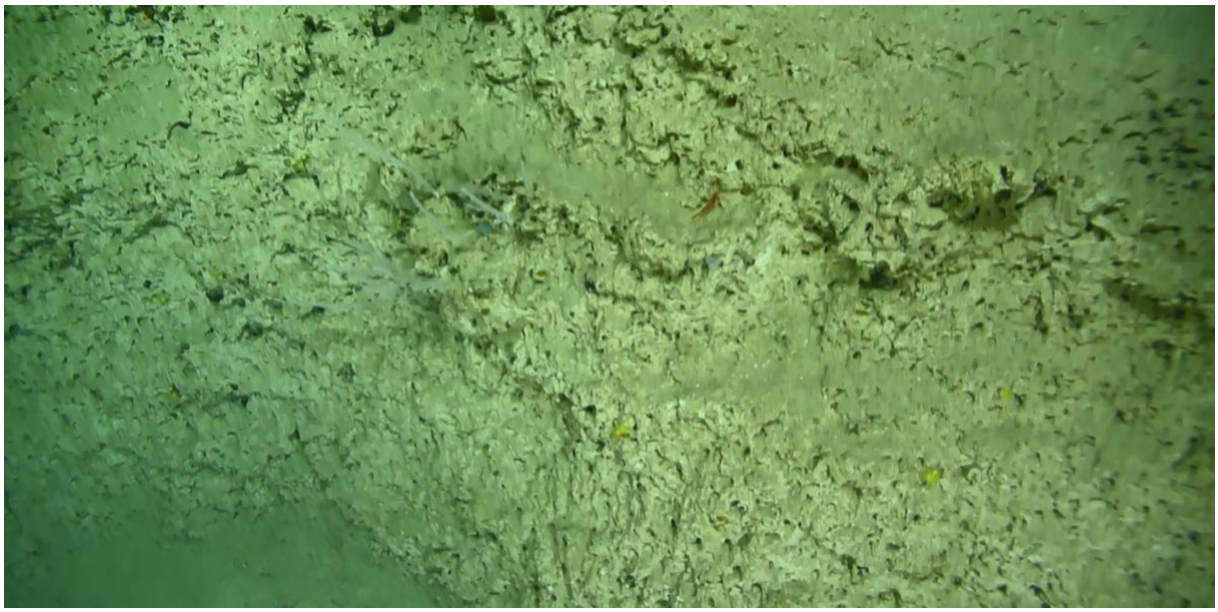
High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Cnidaria

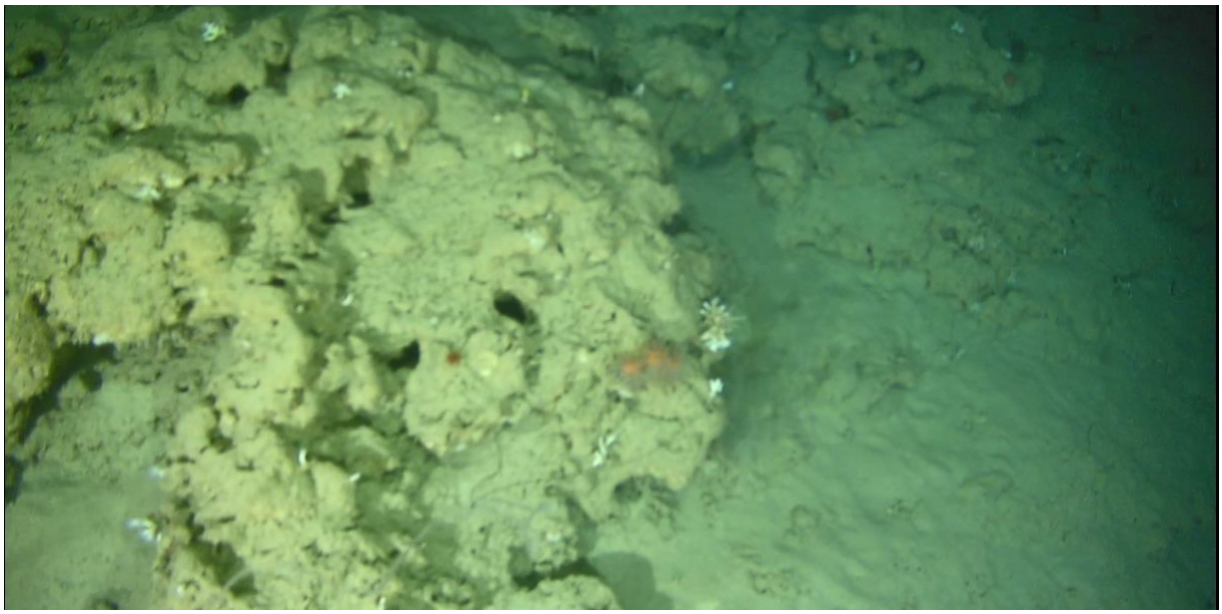


High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Sponge and Echinoderm



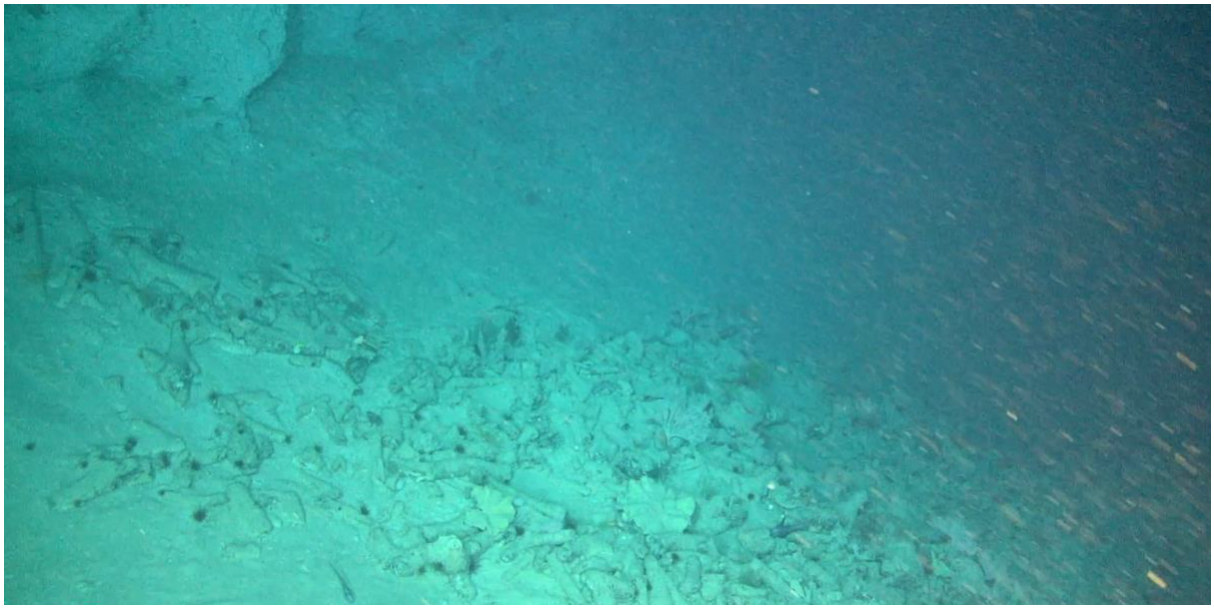
High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Sponge and cnidaria





High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Mixed biota

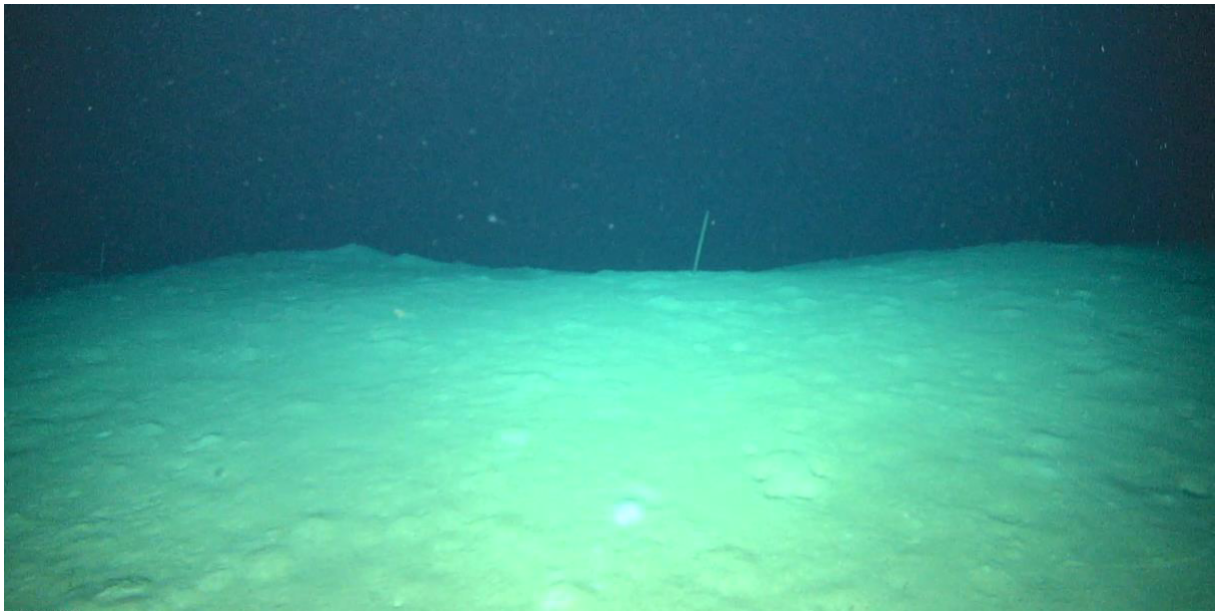




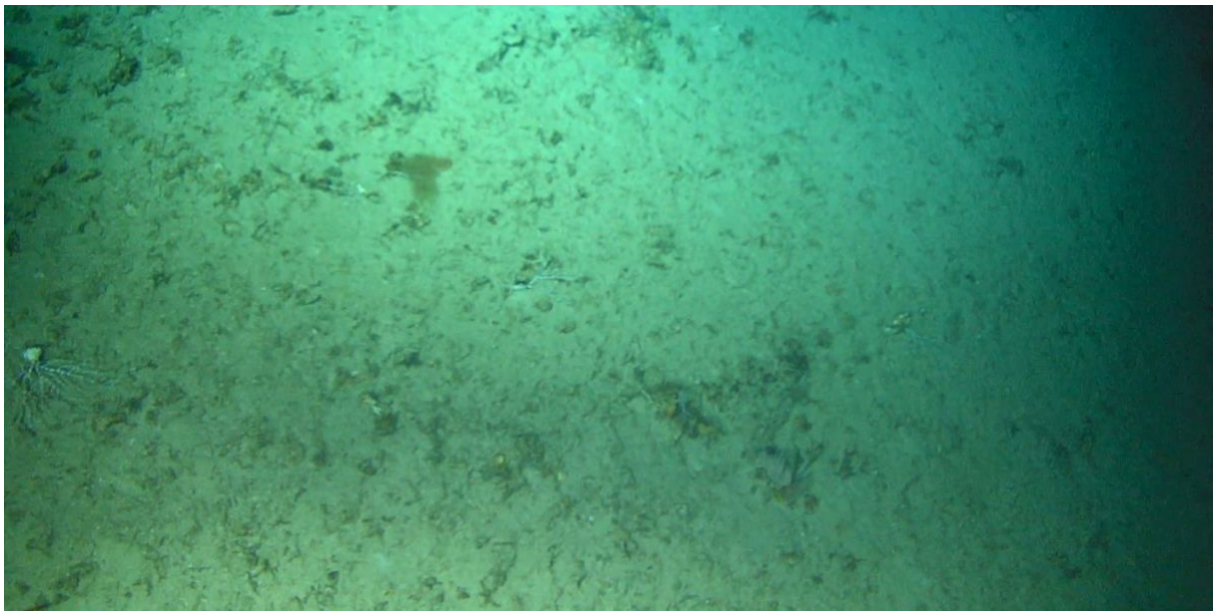
High > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only



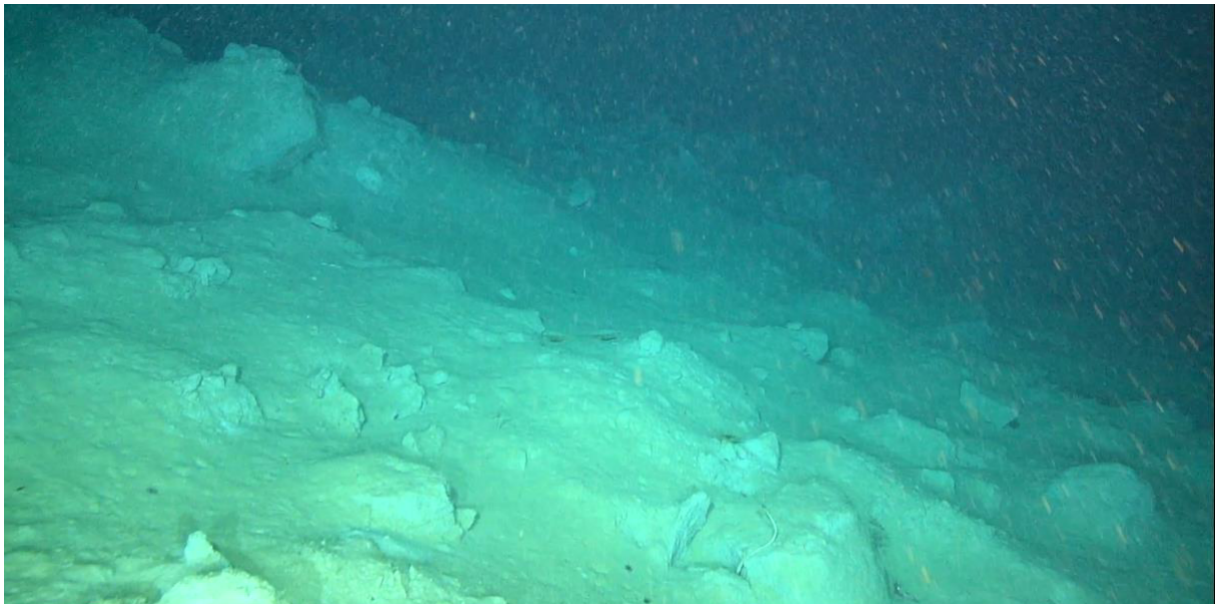
High > Unconsolidated (soft) > Sand/mud (<2 mm) > Bare sediment



Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge



Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



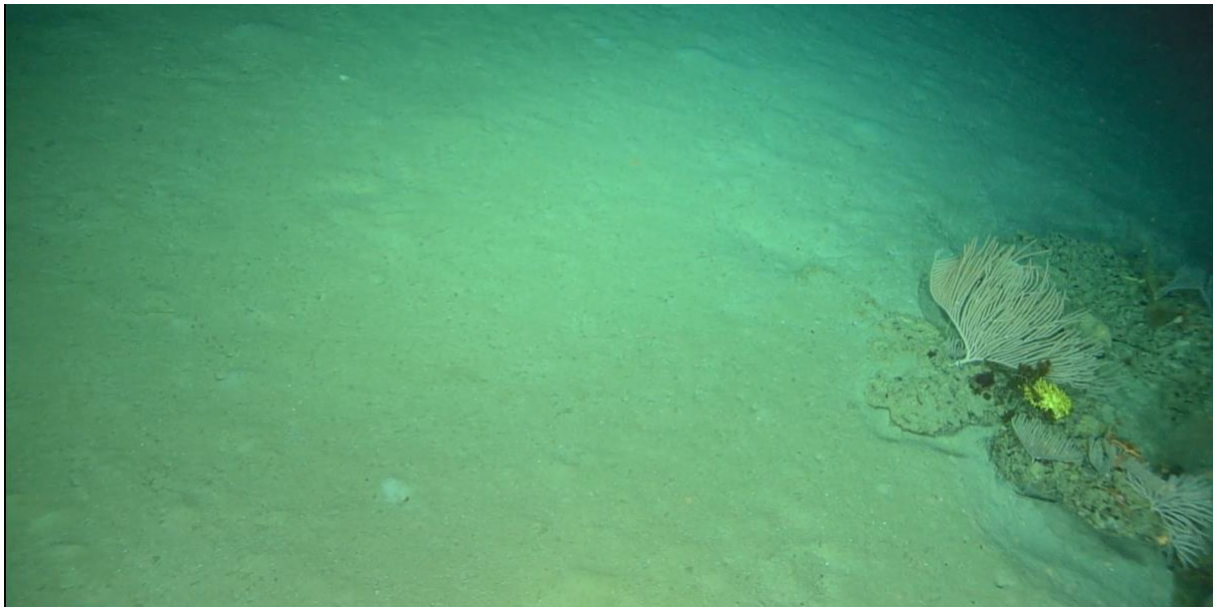


Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge and cnidaria



Low > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota> Mixed biota

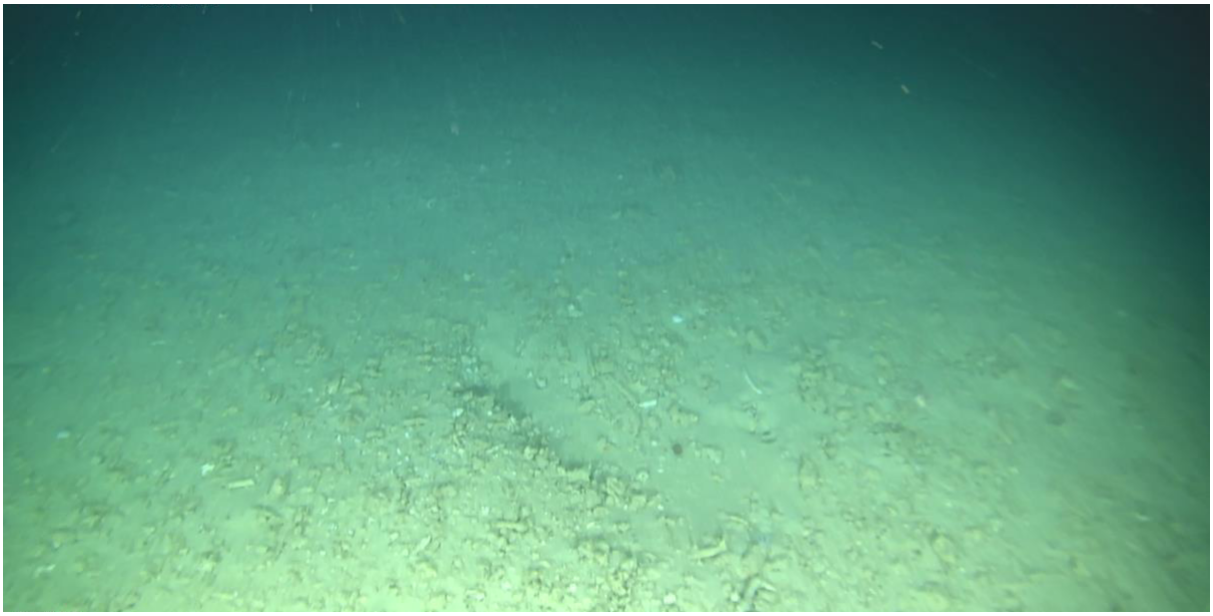




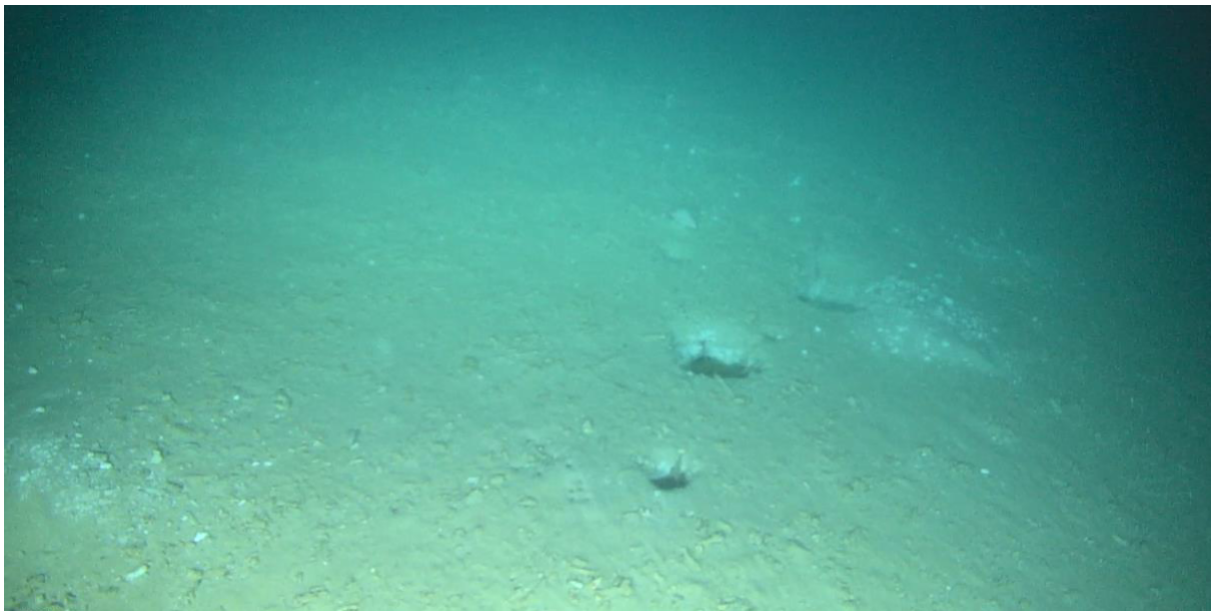
Low > Consolidated (hard) > Cobbles > Biota only > Cnidaria



Low > Consolidated (hard) > Cobbles > Bare sediment



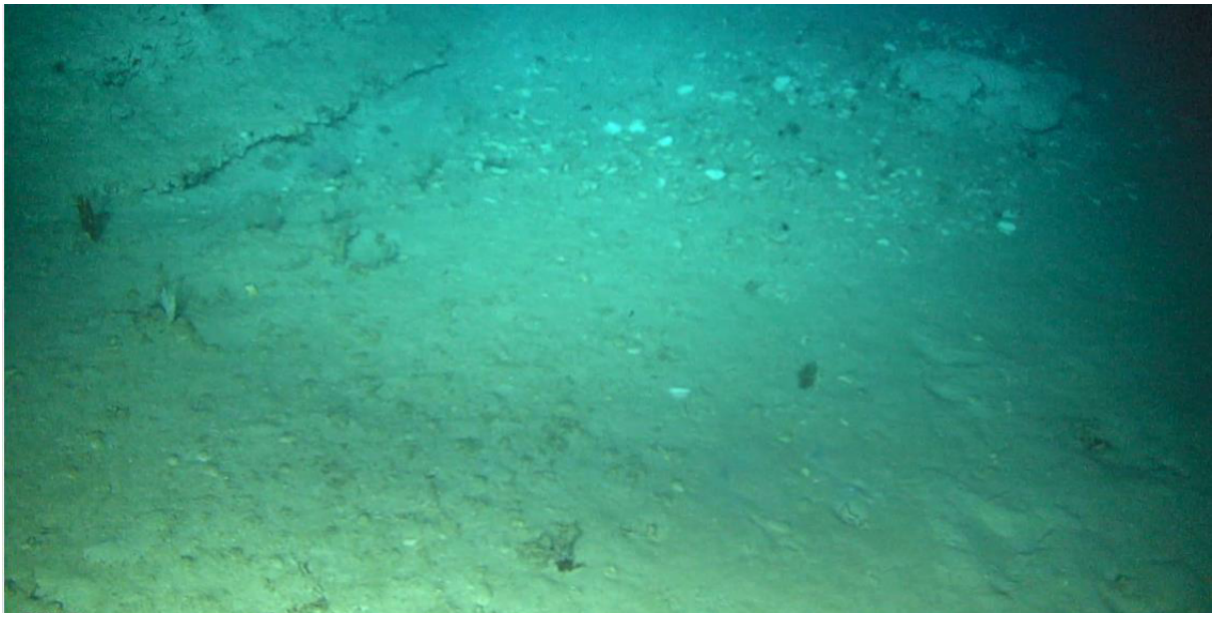
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation and occasional veneer only



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Cnidaria



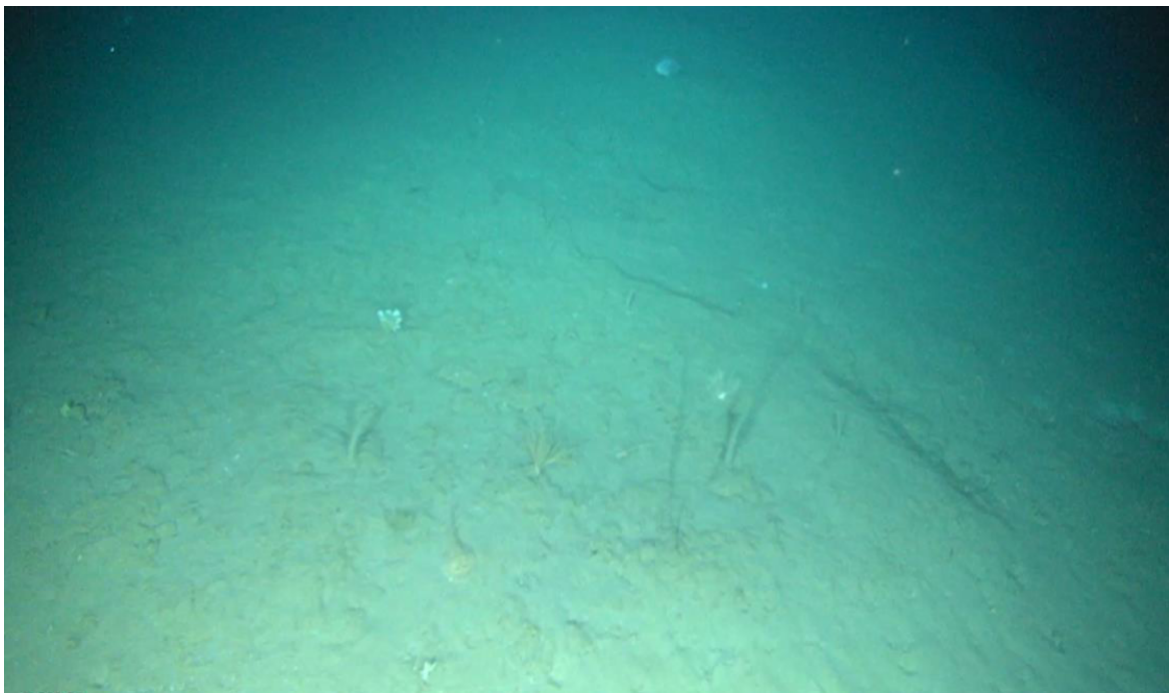
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Sponge



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Sponge and cnidaria



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Mixed biota



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Cnidaria



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Echinoderm



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge and cnidaria



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Mixed biota



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only

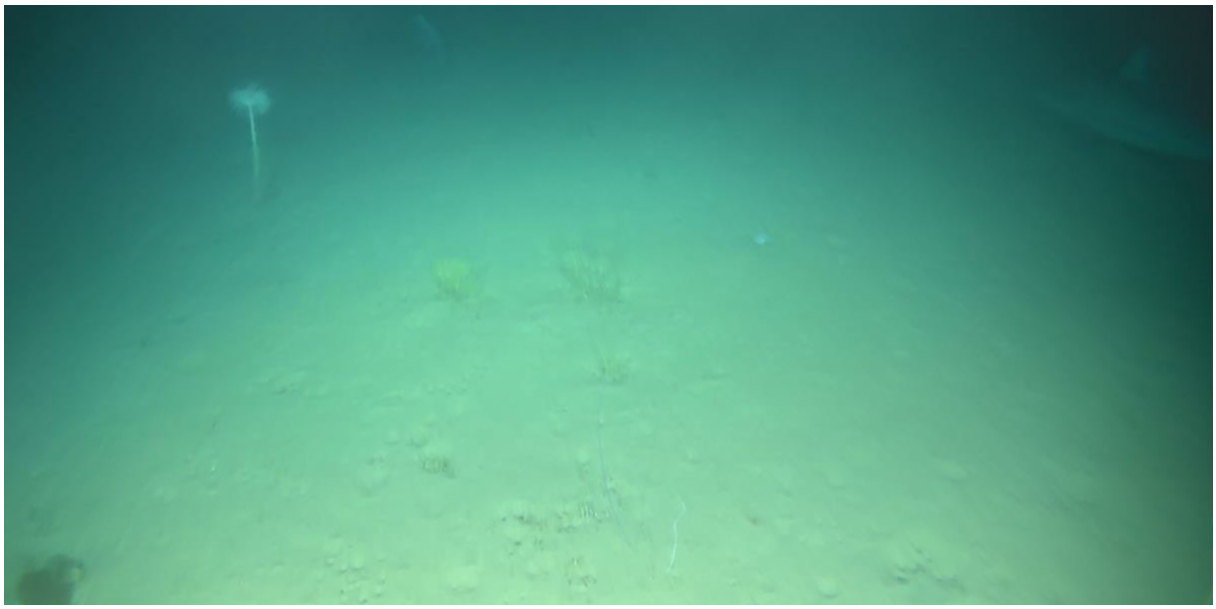


Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Echinoderms



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Cnidaria





Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Cnidaria and echinoderms



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bare sediment



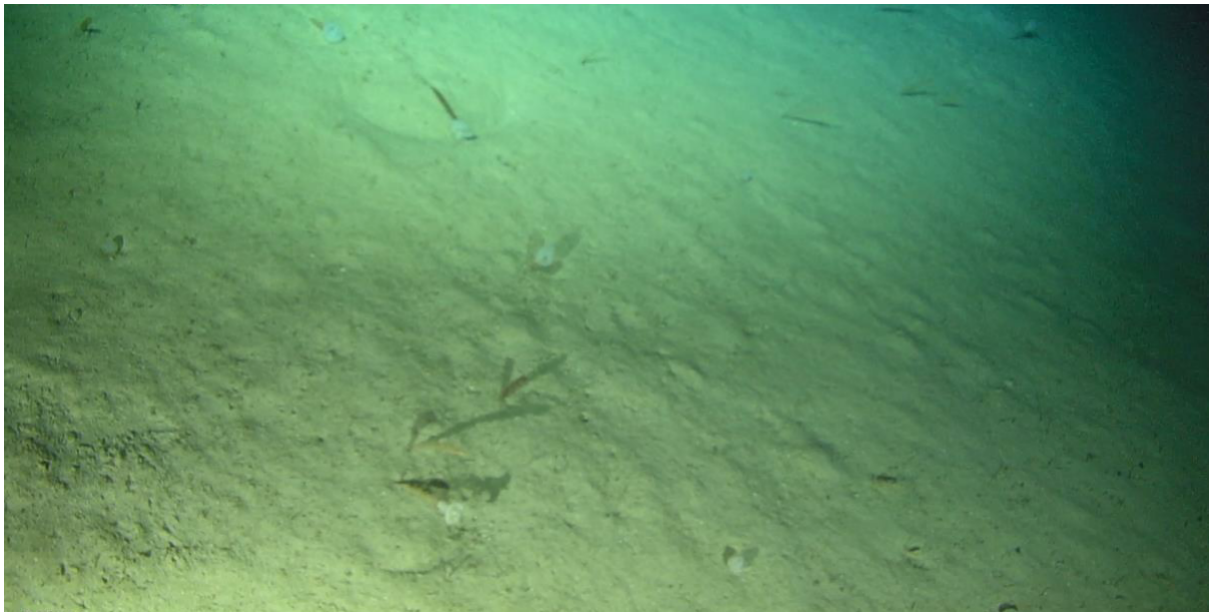
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with bare sediment



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with biota > Sponges and cnidaria



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Sponge



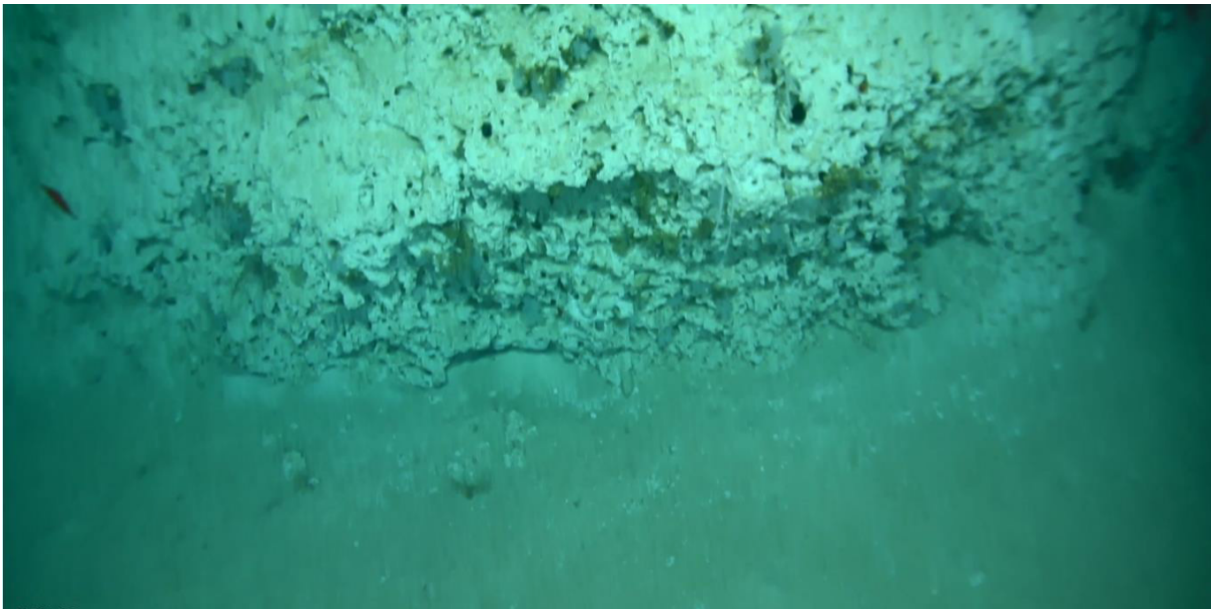
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Sponge and cnidaria



Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge



Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge and cnidaria



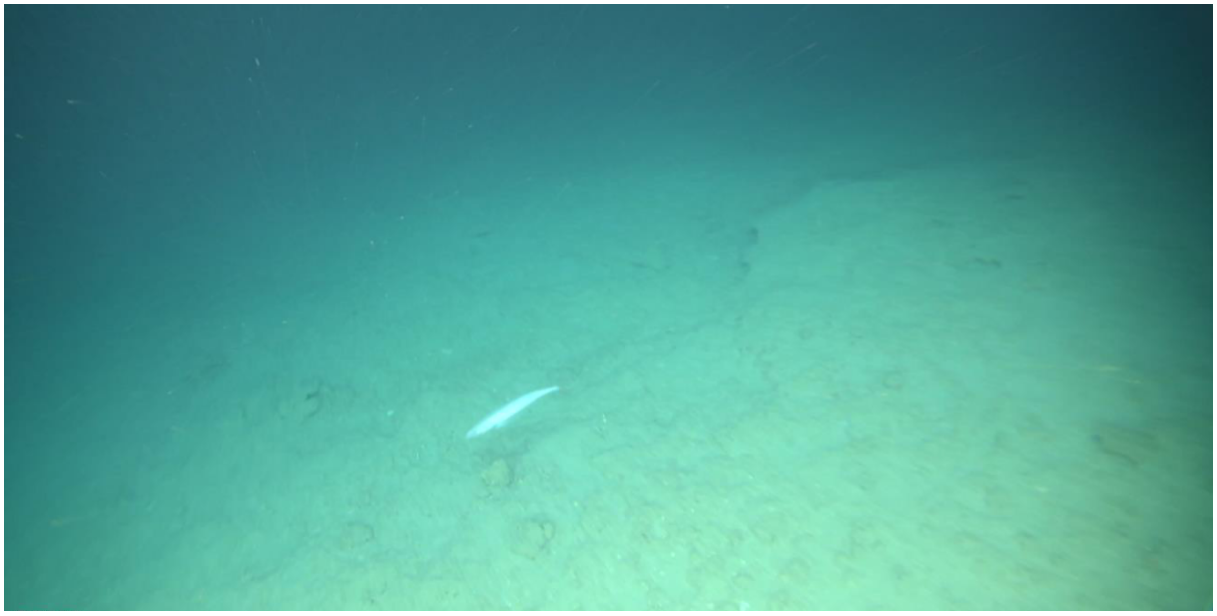
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Mixed biota



Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation only



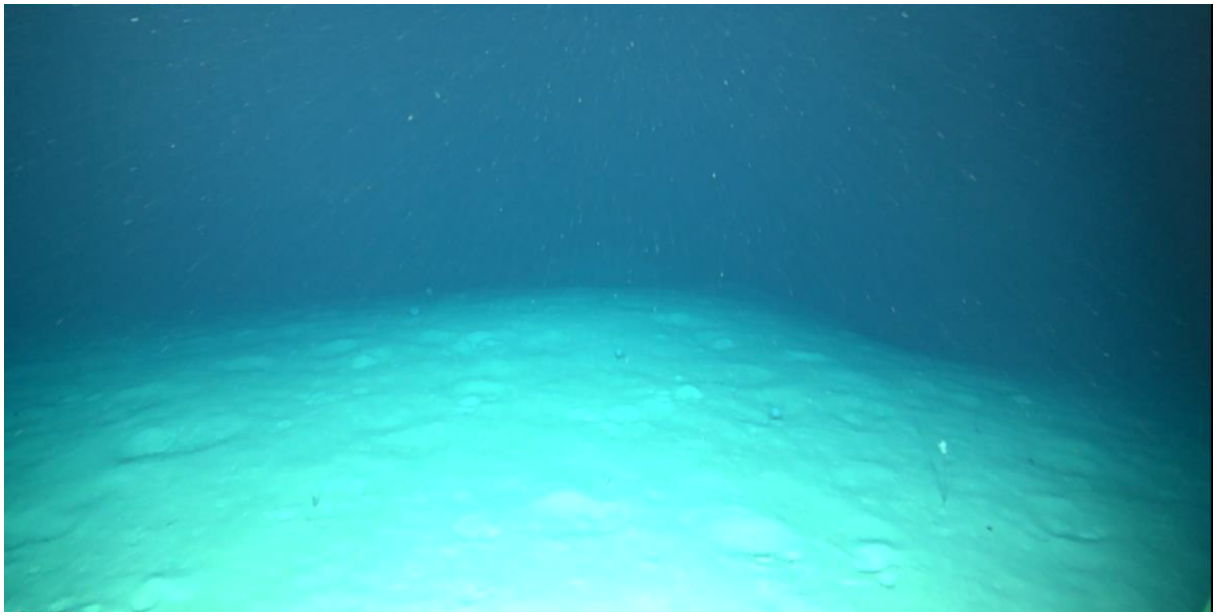
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



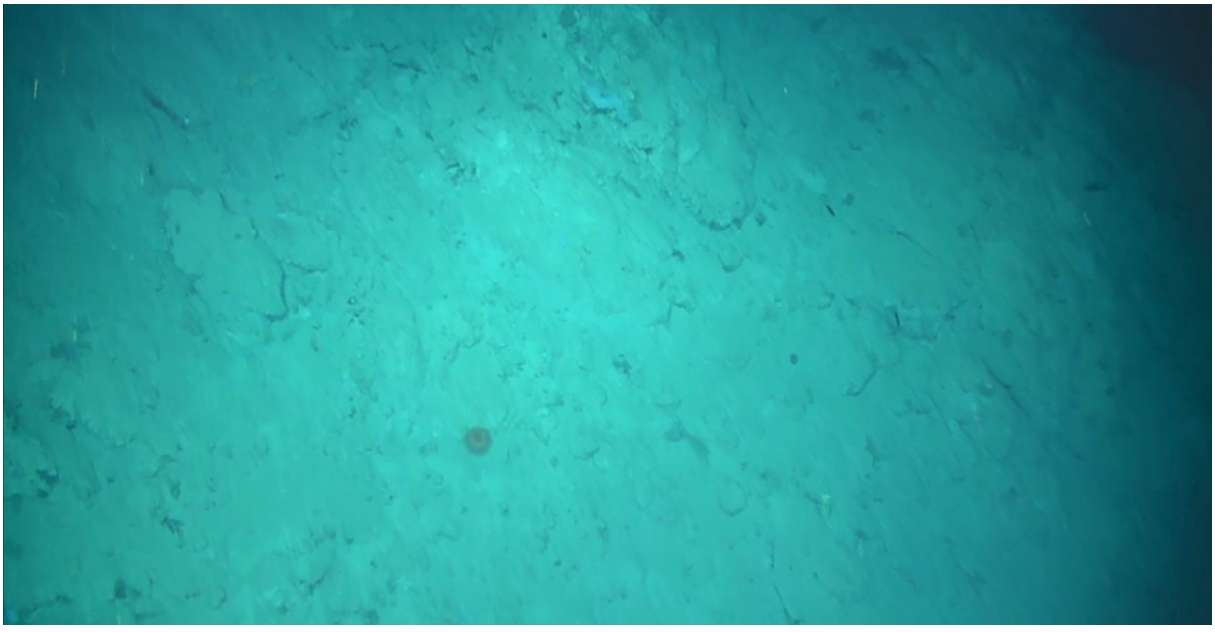
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge and cnidaria



Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota> Sponge and cnidaria



Moderate > Consolidated (hard) > Cobbles > Bioturbation with biota > Sponge and echinoderms



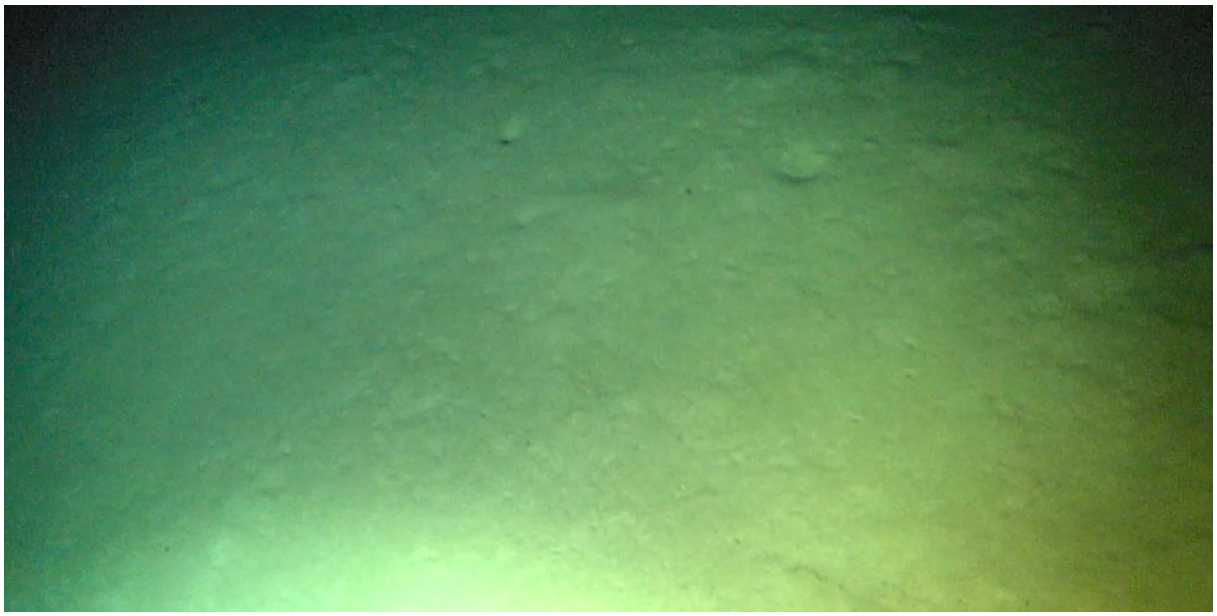
Moderate > Consolidated (hard) > Cobbles > Bare sediment



Moderate > Consolidated (hard) > Cobbles > Biota only > Sponge and cnidaria



Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with occasional veneer



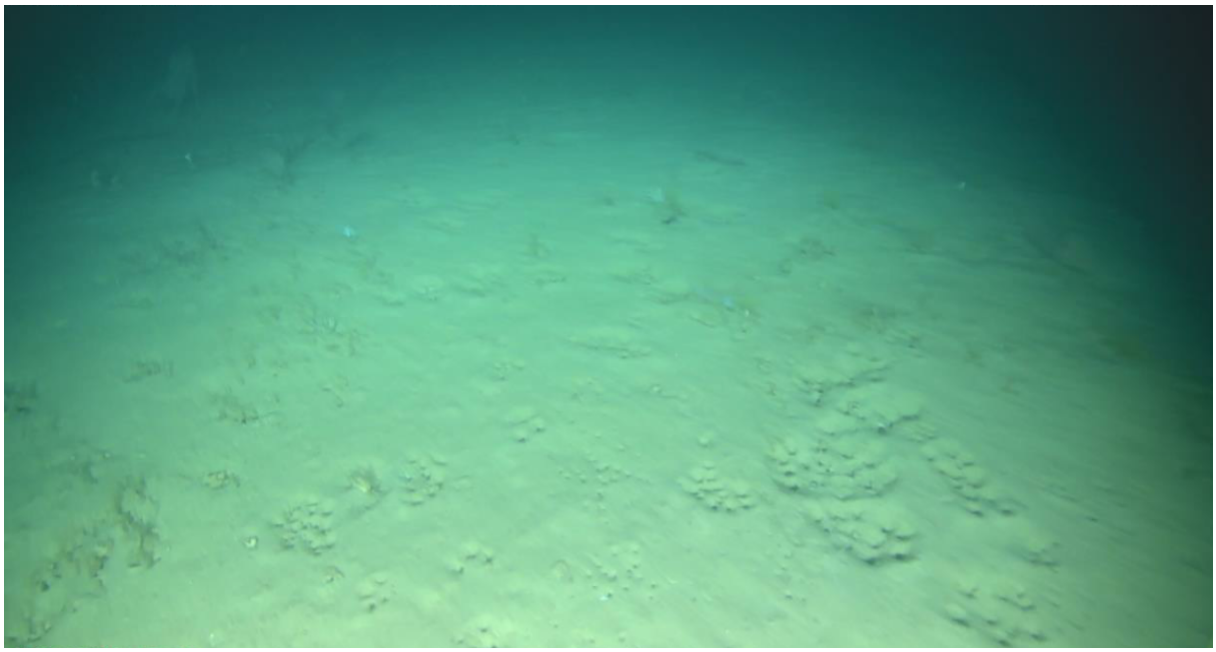
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer> Cnidaria



Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer> Sponge



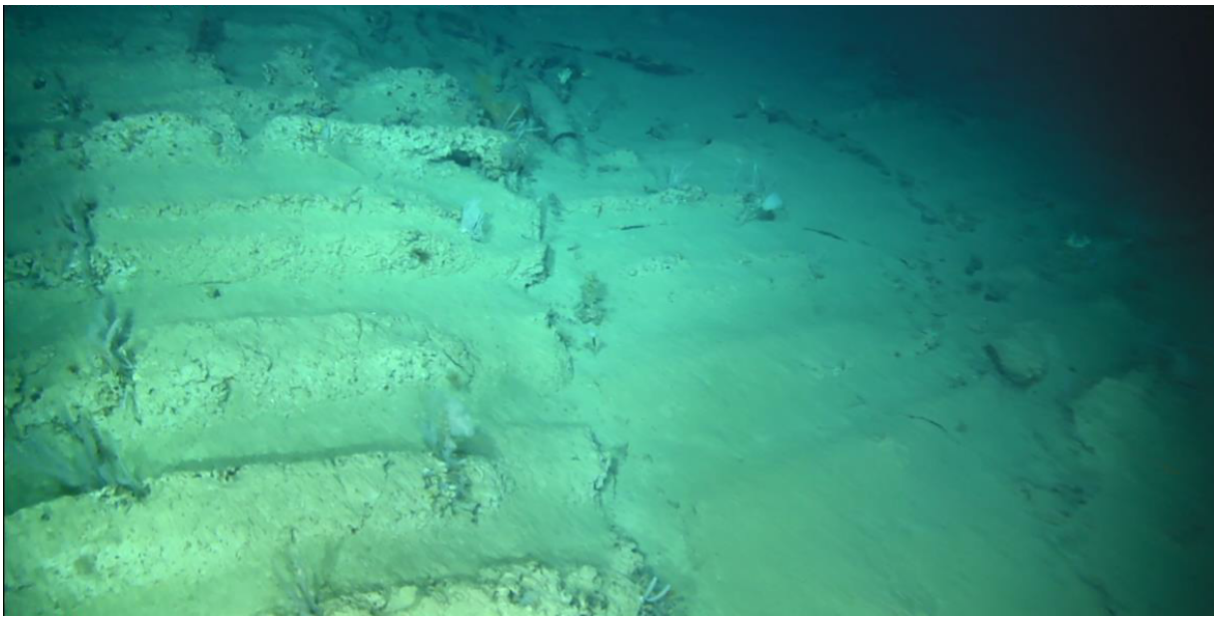
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge



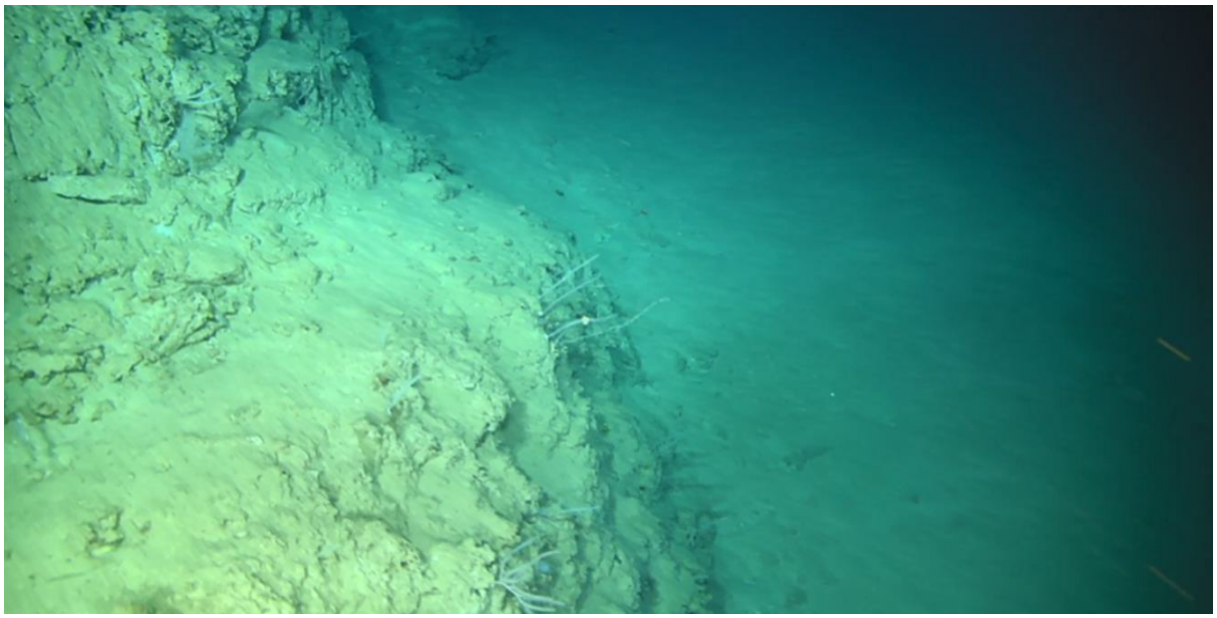
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only



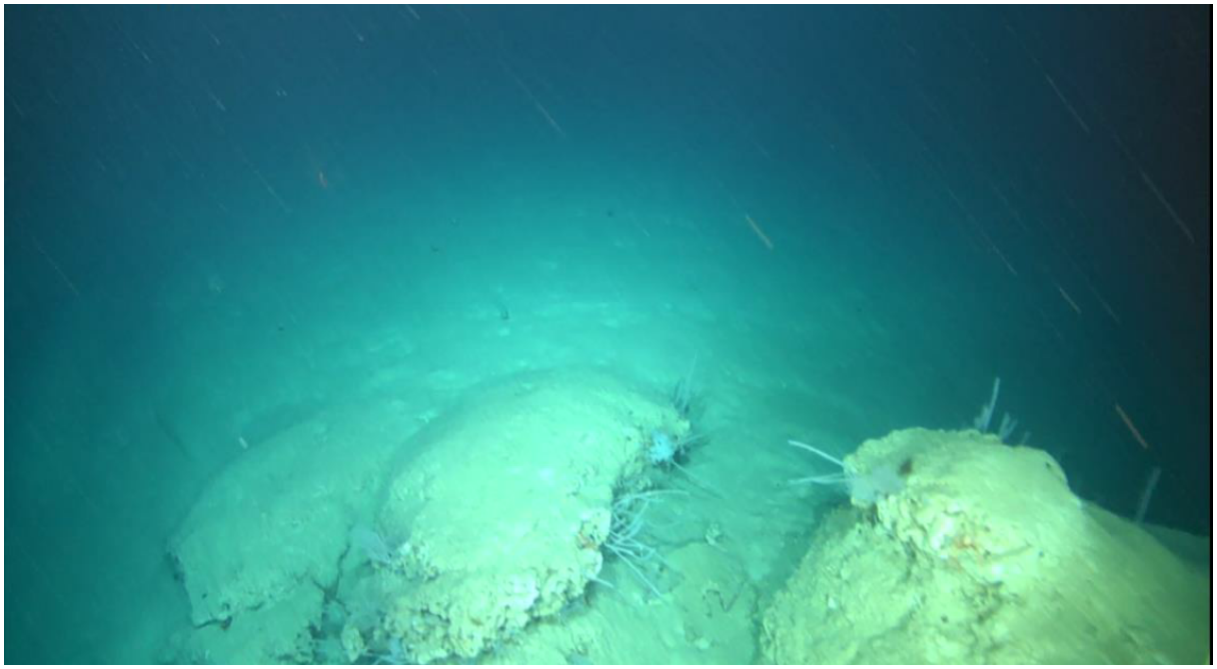
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with biota and sparse veneer > Mixed biota



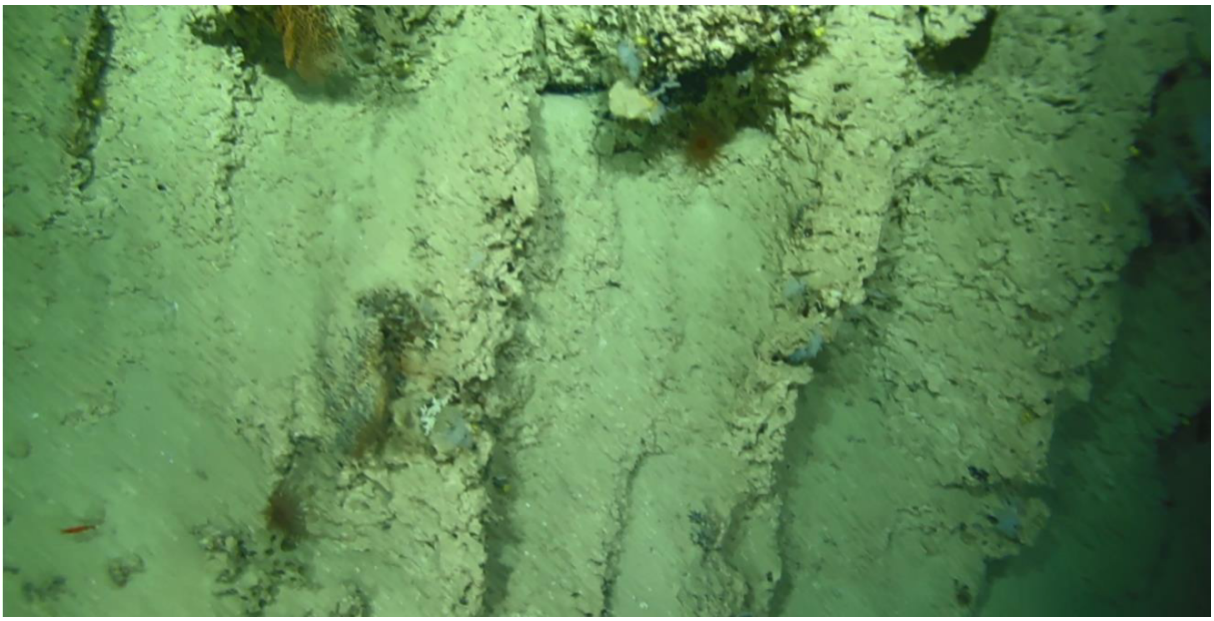
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Veneer with biota > Cnidaria



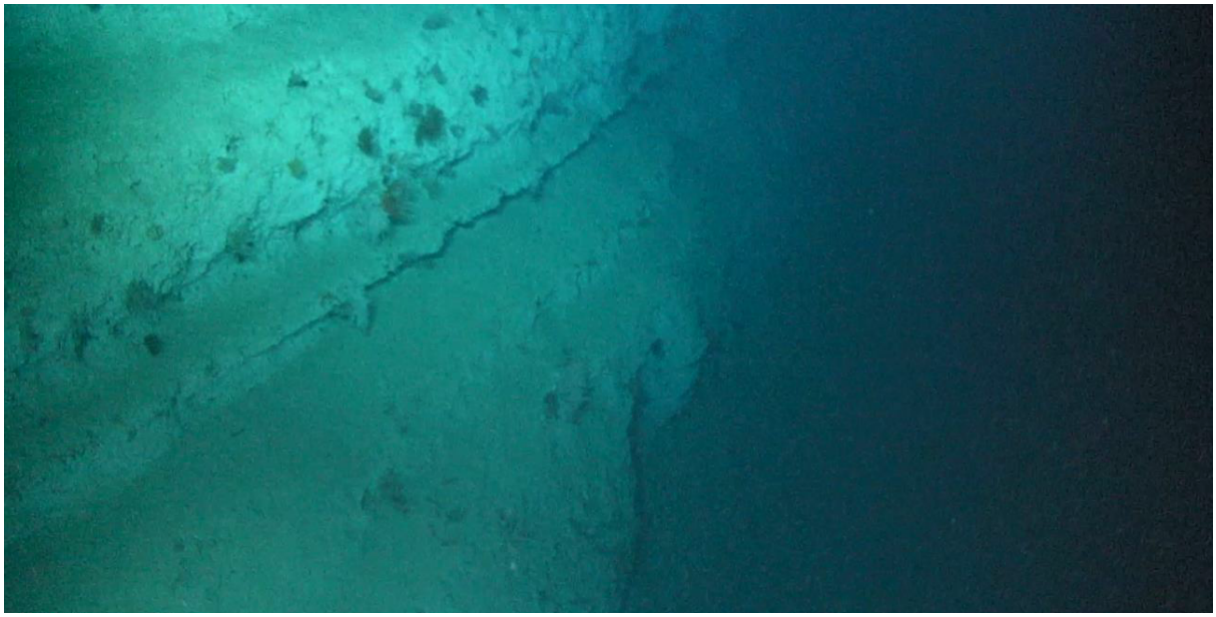
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Veneer with biota > Mixed biota



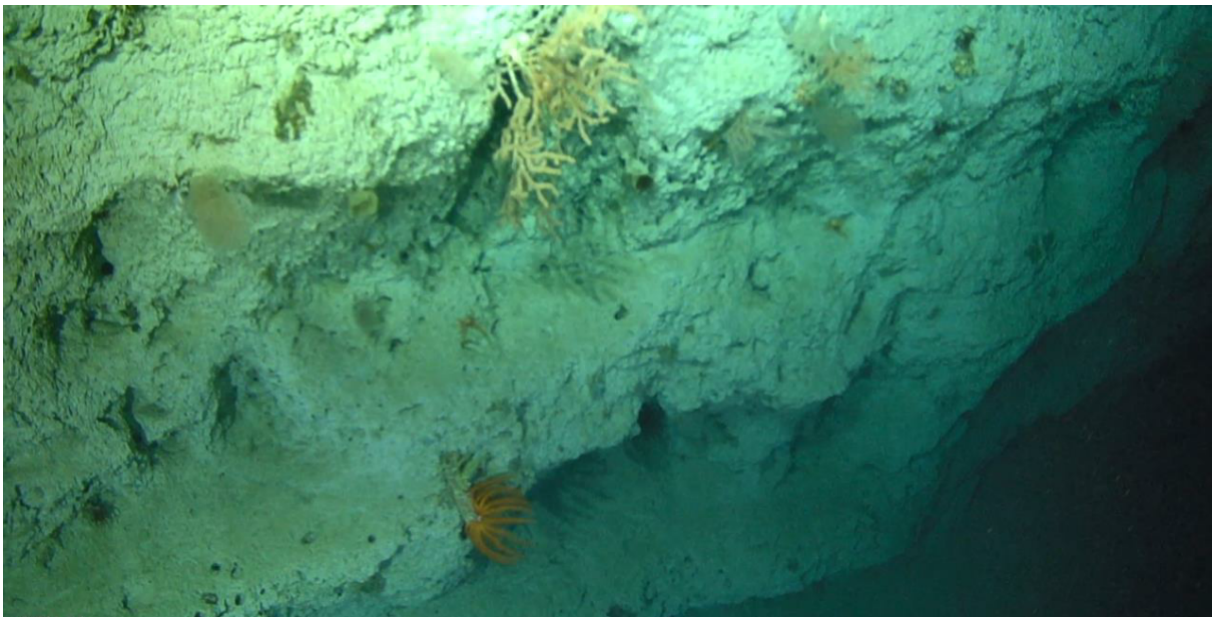
Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Cnidaria



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge



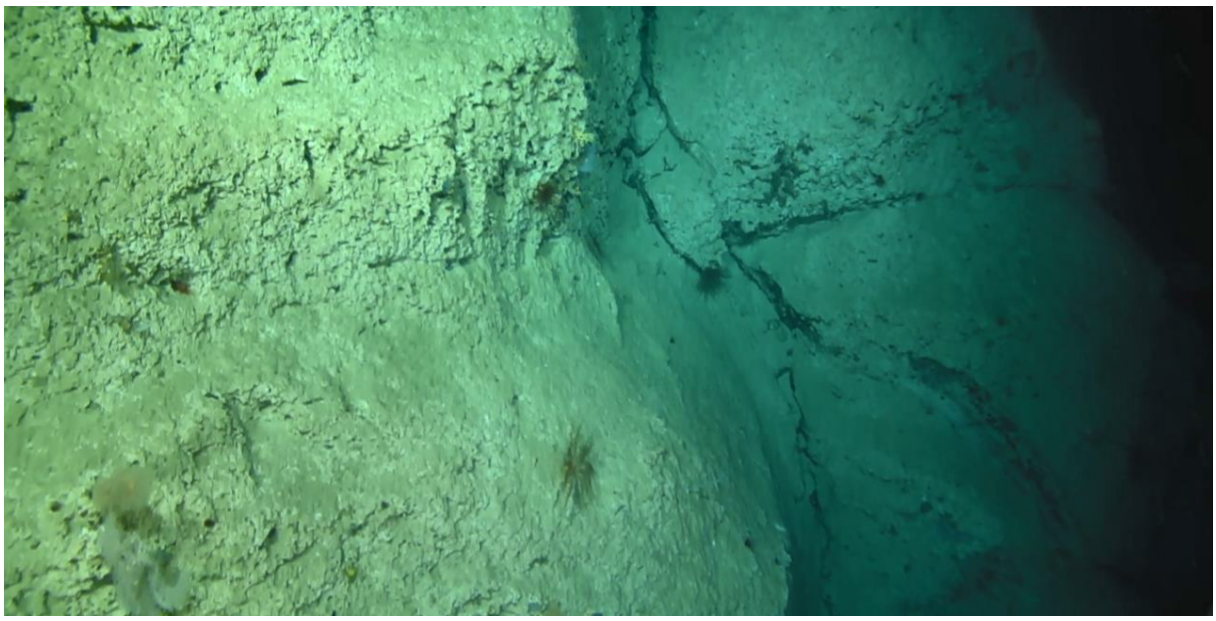
Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Mixed biota



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Mixed biota



Wall > Unconsolidated (soft) >Sand/mud (<2 mm) > Veneer with biota > Mixed biota



Appendix C Video Analysis Quality Assurance and Quality Control

Appendix C Video analysis QAQC

Throughout the benthic habitat video analysis Advisian marine scientists analysed 631 AVI video files in Transect Measure (SeaGIS 2021) software using agreed CATAMI habitat classifications. A video QAQC process was preformed after the initial analysis, where 5% of analysed videos were re-analysed by a different Advisian scientist (Table 1-1). Each QAQC video was re-analysed using the Transect Measure function which assigns a random video frame within a video file. Each random frame was checked using the CATAMI habitat classifications to determine if the appropriate habitat classification had been assigned during that video timestamp. Throughout the re-analysis of 31 QAQC videos none required to be corrected.

Table 1-1 TransectMeasure video analysis QAQC checks.

QAQC Number	File name	Frame	Time (HMS)	Original Classification	QAQC Classification Check
1	Semele Well 4 T3_2022-05-08_181807_Ch1_01.avi	0	17:41.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
2	Acme T1_2022-05-01_122717_Ch1_00.avi	44995	57:01.8	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Bioturbation with no biota	Correct
3	BCH 03 T2_2022-05-03_110838_Ch1_00.avi	8376	14:37.0	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Bioturbation with no biota	Correct
4	Semele Well 4 T2_2022-05-08_173330_Ch1_00.avi	29856	52:59.2	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
5	BCH 03 T3_2022-05-03_130140_Ch1_02.avi	0	02:03.0	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Biota only, Cnidaria	Correct
6	BCH 04_2022-05-02_021434_Ch1_00.avi	7347	19:23.3	Low (<1 m), Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

7	TRNS BCH 11 - BCH 03_2022-05-03_082146_Ch1_02.avi	89	22:10.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
8	TRNS BCH 11 - BCH 03_2022-05-03_072150_Ch1_00.avi	579	22:11.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
9	BCH 33_2022-05-09_162619_Ch1_00.avi	0	25:54.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
10	Chandon DC-1 T2_2022-05-07_045221_Ch1_00.avi	590	51:55.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
11	Chandon DC-1 T1_2022-05-07_044653_Ch1_01.avi	2446	48:05.8	Low (<1 m) Unconsolidated (soft)Sand/mud (<2 mm) Bioturbation with no biota	Correct
12	BCH 25_2022-05-01_095939_Ch1_00.avi	22206	14:13.7	Wall Consolidate (hard) Rock (Outcropping bedrock) Biota only Sponges, Cnidaria	Correct
13	Dionysis NTB3 T1_2022-05-04_152846_Ch1_00.avi	44586	57:53.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

14	Chrysaor Central D1_3 T5_2022-05-04_055432_Ch1_00.avi	0	53:58.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
15	BCH 34_2022-05-09_201041_Ch1_01.avi	8549	15:56.0	Wall Consolidate (hard) Rock (Outcropping bedrock) Biota only Mixed (all 3)	Correct
16	Jansz DC2 T1_2022-05-05_173552_Ch1_00.avi	0	35:25.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
17	BCH 33_2022-05-09_162619_Ch1_00.avi	21569	40:16.8	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
18	STB4 T2_2022-05-03_200849_Ch1_00.avi	0	26:53.5	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
19	TRNS BCH 06 - BCH 09_2022-05-06_113431_Ch1_01.avi	44728	33:58.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
20	TRNS BCH 12 - BCH4_2022-05-01_213849_Ch1_00.avi	27253	56:43.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with biota Mixed (all 3)	Correct
21	BCH 25_2022-05-01_102939_Ch1_01.avi	8302	34:58.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

22	TRNS BCH 30 - BCH 20_2022-04-29_173448_Ch1_00.avi	994	34:42.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
23	BCH 17_2022-04-28_111142_Ch1_00.avi	14040	21:00.6	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Ripples (<10 cm height) with no biota	Correct
24	BCH 01_2022-05-07_024821_Ch1_02.avi	1836	49:09.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
25	BCH 03 T2_2022-05-03_110838_Ch1_00.avi	8376	14:37.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
26	Acme T3_2022-05-01_133845_Ch1_00.avi	37430	03:26.2	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
27	BCH 14_2022-05-04_122516_Ch1_02.avi	2428	40:26.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
28	BCH 14_2022-05-04_112519_Ch1_00.avi	11583	32:27.3	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
29	Acme T4_2022-05-01_140716_Ch1_00.avi	34468	29:59.7	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
30	BCH 01_2022-05-07_020825_Ch1_00.avi	18402	20:17.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct

31	TRNS Jansz DC2 - JMT_2022-05-05_202938_Ch1_02.avi	44922	59:05.9	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

Appendix D
Fish Survey Report

Greater Gorgon Benthic Habitat Survey; Fish and Crustacean assemblages

November 2022

Ben Saunders, Melanie Stott, Karl Schramm, Damon Driessen





Version	Author	Recipients	Organisation	Date
1	Ben Saunders	Mark Westera	Advisian Pty. Ltd.	11/11/2022
2	Ben Saunders	Mark Westera	Advisian Pty. Ltd.	03/02/2023

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List of acronyms and abbreviations

Acronym/Abbreviation	Definition
AAIW	Antarctic Intermediate Water
CAPL	Chevron Australia Pty Ltd
CTD	Conductivity, Temperature and Depth
df	Degrees of Freedom
DistLM	Distance based Linear Model
GBF	Gorgon Gas Development Back Fields
GF	Geomorphic Features
KEF	Key Ecological Features
MC	Monte-Carlo
MS	Mean squares
nMDS	Non-metric Multidimensional Scaling
OPP	Offshore Project Proposal
PERMANOVA	Permutational Multivariate Analysis of Variance
perms	Permutations
P(perm)	P value calculated from permutations of the data
Res	Residuals
ROV	Remotely Operated Vehicle
SE	Standard Error
SICW	Southern Indian Central Water
SS	Sum-of-squares
TSW	Tropical Surface Water
WTR	Western Tryal Rocks

1. Introduction

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area: Geryon, Eurytion, Chandon, Semele, Chrysaur, Dionysus and West Tryal Rocks (WTR) (hereafter; collectively known as Gorgon Gas Development: Backfill Fields, GBF; Figure 1). The fields are located between ~60–130 km north-west of Barrow Island, Western Australia, in water depths ranging from 150 m (WTR) to 1,300 m (Chandon). Multiple subsea facilities such as flowlines, umbilicals and drill centres/well infrastructure sites may be required for the development of each field. Although the final flowlines and umbilical routes have not been identified yet by CAPL, the study sites are focused on indicative flowline and umbilical routes, tie-in locations and indicative drill centres.

The GBF project area spans three Key Ecological Features (KEF) of the Commonwealth marine environment; from the Exmouth Plateau in the west, to the Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour (Figure 1). These KEFs are likely to be relatively topographically complex and support a range of benthic habitats and organisms such as soft deep-sea coral, sea fans (gorgonians), sponges as well as regionally significant stocks of demersal fishes. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd (Advisian) to characterise the marine benthic environment within the GBF project area. Curtin University were commissioned to describe fish and crustacean assemblages within the GBF project area.

In northwest Western Australia, the marine region is recognised as a biodiversity hotspot (Fox and Beckley, 2005), and supports economically important industries, including commercial fisheries (Gaughan and Santoro, 2020) and oil and gas (Bond et al., 2018; McLean et al., 2018). The shallow water fish assemblages in this area are relatively well studied, however, a substantial amount of these industries operate in the deep sea (Armstrong et al., 2012), and the deeper marine habitats and their associated biodiversity are relatively understudied and poorly understood in this region (Currey-Randall et al., 2021). This is because sampling in deep water is expensive and logistically challenging (Saunders et al., 2021; Wellington et al. 2021), and previous studies have relied on extractive and destructive techniques such as trawling (Williams et al. 2001). Research on deep-water ecosystems using non-invasive methods, such as remotely operated vehicles (ROVs) (Schramm et al., 2020; Sward et al., 2019), is important as these ecosystems are vulnerable to anthropogenic impacts (Rogers, 2015)

and they provide structurally diverse and ecologically important habitats for marine species, many of which may not have been described (Appeltans et al., 2012).

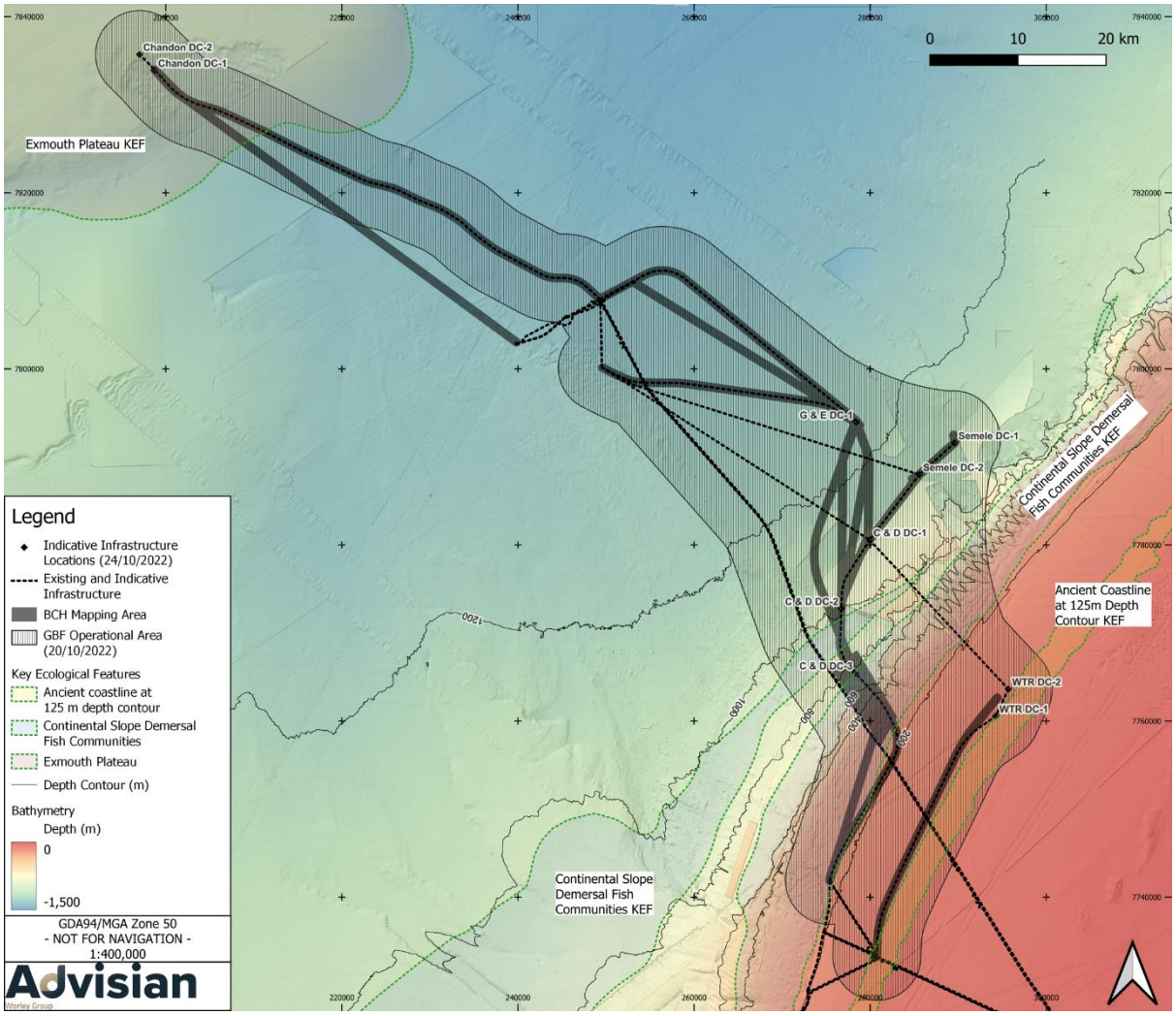


Figure 1. Context map illustrating existing and indicative infrastructure locations, the mapping area and the locations of the Key Ecological Features (KEFs). Map supplied by Advisian Pty. Ltd.

Key ecological features (KEFs) are areas in the marine ecosystem of regional importance as they are recognised as having high biodiversity or significant ecosystem function (Falkner et al., 2009). In northwest Western Australia, there are 13 KEFs, however, there is limited information on the faunal diversity and habitat structure in these areas, particularly those located in deeper water (Currey-Randall et al., 2021). The KEFs in the study area are the Exmouth Plateau, Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour, which are some of the least studied KEFs in Australia (Hayes et al., 2015). As the pressures on the marine environment intensify, the function and biodiversity of the ecosystems associated with KEFs need to be described and understood to manage and mitigate these impacts (Saunders et al., 2021).

The deep sea marine environments in this region are diverse and can be characterised by their geomorphic features (Heap and Harris, 2008), which may be associated with distinctive biological assemblages (Last et al., 2010). In the deeper waters of northwest Western Australia which encompass the study area, the geomorphic features (GFs) of interest are: 1) Plateaus; 2) Trench/troughs; 3) Deep/hole/valleys; and 4) Slopes. Plateaus are defined as areas of high elevation bordered by closely spaced contours of increasing depth, while trenches and troughs can be defined by an elongate depression of V-shaped/flat bottom contours of increasing depth, bordered on both sides by more closely spaced contours of decreasing depth (Heap and Harris, 2008). Deep/hole/valley features are concave or tapered depressions bordered by closely enclosed contours and laterally converging contours of increasing depth (Heap and Harris, 2008).

The aims of this study are:

1) To describe the fish and crustacean assemblages in a regional and environmental context.
2) To describe and compare the fish and crustacean assemblages within the KEFs.
3) To describe and compare the fish and crustacean assemblages within each Geomorphic Feature.

2. Methods

Study Site

The survey was conducted off the north-west coast of Western Australia. The survey encompassed a large area of seabed located between 55 and 185 km to the north-west of Barrow Island in water depths ranging from approximately 130 m to approximately 1270 m. The survey area encompassed three KEFs. These features were the Ancient coastline at 125 m depth contour, the Continental Slope Demersal Fish Communities, and the Exmouth Plateau. The survey also covered four Geomorphic areas (Figure 3). These were the continental slope, trench/trough, deep/hole/valley, and plateau GFs. Each site was classified according to the KEF and GF in which it was situated (Appendix Table 1).

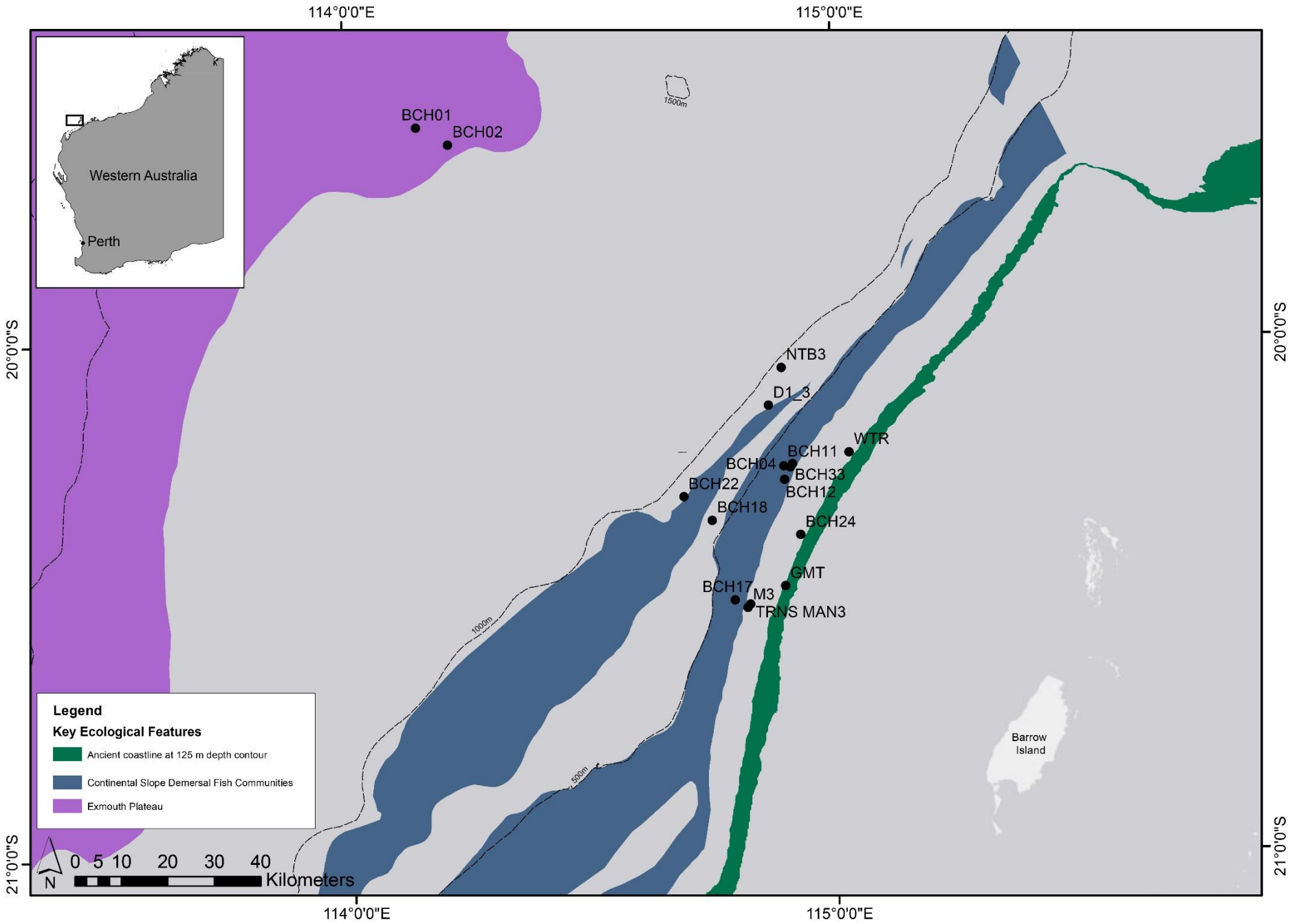


Figure 2. Context map illustrating the survey sites overlaid upon a map of the Key Ecological Features (KEFs) (Falkner et al., 2009). The inset illustrates the location of the study area off the coast of Western Australia.

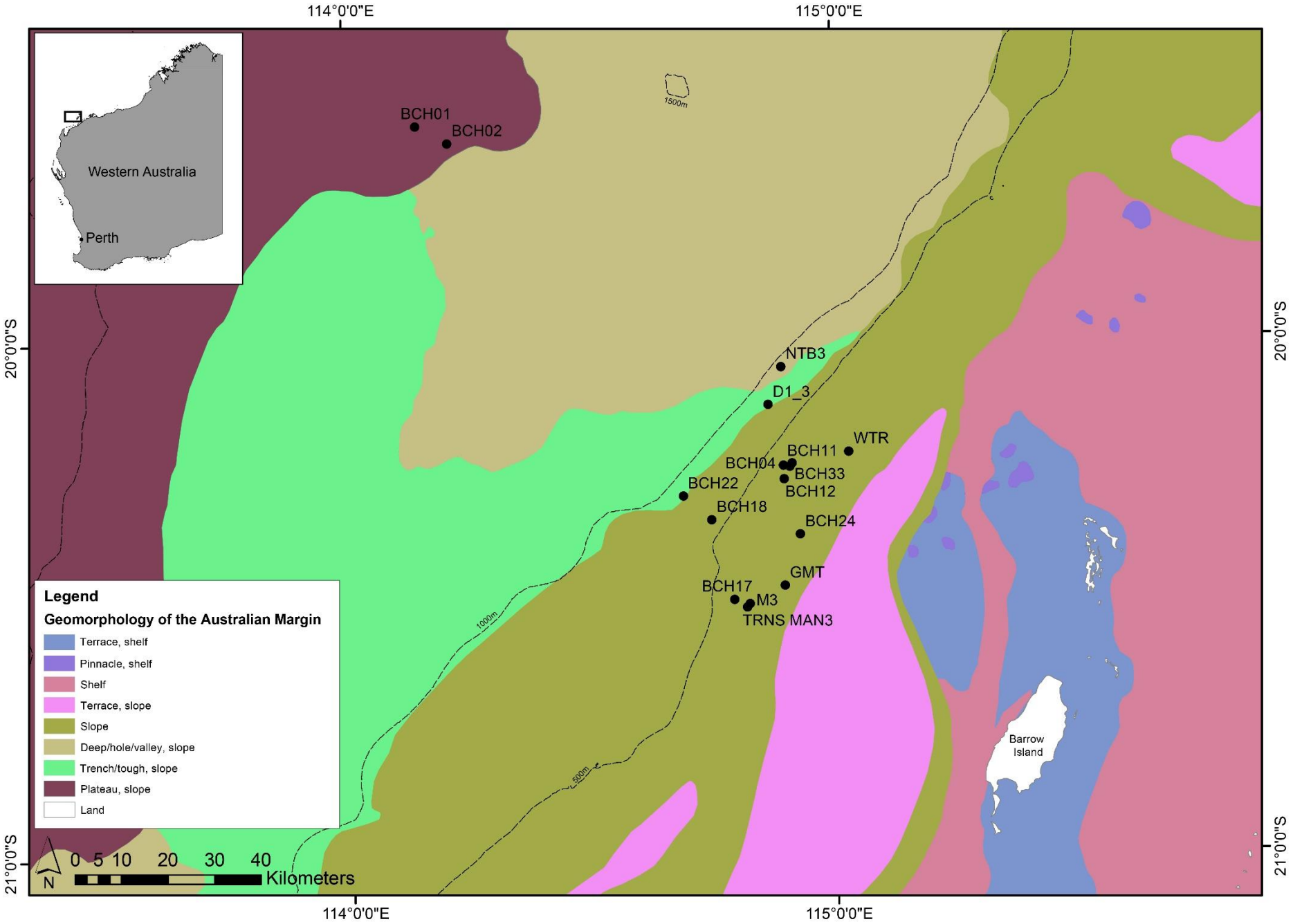


Figure 3. Context map illustrating the survey sites overlaid upon a map of the Geomorphology of the Australian Margin, or Geomorphic features (GFs) (Heap and Harris, 2008). The inset illustrates the location of the study area off the coast of Western Australia.

Video collection and analysis

Video transects were collected using a working class Remotely Operated Vehicle (ROV), fitted with a forward and slightly downward facing high definition video camera and flood lighting.

Video footage was analysed using the EventMeasure Stereo software (SeaGIS 2022). Identifications were made of fish, crustaceans and other mobile invertebrate species. An extensive reference library of images and videos in combination with taxonomic literature (for example Poore et al., 2008; Last & Stevens, 2009; Swainston, 2010; Flynn & Pogonoski, 2012) and online resources (for example Froese & Pauly, 2022; CSIRO, 2022) were used to aid species identification. In many cases identification to species level was not possible. In such cases species were identified to the lowest taxonomic resolution that was possible and the species was labelled with a descriptive annotation. In some cases, it was consistently difficult to observe identifying features, the taxa were very small, or the footage collected was not of a quality that allowed identification of taxa to a low taxonomic resolution. In these cases a conservative approach was taken and these were classified according to morphological descriptions. This was often the case for crustaceans and other mobile invertebrates. When identifying the decapod crustaceans, there were a number of species observed which could have been classified as either Dendrobranchiata (prawns) or Caridea (true shrimp). The only way to distinguish between this suborder and infraorder is by gill structure, which can't be inferred from the video. Therefore we took a conservative approach to identification and these decapod crustaceans are referred to as 'prawn' species differentiated by morphology, for example, Red prawn sp1. By taking this approach diversity could be measured, even where positive identification to low taxonomic level was not possible.

Using the EventMeasure software each fish or mobile invertebrate individual that was encountered along each transect was identified and counted following the principles outlined in Goetze et al. (2019). Where a fish could be positively identified as re-entering the field of view immediately after leaving the field of view it was not re-counted. However, in most cases each individual encountered was recorded.

Initial species identifications were made by analysts with experience in the identification of deep-water Australian fish and crustacean species. Identifications were made in a collaborative environment where difficult identifications could be discussed between analysts. Once analysed another experienced analyst made a secondary species identification check. As it was difficult to describe many of the organisms to a low taxonomic resolution, a particular emphasis was placed on consistent application of identifications and naming conventions.

Environmental situation.

The environmental situation was characterised from Conductivity, Temperature and Depth (CTD) data that were collected for most sites. For each transect site the CTD data for Salinity (PSU) and temperature (°C) were taken as the mean of the last minute (60 observations) of the CTD cast. If a CTD cast was not recorded at a specific site the values were taken from the nearest cast with the most similar depth (Appendix Table 1). The salinity, temperature and depth data were used to characterise the oceanographic conditions and identify the water mass in which each site was located following Woo and Pattiaratchi (2008).

Standardisation of transect length for statistical analysis.

The surveys conducted at each site were of varying transect lengths. To allow robust statistical analysis a standard transect length of 200 m was chosen. This transect length was selected as it is similar to the 250 m length used in similar surveys (Saunders et al., 2021) and only six of the transect sites had a sampled length that was less than 200 m. At transects sites with a sampled length that was less than

200 m the whole length of transect was used. These transect sites and their respective lengths are outlined in Table 1. Because so few transects were less than 200 m in length, and the length of most of these was close to 200 m no multiplication factor or standardisation factor was applied to the abundance data. This allowed the same statistical approach to be used for analysis of the abundance based data (fish/crustacean assemblage data, number of fish/crustaceans) and diversity data (number of fish/crustacean taxa).

Table 1. The transect sites with a total length of less than 200 m

Transect site	Transect length (m)
Chrysaor Central D1_3 T4	189
Dionysus NTB3 T2	112
Dionysus NTB3 T3	191
Gorgon GMT T2	198
Gorgon GMT T3	141
Gorgon GMT T4	172

At transect sites that had a length greater than 200 m, the first 200 m section of the transect were selected for statistical analysis. At sites where the length sampled was greater than 400 m the transect was broken up into multiple replicate 200 m lengths with a 10 m gap to separate transects. These transects sites and their respective number of replicate 200 m transects are listed in Table 2. This approach resulted in a total of 71 replicate transects across the survey area.

Table 2. Transect sites with multiple replicate transects, and the number of replicate transects at each.

Transect site	Number of 200 m transects
BCH 01	6
BCH 02	5
BCH 04	4
BCH 11	4
BCH 12	2
BCH 17	6
BCH 18	3
BCH 22	5
BCH 24	5
BCH 33	3
Dionysus NTB3 T1	3
Gorgon M3 T1	2
Gorgon M3 T4	2
Gorgon M3 T5	2

Statistical analysis

All statistical analysis was conducted using PRIMER version 7 (Clarke & Gorley 2015) and the PERMANOVA + add in for PRIMER (Anderson et al 2008). Fish and crustacean assemblage data were visually assessed for dominant taxa using shade plots. The data were transformed to reduce the influence of any single dominant taxa. Fish assemblage data was fourth root transformed, and the crustacean assemblage data were square root transformed for statistical analysis. A Bray-Curtis similarity matrix was constructed on the transformed data and this was used for further multivariate statistical analysis.

To investigate the effect of depth on the composition of the multivariate fish and crustacean assemblages a Distance based Linear Model (DistLM) was constructed. For this analysis depth was the explanatory variable, and the fish or crustacean assemblages were the dependent variables.

To address the three aims of the study three different statistical designs were used. These were to assess differences in the fish and crustacean assemblages among water masses, among the KEFs, and among the GFs. For each analysis site was nested within the factor of interest as a random factor. The replicate transects were allocated sites according to their location, Figure 3, Appendix Table 1). Transect Trans Man 3 was allocated to site M3 for statistical analysis as this transect was directly adjoining site M3 (Appendix Table 1).

The statistical designs for each test were:

Water Mass

Factor 1 Water Mass, Fixed, three levels; Tropical Surface Water (TSW), Southern Indian Central Water (SICW), Antarctic Intermediate Water (AAIW).

Factor 2 Site, Random, nested within Water Mass, varying levels depending upon replication

Key Ecological Features

Factor 1 KEF, Fixed, four levels; Ancient Coastline at 125 m depth contour, Continental Slope Demersal Fish Communities, Exmouth Plateau, and Outside any KEF.

Factor 2 Site, Random, nested within KEF, varying levels depending upon replication

Geomorphic Features

Factor 1 Geomorphic Feature, Fixed, four levels; slope, trench/trough, deep/hole/valley, plateau.

Factor 2 Site, Random, nested within Geomorphic Feature, varying levels depending upon replication

Non-metric Multidimensional Scaling (nMDS) plots were used to illustrate patterns in the fish and crustacean assemblages according to each of the factors of interest. Vectors were overlaid that illustrate the strength and direction of the Pearson's correlation of individual taxa to the data. Taxa with a correlation of greater than 0.5 are illustrated.

Post-hoc pairwise tests in PERMANOVA were done when statistically significant differences between levels of the factors of interest were detected. Post-hoc pairwise tests were also done where visual differences among means were apparent on the plots, or where the P value of the test for a factor of interest approached the convention of 0.05. This approach to testing for differences was taken following the precautionary principle because of the variable numbers of replicate samples between the levels of the factors of interest. Where the numbers of unique permutations was low Monte-Carlo (MC) bootstrapping was used to calculate the P value.

Univariate tests of the number of fish, number of fish taxa, number of crustaceans, and number of crustacean taxa were carried out according to the same statistical design. For these univariate tests the data were not transformed, and a Euclidean distance resemblance matrix was used. Plots of means and standard errors were used to illustrate patterns among the factors of interest.

3. Results

Environmental situation

The CTD data collected at sampling depth revealed three distinct temperature and salinity regimes (Figure 4). Following Woo and Pattiaratchi (2008) three water masses were identified through the relationship between temperature and salinity (Figure 4B). These were the same three water masses identified in Saunders et al. (2021). The shallowest sites, in water depths less than 150m, were characterised by high temperatures (~28 °C) and salinities of 35.3 PSU (Figure 4). This was identified as the Tropical Surface Water (TSW) water mass. The sites sampled in between 200 and 270 m water depth were characterised by a higher salinity (35.39 – 35.46 PSU) and a water temperature between 15 and 19 °C (Figure 4). These were classified as Southern Indian Central Water (SICW). The deepest sites, at 800 m or greater water depth had cold temperatures (less than 6 °C) and salinity less than 34.8 PSU (Figure 4). This was Antarctic Intermediate Water (AAIW) (Woo and Pattiaratchi, 2008).

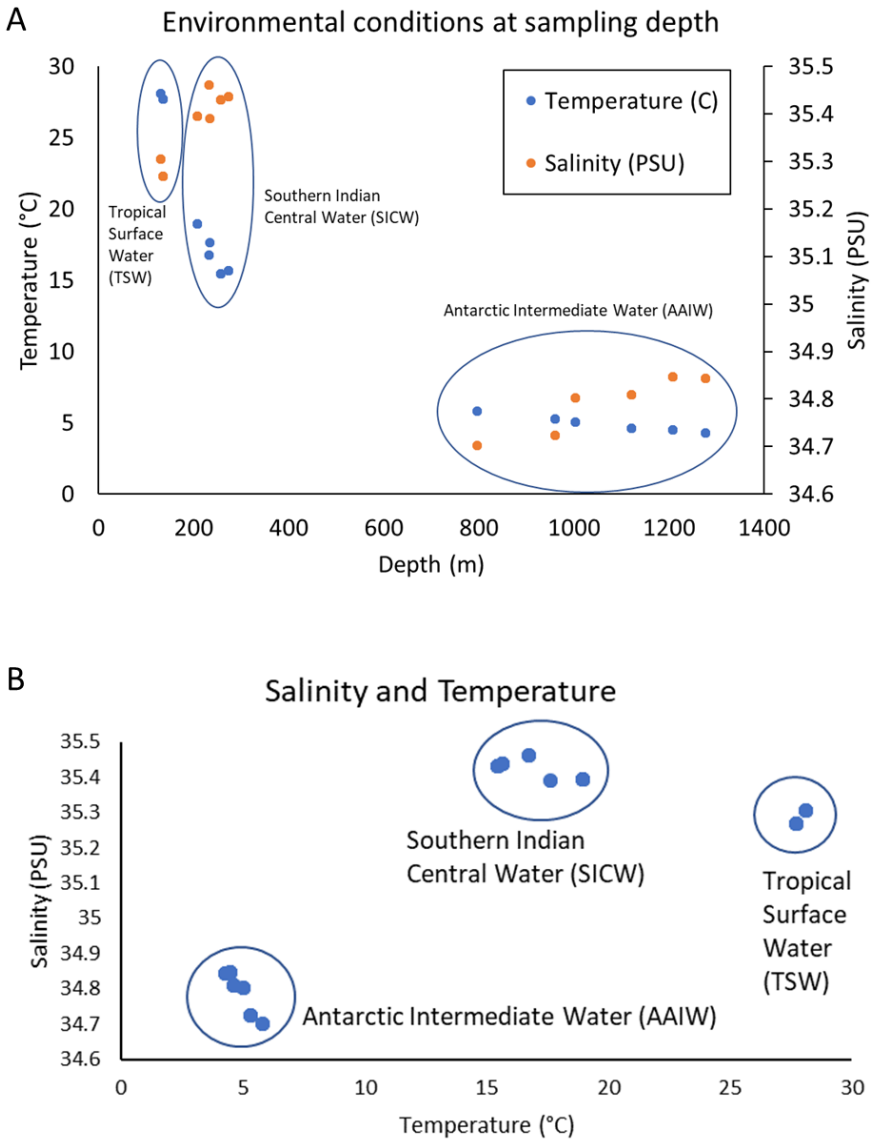


Figure 4. Environmental conditions at sampling depths. A illustrates the change in both Temperature and Salinity with depth. B illustrates the relationship between Salinity and Temperature. Circles indicate groupings of samples by the three identified water masses.

General descriptions of the survey areas

Key Ecological Feature (KEF)

Continental Slope Demersal Fish Communities

Within the Continental Slope Demersal Fish Communities KEF, a total of 4.11 km of transect was analysed, where 28 fish taxa were recorded with a total of 519 fish. The fish assemblage was dominated by Trevallies (Carangidae), with 4 species from 3 genera accounting for 271 of the individuals observed. The five most abundant fish taxa were *Decapterus* sp1, *Seriola dumerili*, an unidentified bait fish, *Decapterus kurroides,* and Synodontidae sp2 (Table 3). Five transect sites were located within the Continental Slope Demersal Fish Communities KEF. These were BCH04, BCH11, BCH12, BCH17, and BCH33. The transect length at these sites was 867 m, 932 m, 412 m, 1280 m, and 619 m respectively. At BCH04 the most abundant fish taxa were an unidentified bait fish, Synodontidae sp2, and *Decapterus* sp1, accounting for 82 of the 105 individuals recorded on the transect (Appendix Table 2). The most abundant taxa at BCH11 were *Seriola dumerili*, *Decapterus* sp1, and Synodontidae sp2, which accounted for over 93% of the total recorded individuals at the site (Appendix Table 2). *Decapterus* sp1 and Synodontidae sp2 were also the most abundant taxa at BCH17, whereas site BCH12 was dominated by *Decapterus kurroides* (Appendix Table 2). BCH33 had a large number of an unidentified anguilliform fish taxa and an abundance of Synodontidae sp3 and *Pristipomoides typus* (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 3. Most abundant fish taxa in the Continental Slope Demersal Fish Communities KEF transects

Family	Taxa	Number of individuals
Carangidae	*Decapterus kurroides*	63
	Decapterus sp1	103
	Seriola dumerili	91
Synodontidae	Synodontidae sp2	52
N/A	unidentified bait fish	69

Only two of the five sites in Continental Slope Demersal Fish Communities KEF recorded crustaceans; BCH04 and BCH17. At these sites, a total of 5 crustaceans were recorded, with each being different taxa. Two were from the infraorder Anomura, one from the infraorder Brachyura, one from the infraorder Achelata, and one unknown (Table 4). Images of the ten most abundant crustacean taxa across the survey area are presented in Appendix 1 Table 29.

Table 4. Crustacean taxa in the Continental Slope Demersal Fish Communities KEF transects

Infraorder	Family	Taxa	Number of individuals
Anomura	Galatheidae	Galatheidae sp. G	1
Brachyura	Homolidae	Homolidae spH	1
Achelata	Ibacinae	*Ibacus* spI	1
Anomura	Parapaguridae	Parapaguridae spPP	1
unknown	N/A	Red prawn sp7	1

Ancient Coastline at 125 m depth contour

The Ancient Coastline at 125 m depth contour KEF sites recorded 13 fish taxa with a total of 18,011 individuals along 1.03 km of transect. The fish assemblage was dominated by Trevallies (Carangidae), with three species representing 14,231 of the total individuals. The most abundant fish taxa were *Carangoides* sp1, an unidentified baitfish, *Seriola dumerili*, *Carcharhinus* sp1, and *Rachycentron canadum* (Table 5). The five transects which make up the Ancient Coastline at 125 m depth contour KEF were all located at the Gorgon GMT site, with transect lengths of 269 m, 198 m, 141 m, 172 m, and 247 m, respectively. At transect 1 (T1) the most abundant fish taxa were an unidentified baitfish species and *Carangoides* sp1 which together made up 3,451 of the 3,591 total observed number of fish (Appendix Table 2). *Carangoides* sp1 represented more than 95% of the total observed fish individuals in T2, with the next most abundant taxa being *Seriola dumerili* (Appendix Table 2). T3 and T5 were also dominated by *Carangoides* sp1, representing more than 94% and 97% of the total fish respectively, with *Seriola dumerili* as the next most abundant taxa in T3, and *Carcharhinus* sp1 in T5 (Appendix Table 2). *Carangoides* sp1 was also the most abundant taxa in T4, with unidentified bait fish the second most abundant taxa recorded in the transect (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 5. Most abundant fish taxa in the Ancient Coastline at 125m depth contour KEF transects

Family	Taxa	Number of individuals
Carangidae	*Carangoides* sp1	13,835
	Seriola dumerili	381
Carcharhinidae	*Carcharhinus* sp1	189
Rachycentridae	*Rachycentron canadum*	45
N/A	unidentified baitfish	3,454

Only one crustacean was recorded in the Ancient Coastline at 125m depth contour KEF, at the Gorgon GMT T1 site; an unidentified prawn species (Appendix Table 3).

Exmouth Plateau

The Exmouth Plateau KEF was represented by two sites; BCH01 and BCH02, which recorded a total of 165 individuals from 14 taxa in 2.57 km of transect. The lengths of the transect at each site were 1437 m and 1129 m respectively. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois* sp1, together representing over 65% of the total number of individual fish recorded. Other abundant taxa included *Aldrovandia* sp1, *Aldrovandia* sp2, and Macrouridae sp2 (Table 6). At BCH01, *Bathypterois* sp1 was the most abundant taxa with 30 of the total 73 individual fish, with the second most abundant taxa being an unidentified anguilliform fish (Appendix Table 2). The same two taxa were also the most abundant at the BCH02 site, but the unidentified anguilliform fish was by far the most dominant, representing almost 60% of the total recorded individual fish for the transect (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 6. Most abundant fish taxa in the Exmouth Plateau KEF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	70
Ipnopidae	*Bathypterois* sp1	38
Halosauridae	*Aldrovandia* sp1	11
	Aldrovandia sp2	7
Macrouridae	Macrouridae sp2	8

The crustacean assemblage for the Exmouth Plateau KEF consisted of seven taxa with a total of 228 individuals recorded. Red prawn sp7 was the most dominant crustacean taxa representing over 81% of the total number of individuals. The next most abundant species was pink prawn sp9 and orange prawn sp8 (Table 7). At BCH01, red prawn sp7 dominated the site with 107 of the recorded 128 total individuals, with pink prawn sp9 the next most abundant taxa with 9 individuals (Appendix Table 3). Similarly, red prawn sp7 and pink prawn sp9 at BCH02 accounted for 78% and 14% of the total number of individuals recorded respectively (Appendix Table 3). Images of the ten most abundant crustacean taxa across the survey area are presented in Appendix 1 Table 29.

Table 7. Most abundant crustacean taxa in the Exmouth Plateau KEF transects

Taxa	Number of individuals
Red prawn sp7	185
Pink prawn sp9	23
Orange Prawn sp8	9

Sites outside the KEFs

There were 21 sites outside of the KEF areas, with a total of 9.05 km of transect analysed, with transect lengths ranging from 112 m to 1242 m (Table 8). These sites recorded a total of 15,828 individual fish from 41 taxa. The five most abundant taxa from these sites were *Trachurus novaezelandiae, Seriola dumerili,* an unidentified baitfish species, an unidentified anguilliform fish species, and *Carcharhinus* sp1 (Table 9). 11,007 of the total individual fish were recorded at the BCH24 site, which was dominated by *Trachurus novaezelandiae* (78% of total individuals) and an unidentified baitfish species (21% of total individuals; Appendix Table 3). The Gorgon M3 sites were dominated by *Seriola dumerili* (99% of total individuals), whereas the WTR DC-1 sites had a high abundance of the unidentified baitfish species and *Trachurus novaezelandiae* (Appendix Table 2). Site BCH18 had an unidentified anguilliform fish species as its most abundant taxa, followed by Macrouridae sp2, while the TRNS MAN3 to T3 transect was dominated by *Seriola dumerili* (Appendix Table 2). The other sites (BCH22, Chrysaor Central D1_3 transects and Dionysus NTB3 transects) are summarised in their Geomorphic Feature (GF) sections. Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 8. Transect lengths of sites outside of the KEF areas

Site	Transect length (m)
BCH18	677
BCH22	1137
BCH24	1242
Chrysaor Central D1_3 T1	379
Chrysaor Central D1_3 T2	227
Chrysaor Central D1_3 T3	214
Chrysaor Central D1_3 T4	189
Dionysus NTB3 T1	690
Dionysus NTB3 T2	112
Dionysus NTB3 T3	191
Dionysus NTB3 T4	271
Gorgon M3 T1	546
Gorgon M3 T2	332
Gorgon M3 T3	359
Gorgon M3 T4	455
Gorgon M3 T5	407
TRNS MAN3 to T3	359
WTR DC-1 T1	366
WTR DC-1 T2	316
WTR DC-1 T3	271
WTR DC-1 T4	314

Table 9. Most abundant fish taxa in the sites outside of the KEF areas

Family	Taxa	Number of individuals
Carangidae	*Trachurus novaezelandiae*	8720
	Seriola dumerili	3858
Carcharhinidae	*Carcharhinus* sp1	101
N/A	unidentified baitfish	2685
N/A	unidentified anguilliform fish	155

Crustaceans were recorded in half of the sites outside the KEF areas; BCH18 and BCH22, the Chrysaor Central D1_3 transects, the Dionysus NTB3 transects, and at WTR DC-1 T1. A total of 694 individuals were recorded from 12 taxa, with all sites dominated by red prawn sp7 (Appendix Table 3). Red prawn sp7 accounted for 122 of the 143 total individuals observed on the BCH18 transect, whereas at WTR DC-1 T1 there was only one crustacean recorded; an unidentified prawn species (Appendix Table 3). The crustacean assemblages at the other sites (the Chrysaor Central D1_3 transects and the Dionysus NTB3 transects) are summarised in the GF section below.

General descriptions of the survey areas.

Geomorphic Feature (GF)

Deep/hole/valley

In the Deep/hole/valley GF there were 16 fish taxa and a total of 187 individuals recorded from 1.26 km of transect. The fish assemblage was dominated by an unidentified anguilliform fish species, representing 54% of the individuals observed. The next most abundant taxa were *Aldrovandia* sp1, followed by Macrouridae sp1, *Aldrovandia* sp2, and *Aldrovandia affinis* (Table 10). The four transects which make up the Deep/hole/valley GF were all located at the Dionysus NTB3 site. The first transect (T1) was dominated by the unidentified anguilliform fish species, accounting for 48 of the 70 recorded individuals (Appendix Table 2). This was similar for T2 and T4, with the unidentified anguilliform fish species most abundant in both transects and the 3 *Aldrovandia* species accounting for the vast majority of the remaining taxa recorded (Appendix Table 2). T3 again had the unidentified anguilliform fish as the most abundant taxa but was followed by Macrouridae sp1 and *Aldrovandia* sp1 (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 10. Most abundant fish taxa in the Deep/hole/valley GF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	101
Halosauridae	*Aldrovandia* sp1	19
	Aldrovandia sp2	8
	Aldrovandia affinis	7
Macrouridae	Macrouridae sp2	11

The crustacean assemblage in the Deep/hole/valley GF consisted of 110 individuals recorded from four taxa. The assemblage was dominated by red prawn sp7 which accounted for almost 71% of the total individuals across the sites (Table 11). The first transect (T1) had the highest number of individuals recorded, with the red prawn species as the most abundant taxa, representing 71% of the total number of individuals, with orange prawn sp8 as the next most abundant taxa (Appendix Table 3). T2 and T3 also had red prawn sp7 as the most abundant taxa, representing 83% and 71% of total individuals respectively, and both had a second red prawn, sp11 as the next most abundant taxa (Appendix Table 3). Red prawn sp7 again was the most abundant taxa in T4, followed by orange prawn sp8 and a second red prawn sp11 (Appendix Table 3).

Table 11. Crustacean taxa in the Deep/hole/valley GF transects

Taxa	Number of individuals
Red prawn sp7	78
Red prawn sp11	16
Orange prawn sp8	14
Pink prawn sp9	2

Slope

The Slope GF was made up of 22 sites with a total of 10.78 km of transect analysed, where 51 fish taxa were recorded with a total of 34,042 individuals. The fish assemblage was dominated by Trevallies (Carangidae) with 27,086 individuals from seven taxa. The five most abundant species were *Carangoides* sp1, *Trachurus novaezelandiae*, *Seriola dumerili*, an unidentified baitfish species, and *Carcharhinus* sp1, which together accounted for 98% of the total individuals (Table 12). The 22 sites in the Slope GF were BCH04, BCH11, BCH12, BCH17, BCH18, BCH24 and BCH33, the 5 Gorgon GMT transects, the 5 Gorgon M3 transects, the 4 WTR DC-1 transects, and the TRNS MAN3 to T3 site. Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 12. Most abundant fish taxa in the Slope GF transects

Family	Taxa	Number of individuals
Carangidae	*Carangoides* sp1	13,835
	Trachurus novaezelandiae	8,720
	Seriola dumerili	4,330
Carcharhinidae	*Carcharhinus* sp1	290
N/A	unidentified baitfish	6,208

Only five sites in the Slope GF contained crustaceans; BCH04, BCH17, BCH18 Gorgon GMT T1, and WTR DC-1 T1. The crustacean assemblage consisted of 150 individuals recorded from 11 taxa. Of these, 143 (95% of the total individuals) crustaceans were recorded from the BCH18 transect, which was dominated by two red prawn species, red prawn sp7 and red prawn sp11 (Appendix Table 3).

Plateau

The plateau GF contains the same two sites as the Exmouth plateau KEF (BCH01 and BCH02), so the fish and crustacean assemblages for this GF have been summarised above.

Trench/Trough

The Trench/Trough GF contained 129 individual fish from 17 taxa, recorded from 2.15 km of transect. The fish assemblage was distinguished by Macrouridae species, Halosauridae species, and an unidentified anguilliform species, which accounted for almost 88% of the total recorded individuals. The five most abundant taxa were the unidentified anguilliform species, *Aldrovandia* sp1, Macrouridae sp1, Macrouridae sp2, and Macrouridae sp4 (Table 13). Five transect sites were located in the Trench/Trough GF; BCH22 and the four Chrysaor Central D1_3 transects. Of the total individual fish, 70 were recorded at the BCH22 site, where the most abundant taxa was *Aldrovandia* sp1, followed by Macrouridae sp2 (Appendix Table 2). At the Chrysaor Central D1_3 sites, each transect had 9-18 total individual fish recorded, with the unidentified anguilliform species being the most abundant taxa for each site (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 13. Most abundant fish taxa in the Trench/Trough GF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	39
Halosauridae	*Aldrovandia* sp1	18
Macrouridae	Macrouridae sp1	7
	Macrouridae sp2	17
	Macrouridae sp4	17

The crustacean assemblage in the Trench/Trough GF consisted of eight taxa with 440 total individuals recorded. The assemblage was dominated by red prawn sp7, which made up almost 85% of the total individuals. The other abundant crustacean species included a dark prawn species (Dark prawn sp10), red prawn sp11, orange prawn sp8, and pink prawn sp9 (Table 14). Of the recorded crustaceans, 312 were found at the BCH22 site, which had red prawn sp7 as the most abundant taxa, representing almost 87% of the total individuals on that transect (Appendix Table 3). At the Chrysaor Central D1_3 sites T1-T4, the same red prawn species was also the most abundant taxa for each transect, representing 80%, 72%, 89%, and 75% of the total number of individuals on each respective transect (Appendix Table 3).

Table 14. Crustacean taxa in the Trench/Trough GF transects

Taxa	Number of individuals
Red prawn sp7	373
Dark prawn sp10	35
Red prawn sp11	12
Orange prawn sp8	10
Pink prawn sp9	6

Invertebrates

A total of 1,093 invertebrate individuals from 31 taxa were recorded across all sites. The invertebrate assemblage included 1 feather star (Cormatulida) species, 7 jellyfish (Scyphozoa) species, 7 sea cucumber (Holothuroidea) species, 8 sea star (Asteroidea) species, 7 sea urchin (Echinoidea) species and 1 squid (Cephlapod) species (Appendix Table 4). The assemblage was dominated by a brown jellyfish species (spJB) which accounted for 54% of the total number of individuals and were almost all recorded at site BCH22 (Appendix Table 4). The next most abundant taxa were *Peniagone* spPG, a purple sea cucumber species, Phormosomatidae spPH, and a purple sea urchin species (Table 15). Images of the ten most abundant invertebrate taxa are presented in Appendix 1 Table 30.

Table 15. Most abundant invertebrate taxa across all sites

Family	Taxa	Number of individuals
N/A	Brown jellyfish spJB	590
Elpidiidae	*Peniagone* spPG	83
N/A	Purple sea cucumber spSCP	64
Phormosomatidae	Phormosomatidae spPH	63
N/A	Purple sea urchin spSUBP	55

Statistical analysis

Fish assemblage

Across the whole survey area depth was an important predictor of the multivariate composition of the fish assemblage. A DistLM analysis found that depth alone explained 27% of the variation in the fish assemblage composition. (R^2 = 0.27177, Pseudo $F_{(1,69)}$ = 25.751, P<0.001).

Tests of differences in fish assemblage composition between water masses.

There was a significant difference in the fish assemblages of each of the three water masses (Table 16, Figure 5). The deeper water fish assemblages of the AAIW mass were different to the shallower water fish assemblages in both the SICW and the TSW water masses (Table 17). While some species were shared, the fish assemblage composition of the SICW and the TSW were also significantly different to one another (Table 19). The deeper waters of the AAIW were characterised by species that were correlated toward the left of the nMDS plot (Figure 5). These taxa included two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of Unidentified anguilliform fish, and a *Bathypterois* species (Ipnopidae). The fish assemblages of the TSW were separated from those of the SICW by a greater abundance of *Trachurus novaezelandiae* (Carangidae), an unidentified bait fish, and whaler shark *Carcharhinus* sp1 (Figure 5). The SICW water mass was characterised by a high abundance of *Seriola dumerilii* (Carangidae) and *Carcharhinus plumbeus*.

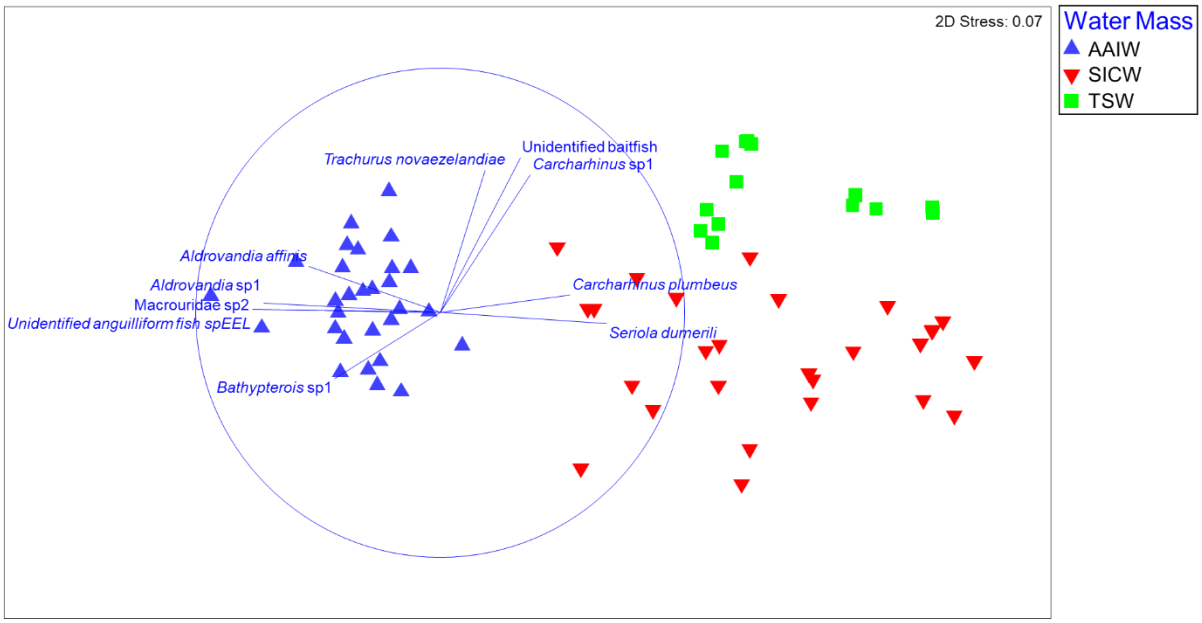


Figure 5. Non-metric Multidimensional Scaling Plot illustrating the difference in the multivariate composition of the fish assemblages among the Antarctic Intermediate Water (AAIW), Southern Indian Central Water (SICW) and Tropical Surface Water (TSW) masses. The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

Table 16. Results of multivariate and univariate PERMANOVA tests for differences among water masses for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	91807	45903	5.691	**<0.001**
Site(Water Body)	12	102640	8553	6.677	<0.001
Res	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	25538000	12769000	8.2766	**0.004**
Site(Water Body)	12	19772000	1647600	20.078	<0.001
Res	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	18.854	9.43	0.513	0.611
Site(Water Body)	12	233.970	19.50	7.626	<0.001
Res	56	143.180	2.56		

Table 17. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between water masses. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between water masses			
Groups	t	P(perm)	perms
AAIW, SICW	2.79	**0.002**	9921
AAIW, TSW	2.93	**0.006**	8939
SICW, TSW	1.43	**0.040**	9435

The mean number of fish per transect was much greater in the TSW mass than in either the SICW or the AIW masses (Figure 6). Despite this, there was no statistically significant difference in the mean number of fish taxa per transect between water masses (Figure 7). On average each transect had between four and six fish taxa.

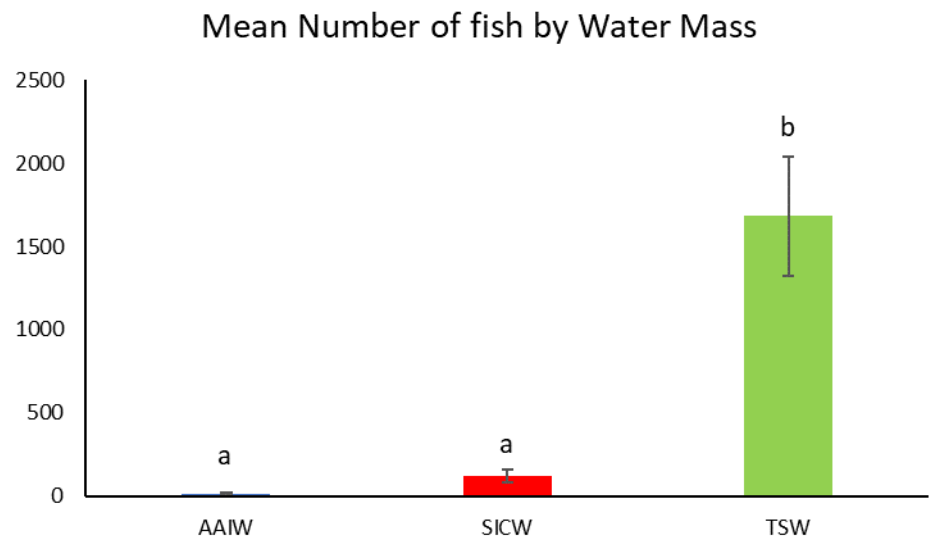


Figure 6. The mean (+- 1SE) number of fish per transcent within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

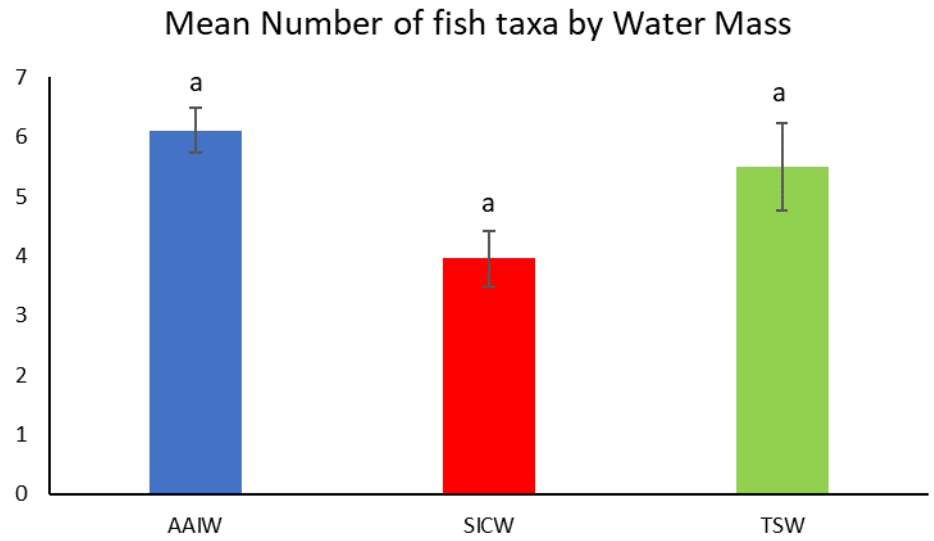


Figure 7. The mean (+- 1SE) number of fish taxa per transcent within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Fish assemblages among Key Ecological Features

There was a significant difference in the composition of the multivariate fish assemblage among the KEFs (Table 18). The fish assemblages of the Continental Slope Demersal Fish Communities KEF was different to those found at the Exmouth Plateau KEF and outside any KEFs (Table 19). This difference was driven by a number of fish species that were correlated toward the left of the nMDS plot (Figure 8a) in the direction of the deeper water samples from the Exmouth Plateau KEF and areas outside any KEF. These taxa included two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of Unidentified anguilliform fish, and a *Bathypterois* (Ipnopidae) species.

There was no statistically significant difference in the total number of fish among KEFs (Table 18). However, the P value of 0.054 is very close to the convention of α = 0.05, so post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist between KEFs. There was a much greater mean number of fish per transect at the Ancient Coastline at 125m depth contour KEF than at any of the other KEFs (Figure 9). In contrast, there was no statistically significant difference in the mean number of fish taxa between KEFs. Similar numbers of fish taxa were recorded at each KEF (Figure 10).

Table 18. Results of multivariate and univariate PERMANOVA tests for differences among Key Ecological Features (KEFs) for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	70242	23414	1.918	**0.012**
Site(KEF)	11	132420	12038	9.397	<0.001
Residual	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	38602000	12867000	13.296	0.054
Site(KEF)	11	10490000	953640	11.621	0.001
Residual	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	60.55	20.18	0.978	0.455
Site(KEF)	11	224.13	20.38	7.969	<0.001
Residual	56	143.18	2.56		

Table 19. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between Key Ecological Features. Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
Exmouth Plateau, Continental Slope Demersal Fish Communities	2.15	**0.012**	1253	**0.004**
Exmouth Plateau, Outside KEF	1.01	0.220	8855	0.406
Exmouth Plateau, Ancient Coastline at 125 m depth contour	2.45	0.335	3	0.090
Continental Slope Demersal Fish Communities, Outside KEF	1.50	0.050	9926	**0.043**
Continental Slope Demersal Fish Communities, Ancient Coastline at 125 m depth contour	1.56	0.027	360	0.059
Outside KEF, Ancient Coastline at 125 m depth contour	1.15	0.437	6189	0.258

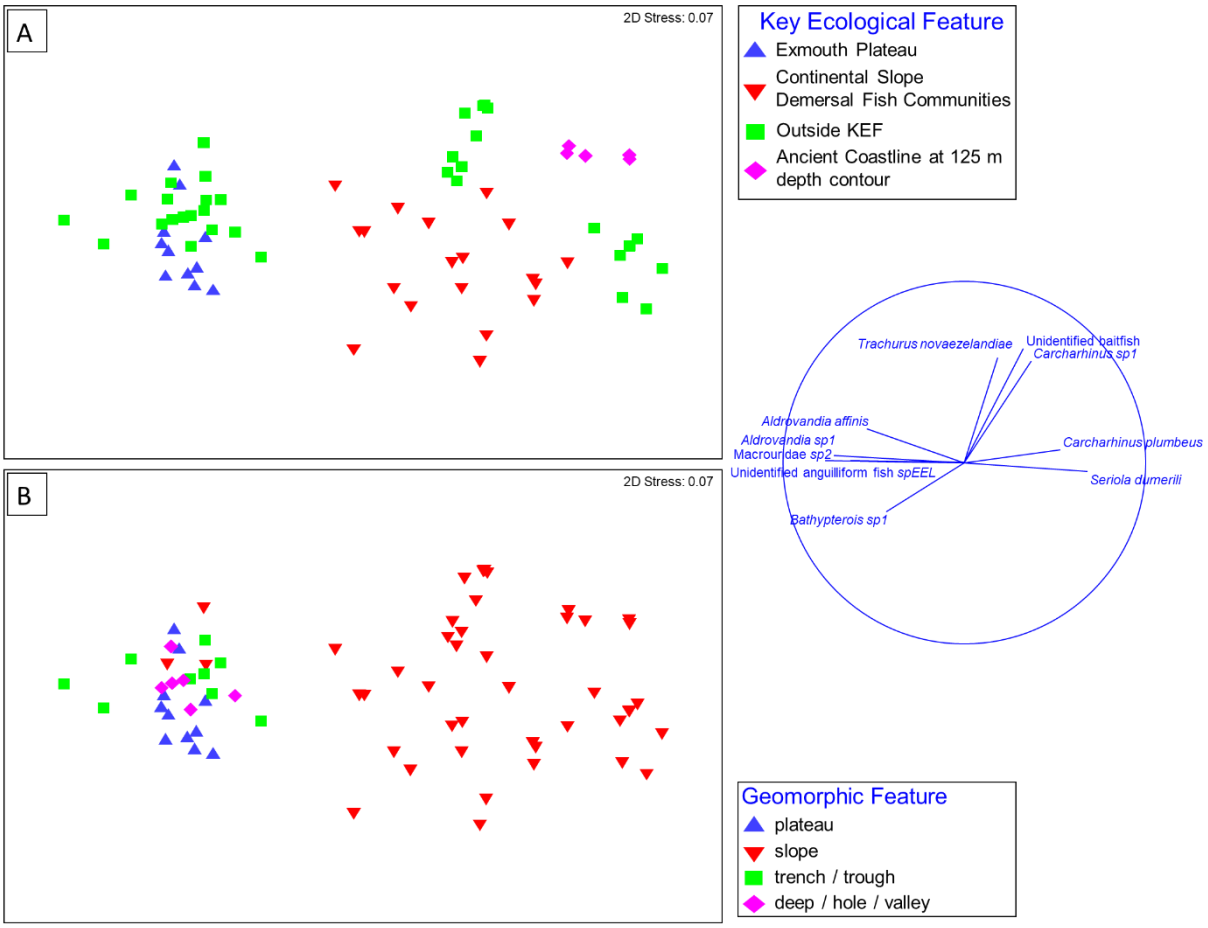


Figure 8. Non-metric Multidimensional Scaling Plots illustrating the difference in the multivariate composition of the fish assemblages among Key Ecological Features (KEFs) (A) and Geomorphic Features (GFs) (B). The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

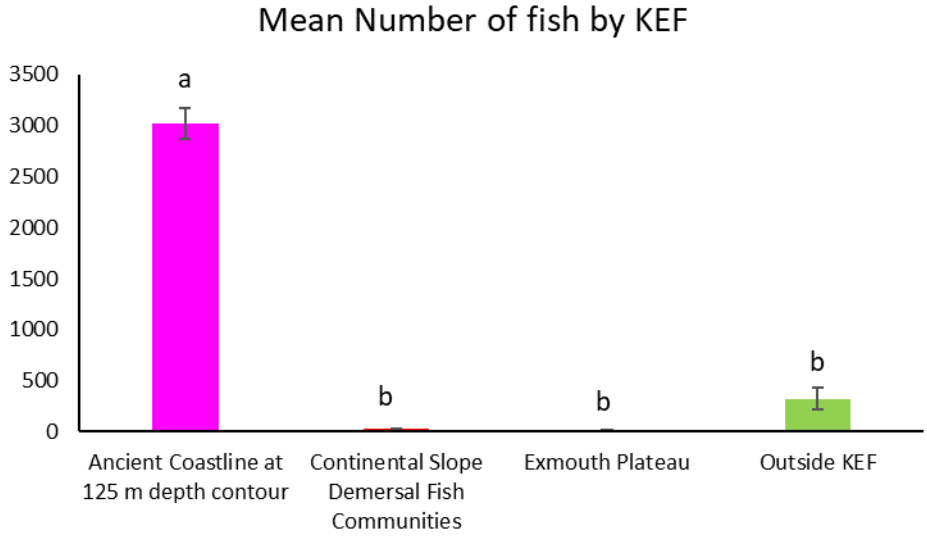


Figure 9. The mean (+- 1SE) number of fish per transect within each Key Ecological Feature (KEF). Letters above bars indicate statistically similar means at α = 0.05.

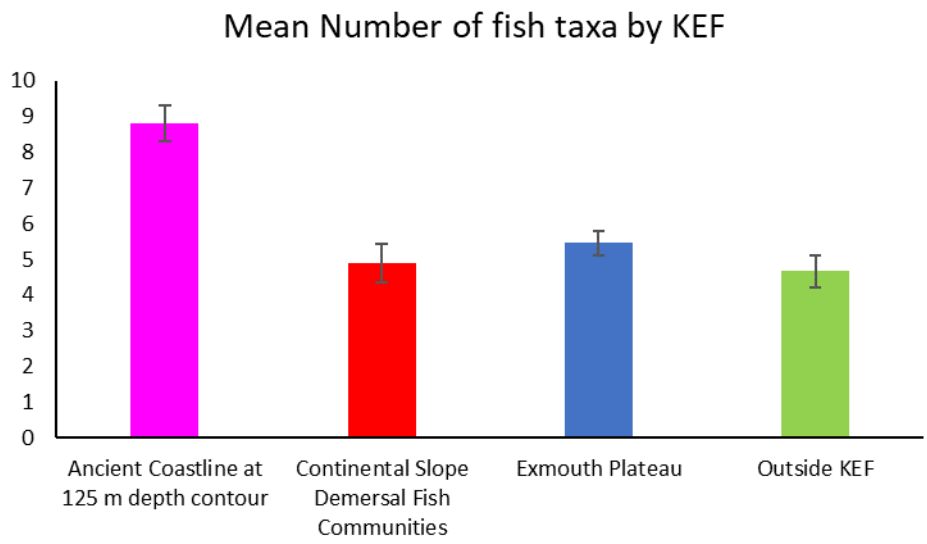


Figure 10. The mean (+- 1SE) number of fish taxa per transect within each Key Ecological Feature (KEF).

Tests of differences in Fish assemblages among Geomorphic Features

There was a significant difference in the composition of the multivariate fish assemblage among the GFs (Table 20Table 18). The fish assemblage of the slope GF was different to the plateau GF and the trench / trough GF (Table 21). This difference was driven by a number of fish species that were correlated toward the right of the nMDS plot (Figure 8b) in the direction of the shallower water slope samples. These taxa included *Trachurus novaezelandiae* (Carangidae), Unidentified baitfish, *Carcharhinus* sp1, *Carcharhinus plumbeus* (Carcharhinidae), and *Seriola dumerilii* (Carangidae) (Figure 8b).

There was no statistically significant difference in the total number of fish or the number of fish taxa per transect among GFs (Table 20). Qualitatively, the mean number of fish appeared higher on the slope GF than any other GFs (Figure 11), but there was a lot of variation in the number of fish associated with the slope among samples which is indicated by the large error bar (Figure 11). There was a similar number of fish taxa recorded among the GFs (Figure 12).

Table 20. Results of multivariate and univariate PERMANOVA tests for differences among Geomorphic Features (GFs) for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	75269	25090	1.790	**0.016**
Site(GF)	11	131010	11910	9.297	<0.001
Residual	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	3935300	1311800	0.29333	0.652
Site(GF)	11	43753000	3977500	48.47	<0.001
Residual	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	16.984	5.66	0.221	0.891
Site(GF)	11	264.02	24.00	9.387	<0.001
Residual	56	143.18	2.56		

Table 21. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between Geomorphic Features (GFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between GFs				
Groups	t	P(perm)	perms	P(MC)
plateau, slope	1.61	0.010	9904	**0.020**
plateau, trench / trough	1.34	0.253	24	0.212
plateau, deep / hole / valley	0.80	0.672	6	0.639
slope, trench / trough	1.47	0.035	9907	**0.041**
slope, deep / hole / valley	1.19	0.084	9854	0.207
trench / trough, deep / hole / valley	0.98	0.673	6	0.526

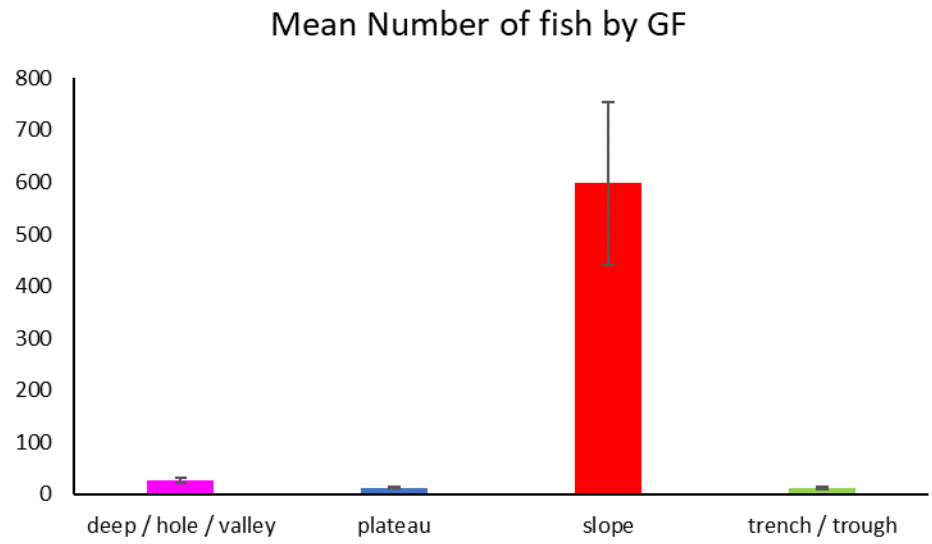


Figure 11. The mean (+- 1SE) number of fish per transect within each Geomorphic Feature (GF).

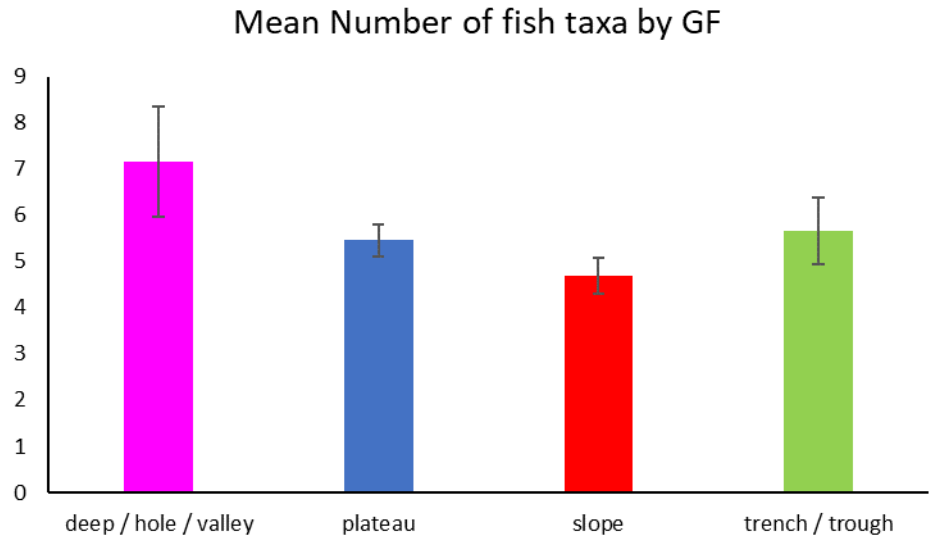


Figure 12. The mean (+- 1SE) number of fish taxa per transect within each Geomorphic Feature (GF).

Crustaceans

Across the whole survey area depth was a very important predictor of the multivariate composition of the crustacean assemblage. A DistLM analysis found that depth alone explained 73% of the variation in the crustacean assemblage composition (R^2 = 0.72716, Pseudo $F_{(1,69)}$ = 183.9, P<0.001).

Tests of differences in crustacean assemblage composition between water masses.

There was a significant difference in the crustacean assemblages of the three water masses (Figure 13, Table 22). Crustaceans were predominantly found in the deeper AAIW mass, and so the crustacean assemblage here was different to the shallower water SICW and the TSW water masses, which were not significantly different (Table 23). The abundance of all crustacean species was greater in the

deeper waters of the AAIW, and correlated toward the right side of the nMDS plot (Figure 13). The most strongly correlated taxa were all prawns (Figure 13).

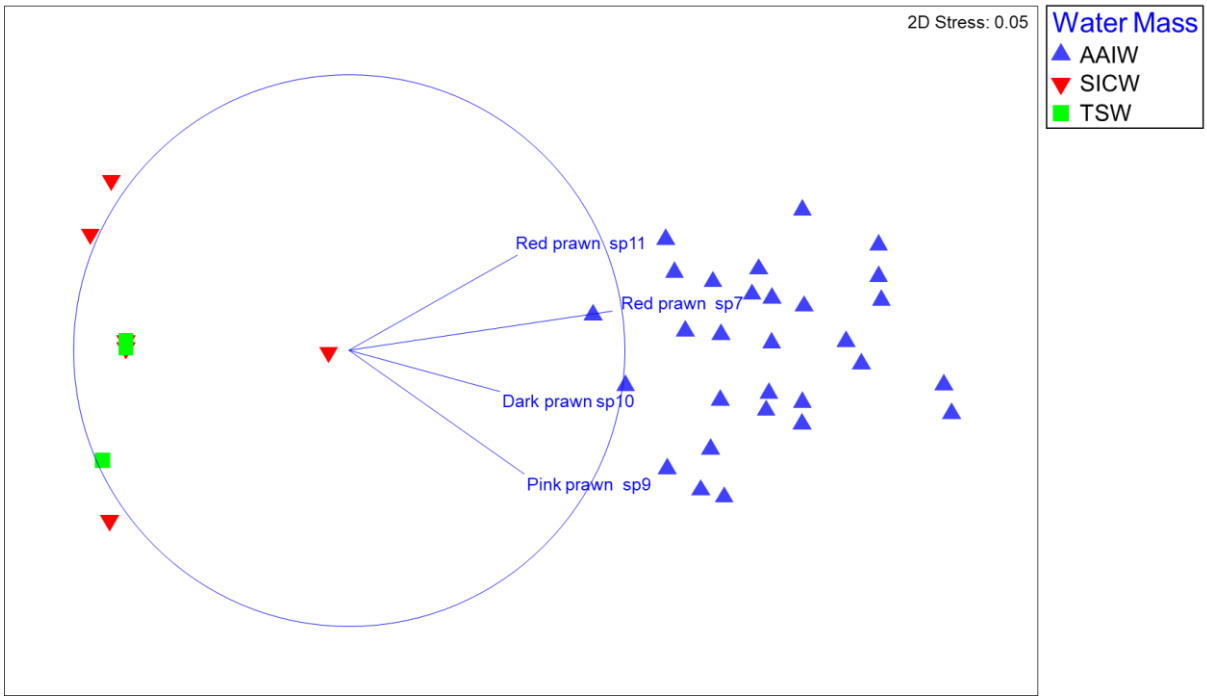


Figure 13. Non-metric Multidimensional Scaling Plot illustrating the difference in the multivariate composition of the crustacean assemblages among water masses. The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

Table 22. Results of multivariate and univariate PERMANOVA tests for differences among water masses for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	82894	41447	50.744	**<0.001**
Site(Water Body)	12	10287	857	3.385	<0.001
Res	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	12377	6189	11.572	**0.004**
Site(Water Body)	12	6857	571	23.341	<0.001
Res	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	149	74.50	85.218	**<0.001**
Site(Water Body)	12	10.766	0.90	1.617	0.115
Res	56	31.067	0.55		

Table 23. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between water masses. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between water masses			
Groups	t	P(perm)	perms
AAIW, SICW	8.36	**0.001**	9800
AAIW, TSW	6.08	**0.005**	8828
SICW, TSW	1.51	0.058	1193

The mean number of crustaceans, and the mean number of crustacean taxa were both significantly greater in the Antarctic Intermediate Water mass than either the Southern Indian Central or the Tropical Surface water masses (Table 22, Figure 14, Figure 15.). There was an average of 27 individual crustaceans and 3 crustacean taxa per transect in the AAIW water mass. The number of crustaceans and the number of crustacean taxa were similarly low in both the AAIW and the TSW water masses (Figure 14, Figure 15)

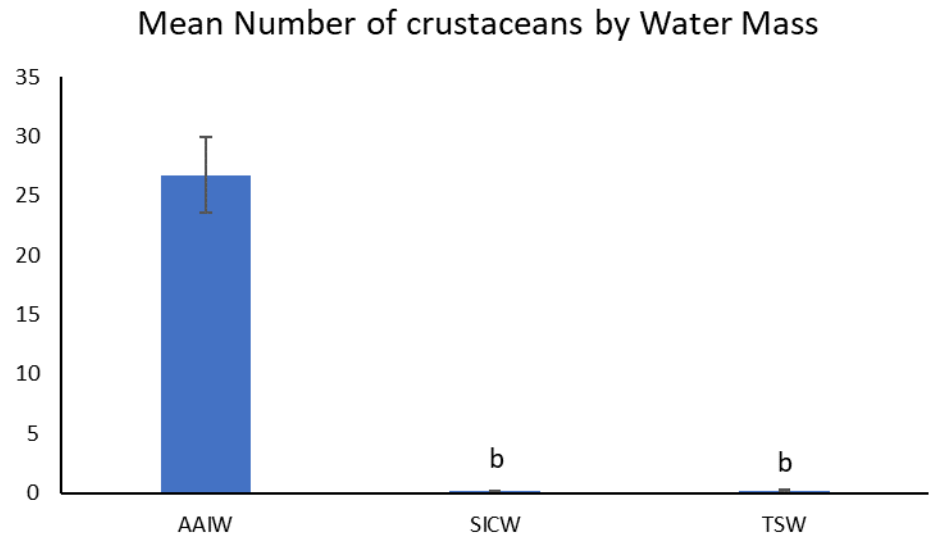


Figure 14. The mean (+- 1SE) number of crustaceans per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

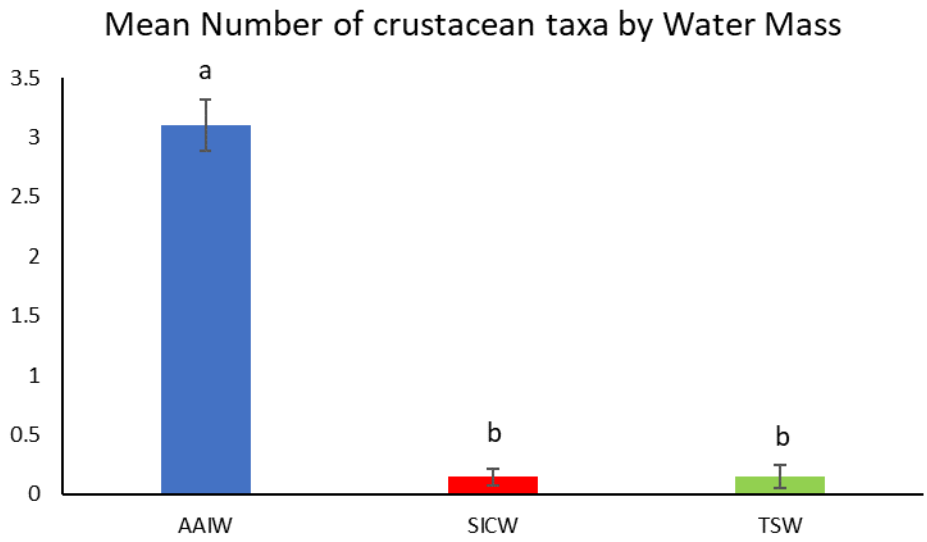


Figure 15. The mean (+- 1SE) number of crustacean taxa per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Crustacean assemblages among Key Ecological Features

There was not a statistically significant difference in the composition of the multivariate crustacean assemblage among the KEFs (Table 24). However, the P value of 0.057 is very close to the convention of α = 0.05, so post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist (Table 25). The crustacean assemblage of the Exmouth Plateau KEF was significantly different to that of the Continental Slope Demersal Fish Communities KEF and the Ancient Coastline at 125 m depth contour KEF (Table 25). The crustacean assemblage of the Continental Slope Demersal Fish Communities KEF was also different to the crustacean assemblage at areas Outside any KEF. These differences were driven by the crustacean taxa that were all correlated toward the right of the nMDS plot (Figure 16Figure 8a) in the direction of the deeper water samples from the Exmouth Plateau KEF and deeper areas outside any KEF. These taxa were all Prawn taxa.

There was no overall statistically significant difference in the total number of crustaceans among GFs (Table 24). However, qualitatively there was a greater number of crustaceans and crustacean taxa at the Exmouth Plateau and Outside KEFs than elsewhere. So post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist between KEFs.

There was a greater mean number of crustaceans, and a greater mean number of crustacean taxa at the Exmouth Plateau KEF than at the Ancient Coastline and Continental Slope Demersal Fish Communities KEFs (Figure 17, Figure 18). The mean number of crustaceans and number of crustacean taxa per transect Outside any KEF was also high, and statistically similar to the Exmouth Plateau KEF (Figure 17, Figure 18). However, there was variability within the Outside KEF samples, and the mean number of crustaceans was statistically similar to the mean number of crustaceans within the Ancient Coastline KEF (Figure 17). Similarly, the mean number of crustacean taxa Outside KEF was statistically similar to the number of crustacean taxa at both the Ancient Coastline and Continental Slope Demersal Fish KEFs (Figure 17, Figure 18).

Table 24. Results of multivariate and univariate PERMANOVA tests for differences among Key Ecological Features (KEFs) for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	42662	14221	2.646	**0.057**
Site(KEF)	11	58272	5297	20.915	<0.001
Residual	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	5082	1694	1.2431	0.283
Site(KEF)	11	14772	1343	54.851	<0.001
Residual	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	65.191	21.73	2.298	0.133
Site(KEF)	11	102.53	9.32	16.801	<0.001
Residual	56	31.067	0.55		

Table 25. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between Key Ecological Features (KEFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
Exmouth Plateau, Continental Slope Demersal Fish Communities	10.66	0.038	270	**<0.001**
Exmouth Plateau, Outside KEF	0.97	0.418	8110	0.383
Exmouth Plateau, Ancient Coastline at 125 m depth contour	5.48	0.339	3	**0.014**
Continental Slope Demersal Fish Communities, Outside KEF	2.01	0.071	9826	**0.045**
Continental Slope Demersal Fish Communities, Ancient Coastline at 125 m depth contour	1.18	0.390	72	0.260
Outside KEF, Ancient Coastline at 125 m depth contour	0.92	0.752	4395	0.414

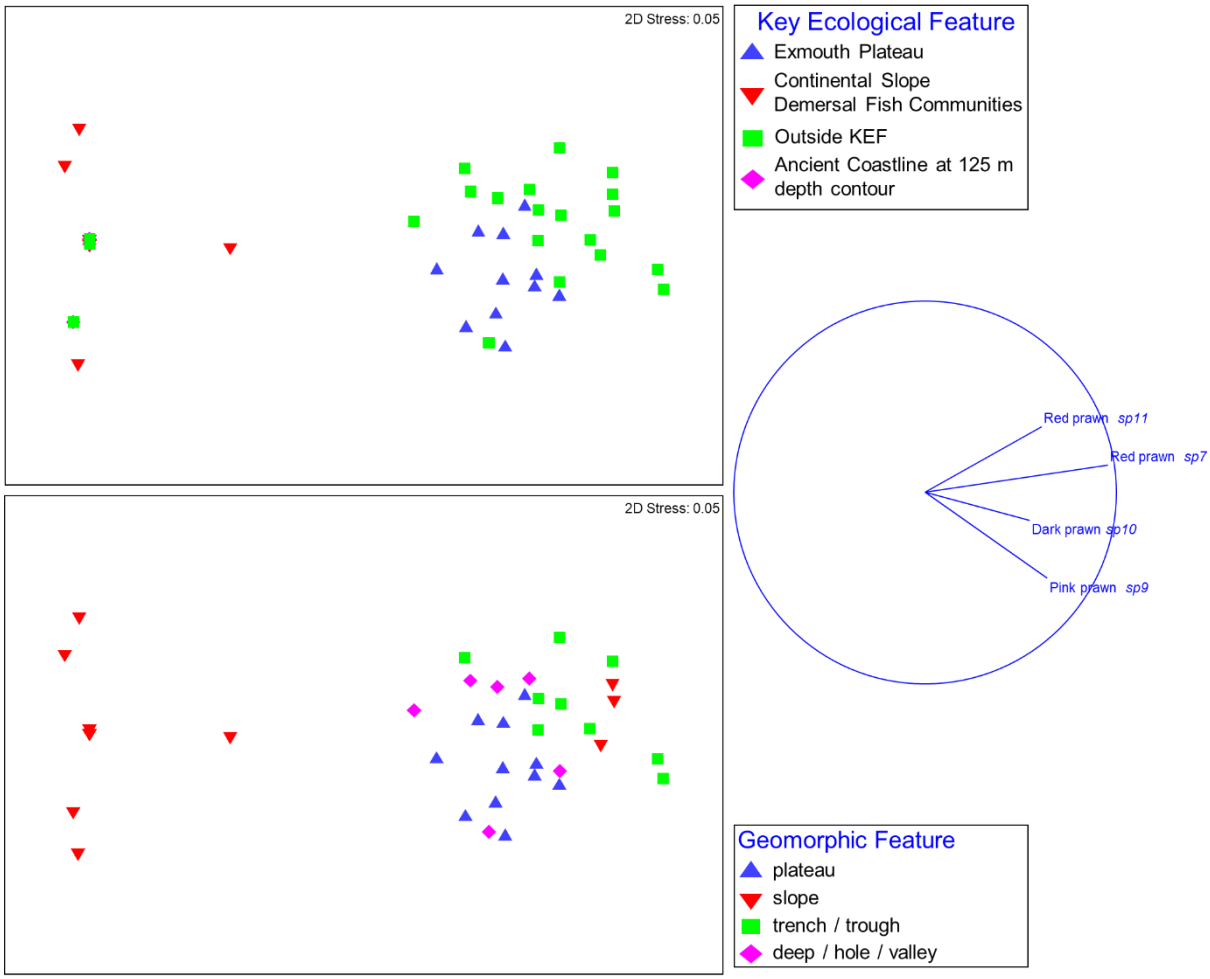


Figure 16. Non-metric Multidimensional Scaling Plots illustrating the difference in the multivariate composition of the crustacean assemblages among Key Ecological Features (KEFs) (A) and Geomorphic Features (GFs) (B). The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

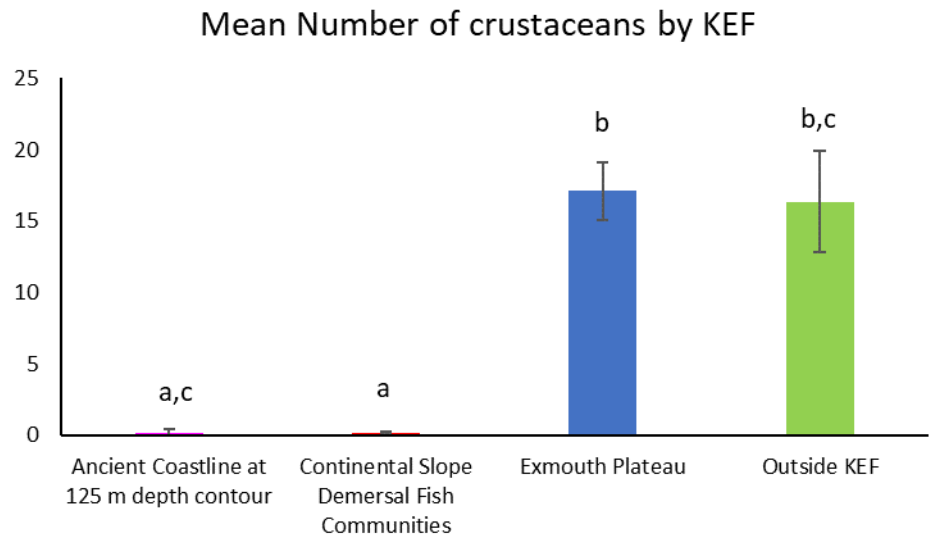


Figure 17. The mean (+- 1SE) number of crustaceans per transect within each Key Ecological Feature. Letters above bars indicate statistically similar means at α = 0.05.

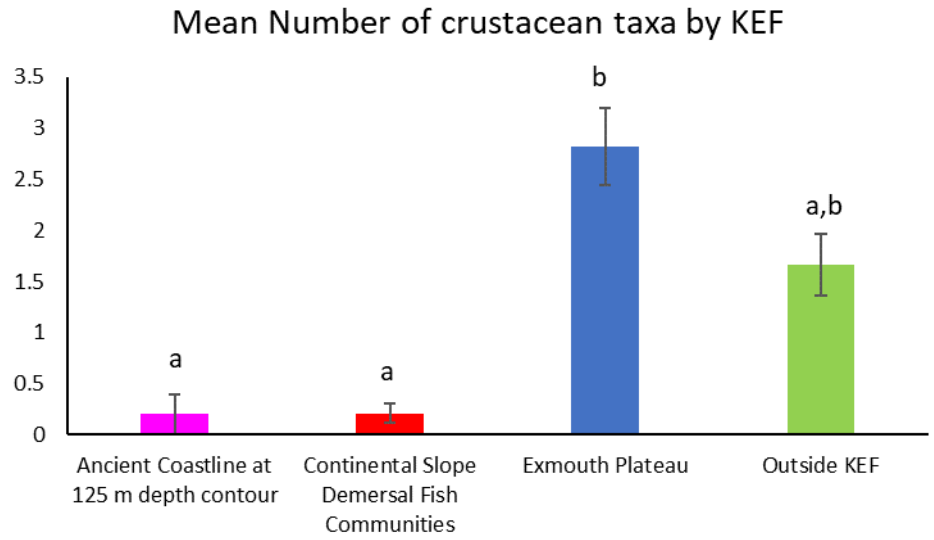


Figure 18. The mean (+- 1SE) number of crustacean taxa per transect within each Key Ecological Feature. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Crustacean assemblages among Geomorphic Features

There was a significant difference in the composition of the multivariate crustacean assemblage among the GFs (Table 26Table 20Table 18). The crustacean assemblage of the slope GF was different to the plateau GF, the trench / trough GF, and the Deep / hole / valley GF (Table 27). The crustacean assemblages of the plateau GF, the trench / trough GF, and the Deep / hole / valley GF were statistically similar (Table 27). The difference between the slope GF and the other GFs was driven by the crustacean taxa that were all correlated toward the right of the nMDS plot (Figure 16Figure 8b) in the direction of the deeper water samples and away from the shallower water samples of the slope GF.

There was no statistically significant difference in the total number of crustaceans per transect among GFs (Table 26). Qualitatively, the mean number of crustaceans appeared lowest on the slope GF and highest at the trench / trough GFs (Figure 19). Post-hoc pairwise tests confirmed that the mean number of crustaceans per transect was higher in the trench / trough GF than the slope GF (Figure 19). However, these were both statistically similar to the deep / hole / valley GF and the plateau GFs (Figure 19).

There was a statistically significant difference in the mean number of crustacean taxa per transect among the GFs (Table 26, Figure 20). The number of crustacean taxa at the trench / trough GF was higher than at the plateau or slope GFs (Figure 20). The number of crustacean taxa per transect in the plateau GF was also greater than at the slope GF (Figure 20). The mean number of crustacean taxa per transect at the deep / hole / valley GF was statistically similar to all the other GFs (Figure 20).

Table 26. Results of multivariate and univariate PERMANOVA tests for differences among Geomorphic Features (GFs) for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	67022	22341	9.695	**0.001**
Site(GF)	11	22393	2036	8.037	<0.001
Residual	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	9210	3070	4.0291	0.083
Site(GF)	11	7401	673	27.481	<0.001
Residual	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	85.046	28.35	4.709	**0.017**
Site(GF)	11	58.57	5.32	9.598	<0.001
Residual	56	31.067	0.55		

Table 27. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between Geomorphic Features (GFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
plateau, slope	3.81	**0.019**	9505	**0.001**
plateau, trench / trough	1.42	0.164	6	0.211
plateau, deep / hole / valley	1.69	0.000	3	0.196
slope, trench / trough	4.00	**0.015**	9423	**0.001**
slope, deep / hole / valley	2.68	**0.093**	7761	**0.010**
trench / trough, deep / hole / valley	1.16	0.326	3	0.398

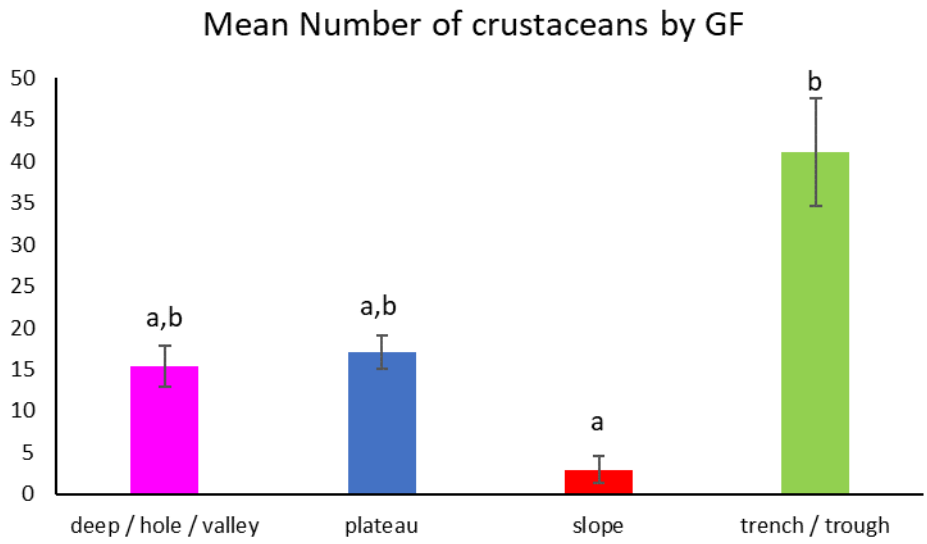


Figure 19. The mean (+- 1SE) number of crustaceans per transect within each Geomorphic Feature (GFs). Letters above bars indicate statistically similar means at α = 0.05.

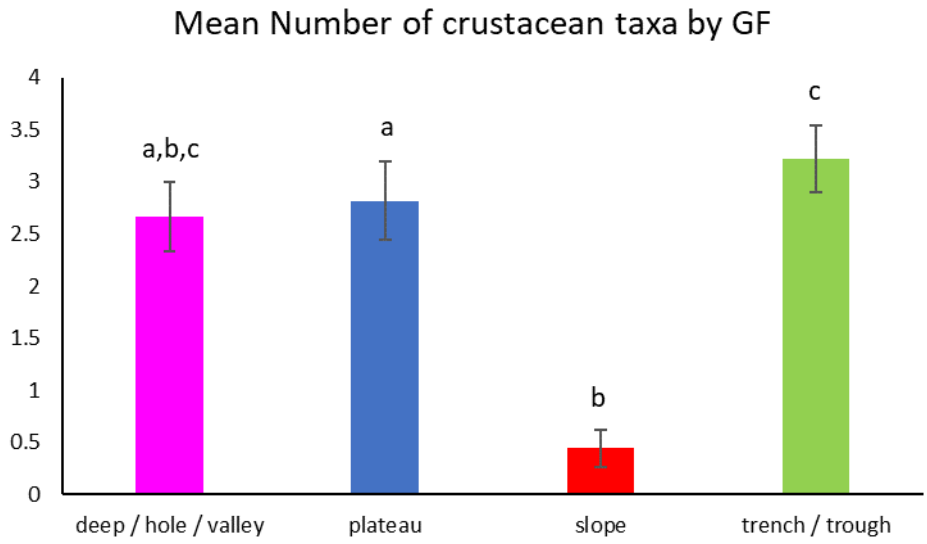


Figure 20. The mean (+- 1SE) number of Crustacean taxa per transect within each Geomorphic Feature (GF). Letters above bars indicate statistically similar means at α = 0.05.

4. Discussion

Distinct fish and crustacean assemblages were recorded across the survey area. These were strongly influenced by water depth, and the three water masses that were identified. Most notably, almost all crustaceans and crustacean taxa were recorded at the deeper sites in the AAIW mass. There was also a clear distinction in the fish assemblages, with the deeper sites being characterised by Macrouridae (rat tails), Halosauridae (halosaurs) and unidentified anguilliform (eel like) fishes. The shallower sites of the TSW mass and the Ancient Coastline at 125 m contour KEF were characterised by sharks and Carangidae such as *Trachurus novaezelandiae* (yellowtail scad). These shallower areas had a much greater number of fish recorded than elsewhere, with a mean of 3,000 fish per transect in the Ancient Coastline at 125 m contour KEF, and 1,700 fish per transect across all sites in the TSW. The fish assemblages of the deeper continental slope were also dominated by Carangidae, but here different taxa including two species of scad, *Decapterus kurroides* and *Decapterus* sp1, and *Seriola dumerili* (amberjack) were recorded. This zone was characterised by the SICW mass and included the slope GF and the Continental Slope Demersal Fish Communities KEF. Although there were large differences in the number of fish observed across the survey area among water masses, KEFs and GFs, the average diversity of fishes remained consistent across the survey area. While the deeper sites had lower numbers of fishes, the number of fish taxa was the same as at the shallower sites.

There were differences in patterns of assemblage composition, abundance and number of taxa in both the fish and crustaceans sampled that were associated with the deeper waters of greater than 800 m depth and the AAIW mass. A similar pattern was described by Saunders et al. (2021) and has previously been reported (Last et al., 2011). This faunal break can be attributed to the influence of the AAIW (Williams et al., 2001). This deep-water current is cold and has a lower salinity than the shallower water masses identified in this survey. The AAIW has a strong influence on the distribution of fish communities in the south-west region between the Great Australian Bight and north of the Ningaloo Reef. The depth of the AAIW fluctuates from 875 m at 27.50°S to 520 m around 21.50°S (Williams et al., 1996; 2001; Woo and Pattiaratchi, 2008). There was a break in the water depth of the samples collected during this survey, with no samples collected between 280 and 800 m water depth. Therefore the transition zone between water masses could not be identified. A recent survey in a similar area covered water depths between 360 and 870 m and identified that a similar faunal break occurred between 700 and 800 m water depth (Saunders et al., 2021). A break between mid-slope and shelf-break fish assemblages at water depths of between 700 and 900 m was also reported by Williams et al. (2001) in the northern area of their survey, which is a similar location to this one.

There were some limitations associated with the survey method that are likely to have influenced the fish and crustacean data that was recorded. The identification of many of the individuals observed was difficult because of the small size, distance from the camera, and the slight downward facing camera angle. For this reason, a conservative approach was taken where there was uncertainty in the identification, and many taxa were pooled to higher taxonomic groups. In particular, the group of unidentified anguilliform fishes and unidentified baitfish are likely to include multiple taxa. This could be partially mitigated by mounting video cameras lower down on the ROV platform, and facing directly forward, although this set up was used in Saunders et al. (2021) and similar issues with identification were encountered. In addition, some of the shallower sites sampled had very high abundances of fish, particularly *Decapterus* spp. (scads). Following the established procedure (Goetze et al., 2019) all fish encountered along a transect were counted, unless they could be positively identified as having been already counted, and to have re-entered the transect. Therefore, it's possible that the abundances of these species may be inflated due to re-counts of the same individual. With a single video camera

recording it is not possible to define the transect width and height, which could also lead to inflated numbers. A stereo-video system (Saunders et al., 2021) would overcome this issue by allowing the transect dimensions to be defined, and the three-dimensional position of each fish within the transect to be identified.

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6. Appendix 1. Images of the most abundant fish, crustacean and mobile invertebrate taxa

Table 28. Images of the most abundant fish taxa across the survey area. Images of all the fish identified within the body of the report are listed. Images are organised alphabetically by family followed by taxa.

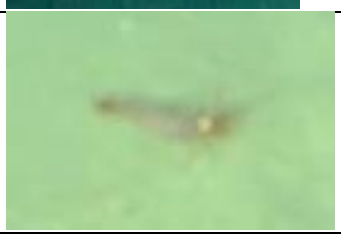
Family	Taxa	Image
Carangidae	*Carangoides* sp1	
Carangidae	*Decapterus kurroides*	
Carangidae	*Decapterus* sp1	
Carangidae	*Seriola dumerili*	

Family	Taxa	Image
Carangidae	*Trachurus novaezelandiae*	
Carcharhinidae	*Carcharhinus* sp1	
Halosauridae	*Aldrovandia affinis*	
Halosauridae	*Aldrovandia* sp1	
Halosauridae	*Aldrovandia* sp2	
Ipnopidae	*Bathypterois* sp1	

Family	Taxa	Image
Macrouridae	Macrouridae sp1	
Macrouridae	Macrouridae sp2	
Macrouridae	Macrouridae sp4	
Rachycentridae	*Rachycentron canadum*	
Synodontidae	Synodontidae sp2	
N/A	unidentified anguilliform fish	

Family	Taxa	Image
N/A	unidentified baitfish	

Table 29. Images of the ten most abundant crustacean taxa across the survey area. Images are organised alphabetically by family followed by taxa.

Family	Taxa	Image
Galatheidae	Galatheidae sp. G	
Homolidae	Homolidae spH	
Ibacinae	*Ibacus* spI	
Parapaguridae	Parapaguridae spPP	
N/A	Dark prawn sp10	
N/A	Orange prawn sp8	
N/A	Pink prawn sp9	

Family	Taxa	Image
N/A	Red prawn sp7	
N/A	Red prawn sp11	
N/A	Unidentified prawn species	

Table 30. Images of the ten most abundant mobile invertebrate taxa across the survey area. Images are organised alphabetically by family followed by taxa.

Family	Taxa	Image
Elpidiidae	*Peniagone* spPG	
Pelagothuriidae	*Enypniastes eximia*	
Phormosomatidae	Phormosomatidae spPH	
N/A	Brown jellyfish spJB	
N/A	Cormatulida sp. C	
N/A	Purple jellyfish spJP	

Family	Taxa	Image
N/A	Purple sea cucumber spSCP	
N/A	Purple sea urchin spSUBP	
N/A	Purple sea urchin small spSUP	
N/A	Sea star white spSSW	

Appendix E Sediment and Water Chain of Custody

Environmental Division
Brisbane
Work Order Reference
EB2215199

Telephone : + 61-7-3243 7222

CHAIN OF CUSTODY

ALS Laboratory: please tick →

ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com
NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com
PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

CLIENT:	Advisian	**TURNAROUND REQUIREMENTS :** (Standard TAT may be longer for some tests e.g. Ultra Trace Organics)	☐ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date):
OFFICE:	Lvl 14, 240 St Georges Terrace, Perth		
PROJECT:	Gorgon Benthic Survey 2022	**ALS QUOTE NO.:**	EP-246-22_V2
ORDER NUMBER:	1		
PROJECT MANAGER:	Mark Westera	**CONTACT PH:**	0422 489 803
SAMPLER:	Luca Chiaroni, Stephanie Watts	**SAMPLER MOBILE:**	0498 014 575
COC emailed to ALS?	(YES / NO)	**EDD FORMAT (or default):**	
Email Reports to (will default to PM if no other addresses are listed):	mark.westera@advisian.com		
Email Invoice to (will default to PM if no other addresses are listed):	mark.westera@advisian.com		

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 3 4 5 6 5 6 7

OF: 1 2 3 4 3 4 5 6 5 6 7

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact? Yes No N/A

Cooling Method: ICE ICEPACK NONE

Cooler Temperature (°C):

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Luca Chiaroni			
DATE/TIME:	DATE/TIME: 27/5/22 11:36	DATE/TIME:	DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE ONLY — SAMPLE DETAILS (MATRIX: SOLID (S) WATER (W)) — CONTAINER INFORMATION — ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price). Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Chromium (III & VI) - Total	Chromium (III & VI) - Dissolved	Mercury (Total)	Mercury (Dissolved)	DOC	TOC	TDS	TP/TN			Additional Information
0																					
EP2205756-001	WTR DC-1_SURFACE_1	20220509	W		10				X	X	X	X	X	X	X	X		X			
EP2205756-011	GORGON GMT_SEABED_1	20220510	W		10				X	X	X	X	X	X	X	X		X			
TOTAL					20	0	0	0	2	2	2	2	2	2	2	2	0	2			

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

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Brisbane
Work Order Reference
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CHAIN OF CUSTODY

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NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com

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CLIENT:	Advisian	**TURNAROUND REQUIREMENTS :** (Standard TAT may be longer for some tests e.g. Ultra Trace Organics)	☐ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date):
OFFICE:	Lvl 14, 240 St Georges Terrace, Perth		
PROJECT:	Gorgon Benthic Survey 2022	**ALS QUOTE NO.:**	EP-246-22_V2
ORDER NUMBER:	1		
PROJECT MANAGER:	Mark Westera	**CONTACT PH:**	0422 489 803
SAMPLER:	Luca Chiaroni, Stephanie Watts	**SAMPLER MOBILE:**	0498 014 575
COC emailed to ALS?	(YES / NO)	**EDD FORMAT (or default):**	
Email Reports to (will default to PM if no other addresses are listed):	mark.westera@advisian.com		
Email Invoice to (will default to PM if no other addresses are listed):	mark.westera@advisian.com		

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 3 4 5 6 5 8 7

OF: 1 2 3 4 3 4 5 6 5 6 7

FOR LABORATORY USE ONLY (Circle)

Custody seal intact? Yes / No / N/A

Cooler temperature (°C)

Sample temperature (°C)

Other comments:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Luca Chiaroni			
DATE/TIME:	DATE/TIME: 27/5/22 11:36	DATE/TIME:	DATE/TIME:

ALS USE ONLY — SAMPLE DETAILS (MATRIX: SOIL/S WATER/W) — CONTAINER INFORMATION

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price)
Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Chromium (III & VI) - Total	Chromium (III & VI) - Dissolved	Mercury (Total)	Mercury (Dissolved)	DOC	TOC	TDS	TP/TN			Additional Information
																					Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
EP2205756-001	WTR DC-1_SURFACE_1	20220509	W		10				X	X	X	X	X	X	X	X		X			
EP2205756-011	GORGON GMT_SEABED_1	20220510	W		10				X	X	X	X	X	X	X	X		X			
TOTAL					20	0	0	0	2	2	2	2	2	2	2	2	0	2			

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; NP=NaOH preserved Plastic; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY

ALS Laboratory: please tick →

BRISBANE 32 Shand Street Stafford QLD 4053
Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

Environmental Division Brisbane
Work Order Reference
EB2215235

Telephone : +61-7-3243 7222

CLIENT: Advisian	TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics)	☐ Standard TAT (List due date): AS SOON AS POSSIBLE ☐ Non Standard or urgent TAT (List due date):	FOR LABORATO Custody Seal Intact Free (Dry) Frozen Ice Random Sample Te Other Comments
OFFICE: Lvl 14, 240 St Georges Terrace, Perth			
PROJECT: Gorgon Benthic Survey 2022	ALS QUOTE NO.: EP-246-22_V2	COC SEQUENCE NUMBER (Circle)	
ORDER NUMBER: 1		COC: 1 2 3 4 5 6 7	
PROJECT MANAGER: Mark Westera	CONTACT PH: 0422 489 803	OF: 1 2 3 4 5 6 7	
SAMPLER: Luca Chiaroni, Stephanie Watts	SAMPLER MOBILE: 0498 014 575	RELINQUISHED BY:	RECEIVED BY:
COC emailed to ALS? (YES)	EDD FORMAT (or default):	*Luca Chiaroni/Steph Watts*	DATE/TIME: 27/5/22 11:30
Email Reports to (will default to PM if no other addresses are listed): mark.westera@advisian.com; connor.campbell@advisian.com		DATE/TIME: 26/05/22 1100	RELINQUISHED BY:
Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com; connor.campbell@advisian.com			DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE ONLY	AMBIENT SOIL (S) / WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAHs if TRH recorded	Metals (total only)	TOC (Total organic carbon) (%)	Particle Size Distribution (laser diffraction and wet sieving)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	Retain Excess sample for PSD anaysis	
EP2205801-003	SEMELE WELL-4_1_3	20220508	S	150ml jar	1	x	x		x			x	x		
EP2205801-002	SEMELE WELL-4_1_2	20220508	S	150ml jar	1	x	x		x			x	x		
EP2205801-004	WTR DC-1-4_1_1	20220509	S	150ml jar	1	x	x		x			x	x		
EP2205801-009	WTR DC-2_2_3	20220509	S	150ml jar	1	x	x		x			x	x		
				TOTAL	4	4	4		4			4	4		

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
[redacted]															
5	STB4_SURFACE_1	20220430	W	500ml clear plastic Green label -(P)	1								X		
5	STB4_SURFACE_1	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
5	STB4_SURFACE_1	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
5	STB4_SURFACE_1	20220430	W	40ml glass vial - (VS)	2		X								
5	STB4_SURFACE_1	20220430	W	40ml glass vial - filtered (VS)	1						X				
5	STB4_SURFACE_1	20220430	W	40ml glass vial - (VS)	1							X			FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
5	STB4_SURFACE_1	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
5	STB4_SURFACE_1	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
5	STB4_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
6	STB4_SURFACE_2	20220430	W	500ml clear plastic Green label -(P)	1								X		
6	STB4_SURFACE_2	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
6	STB4_SURFACE_2	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
6	STB4_SURFACE_2	20220430	W	40ml glass vial - (VS)	2		X								
6	STB4_SURFACE_2	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE
6	STB4_SURFACE_2	20220430	W	40ml glass vial - (VS)	1							X			
6	STB4_SURFACE_2	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
6	STB4_SURFACE_2	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
6	STB4_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
7	STB4_SEABED_1	20220430	W	500ml clear plastic Green label -(P)	1								X		
7	STB4_SEABED_1	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
7	STB4_SEABED_1	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
7	STB4_SEABED_1	20220430	W	40ml glass vial - (VS)	2		X								
7	STB4_SEABED_1	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE
7	STB4_SEABED_1	20220430	W	40ml glass vial - (VS)	1							X			
7	STB4_SEABED_1	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
7	STB4_SEABED_1	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
7	STB4_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
8	STB4_SEABED_2	20220430	W	500ml clear plastic Green label -(P)	1								X		
8	STB4_SEABED_2	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
8	STB4_SEABED_2	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
8	STB4_SEABED_2	20220430	W	40ml glass vial - (VS)	2		X								
8	STB4_SEABED_2	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
8	STB4_SEABED_2	20220430	W	40ml glass vial - (VS)	1							X			
8	STB4_SEABED_2	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
8	STB4_SEABED_2	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
8	STB4_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
				TOTAL	80	8	8	8	8	8	8	8	8	8	

0

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAHs if TRH recorded	Metals (total only)	TOC (Total organic carbon) (%)	Particle Size Distribution (laser diffraction and wet sieving)	Retain Excess sample for PSD anaysis	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
[redacted]													
17	STB4_1_1	20220501	S	250ml JAR	1	x	x	x	x	x		x	
18	STB4_1_2	20220501	S	250ml JAR	1	x	x	x	x	x		x	
19	STB4_1_3	20220501	S	250ml JAR	1	x	x	x	x	x		x	
17	STB4_1_1	20220501	S	B (500mL bag)	1								
18	STB4_1_2	20220501	S	B (500mL bag)	1								
19	STB4_1_3	20220501	S	B (500mL bag)	1								
				TOTAL	39								

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved G
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY

ALS Environmental

ALS Laboratory: please tick →

ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com

BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com

MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com

MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com

MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com

NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com

NOWRA 4/10 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com

PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com

TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com

WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: Advisian	TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics) ☐ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date):
OFFICE: Lvl 14, 240 St Georges Terrace, Perth	
PROJECT: Gorgon Benthic Survey 2022	ALS QUOTE NO.: EP-246-22_V2
ORDER NUMBER: 1	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 3 4 5 6 5 6 7 OF: 1 2 3 4 3 4 5 6 5 6 7
PROJECT MANAGER: Mark Westera	CONTACT PH: 0422 489 803
SAMPLER: Luca Chiaroni, Stephanie Watts	SAMPLER MOBILE: 0498 014 575
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default):
Email Reports to (will default to PM if no other addresses are listed): mark.westera@advisian.com	
Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com	
COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:	

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Luca Chiaroni	EG		
DATE/TIME:	DATE/TIME: 10/5/22 1620	DATE/TIME:	

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact?	Yes	No	N/A
Free ice / frozen ice bricks present upon receipt?	Yes	No	N/A
Random Sample Temperature on Receipt:		°C	
Other comments:			

Environmental Division Perth

Work Order Reference

EP2205671

Telephone : -- 61-8-9406 1301

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	
1	NTB3_SURFACE_1	20220504	W	500ml clear plastic Green label -(P)	1										X		
1	NTB3_SURFACE_1	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
1	NTB3_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
1	NTB3_SURFACE_1	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - (VS)	2		X										
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - (VS)	1									X			
1	NTB3_SURFACE_1	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
1	NTB3_SURFACE_1	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
1	NTB3_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1				X								
1	NTB3_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1					X							
2	NTB3_SURFACE_2	20220504	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
2	NTB3_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - (VS)	2		X										
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - (VS)	1									X			
2	NTB3_SURFACE_2	20220504	W	100ml Amber Glass - orange label (AG)	1	X											

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
2	NTB3_SURFACE_2	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
2	NTB3_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1				X								
2	NTB3_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	500ml clear plastic Green label -(P)	1										X		
3	NTB3_SEABED_1	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
3	NTB3_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
3	NTB3_SEABED_1	20220504	W	40ml glass vial - (VS)	2		X										
3	NTB3_SEABED_1	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	40ml glass vial - (VS)	1									X			
3	NTB3_SEABED_1	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
3	NTB3_SEABED_1	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
3	NTB3_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1				X								
3	NTB3_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	500ml clear plastic Green label -(P)	1										X		
4	NTB3_SEABED_2	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
4	NTB3_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
4	NTB3_SEABED_2	20220504	W	40ml glass vial - (VS)	2		X										
4	NTB3_SEABED_2	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	40ml glass vial - (VS)	1									X			
4	NTB3_SEABED_2	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
4	NTB3_SEABED_2	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
4	NTB3_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1				X								
4	NTB3_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
5	G-E DC_SURFACE_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - (VS)	2		X										
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - (VS)	1									X			
5	G-E DC_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
5	G-E DC_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
5	G-E DC_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1				X								
5	G-E DC_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1					X							
6	G-E DC_SURFACE_2	20220505	W	500ml clear plastic Green label -(P)	1												FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1										X		
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - purple label - (SP)	1							X					FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - (VS)	2		X									X	
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - (VS)	1									X			
6	G-E DC_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
6	G-E DC_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
6	G-E DC_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1				X								
6	G-E DC_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1					X							
7	G-E DC_SEABED_1	20220505	W	500ml clear plastic Green label -(P)	1												FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1										X		
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - purple label - (SP)	1							X					FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - (VS)	2		X									X	
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - (VS)	1									X			
7	G-E DC_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
7	G-E DC_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
7	G-E DC_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1				X								
7	G-E DC_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
8	G-E DC_SEABED_2	20220505	W	500ml clear plastic Green label -(P)	1										X		
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - (VS)	2		X										
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - (VS)	1									X			
8	G-E DC_SEABED_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
8	G-E DC_SEABED_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
8	G-E DC_SEABED_2	20220505	W	60ml plastic red/green label - (P)	1				X								
8	G-E DC_SEABED_2	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
9	QAQC_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
9	QAQC_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
9	QAQC_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
9	QAQC_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
9	QAQC_1	20220505	W	40ml glass vial - (VS)	2		X										
9	QAQC_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
9	QAQC_1	20220505	W	40ml glass vial - (VS)	1									X			
9	QAQC_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
9	QAQC_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
9	QAQC_1	20220505	W	60ml plastic red/green label - (P)	1				X								
9	QAQC_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
10	JANSZ JMT_SURFACE_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - (VS)	2		X										
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - (VS)	1									X			

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED Including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
10	JANSZ JMT_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
10	JANSZ JMT_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
10	JANSZ JMT_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1				X								
10	JANSZ JMT_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	500ml clear plastic Green label -(P)	1										X		
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - (VS)	2		X										
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - (VS)	1									X			
11	JANSZ JMT_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
11	JANSZ JMT_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
11	JANSZ JMT_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1				X								
11	JANSZ JMT_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - (VS)	2		X										
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - (VS)	1									X			
12	JANSZ JMT_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
12	JANSZ JMT_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
12	JANSZ JMT_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1				X								
12	JANSZ JMT_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
13	BCH28_SURFACE_1	20220506	W	500ml clear plastic Green label -(P)	1										X		
13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - (VS)	2		X										
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - (VS)	1									X			
13	BCH28_SURFACE_1	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
13	BCH28_SURFACE_1	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
13	BCH28_SURFACE_1	20220506	W	60ml plastic red/green label - (P)	1				X								
13	BCH28_SURFACE_1	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	500ml clear plastic Green label -(P)	1										X		
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - (VS)	2		X										
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - (VS)	1									X			
14	BCH28_SURFACE_2	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
14	BCH28_SURFACE_2	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
14	BCH28_SURFACE_2	20220506	W	60ml plastic red/green label - (P)	1				X								
14	BCH28_SURFACE_2	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	500ml clear plastic Green label -(P)	1										X		
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - blue label -(NP)	1						X	X					
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - blue label -(NP)	1												FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
15	BCH28_SEABED_1	20220506	W	40ml glass vial - (VS)	2		X										
15	BCH28_SEABED_1	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	40ml glass vial - (VS)	1									X			
15	BCH28_SEABED_1	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
15	BCH28_SEABED_1	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
15	BCH28_SEABED_1	20220506	W	60ml plastic red/green label - (P)	1				X								

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
15	BCH28_SEABED_1	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	500ml clear plastic Green label -(P)	1										X		
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
16	BCH28_SEABED_2	20220506	W	40ml glass vial - (VS)	2		X										
16	BCH28_SEABED_2	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	40ml glass vial - (VS)	1									X			
16	BCH28_SEABED_2	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
16	BCH28_SEABED_2	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
16	BCH28_SEABED_2	20220506	W	60ml plastic red/green label - (P)	1				X								
16	BCH28_SEABED_2	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	500ml clear plastic Green label -(P)	1										X		
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - (VS)	2		X										
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - (VS)	1									X			
17	CHANDON DC-1_SURFACE_1	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
17	CHANDON DC-1_SURFACE_1	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml plastic red/green label - (P)	1				X								
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
18	CHANDON DC-1_SURFACE_2	20220507	W	500ml clear plastic Green label -(P)	1										X		
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - (VS)	2		X										
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - (VS)	1									X			
18	CHANDON DC-1_SURFACE_2	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
18	CHANDON DC-1_SURFACE_2	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml plastic red/green label - (P)	1				X								
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml plastic red/green label - (P)	1					X							
19	CHANDON DC-1_SEABED_1	20220507	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - blue label -(NP)	1							X					
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - (VS)	2		X										
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - (VS)	1									X			
19	CHANDON DC-1_SEABED_1	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
19	CHANDON DC-1_SEABED_1	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
19	CHANDON DC-1_SEABED_1	20220507	W	60ml plastic red/green label - (P)	1				X								
19	CHANDON DC-1_SEABED_1	20220507	W	60ml plastic red/green label - (P)	1					X							
20	CHANDON DC-1_SEABED_2	20220507	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - blue label -(NP)	1							X					
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - (VS)	2		X										
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - (VS)	1									X			
20	CHANDON DC-1_SEABED_2	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
20	CHANDON DC-1_SEABED_2	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
20	CHANDON DC-1_SEABED_2	20220507	W	60ml plastic red/green label - (P)	1				X								
20	CHANDON DC-1_SEABED_2	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
				TOTAL	240	20	20	20	20	20	20	20	20	20	20	20	

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VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

| | | |

CHAIN OF CUSTODY

ALS Laboratory: please tick →

CLIENT: Advisian	TURNAROUND REQUIREMENTS: ☐ Standard TAT (List due date): (Standard TAT may be longer for some tests e.g. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	FOR LABORATORY USE ONLY (Circle) Custody seal intact? Yes No N/A; Temperature / Temperature blank present upon receipt? Yes No N/A; Cooler/Sample Temperature on Receipt: °C; Cooler comments:
OFFICE: Lvl 14, 240 St Georges Terrace, Perth		
PROJECT: Gorgon Benthic Survey 2022	ALS QUOTE NO.: EP-246-22_V2	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 5 6 7 OF: 1 2 3 4 5 6 7
ORDER NUMBER: 1		
PROJECT MANAGER: Mark Westera	CONTACT PH: 0422 489 803	
SAMPLER: Luca Chiaroni, Stephanie Watts	SAMPLER MOBILE: 0498 614 575	RELINQUISHED BY: Luca Chiaroni/Steph Watts; RECEIVED BY: NO; RELINQUISHED BY: ; RECEIVED BY:
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default):	
Email Reports to (will default to PM if no other addresses are listed): mark.westera@advisian.com		DATE/TIME: 04/05/22 1045; DATE/TIME: 12/5/22 9:00; DATE/TIME: ; DATE/TIME:
Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com		

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).							Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAHs if TRH recorded	Metals (total only)	TOC (Total organic carbon) (%)	Particle Size Distribution (laser diffraction and wet sieving)	Retain Excess sample for PSD analysis	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
	SEMELE WELL-3_1_1	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	SEMELE WELL-3_1_1	20220508	S	B (500mL bag)	1						x		
	SEMELE WELL-3_1_2	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	SEMELE WELL-3_1_2	20220508	S	B (500mL bag)	1						x		
	SEMELE WELL-3_1_3	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	SEMELE WELL-3_1_3	20220508	S	B (500mL bag)	1						x		
11 ✓	SEMELE WELL-4_1_1	20220508	S	150ml JAR	1	x	x	x	x	x		x	
✓	SEMELE WELL-4_1_1	20220508	S	B (500mL bag)	1						x		
2 ✓	SEMELE WELL-4_1_2	20220508	S	150ml JAR	1	x	x	x	x	x		x	
✓	SEMELE WELL-4_1_2	20220508	S	B (500mL bag)	1						x		
3 ✓	SEMELE WELL-4_1_3	20220508	S	150ml JAR	1	x	x	x	x	x		x	
✓	SEMELE WELL-4_1_3	20220508	S	B (500mL bag)	1						x		
4 ✓	WTR DC-1-4_1_1	20220509	S	150ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1-4_1_1	20220509	S	B (500mL bag)	1						x		
5 ✓	WTR DC-1_1_2	20220509	S	150ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1_1_2	20220509	S	B (500mL bag)	1						x		
6 ✓	WTR DC-1_1_3	20220509	S	150ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1_1_3	20220509	S	B (500mL bag)	1						x		
7 ✓	WTR DC-1_2_1	20220509	S	250ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1_2_1	20220509	S	B (500mL bag)	1						x		
8 ✓	WTR DC-1_2_2	20220509	S	250ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1_2_2	20220509	S	B (500mL bag)	1						x		
9 ✓	WTR DC-1_2_3	20220509	S	250ml JAR	1	x	x	x	x	x		x	
✓	WTR DC-1_2_3	20220509	S	B (500mL bag)	1						x		
10 ✓	QAQC_BLANK 2	20220409	S	250ml JAR	1	x	x	x	x	x		x	

Appendix F Laboratory Reports for Sediment Samples

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2215235**	Page	: 1 of 5
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MARK WESTERA	Contact	: Customer Services EB
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3243 7222
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 27-May-2022 10:00
Order number	: 1	Date Analysis Commenced	: 01-Jun-2022
C-O-C number	: ----	Issue Date	: 09-Jun-2022 13:38
Sampler	: Luca Chiaroni, Stephanie Watts		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 4		
No. of samples analysed	: 4		

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, unless the sampling was conducted by ALS. 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*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Timothy Creagh	2IC Organic Chemist	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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.

- EG048G (Hexavalent Chromium by Alkaline Digestion): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EG005T (Total Metals by ICP-AES): EB2215171-003 shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215331-031 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215331-033 shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215290-003 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG048G (Hexavalent Chromium by Alkaline Digestion): Sample EB2215235_001 (SEMELE WELL-4_1_3) shows poor matrix spike recovery due to matrix interferences.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_3	SEMELE WELL-4_1_2	WTR DC-1_4_1_1	WTR DC-2_2_3	----
			Sampling date / time	08-May-2022 17:08	08-May-2022 17:08	09-May-2022 17:09	09-May-2022 17:09	----
Compound	CAS Number	LOR	Unit	EB2215235-001	EB2215235-002	EB2215235-003	EB2215235-004	--------
				Result	Result	Result	Result	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	57.6	58.2	35.4	35.0	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	3300	3460	1570	1490	----
Iron	7439-89-6	50	mg/kg	5130	5380	2800	2720	----
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	80	90	30	30	----
Chromium	7440-47-3	2	mg/kg	24	25	14	13	----
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.62	1.63	1.27	1.23	----
Cadmium	7440-43-9	0.1	mg/kg	0.3	0.3	0.1	0.1	----
Chromium	7440-47-3	1.0	mg/kg	30.3	30.5	17.4	15.9	----
Copper	7440-50-8	1.0	mg/kg	12.8	13.2	3.7	3.4	----
Cobalt	7440-48-4	0.5	mg/kg	3.1	3.1	1.5	1.4	----
Lead	7439-92-1	1.0	mg/kg	2.6	2.7	1.6	1.5	----
Manganese	7439-96-5	10	mg/kg	173	216	96	92	----
Nickel	7440-02-0	1.0	mg/kg	18.9	19.1	7.5	7.1	----
Silver	7440-22-4	0.1	mg/kg	0.1	0.1	<0.1	<0.1	----
Zinc	7440-66-6	1.0	mg/kg	20.6	20.8	6.2	5.9	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	0.02	0.02	<0.01	<0.01	----
EG048: Hexavalent Chromium (Alkaline Digest)								
Hexavalent Chromium	18540-29-9	0.5	mg/kg	<4.0	<4.0	<2.0	<2.0	----
EG049: Trivalent Chromium								
Trivalent Chromium	16065-83-1	2	mg/kg	24	25	14	13	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	----
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	SEMELE WELL-4_1_3	SEMELE WELL-4_1_2	WTR DC-1_4_1_1	WTR DC-2_2_3	----
				Sampling date / time	08-May-2022 17:08	08-May-2022 17:08	09-May-2022 17:09	09-May-2022 17:09	----
Compound	CAS Number	LOR	Unit		EB2215235-001	EB2215235-002	EB2215235-003	EB2215235-004	--------
					Result	Result	Result	Result	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued									
>C10 - C16 Fraction	----	50	mg/kg		<50	<50	<50	<50	----
>C16 - C34 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg		<50	<50	<50	<50	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg		<50	<50	<50	<50	----
EP080: BTEXN									
Benzene	71-43-2	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	----
Toluene	108-88-3	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	----
Ethylbenzene	100-41-4	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	----
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	----
ortho-Xylene	95-47-6	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	----
^ **Sum of BTEX**	----	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	----
^ **Total Xylenes**	----	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	----
Naphthalene	91-20-3	1	mg/kg		<1	<1	<1	<1	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.2	%		**104**	**91.8**	**94.6**	**95.7**	----
Toluene-D8	2037-26-5	0.2	%		**84.7**	**73.3**	**72.4**	**73.5**	----
4-Bromofluorobenzene	460-00-4	0.2	%		**101**	**90.5**	**92.4**	**89.5**	----

Surrogate Control Limits

Sub-Matrix: **SOIL**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	53	134
Toluene-D8	2037-26-5	60	131
4-Bromofluorobenzene	460-00-4	59	127

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
			Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	60.6	61.3	61.4	39.1	42.0
EA150: Particle Sizing								
+75µm	----	1	%	4	3	2	49	48
+150µm	----	1	%	2	1	1	11	10
+300µm	----	1	%	1	<1	<1	2	2
+425µm	----	1	%	<1	<1	<1	1	<1
+600µm	----	1	%	<1	<1	<1	<1	<1
+1180µm	----	1	%	<1	<1	<1	<1	<1
+2.36mm	----	1	%	<1	<1	<1	<1	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	35	34	36	14	15
Silt (2-60 µm)	----	1	%	60	60	58	30	29
Sand (0.06-2.00 mm)	----	1	%	5	6	6	56	56
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.41	2.30	2.38	2.44	2.43
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4760	5140	4960	2260	2240
Iron	7439-89-6	50	mg/kg	6600	6990	6650	3390	3500
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	110	110	100	40	50
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.72	1.76	1.75	1.25	1.28
Cadmium	7440-43-9	0.1	mg/kg	0.4	0.4	0.4	0.1	0.1
Chromium	7440-47-3	1.0	mg/kg	30.8	32.6	31.3	16.7	16.7
Copper	7440-50-8	1.0	mg/kg	13.6	14.5	13.5	3.8	3.9
Cobalt	7440-48-4	0.5	mg/kg	3.1	3.4	3.2	1.4	1.5
Lead	7439-92-1	1.0	mg/kg	2.8	2.9	2.8	1.5	1.6

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
			Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**186**	**221**	**186**	**95**	**99**
Nickel	7440-02-0	1.0	mg/kg	**19.6**	**20.8**	**19.7**	**7.5**	**7.7**
Silver	7440-22-4	0.1	mg/kg	**0.2**	**0.1**	**0.1**	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**22.8**	**23.9**	**22.2**	**6.7**	**6.8**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	**0.02**	**0.01**	**0.02**	<0.01	<0.01
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**1.30**	**1.20**	**1.19**	**0.50**	**0.52**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	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
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP080S: TPH(V)/BTEX Surrogates								

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
				Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
					EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
					Result	Result	Result	Result	Result
EP080S: TPH(V)/BTEX Surrogates - Continued									
1.2-Dichloroethane-D4	17060-07-0	0.2	%		**64.4**	**71.5**	**68.2**	**67.1**	**71.7**
Toluene-D8	2037-26-5	0.2	%		**79.0**	**69.7**	**67.1**	**77.7**	**81.4**
4-Bromofluorobenzene	460-00-4	0.2	%		**71.8**	**64.4**	**61.2**	**69.4**	**76.7**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	40.3	40.6	40.9	40.4	----
Moisture Content	----	1.0	%	----	----	----	----	7.3
EA150: Particle Sizing								
+75µm	----	1	%	47	52	56	54	----
+150µm	----	1	%	12	12	15	12	----
+300µm	----	1	%	2	2	3	2	----
+425µm	----	1	%	<1	1	2	1	----
+600µm	----	1	%	<1	<1	<1	<1	----
+1180µm	----	1	%	<1	<1	<1	<1	----
+2.36mm	----	1	%	<1	<1	<1	<1	----
+4.75mm	----	1	%	<1	<1	<1	<1	----
+9.5mm	----	1	%	<1	<1	<1	<1	----
+19.0mm	----	1	%	<1	<1	<1	<1	----
+37.5mm	----	1	%	<1	<1	<1	<1	----
+75.0mm	----	1	%	<1	<1	<1	<1	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	15	12	12	14	----
Silt (2-60 µm)	----	1	%	30	28	26	29	----
Sand (0.06-2.00 mm)	----	1	%	55	60	62	57	----
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	----
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.36	2.36	2.42	2.42	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2480	2280	2230	2400	----
Iron	7439-89-6	50	mg/kg	3630	3530	3510	3610	----
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	40	40	40	50	----
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.30	1.23	1.30	1.29	----
Cadmium	7440-43-9	0.1	mg/kg	0.1	0.1	0.1	0.2	----
Chromium	7440-47-3	1.0	mg/kg	17.7	16.7	16.7	17.5	----
Copper	7440-50-8	1.0	mg/kg	4.0	3.8	3.8	3.9	----
Cobalt	7440-48-4	0.5	mg/kg	1.5	1.5	1.5	1.5	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
					Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued									
Lead	7439-92-1	1.0	mg/kg		**1.6**	**1.6**	**1.6**	**1.6**	----
Manganese	7439-96-5	10	mg/kg		**101**	**96**	**101**	**102**	----
Nickel	7440-02-0	1.0	mg/kg		**8.1**	**7.7**	**7.3**	**7.8**	----
Silver	7440-22-4	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	1.0	mg/kg		**6.9**	**6.7**	**6.6**	**6.8**	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	----
EP003: Total Organic Carbon (TOC) in Soil									
Total Organic Carbon	----	0.02	%		**0.52**	**0.47**	**0.46**	**0.49**	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	10	mg/kg		<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg		<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
C29 - C36 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg		<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
C6 - C10 Fraction	C6_C10	10	mg/kg		<10	<10	<10	<10	<10
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	10	mg/kg		<10	<10	<10	<10	<10
>C10 - C16 Fraction	----	50	mg/kg		<50	<50	<50	<50	----
>C16 - C34 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	mg/kg		<100	<100	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg		<50	<50	<50	<50	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg		<50	<50	<50	<50	----
EP080: BTEXN									
Benzene	71-43-2	0.2	mg/kg		<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	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
^ **Total Xylenes**	----	0.5	mg/kg		<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg		<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
					Result	Result	Result	Result	Result
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.2	%		**67.5**	**67.6**	**65.6**	**66.3**	**82.0**
Toluene-D8	2037-26-5	0.2	%		**76.0**	**76.8**	**74.5**	**75.7**	**95.3**
4-Bromofluorobenzene	460-00-4	0.2	%		**68.8**	**68.8**	**69.3**	**69.1**	**84.9**

Surrogate Control Limits

Sub-Matrix: **SOIL**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	63	132
Toluene-D8	2037-26-5	66	125
4-Bromofluorobenzene	460-00-4	60	124

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EP003: Total Organic Carbon (TOC) in Soil

Analysis conducted by ALS Newcastle, NATA accreditation no. 825, site no. 1656 (Chemistry) 9854 (Biology).

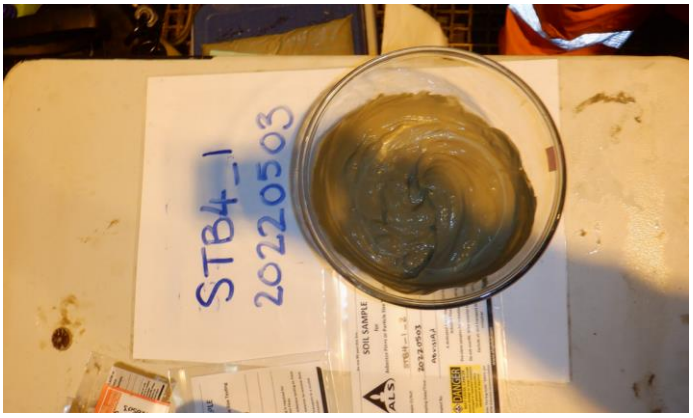
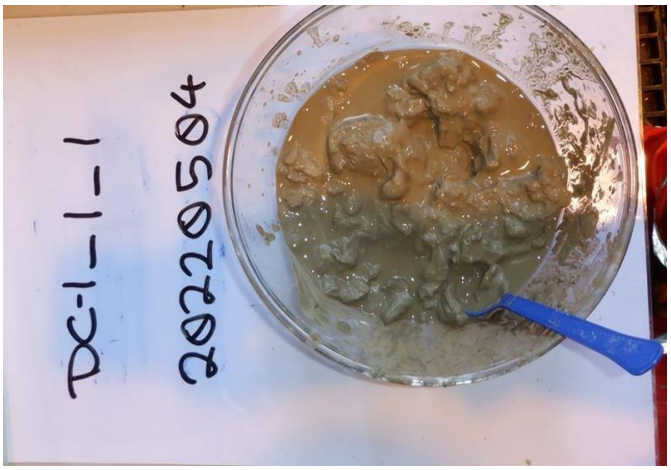
(SOIL) EA150: Soil Classification based on Particle Size

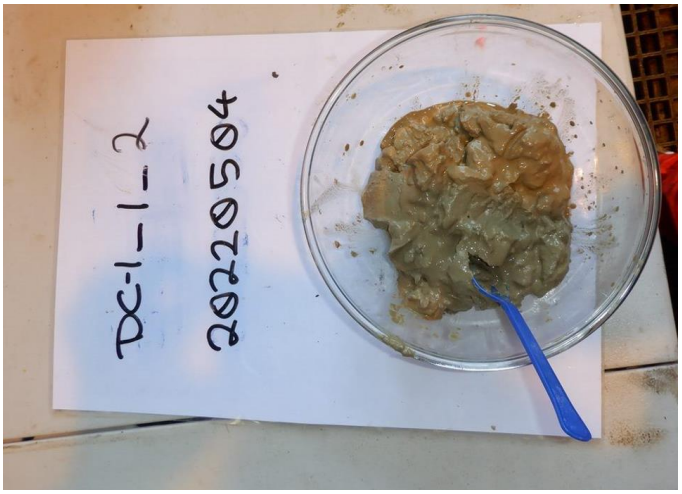
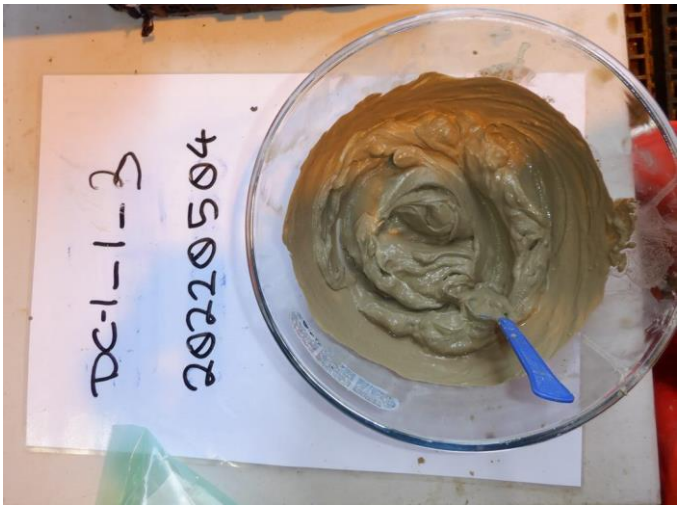
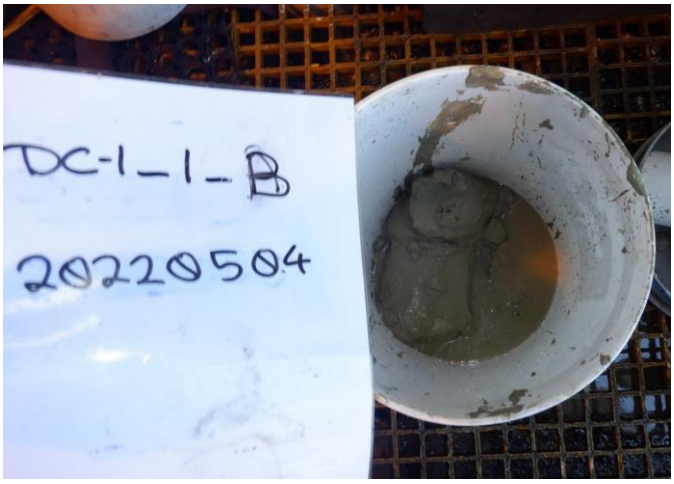
(SOIL) EA150: Particle Sizing

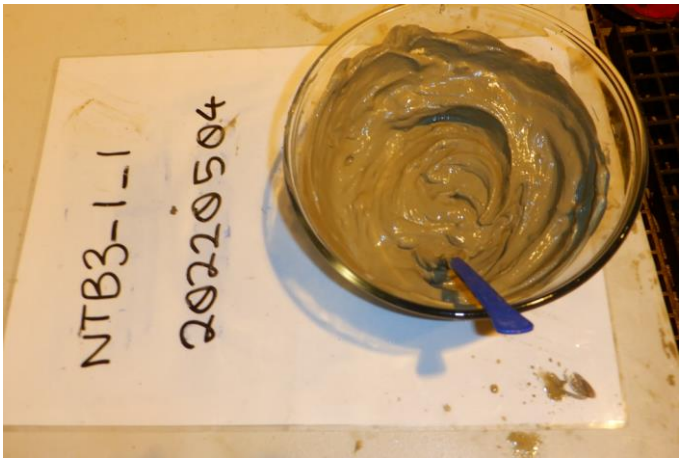
(SOIL) EA152: Soil Particle Density

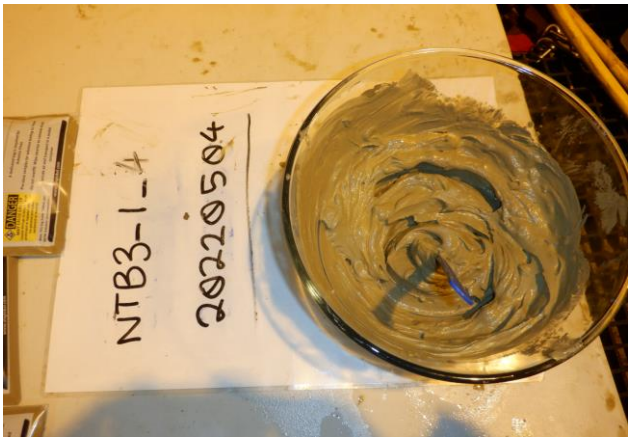
Appendix G Sediment Core Photos

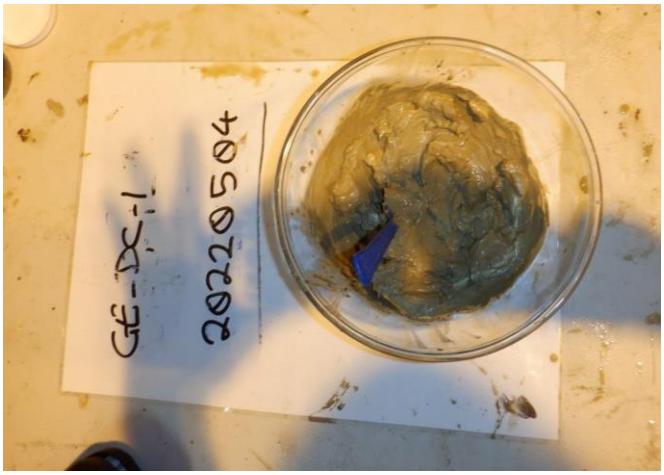
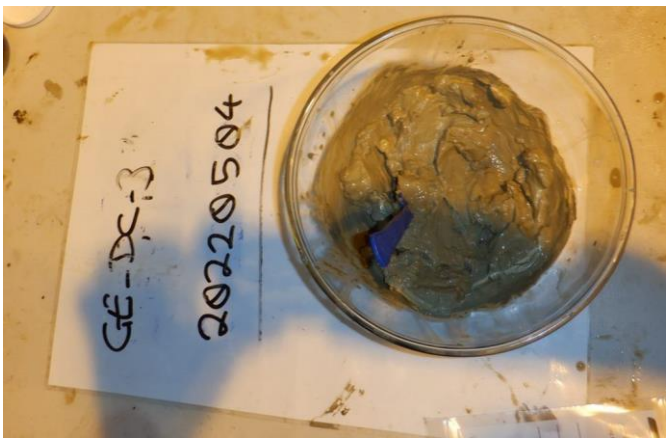
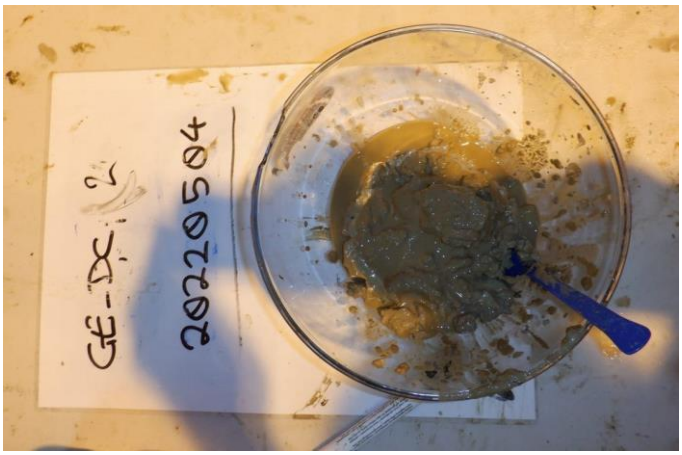
Appendix Sediment core photos

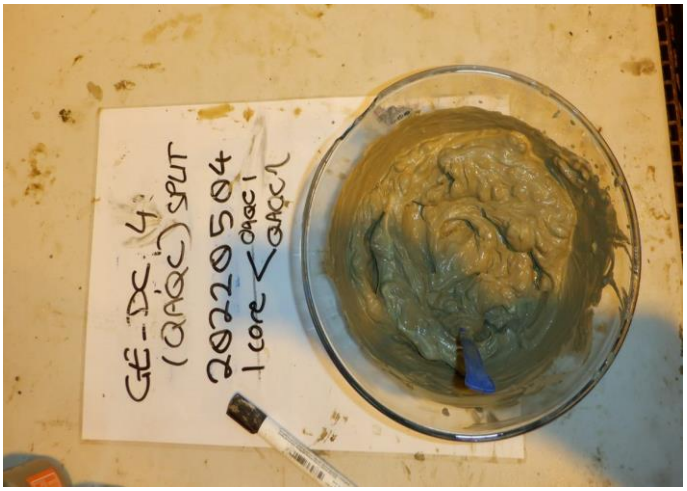
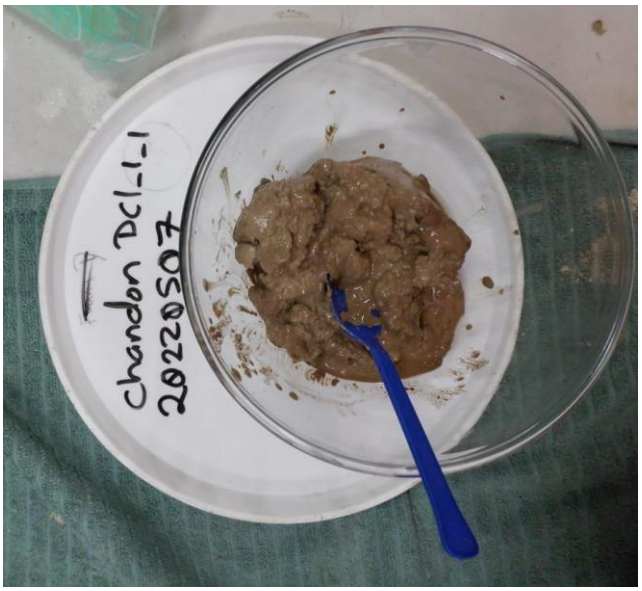
STB4_1	
STB4_3	
DC-1_1_1	

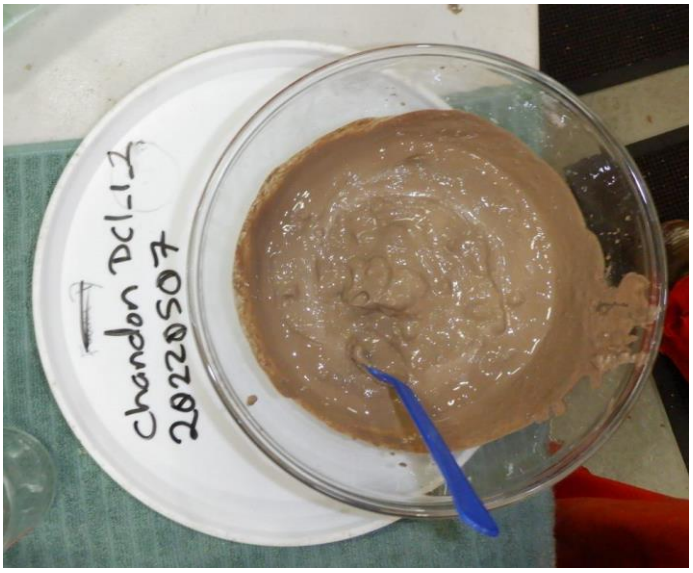
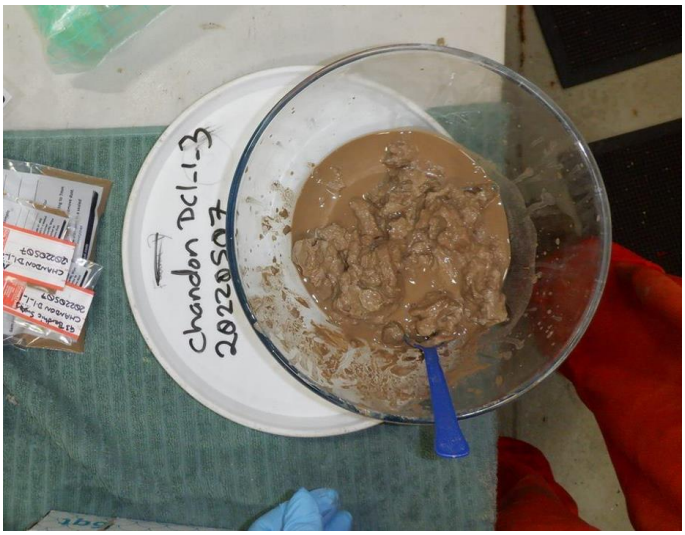
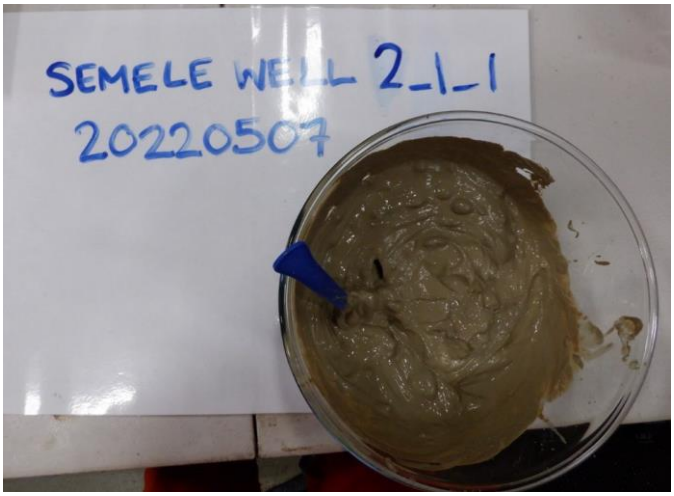
Site/Sample	Photo
DC-1_1_2	
DC-1_1_3	
DC-1_1_B	

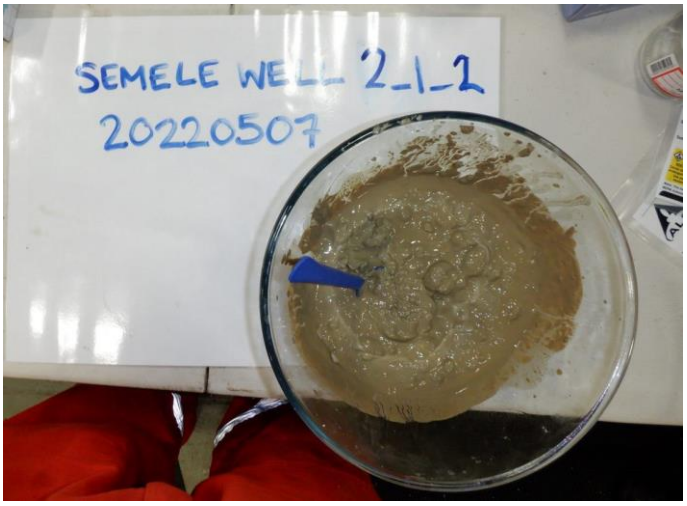
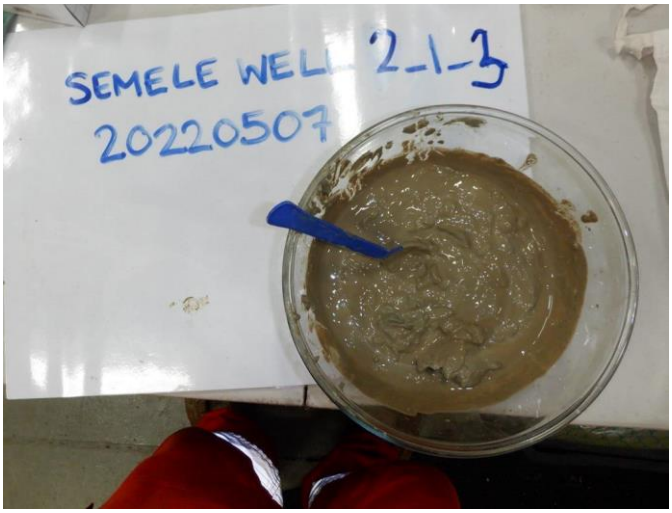
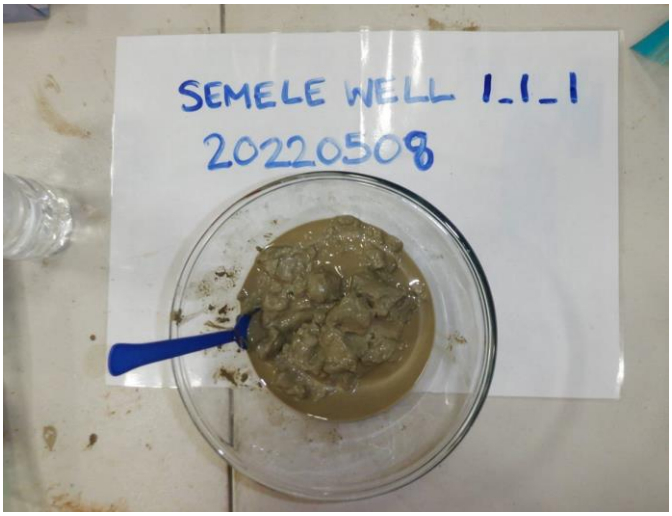
Site/Sample	Photo
NTB3_1_1	
NTB3_1_1	
NTB3_1_3	

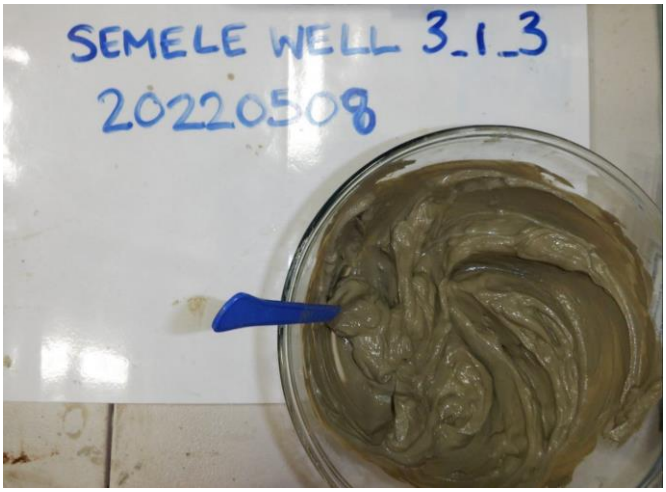
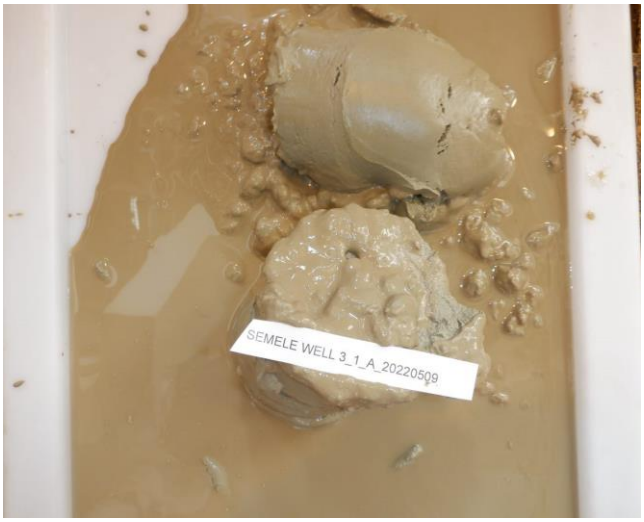
Site/Sample	Photo
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NTB3_1_A	
NTB3_1_B	

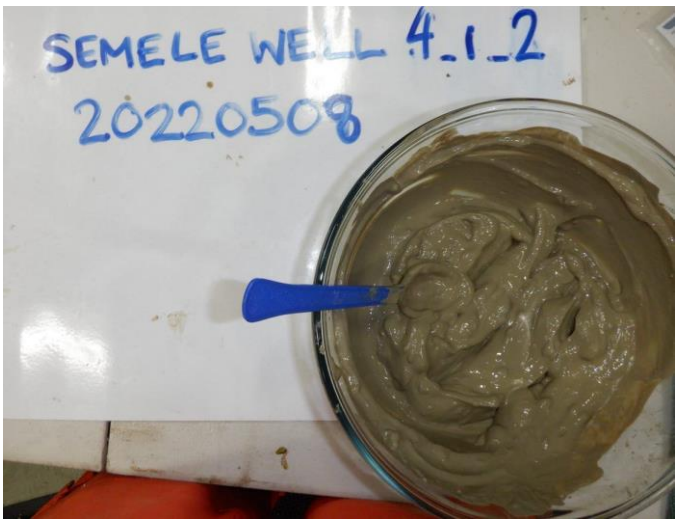
Site/Sample	Photo
GE_DC-1	
GE_DC-3	
GE_DC-2	

Site/Sample	Photo
GE_DC-4	
Chandon DC1_1_1	

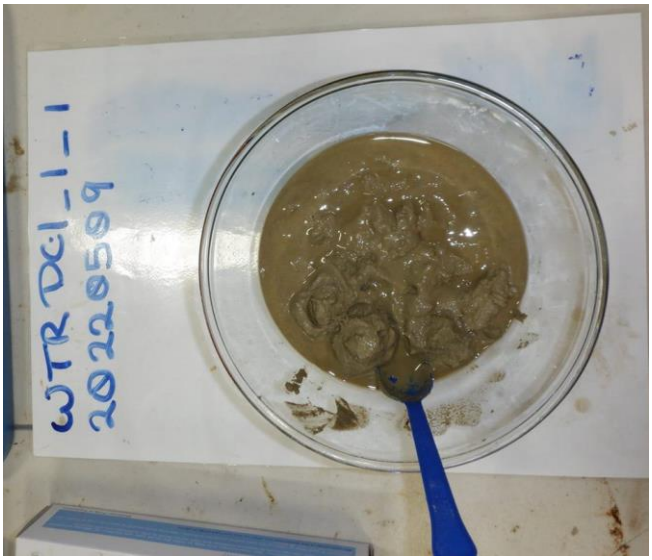
Site/Sample	Photo
Chandon DC1_1_2	
Chandon DC1_1_3	
SEMELE WELL 2_1_1	

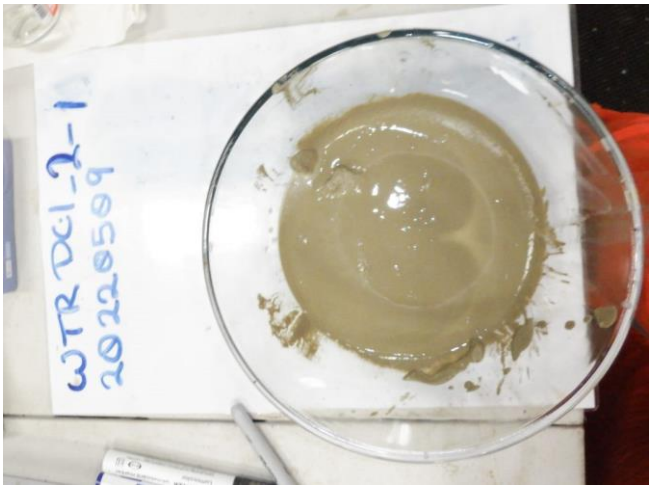
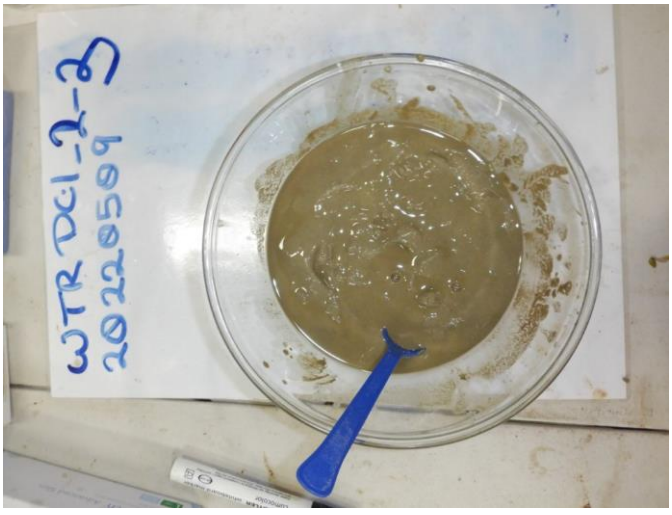
Site/Sample	Photo
SEMELE WELL 2_1_2	
SEMELE WELL 2_1_3	
SEMELE WELL 1_1_1	

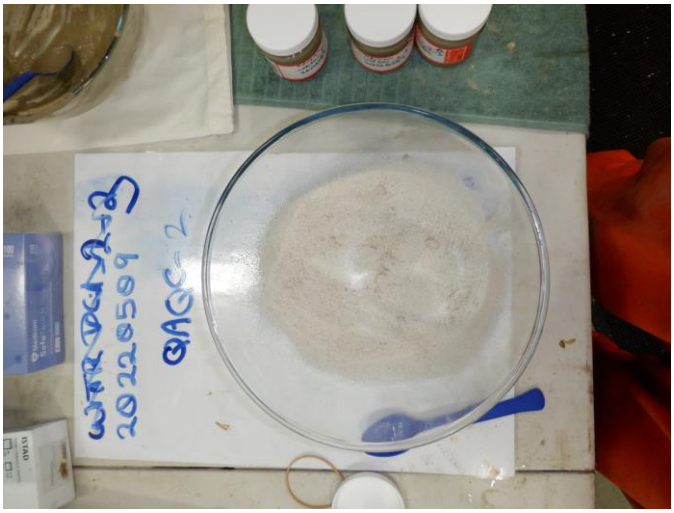
Site/Sample	Photo
SEMELE WELL 3_1_1	
SEMELE WELL 3_1_3	
SEMELE WELL 3_1_A	

Site/Sample	Photo
SEMELE WELL 3_1_B	
SEMELE WELL 4_1_2	

Site/Sample	Photo
SEMELE WELL 4_1_A	
SEMELE WELL 4_2_B	

Site/Sample	Photo
WTR DC1_1_1	
WTR DC1_1_2	
WTR DC1_1_3	

Site/Sample	Photo
WTR DC1_2_1	
WTR DC1_2_2	
WTR DC1_2_3	

Site/Sample	Photo
QAQC-2	

Appendix H Laboratory Reports for Water Samples

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2215199**	Page	: 1 of 4
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MARK WESTERA	Contact	: Customer Services EB
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3243 7222
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 30-May-2022 13:54
Order number	: 1	Date Analysis Commenced	: 01-Jun-2022
C-O-C number	: ----	Issue Date	: 09-Jun-2022 08:49
Sampler	: Luca Chiaroni, Stephanie Watts		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 2		
No. of samples analysed	: 2		

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, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

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*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Matt Frost	Assistant Laboratory Manager	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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.

- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- **Metals analysis will be conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.**
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	GORGON GMT_SEABED_1	----	----	----
			Sampling date / time	09-May-2022 17:09	10-May-2022 17:10	----	----	----
Compound	CAS Number	LOR	Unit	EB2215199-001	EB2215199-002	--------	--------	--------
				Result	Result	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.5**	**1.4**	----	----	----
Barium	7440-39-3	1	µg/L	**5**	**5**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	----	----	----
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.5**	----	----	----
Barium	7440-39-3	1	µg/L	**6**	**6**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	----	----	----
Copper	7440-50-8	0.2	µg/L	**0.3**	<0.2	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.5	<0.5	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	WTR DC-1_SURFACE_1	GORGON GMT_SEABED_1	----	----	----
				Sampling date / time	09-May-2022 17:09	10-May-2022 17:10	----	----	----
Compound	CAS Number	LOR	Unit		EB2215199-001	EB2215199-002	--------	--------	--------
					Result	Result	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		<0.5	<0.5	**----**	**----**	**----**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.05	<0.05	**----**	**----**	**----**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		<1	<1	**----**	**----**	**----**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**1**	<1	**----**	**----**	**----**

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(WATER) EG035T: Total Recoverable Mercury by FIMS

(WATER) EG035F: Dissolved Mercury by FIMS

(WATER) EG093F: Dissolved Metals in Saline Water by ORC-ICPMS

(WATER) EG093T_LL: Total Metals in Saline Water by ORC-ICPMS

(WATER) EG093T: Total Metals in Saline Water by ORC-ICPMS

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP2205671**	Page	: 1 of 15
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MARK WESTERA	Contact	: Customer Services EP
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: ----	Telephone	: +61-8-9406 1301
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 10-May-2022 16:20
Order number	: ----	Date Analysis Commenced	: 12-May-2022
C-O-C number	: ----	Issue Date	: 17-May-2022 17:16
Sampler	: Luca Chiaroni, STEPHANIE WATTS		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 20		
No. of samples analysed	: 20		

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, unless the sampling was conducted by ALS. 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*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP002, EP005: It has been noted that the result for Dissolved Organic Carbon is greater than the result for Total Organic Carbon for samples #002, 010, 011 & 013-018 however the difference is within the limits of experimental variation.
- EG093 and EG093-LL: It is recognised that some total analyte concentrations are less than dissolved for various samples. However, the difference is within experimental variation of the methods.
- EG093-LL: Dissolved and Total Cu results for sample EP2205671 -018 has been confirmed by re-preparation and re-analysis.
- EK061G/EK067G (TKN/TP): LOR for samples EP2205671-001, -006, -013, -014, -017 and -018 raised due to the high amount of TDS present.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
				Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
					EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**38400**	**38200**	**36900**	**37100**	**38100**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.7**	**1.8**	**1.9**	**1.9**	**1.8**
Barium	7440-39-3	1	µg/L		**5**	**4**	**12**	**12**	**5**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L		**0.2**	**0.3**	**0.3**	**0.3**	**0.3**
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L		<5	**7**	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	**0.6**	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.7**	**1.7**	**1.8**	**1.8**	**1.7**
Barium	7440-39-3	1	µg/L		**5**	**5**	**12**	**12**	**5**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
			Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	**0.2**	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	**0.7**	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	**0.3**	<0.2	**0.2**	**0.4**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	**0.40**	**0.39**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.2**	**0.2**	**0.7**	**0.7**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.02	**0.03**	**0.11**	**0.13**	**0.03**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	<1	**1**	<1	<1	<1
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	<1	<1	<1
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

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
			Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
^ >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	%	**92.0**	**91.2**	**92.5**	**91.8**	**88.2**
Toluene-D8	2037-26-5	2	%	**102**	**125**	**124**	**126**	**123**
4-Bromofluorobenzene	460-00-4	2	%	**104**	**104**	**114**	**108**	**98.4**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
				Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
					EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**38600**	**37600**	**38500**	**38100**	**38300**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.6**	**1.8**	**1.8**	**1.7**	**1.7**
Barium	7440-39-3	1	µg/L		**5**	**12**	**13**	**13**	**5**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L		<0.2	**0.2**	<0.2	<0.2	**0.4**
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	**8**
Lead	7439-92-1	0.2	µg/L		<0.2	**0.5**	<0.2	**0.5**	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	**6**	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.7**	**1.8**	**1.8**	**1.8**	**1.7**
Barium	7440-39-3	1	µg/L		**5**	**13**	**13**	**13**	**5**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		**0.6**	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
				Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	**0.5**	<0.2	**0.5**	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L		**0.2**	**0.2**	<0.2	<0.2	**0.6**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.39**	**0.40**	**0.39**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	**0.3**	**0.3**	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	**0.7**	**0.7**	**0.6**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.02	**0.09**	**0.09**	**0.03**	**0.08**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		<1	<1	<1	<1	**2**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	<1	<1	<1	<1
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

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>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	%	**90.1**	**90.5**	**92.2**	**93.4**	**90.2**
Toluene-D8	2037-26-5	2	%	**121**	**124**	**123**	**122**	**126**
4-Bromofluorobenzene	460-00-4	2	%	**112**	**106**	**95.6**	**108**	**107**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
				Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
					EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**38700**	**38700**	**38900**	**39200**	**38600**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.6**	**1.7**	**1.6**	**1.5**	**1.6**
Barium	7440-39-3	1	µg/L		**5**	**13**	**5**	**5**	**13**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L		<0.2	<0.2	**0.3**	**0.3**	<0.2
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	**6**	<5
Arsenic	7440-38-2	0.5	µg/L		**1.8**	**1.9**	**1.6**	**1.7**	**1.8**
Barium	7440-39-3	1	µg/L		**5**	**13**	**5**	**5**	**13**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
				Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L		<0.2	**0.3**	**0.3**	**0.2**	<0.2
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.40**	<0.01	<0.01	**0.40**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	**0.3**	**0.3**	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	**0.7**	**0.3**	**0.2**	**0.7**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.03**	**0.10**	<0.02	<0.02	**0.09**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	<1	**1**	**1**	**1**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	<1	<1	<1	<1
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

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
				Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
					Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued									
>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	%		**89.8**	**91.7**	**90.5**	**89.0**	**93.1**
Toluene-D8	2037-26-5	2	%		**122**	**123**	**123**	**121**	**125**
4-Bromofluorobenzene	460-00-4	2	%		**100**	**105**	**99.5**	**99.4**	**103**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
				Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
					EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**39100**	**38200**	**37800**	**38200**	**39000**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L		**1.8**	**1.7**	**1.6**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L		**13**	**5**	**5**	**13**	**13**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L		<0.2	**0.3**	**1.6**	<0.2	**0.2**
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		**0.2**	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	**0.7**
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		**6**	<5	<5	<5	**9**
Arsenic	7440-38-2	0.5	µg/L		**1.9**	**1.8**	**1.8**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L		**13**	**7**	**5**	**12**	**12**
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
				Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
					EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L		<0.2	**0.3**	**1.4**	<0.2	**0.3**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.40**	<0.01	<0.01	**0.40**	**0.41**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.3**	**0.2**	**0.3**	**0.3**	**0.4**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		**0.7**	**0.2**	**0.3**	**0.7**	**0.8**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.08**	<0.02	<0.02	**0.11**	**0.11**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	**2**	**1**	<1	<1
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	**1**	**1**	**1**	<1
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

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
				Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
					EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
					Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued									
>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	%		**90.5**	**97.8**	**94.9**	**93.3**	**90.1**
Toluene-D8	2037-26-5	2	%		**125**	**121**	**122**	**123**	**125**
4-Bromofluorobenzene	460-00-4	2	%		**102**	**99.4**	**101**	**104**	**99.4**

Surrogate Control Limits

Sub-Matrix: **WATER**		Recovery Limits (%)	
Compound	*CAS Number*	*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

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP2205756**	Page	: 1 of 14
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MARK WESTERA	Contact	: Customer Services EP
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: ----	Telephone	: +61-8-9406 1301
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 12-May-2022 09:00
Order number	: 1	Date Analysis Commenced	: 13-May-2022
C-O-C number	: ----	Issue Date	: 20-May-2022 17:21
Sampler	: Luca Chiaroni, STEPHANIE WATTS		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 12		
No. of samples analysed	: 12		

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, unless the sampling was conducted by ALS. 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*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP002, EP005: It is noted that the results for Dissolved Organic Carbon are greater than the results for Total Organic Carbon for samples #002 & 007, however the results are within the limits of experimental variation.
- EG093 and EG093-LL: It is recognised that some total analyte concentrations are less than dissolved for various samples. However, the difference is within experimental variation of the methods.
- EK061G/EK067G (TKN/TP): LOR for samples EP2205756-009, -010, -011 and -012 raised due to the high amount of TDS present.
- EG094: Positive metals results for samples EP2205756-005 to -008 have been confirmed by re-preparation and re-analysis.
- EG094 and EG094-LL: It is recognised that total Cu, Zn concentrations are less than dissolved for samples EP2205756-005 to -008. However, the difference is within experimental variation of the methods.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
					EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**39300**	**40000**	**38400**	**40000**	**166**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		----	----	----	----	<0.001
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		----	----	----	----	<0.001
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	----
Arsenic	7440-38-2	0.5	µg/L		**1.9**	**1.9**	**1.9**	**1.8**	----
Barium	7440-39-3	1	µg/L		**5**	**4**	**5**	**5**	----
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	----
Copper	7440-50-8	0.2	µg/L		<0.2	**0.5**	<0.2	<0.2	----
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	----
Iron	7439-89-6	5	µg/L		<5	<5	<5	<5	----
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	----
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L		<5	<5	**5**	<5	----
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	<5	----
Arsenic	7440-38-2	0.5	µg/L		**1.8**	**1.9**	**1.9**	**1.8**	----
Barium	7440-39-3	1	µg/L		**6**	**4**	**4**	**5**	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	<0.5	**0.7**	----
Iron	7439-89-6	5	µg/L		<5	<5	<5	**7**	----
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	<0.2	**0.2**	----
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L		<5	<5	<5	<5	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	<0.05	<0.05	----
Copper	7440-50-8	0.2	µg/L		<0.2	**0.9**	<0.2	<0.2	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		----	----	----	----	<5
Arsenic	7440-38-2	0.2	µg/L		----	----	----	----	<0.2
Barium	7440-39-3	0.5	µg/L		----	----	----	----	**1.1**
Cadmium	7440-43-9	0.05	µg/L		----	----	----	----	<0.05
Chromium	7440-47-3	0.2	µg/L		----	----	----	----	<0.2
Cobalt	7440-48-4	0.02	µg/L		----	----	----	----	<0.02
Copper	7440-50-8	0.05	µg/L		----	----	----	----	**0.33**
Iron	7439-89-6	2	µg/L		----	----	----	----	<2
Lead	7439-92-1	0.1	µg/L		----	----	----	----	<0.1
Manganese	7439-96-5	0.5	µg/L		----	----	----	----	<0.5
Nickel	7440-02-0	0.5	µg/L		----	----	----	----	<0.5
Silver	7440-22-4	0.1	µg/L		----	----	----	----	<0.1
Zinc	7440-66-6	1	µg/L		----	----	----	----	**3**
EG094T: Total metals in Fresh water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		----	----	----	----	<5
Arsenic	7440-38-2	0.2	µg/L		----	----	----	----	<0.2
Barium	7440-39-3	0.5	µg/L		----	----	----	----	**3.4**
Cadmium	7440-43-9	0.05	µg/L		----	----	----	----	<0.05
Chromium	7440-47-3	0.2	µg/L		----	----	----	----	<0.2
Cobalt	7440-48-4	0.02	µg/L		----	----	----	----	<0.02
Copper	7440-50-8	0.05	µg/L		----	----	----	----	**0.35**
Iron	7439-89-6	2	µg/L		----	----	----	----	<2

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
					Result	Result	Result	Result	Result
EG094T: Total metals in Fresh water by ORC-ICPMS - Continued									
Lead	7439-92-1	0.1	µg/L		----	----	----	----	<0.1
Manganese	7439-96-5	0.5	µg/L		----	----	----	----	<0.5
Nickel	7440-02-0	0.5	µg/L		----	----	----	----	<0.5
Silver	7440-22-4	0.1	µg/L		----	----	----	----	<0.1
Zinc	7440-66-6	1	µg/L		----	----	----	----	**2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	**0.01**	**0.01**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.2**	**0.4**	**0.3**	**0.2**	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.2**	**0.4**	**0.3**	**0.2**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.02**	**0.05**	**0.06**	**0.03**	<0.01
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	**2**	**2**	**2**	**1**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**1**	**1**	**2**	**2**	**1**
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	<20	<20	<20	**40**
C10 - C14 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L		<100	<100	<100	<100	**130**
C29 - C36 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L		<50	<50	<50	<50	**130**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
C6 - C10 Fraction	C6_C10	20	µg/L		<20	<20	<20	<20	**40**
^ 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

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit		EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
					Result	Result	Result	Result	Result
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	**25**
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	**3**
ortho-Xylene	95-47-6	2	µg/L		<2	<2	<2	<2	**2**
^ **Total Xylenes**	----	2	µg/L		<2	<2	<2	<2	**5**
^ **Sum of BTEX**	----	1	µg/L		<1	<1	<1	<1	**30**
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	%		**111**	**107**	**113**	**106**	**98.1**
Toluene-D8	2037-26-5	2	%		**100**	**100**	**99.9**	**101**	**100**
4-Bromofluorobenzene	460-00-4	2	%		**101**	**101**	**100**	**98.0**	**100.0**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
					EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		<10	**35**	**160**	**38700**	**38800**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Trivalent Chromium	16065-83-1	0.001	mg/L		----	----	----	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Trivalent Chromium	16065-83-1	0.001	mg/L		----	----	----	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		----	----	----	<5	<5
Arsenic	7440-38-2	0.5	µg/L		----	----	----	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L		----	----	----	**5**	**4**
Cadmium	7440-43-9	0.2	µg/L		----	----	----	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		----	----	----	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L		----	----	----	**0.3**	**1.7**
Cobalt	7440-48-4	0.05	µg/L		----	----	----	<0.05	<0.05
Iron	7439-89-6	5	µg/L		----	----	----	<5	<5
Lead	7439-92-1	0.2	µg/L		----	----	----	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L		----	----	----	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		----	----	----	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		----	----	----	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		----	----	----	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		----	----	----	<5	<5
Arsenic	7440-38-2	0.5	µg/L		----	----	----	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L		----	----	----	**5**	**5**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
					EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
					Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Cadmium	7440-43-9	0.2	µg/L		----	----	----	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L		----	----	----	<0.5	<0.5
Iron	7439-89-6	5	µg/L		----	----	----	<5	<5
Lead	7439-92-1	0.2	µg/L		----	----	----	**7.4**	<0.2
Manganese	7439-96-5	0.5	µg/L		----	----	----	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L		----	----	----	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L		----	----	----	<0.1	<0.1
Zinc	7440-66-6	5	µg/L		----	----	----	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		----	----	----	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L		----	----	----	**0.3**	**1.2**
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	<5	----	----
Arsenic	7440-38-2	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Barium	7440-39-3	0.5	µg/L		<0.5	**30.3**	**7.4**	----	----
Cadmium	7440-43-9	0.05	µg/L		<0.05	<0.05	<0.05	----	----
Chromium	7440-47-3	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Cobalt	7440-48-4	0.02	µg/L		<0.02	<0.02	<0.02	----	----
Copper	7440-50-8	0.05	µg/L		**0.31**	**0.14**	**0.34**	----	----
Iron	7439-89-6	2	µg/L		<2	<2	<2	----	----
Lead	7439-92-1	0.1	µg/L		<0.1	<0.1	<0.1	----	----
Manganese	7439-96-5	0.5	µg/L		<0.5	**0.7**	<0.5	----	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	----	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	----	----
Zinc	7440-66-6	1	µg/L		**2**	**3**	**2**	----	----
EG094T: Total metals in Fresh water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	**5**	----	----
Arsenic	7440-38-2	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Barium	7440-39-3	0.5	µg/L		<0.5	**37.2**	**34.2**	----	----
Cadmium	7440-43-9	0.05	µg/L		<0.05	<0.05	<0.05	----	----
Chromium	7440-47-3	0.2	µg/L		<0.2	<0.2	<0.2	----	----
Cobalt	7440-48-4	0.02	µg/L		<0.02	<0.02	<0.02	----	----
Copper	7440-50-8	0.05	µg/L		**0.22**	**0.39**	**0.30**	----	----
Iron	7439-89-6	2	µg/L		<2	<2	**5**	----	----

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
					EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
					Result	Result	Result	Result	Result
EG094T: Total metals in Fresh water by ORC-ICPMS - Continued									
Lead	7439-92-1	0.1	µg/L		<0.1	<0.1	**0.3**	**----**	**----**
Manganese	7439-96-5	0.5	µg/L		<0.5	**0.8**	<0.5	**----**	**----**
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	<0.5	**----**	**----**
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	<0.1	**----**	**----**
Zinc	7440-66-6	1	µg/L		**1**	**2**	**2**	**----**	**----**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		<0.1	<0.1	<0.1	**0.2**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.02	<0.02
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		<1	**2**	**3**	**2**	**1**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	**1**	**4**	**2**	**1**
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		**60**	**30**	**30**	<20	<20
C10 - C14 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L		**130**	**160**	**2160**	<100	<100
C29 - C36 Fraction	----	50	µg/L		<50	<50	**1690**	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L		**130**	**160**	**3850**	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
C6 - C10 Fraction	C6_C10	20	µg/L		**60**	**30**	**40**	<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**	**120**	**160**	<100	<100
>C16 - C34 Fraction	----	100	µg/L		<100	<100	**3730**	<100	<100
>C34 - C40 Fraction	----	100	µg/L		<100	<100	**220**	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L		**100**	**120**	**4110**	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L		**100**	**120**	**160**	<100	<100

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
				Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
					EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
					Result	Result	Result	Result	Result
EP080: BTEXN									
Benzene	71-43-2	1	µg/L		<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L		**40**	**20**	**22**	<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		**5**	**2**	**3**	<2	<2
ortho-Xylene	95-47-6	2	µg/L		**4**	<2	**2**	<2	<2
^ **Total Xylenes**	----	2	µg/L		**9**	**2**	**5**	<2	<2
^ **Sum of BTEX**	----	1	µg/L		**49**	**22**	**27**	<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	%		**102**	**98.4**	**98.0**	**116**	**106**
Toluene-D8	2037-26-5	2	%		**99.0**	**102**	**102**	**103**	**105**
4-Bromofluorobenzene	460-00-4	2	%		**96.5**	**96.7**	**99.7**	**100**	**106**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
				Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit		EP2205756-011	EP2205756-012	--------	--------	--------
					Result	Result	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**40000**	**39800**	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	ug/L		<0.1	<0.1	----	----	----
EG049G LL-F: Dissolved Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	----	----	----
EG049G LL-T: Total Trivalent Chromium - Low Level									
Trivalent Chromium	16065-83-1	0.001	mg/L		<0.001	<0.001	----	----	----
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	----	----	----
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level									
Hexavalent Chromium	18540-29-9	0.001	mg/L		<0.001	<0.001	----	----	----
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L		**2.0**	**1.9**	----	----	----
Barium	7440-39-3	1	µg/L		**4**	**4**	----	----	----
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	----	----	----
Copper	7440-50-8	0.2	µg/L		<0.2	<0.2	----	----	----
Cobalt	7440-48-4	0.05	µg/L		**0.10**	<0.05	----	----	----
Iron	7439-89-6	5	µg/L		<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L		<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L		<5	<5	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS									
Aluminium	7429-90-5	5	µg/L		<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L		**1.9**	**1.9**	----	----	----
Barium	7440-39-3	1	µg/L		**5**	**4**	----	----	----
Cadmium	7440-43-9	0.2	µg/L		<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L		<0.5	<0.5	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
				Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit		EP2205756-011	EP2205756-012	--------	--------	--------
					Result	Result	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued									
Iron	7439-89-6	5	µg/L		<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L		<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L		**1.1**	**0.9**	----	----	----
Nickel	7440-02-0	0.5	µg/L		<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L		<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L		<5	<5	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS									
Cobalt	7440-48-4	0.05	µg/L		<0.05	<0.05	----	----	----
Copper	7440-50-8	0.2	µg/L		<0.2	<0.2	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.2	<0.2	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		<0.2	<0.2	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.03**	**0.02**	----	----	----
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	**2**	----	----	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**2**	**2**	----	----	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L		<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L		<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L		<50	<50	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L		<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
C6 - C10 Fraction	C6_C10	20	µg/L		<20	<20	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L		<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L		<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L		<100	<100	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
				Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit		EP2205756-011	EP2205756-012	--------	--------	--------
					Result	Result	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued									
>C34 - C40 Fraction	----	100	µg/L		<100	<100	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L		<100	<100	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L		<100	<100	----	----	----
EP080: BTEXN									
Benzene	71-43-2	1	µg/L		<1	<1	----	----	----
Toluene	108-88-3	2	µg/L		<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L		<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L		<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L		<2	<2	----	----	----
^ **Total Xylenes**	----	2	µg/L		<2	<2	----	----	----
^ **Sum of BTEX**	----	1	µg/L		<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L		<5	<5	----	----	----
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	2	%		**118**	**106**	----	----	----
Toluene-D8	2037-26-5	2	%		**108**	**99.4**	----	----	----
4-Bromofluorobenzene	460-00-4	2	%		**106**	**94.3**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**		Recovery Limits (%)	
Compound	*CAS Number*	*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

Appendix I Assessment of Quality Assurance and Quality Control Samples

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Appendix I Assessment of QAQC samples

Assessment of Quality Control Samples

Comparisons were made of the laboratory test results for the duplicate samples with the original samples and the Relative Percentage Difference (RPD) calculated as difference/average in order to assess the accuracy of the sampling and laboratory test procedures. The comparisons between the duplicates and the original samples indicate acceptable RPDs when they comply with criteria which are commonly set at:

- Less than 30% for inorganics (metals) and 50% for organics (hydrocarbons and PAHs);
- Less than five times the Laboratory LOR; and,

Where analyte values resulted as < LOR, half the LOR was used to calculate the RPD.

This data validation criteria and process is based off the National Environment Protection Measure (NEPM).

Both water and sediment hydrocarbons (PAH's, BTEXN), values at all sites resulted below the LOR therefore they have all conformed to the above criteria (RPD = 0%), and therefore have not been included or displayed in the tables.

The RPD% for the majority of intra-laboratory and inter-laboratory duplicates had concentrations that complied with the criteria set for acceptable RPDs. Only two exceedances were noted. These included the duplicate sample for (dissolved) iron in water from G-E DC_Seabed (RPD% = 33.33%), and the intra-laboratory samples for (total) manganese in water from Gorgon GMT_Seabed (RPD% = 31.48%).

The RSD% for the majority of replicates had concentrations that complied with the criteria set for acceptable RSDs. Only one exceedance was noted. The replicate samples for cadmium from WTR DC-2 (RSD% = 43.30%) displayed an exceedance.

The RPD/RSD results for the metals were all below 50%. The heterogeneity observed in the duplicate and replicate samples was not deemed significant enough to diminish confidence in the sampling technique or laboratory results. Therefore, it is considered that sampling techniques and laboratory analysis were appropriate.

Table 1 1 Calculated intra-laboratory and replicate RPDs for sediment metal concentrations

Sample Type	Units	Sample ID	Date	Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cr (Chromium)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)
Sediment	**mg/kg**	SEMELE WELL-4_1_3	08/05/2022	0.1	4960	1.75	100	0.4	3.2	31.3	13.5	6650	186	19.7	2.8	22.2	0.02
Sediment	**mg/kg**	*SEMELE WELL-4_1_3	08/05/2022	0.1	3300	1.62	80	0.3	3.1	30.3	12.8	5130	173	18.9	2.6	20.6	0.02
		RPD %		0.00	10.05	1.93	5.56	7.14	0.79	0.81	1.33	6.45	1.81	1.04	1.85	1.87	0.00
Sediment	**mg/kg**	SEMELE WELL-4_1_2	08/05/2022	0.1	5140	1.76	110	0.4	3.4	32.6	14.5	6990	221	20.8	2.9	23.9	0.01
Sediment	**mg/kg**	*SEMELE WELL-4_1_2	08/05/2022	0.1	3460	1.63	90	0.3	3.1	30.5	13.2	5380	216	19.1	2.7	20.8	0.02
		RPD %		0.00	9.77	1.92	5.00	7.14	2.31	1.66	2.35	6.51	0.57	2.13	1.79	3.47	16.67
Sediment	**mg/kg**	WTR DC-1-4_1_1	09/05/2022	0.05	2260	1.25	40	0.1	1.4	16.7	3.8	3390	95	7.5	1.5	6.7	0.005
Sediment	**mg/kg**	*WTR DC-1_4_1_1	09/05/2022	0.05	1570	1.27	30	0.1	1.5	17.4	3.7	2800	96	7.5	1.6	6.2	0.005
		RPD %		0.00	9.01	0.40	7.14	0.00	1.72	1.03	0.67	4.77	0.26	0.00	1.61	1.94	0.00
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	0.05	2400	1.29	50	0.2	1.5	17.5	3.9	3610	102	7.8	1.6	6.8	0.005
Sediment	**mg/kg**	*WTR DC-2_2_3	09/05/2022	0.05	1490	1.23	30	0.1	1.4	15.9	3.4	2720	92	7.1	1.5	5.9	0.005
		RPD %		0.00	11.70	1.19	12.50	16.67	1.72	2.40	3.42	7.03	2.58	2.35	1.61	3.54	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**0.5**	**250**	**5**	**50**	**0.5**	**2.5**	**5**	**5**	**250**	**50**	**5**	**5**	**5**	**0.05**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1 2 Calculated intra-laboratory and replicate RPDs for water (dissolved) metal concentrations

Sample Type	Units	Sample ID	Date	Dissolved Metals															
				Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)	Cr (Chromium) III	Cr (Chromium) VI
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.9	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	-	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1_	09/05/2022	0.05	2.5	1.5	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	2	4	0.1	0.1	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.4	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	8.82	5.56	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	QAQC_1	05/05/2022	0.05	2.5	1.7	13	0.1	0.025	0.25	2.5	0.25	0.25	0.5	2.5	0.05	0.0005	0.0005

Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.25	2.5	0.25	0.25	0.1	2.5	0.05	0.0005	0.0005
		RPD %		0.00	1.43	0.00	0.00	0.00	0.00	0.00	**33.33**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**25**	**2.5**	**5**	**1**	**0.25**	**1**	**25**	**2.5**	**2.5**	**1**	**25**	**0**	**0.005**	**0.005**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-3 Calculated intra-laboratory and replicate RPDs for water (total) metal concentrations.

				Total Metals														
Sample Type	**Units**	**Sample ID**	**Date**	**Ag (Silver)**	**Al (Aluminium)**	**As (Arsenic)**	**Ba (Barium)**	**Cd (Cadmium)**	**Co (Cobalt)**	**Cu (Copper)**	**Fe (Iron)**	**Mn (Manganese)**	**Ni (Nickel)**	**Pb (Lead)**	**Zn (Zinc)**	**Hg (Mercury)**	**Cr (Chromium) III**	**Cr (Chromium) VI**
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.8	6	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.8	6	0.1	0.025	0.3	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.9	5	0.1	0.025	0.025	2.5	1.1	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.5	6	0.1	0.1	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	5.88	4.55	0.00	0.00	0.00	0.00	**31.48**	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	QAQC_1	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.1	2.5	0.25	0.25	0.5	2.5	0.05	0.0005	0.0005
Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	0.0005	0.0005
		RPD %		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**25**	**2.5**	**5**	**1**	**0.25**	**1**	**25**	**2.5**	**2.5**	**1**	**25**	**0**	**0.005**	**0.005**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-4 Calculated intra-laboratory and replicate RPDs for sediment nutrients and other parameters.

Sample Type	Units	Sample ID	Date	Other Parameters		
				Moisture Content	TOC (Total Organic Carbon)	SPD (Soil Particle Distribution)
Sediment	**mg/kg**	SEMELE WELL-4_1_3	08/05/2022	61.4	-	-
Sediment	**mg/kg**	*SEMELE WELL-4_1_3	08/05/2022	57.6	-	-
		RPD %		1.60	-	-
Sediment	**mg/kg**	SEMELE WELL-4_1_2	08/05/2022	61.3	-	-
Sediment	**mg/kg**	*SEMELE WELL-4_1_2	08/05/2022	58.2	-	-
		RPD %		1.30	-	-
Sediment	**mg/kg**	WTR DC-1-4_1_1	09/05/2022	39.1	-	-
Sediment	**mg/kg**	*WTR DC-1_4_1_1	09/05/2022	35.4	-	-
		RPD %		2.48	-	-
Criteria		**RPD <30%**		**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**-**	**-**	**-**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-5 Calculated intra-laboratory and replicate RPDs for water nutrients and other parameters.

Sample Type	Units	Sample ID	Date	Other Parameters				
				TN (Total Nitrogen)	TP (Total Phosphorus)	DOC (Dissolved Organic Carbon)	TOC (Total Organic Carbon)	TDS (Total Dissolved Solids)
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	-	-	-	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1	09/05/2022	0.25	0.025	0.5	1	-
		RPD %		-	-	-	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.1	0.03	1	2	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.25	0.025	0.5	0.5	-
		RPD %		21.43	4.55	16.67	30.00	-
Water	**µg/L**	QAQC_1	05/05/2022	0.5	0.03	0.5	0.5	38100
Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.7	0.09	0.5	0.5	38500

		RPD %		8.33	25.00	0.00	0.00	0.26
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**0.05**	**5**	**5**	**-**

Table 1-6 Calculated replicate RSDs for sediment metal concentrations.

Sample Type	Units	Sample ID	Date	Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cr (Chromium)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)
Sediment	**mg/kg**	WTR DC-2_1_1	09/05/2022	0.05	2280	1.23	40	0.1	1.5	16.7	3.8	3530	96	7.7	1.6	6.7	0.005
Sediment	**mg/kg**	WTR DC-2_2_2	09/05/2022	0.05	2230	1.3	40	0.1	1.5	16.7	3.8	3510	101	7.3	1.6	6.6	0.005
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	0.05	2400	1.29	50	0.2	1.5	17.5	3.9	3610	102	7.8	1.6	6.8	0.005
		RSD %		0.00	3.79	2.97	13.32	**43.30**	0.00	2.72	1.51	1.49	3.23	3.48	0.00	1.49	0.00
Criteria		**RSD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**0.5**	**250**	**5**	**50**	**0.5**	**2.5**	**5**	**5**	**250**	**50**	**5**	**5**	**5**	**0.05**

Table 1-7 Calculated replicate RSDs for sediment nutrients and other parameters.

				Other Parameters		
Sample Type	Units	Sample ID	Date	Moisture Content	TOC (Total Organic Carbon)	SPD (Soil Particle Distribution)
Sediment	**mg/kg**	WTR DC-2_1_1	09/05/2022	40.6	0.47	2.36
Sediment	**mg/kg**	WTR DC-2_2_2	09/05/2022	40.9	0.46	2.42
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	40.4	0.49	2.42
		RSD %		0.62	3.23	1.44
Criteria		**RSD <30%**		**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**-**	**-**	**-**

Appendix J Benthic Infauna Raw Data

Appendix J Benthic infauna raw data

Table 1.1 Benthic infauna raw data across GS3 project sites.

Phylum	Class/Order	Family	morph-sp	CHANDONDC-1_1_A	CHANDONDC1_1_A	D1-3_1_A	D1-3_1_B	GEDC_1_A	GEDC_1_B	NTB3_1_A	NTB3_1_B	SEMELEWELL1_1_A	SEMELEWELL1_1_B	SEMELEWELL2_1_A	SEMELEWELL2_1_B	SEMELEWELL3_1_A	SEMELEWELL3_1_B	SEMELEWELL4_1_A	SEMELEWELL4_1_B	STB4_1_A	STB4_1_B	WTRDC1_1_A	WTRDC1_1_B	WTRDC1_2_A
Sipuncula	Sipuncula	Sipuncula	Sipuncula sp.1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1
Annelida	Polychaeta	Capitellidae	*Notomastus sp1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Annelida	Polychaeta	Orbiniidae	Orbiniidae sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Annelida	Polychaeta	Hartmaniellidae	*Hartmaniella sp1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Annelida	Polychaeta	Pilargidae	*Sigambra sp1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mollusca	Gastropoda	Aplacophora	Aplacophora sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix K ROV depth profiles

Appendix K ROV depth profiles

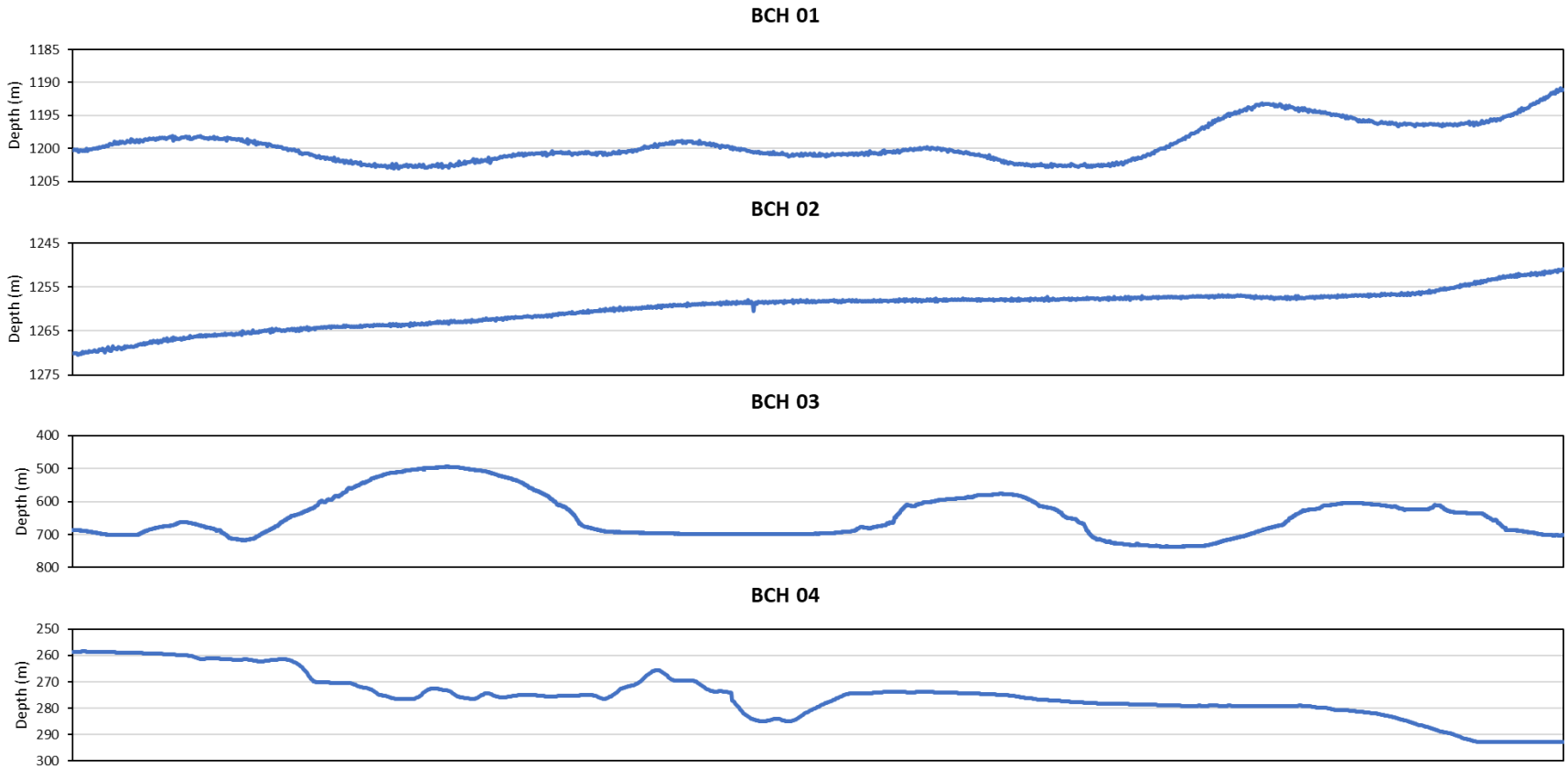


Figure 1.1 ROV depth profiles based on altitude across GS3 sites (BCH01, BCH02, BCH03, and BCH04).

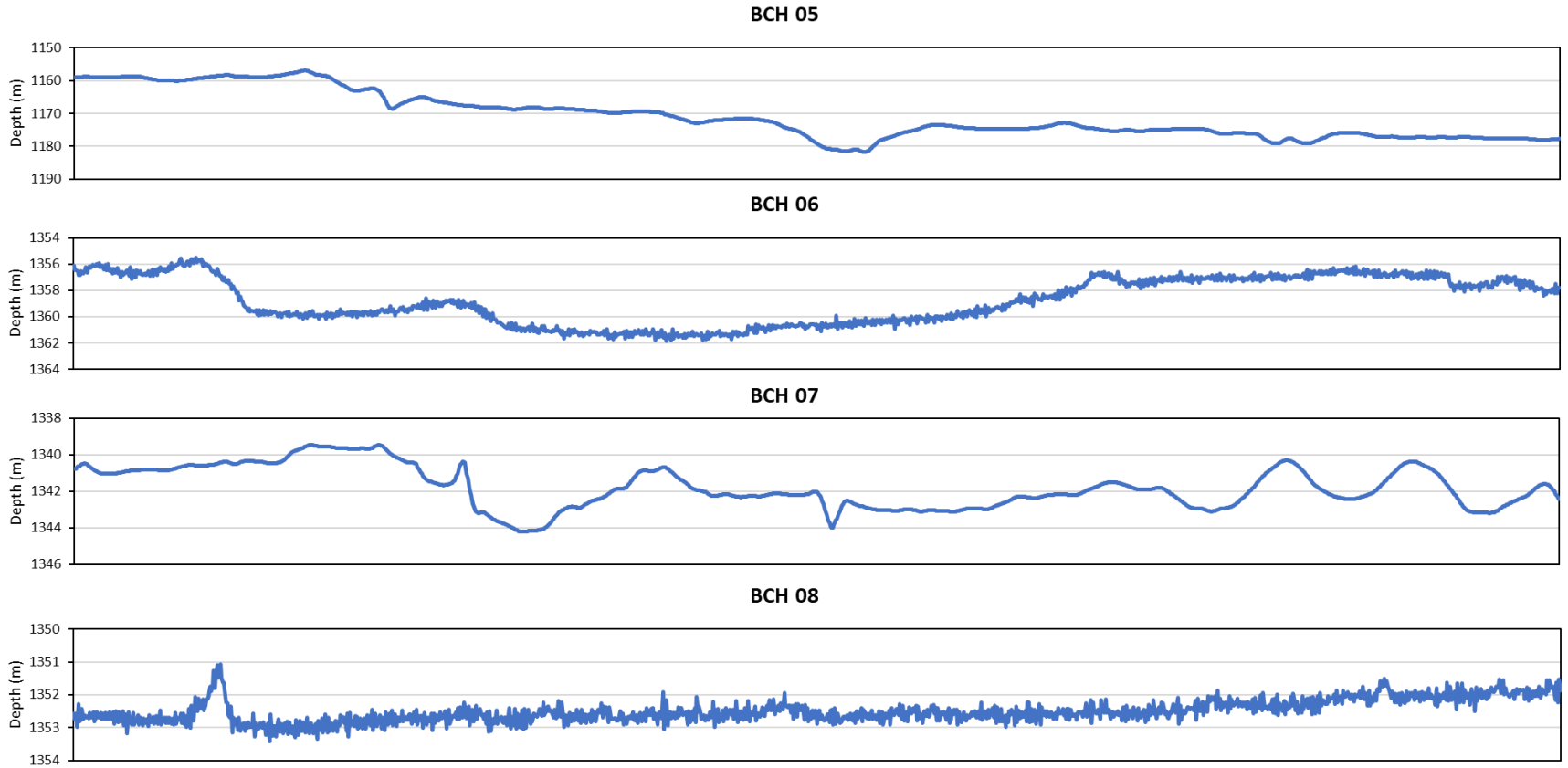


Figure 1-2 ROV depth profiles based on altitude across GS3 sites (BCH05, BCH06, BCH07, and BCH08).

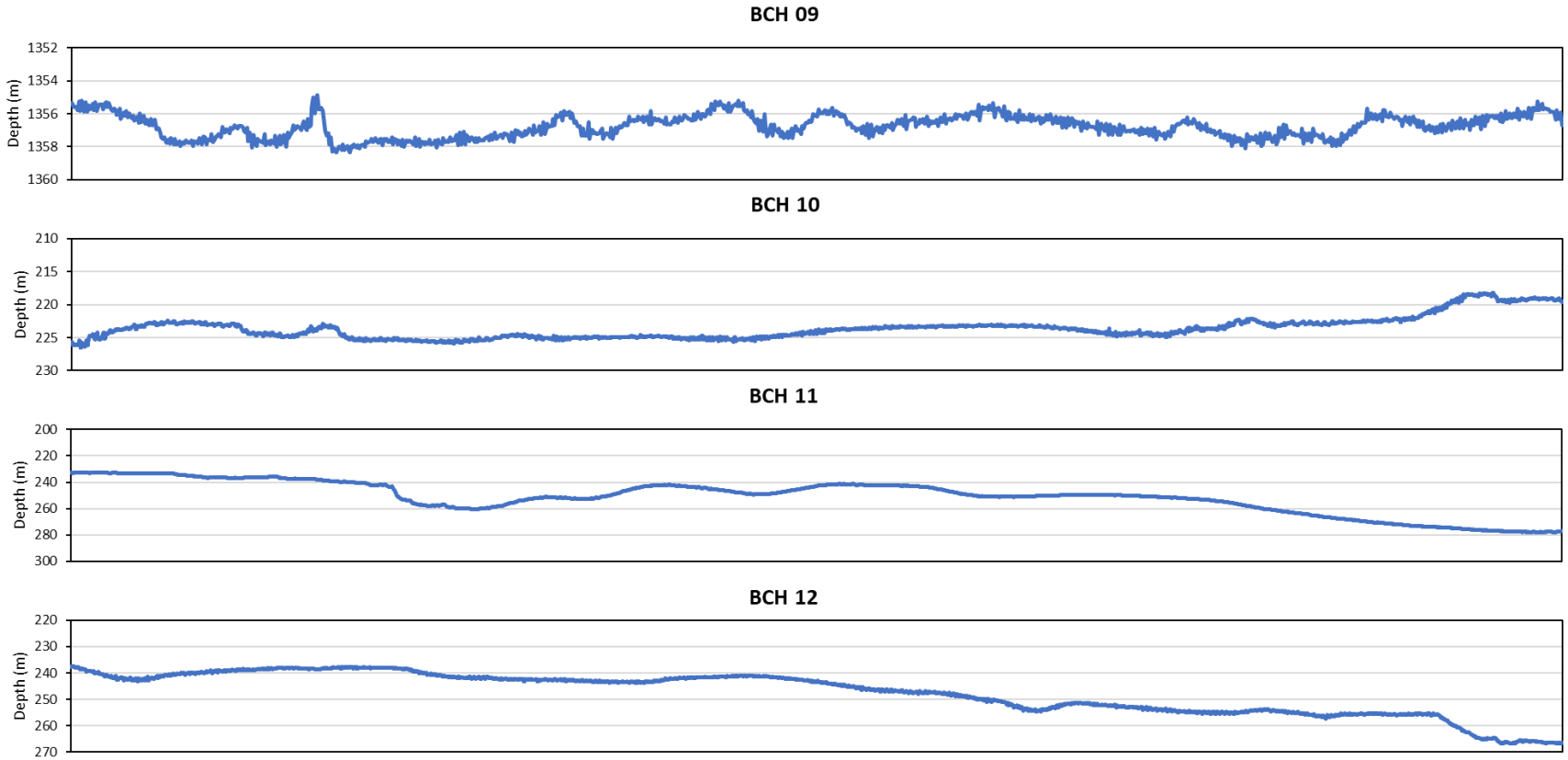


Figure 1-3 ROV depth profiles based on altitude across GS3 sites (BCH05, BCH06, BCH07, and BCH08).

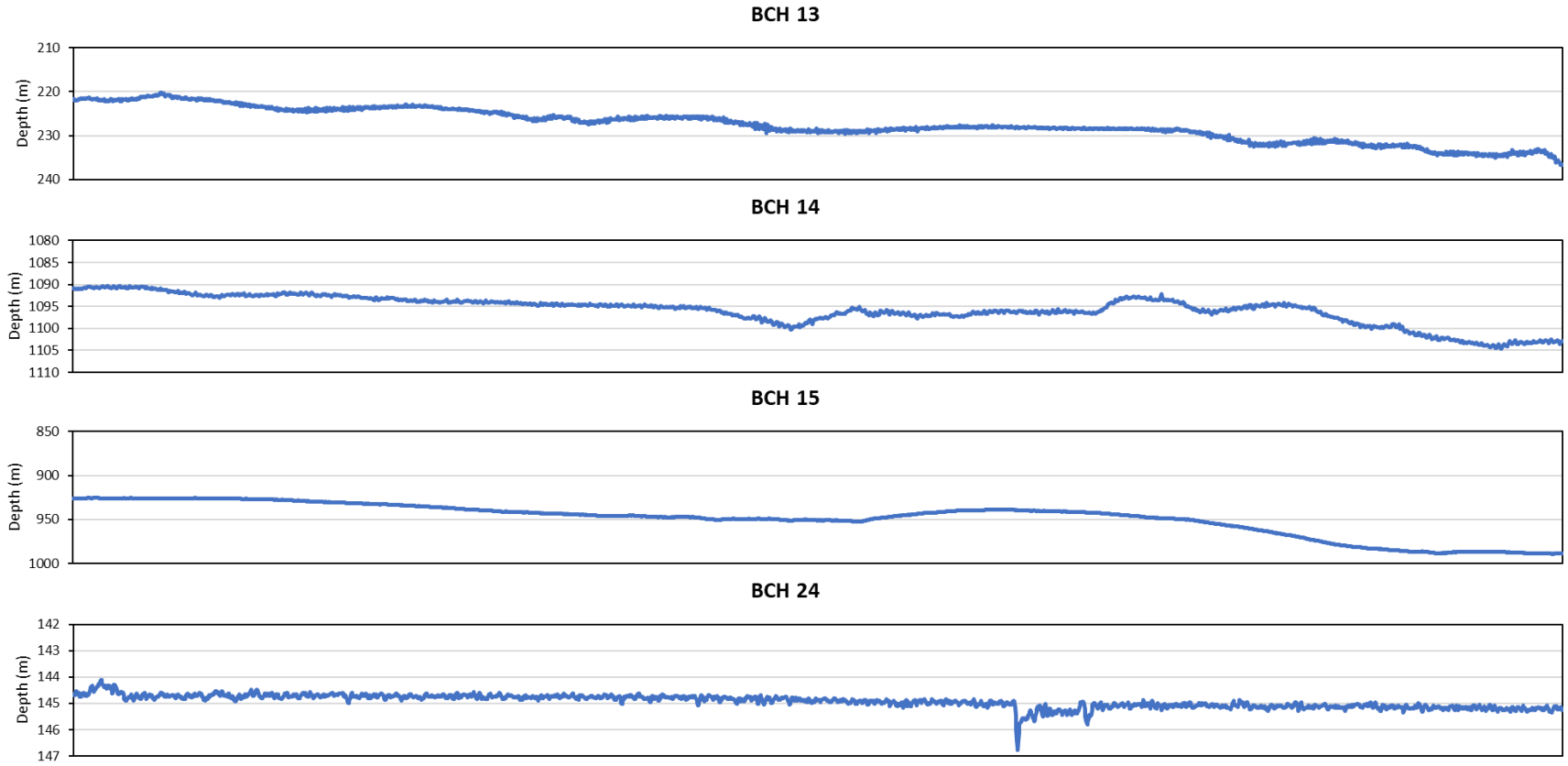


Figure 1-4 ROV depth profiles based on altitude across GS3 sites (BCH13, BCH14, BCH15, and BCH24).

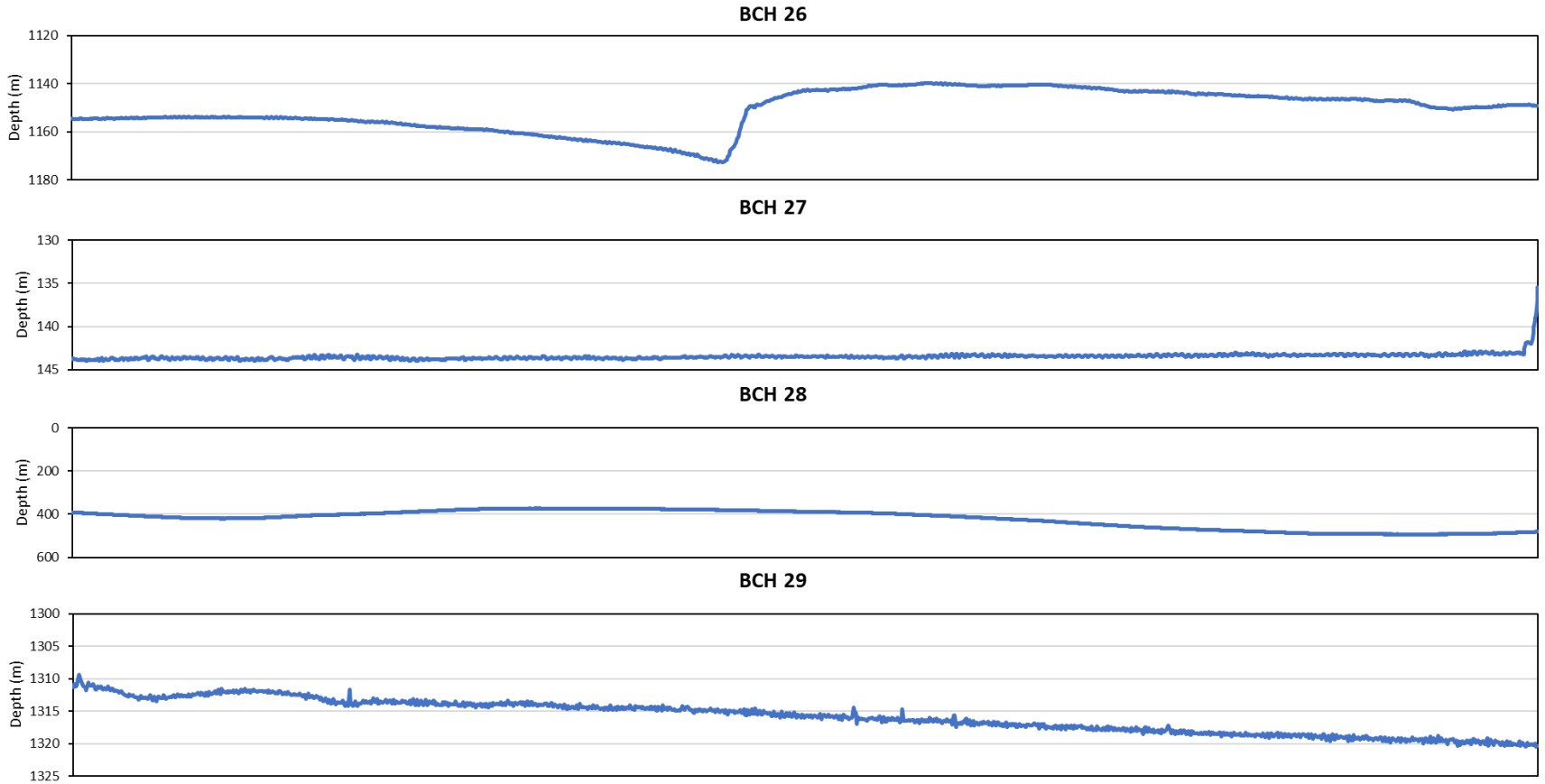


Figure 1-5 ROV depth profiles based on altitude across GS3 sites (BCH26, BCH27, BCH28, and BCH29).

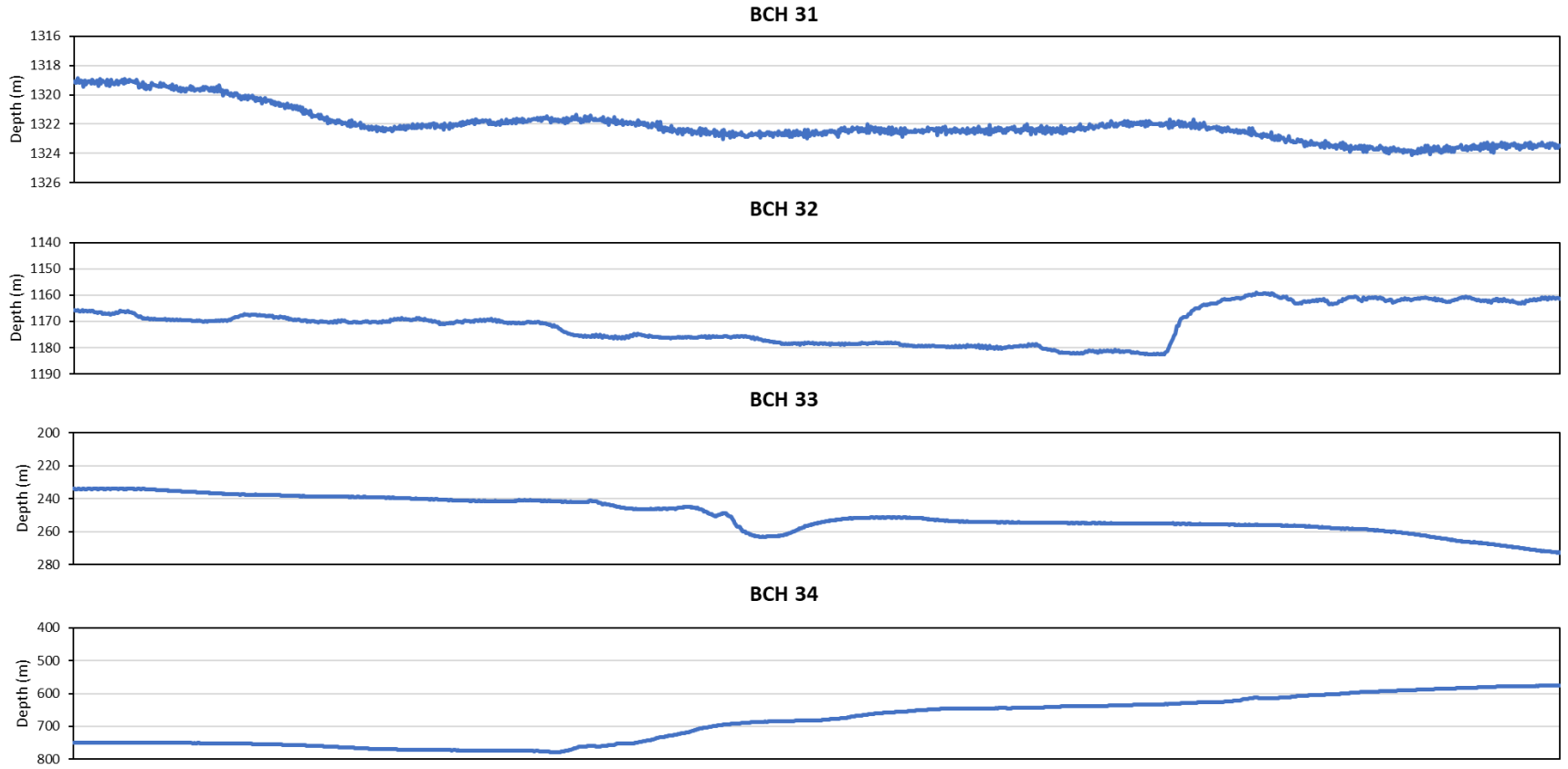


Figure 1-6 ROV depth profiles based on altitude across GS3 sites (BCH31, BCH32, BCH33, and BCH34).

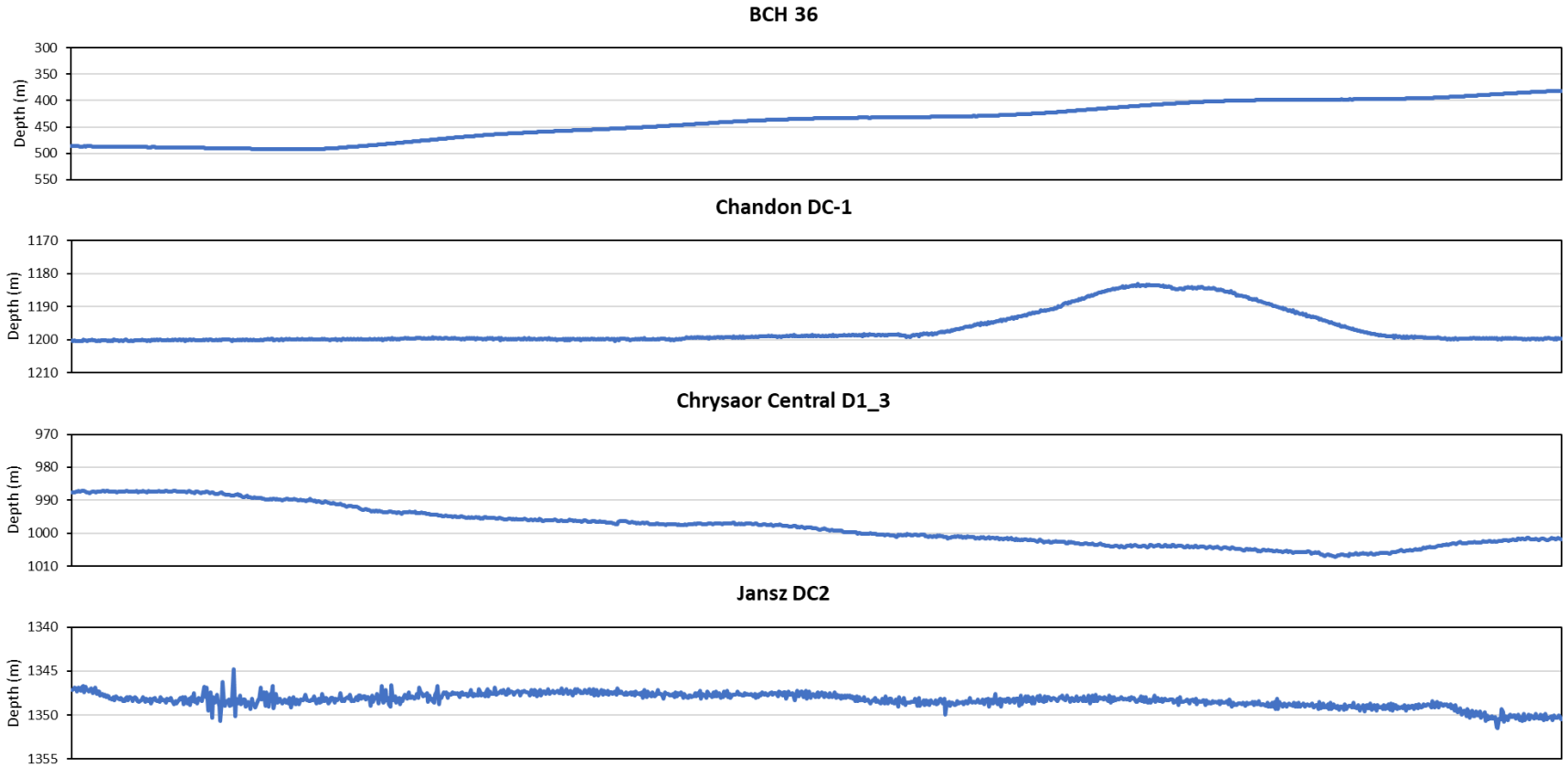


Figure 1-7 ROV depth profiles based on altitude across GS3 sites (BCH36, Chandon DC-1, Chrysaor Central D1 3, and Jansz DC2).

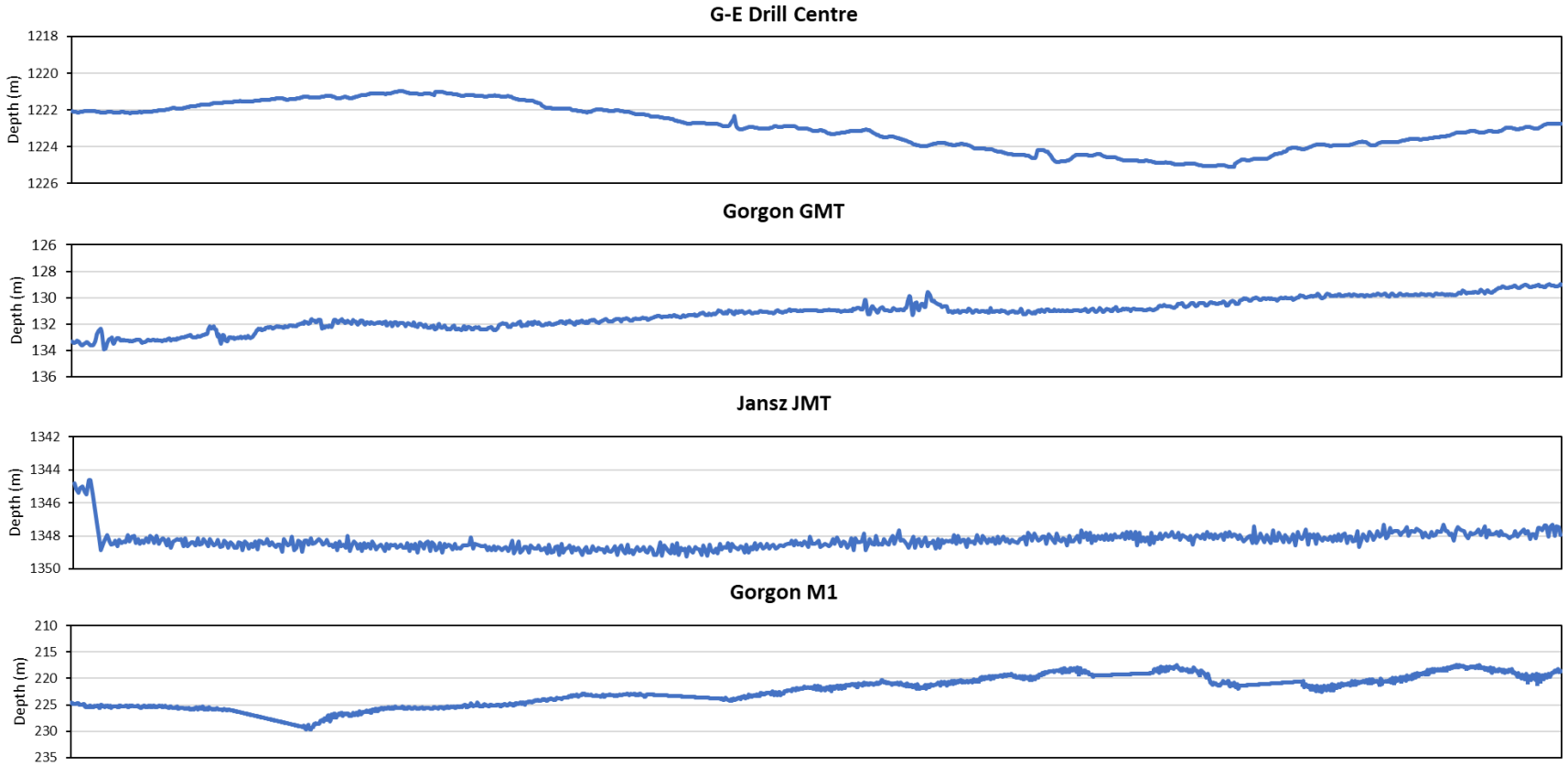


Figure 1-8 ROV depth profiles based on altitude across GS3 sites (G-E Drill Centre, Gorgon GMT, Jansz JMT, and Gorgon M1).

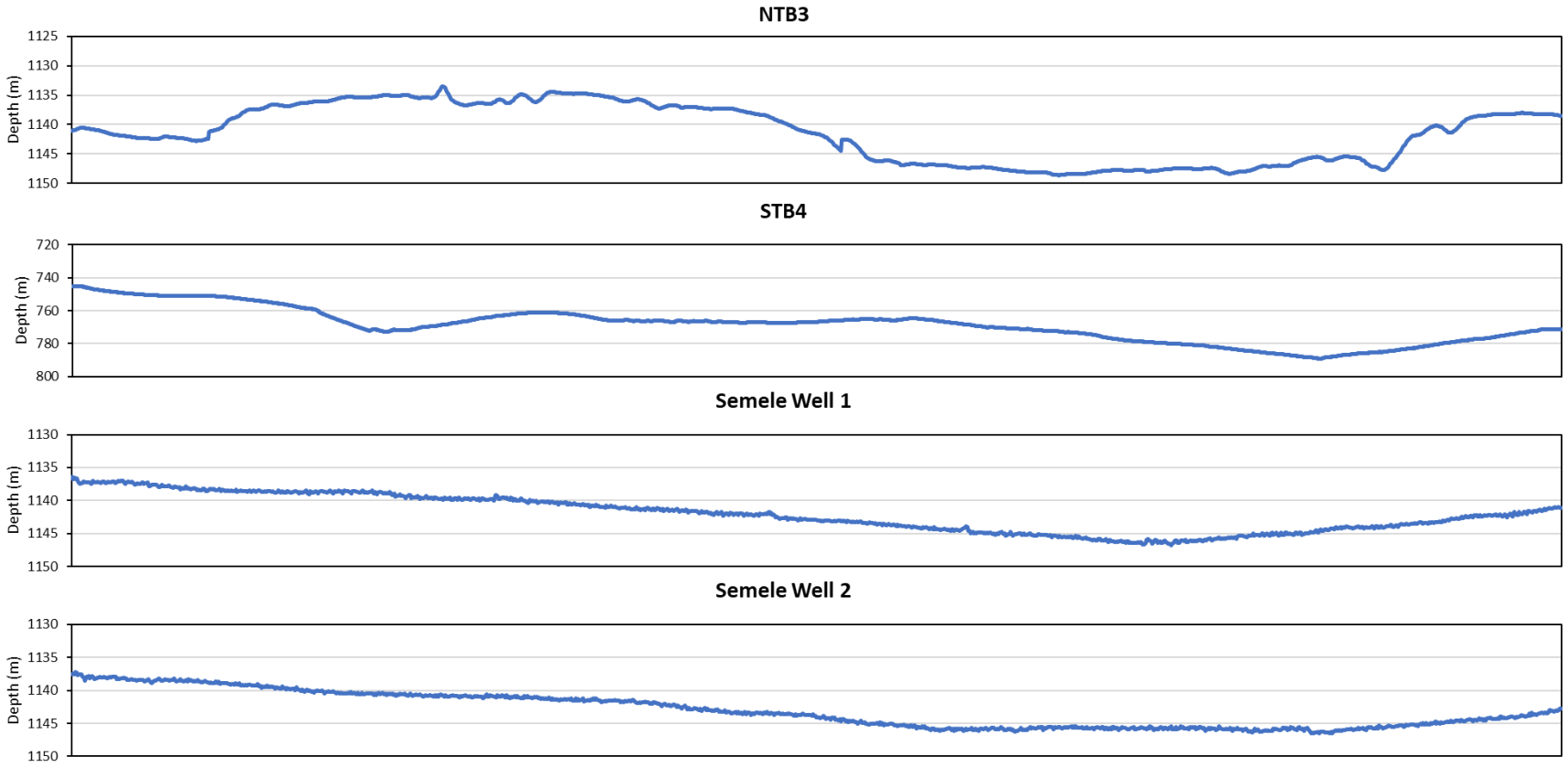


Figure 1-9 ROV depth profiles based on altitude across GS3 sites (NTB3, STB4, Semele Well 1, and Semele Well 2).

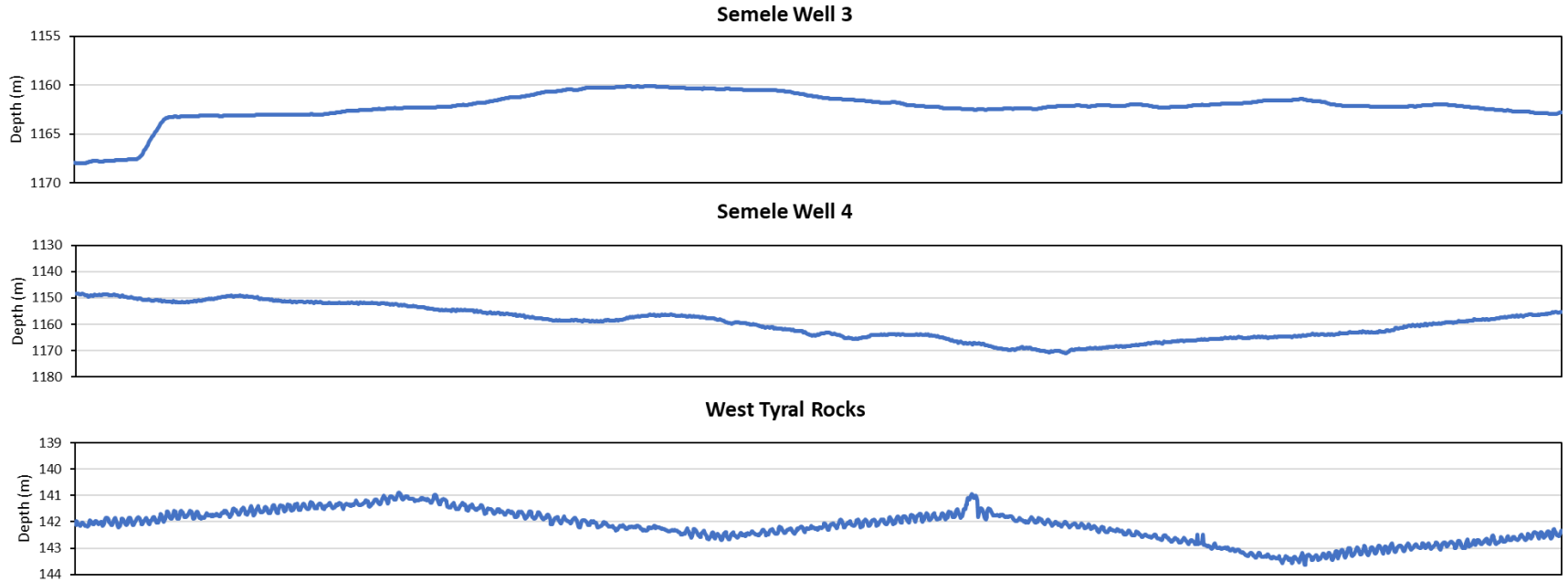


Figure 1-10 ROV depth profiles based on altitude across GS3 sites (Semele Well 3, Semele Well 4, and West Tyral Rocks).

appendix b protected matters search reports

appendix b.1—development area

Australian Government
Department of Climate Change, Energy, the Environment and Water

DEVELOPMENT AREA

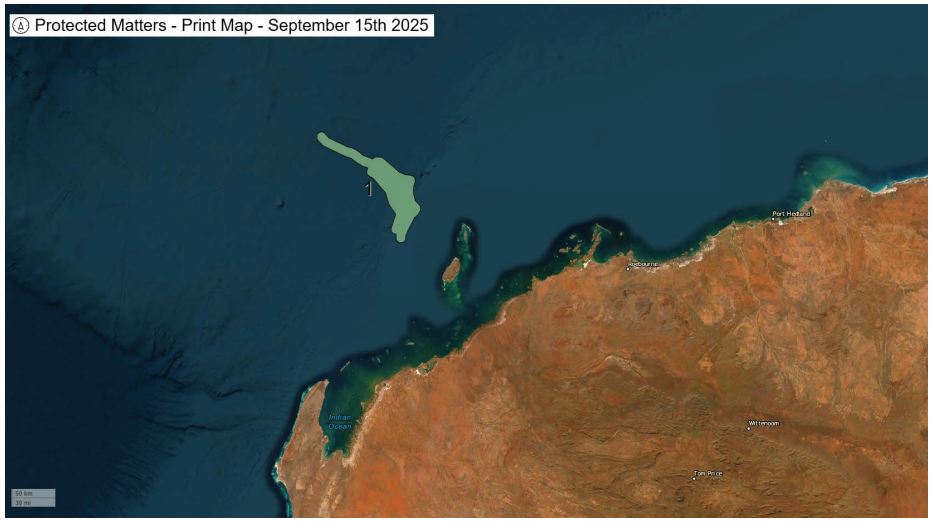
EPBC Act Protected Matters Report

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: 15-Sep-2025

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



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:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	26
Listed Migratory Species:	43

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:	69
Whales and Other Cetaceans:	30
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
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:	None
EPBC Act Referrals:	45
Key Ecological Features (Marine):	3
Biologically Important Areas:	5
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
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

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 acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	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
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour likely 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
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Vulnerable	Species or species habitat may occur within area
Sousa sahulensis Australian Humpback Dolphin [87942]	Vulnerable	Species or species habitat may occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Sea Snake, 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

Scientific Name	Threatened Category	Presence Text
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		
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
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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 likely to occur within area

Listed Migratory Species [Resource Information]		
Scientific Name	Threatened Category	Presence Text
null		
Balaenoptera omurai		
Omura's Whale [87136]		Species or species habitat likely to occur within area
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
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata		
Narrow Sawfish, Knifetooth Sawfish [68448]		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	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

Scientific Name	Threatened Category	Presence Text
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
Carcharias taurus Grey Nurse Shark [64469]		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
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
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		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
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

Scientific Name	Threatened Category	Presence Text
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 likely 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]	Vulnerable	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
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]	Vulnerable	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 Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	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
Pandion haliaetus		
Osprey [952]		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]	Vulnerable	Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	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
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	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
Pandion haliaetus		
Osprey [952]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus		
White-tailed Tropicbird [1014]		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
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Species or species habitat may 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
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
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		
Aipysurus apraefrontalis Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Aipysurus duboisii Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area
Aipysurus laevis Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		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

Scientific Name	Threatened Category	Presence Text
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		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
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area
Hydrophis platura as Pelamis platurus Yellow-bellied Sea Snake [93746]		Species or species habitat may occur within area
Hydrophis stokesii as Astrotia stokesii Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to 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	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 omurai Omura's Whale [87136]		Species or species habitat likely 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
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima 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
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Vulnerable	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 Australian Humpback Dolphin [87942]	Vulnerable	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

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

Habitat Critical to the Survival of Marine Turtles		[Resource Information]
Scientific Name	Behaviour	Presence
All year (Jun - Aug)		
Natator depressus		
Flatback Turtle [59257]	Nesting	Known to occur

Extra Information

EPBC Act Referrals			[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081		Completed
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260		Completed
Gorgon Gas Development	2003/1294		Post-Approval
Project Highclere Cable Lay and Operation	2022/09203		Completed
Controlled action			
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Develop Jansz-lo deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Not controlled action			

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	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
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Not controlled action (particular manner)			
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	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 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
Aperio 3D Marine Seismic Survey, WA	2012/6648	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
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	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
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	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
Harmony 3D Marine Seismic Survey	2012/6699	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
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	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
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	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
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
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	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

Name	Region
Exmouth Plateau	North-west

Biologically Important Areas		[Resource Information]
Scientific Name	Behaviour	Presence
Marine Turtles		
Natator depressus		
Flatback Turtle [59257]	Internesting buffer	Known to occur
Seabirds		
Ardenna tenuirostris		
Short-tailed Shearwater [84292]	Breeding	Known to occur
Sharks		
Rhincodon typus		
Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda		
Pygmy Blue Whale [81317]	Migration	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 is 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 on the contents of this report.

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 point locations and environmental data layers.

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 when time permits.

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 breeding sites; and
- 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.

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appendix b.2—hydrocarbon ecological EMBA

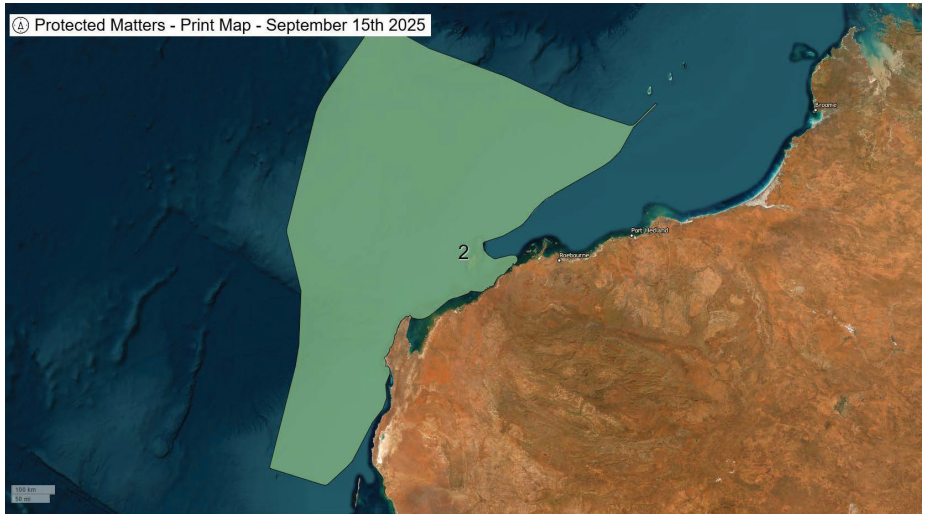
EPBC Act Protected Matters Report

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: 15-Sep-2025

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



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	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	63
Listed Migratory Species:	69

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:	5
Commonwealth Heritage Places:	2
Listed Marine Species:	119
Whales and Other Cetaceans:	33
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	13
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:	30
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	217
Key Ecological Features (Marine):	7
Biologically Important Areas:	37
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
Natural		
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
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

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		
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	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]	Critically 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
Phaethon rubricauda westralis		
Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	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 likely to occur within area
Sternula albifrons		
Little Tern [82849]	Vulnerable	Breeding 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
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
Tringa nebularia		
Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area
CRUSTACEAN		
Kumonga exleyi		
Cape Range Remipede [86875]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Milyeringa justitia		
Barrow Cave Gudgeon [86867]	Endangered	Species or species habitat known to occur within area
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
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 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

Scientific Name	Threatened Category	Presence Text
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 likely to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]	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
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Sousa sahulensis		
Australian Humpback Dolphin [87942]	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 Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Sea Snake, 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
Liasis olivaceus barroni		
Pilbara Olive Python [66699]	Vulnerable	Species or species habitat likely to 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	Congregation or aggregation known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Centrophorus uyato		
Little Gulper Shark [68446]	Conservation Dependent	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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
null		
Balaenoptera omurai Omura's Whale [87136]		Species or species habitat likely to occur within area
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]		Species or species habitat 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
Phaethon rubricauda Red-tailed Tropicbird [994]		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]	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
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
Carcharias taurus		
Grey Nurse Shark [64469]		Congregation or aggregation known 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
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		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
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]	Vulnerable	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	Species or species habitat known to occur within area
Pristis pristis		
Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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]	Vulnerable	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		
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may 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
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	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
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]	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
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]	Endangered	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 - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Unknown	
Commonwealth Land - [52236]	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
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
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]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	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 may 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 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 ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may 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
Hirundo rustica Barn Swallow [662]		Species or species habitat may 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]	Vulnerable	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
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 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
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
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]		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 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]	Vulnerable	Breeding known to 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 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
Tringa nebularia		
Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely 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

Scientific Name	Threatened Category	Presence Text
Campichthys galei Gale's Pipefish [66191]		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 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
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
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

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
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 Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus foliosquama Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Sea Snake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Sea Snake, Mjoberg's Sea Snake [1121]		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
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		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
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		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 Port Darwin Sea Snake, Black-ringed Mangrove Sea Snake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli MacDowell's Sea Snake, Small-headed Sea Snake, [75601]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area
Hydrophis platura as Pelamis platurus Yellow-bellied Sea Snake [93746]		Species or species habitat may occur within area
Hydrophis stokesii as Astrotia stokesii Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to 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 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 omurai Omura's Whale [87136]		Species or species habitat likely 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

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 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 Australian Snubfin Dolphin [81322]	Vulnerable	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

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 Australian Humpback Dolphin [87942]	Vulnerable	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 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)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Ningaloo	Recreational Use Zone (IUCN IV)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles		[Resource Information]
Scientific Name	Behaviour	Presence
All year (Jun - Aug)		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Nov-Feb		
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Oct - Feb		
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Oct - Mar		
Chelonia mydas Green Turtle [1765]	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
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Cape Range	National Park	WA
Cape Range (South)	National Park	WA
Great Sandy Island	Nature Reserve	WA
Great Sandy Island	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) 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
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
Nyingguulu (Ningaloo) Coastal Reserve	5(1)(h) Reserve	WA
Round Island	Nature Reserve	WA
Rowley Shoals	Marine Park	WA
Serrurier Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA
Unnamed WA40322	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Victor Island	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Cape Range Subterranean Waterways	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778		Completed
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081		Completed
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092		Completed
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260		Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033		Completed
Gorgon Gas Development	2003/1294		Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693		Post-Approval
Offshore Dredge Spoil Disposal - Mardie Project	2024/10054		Referral Decision
Optimised Mardie Project ? Additional Triodia Grassland Habitat Clearing	2024/10094		Referral Decision
Optimised Mardie Solar Salt Project	2022/9169		Post-Approval
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	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
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
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 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
Echo-Yodel Production Wells	2000/11	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
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 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
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
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	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
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
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
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
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	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
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
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
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
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
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Mermaid Marine Australia Desalination Project	2011/5916	Not Controlled Action	Completed
Montesa-1 and Bultaco-1 Exploration Wells	2000/102	Not Controlled Action	Completed
North Rankin B gas compression facility	2005/2500	Not Controlled Action	Completed
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	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
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
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
WA-295-P Kerr-McGee Exploration Wells	2001/152	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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
'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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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 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 Manner)	Post-Approval
Agrippina 3D Seismic Marine Survey	2009/5212	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

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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
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 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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
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 reconnaissance survey	2008/4466	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 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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Santos Winchester three dimensional seismic survey - WA-323-P & WA-330-P	2011/6107	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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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 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

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
3D Seismic Survey	2008/4219	Referral Decision	Completed
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	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
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
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas [Resource Information]

Scientific Name	Behaviour	Presence
Dugong		

Scientific Name	Behaviour	Presence
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]	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]	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]	Nesting	Known 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]	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]	Nesting	Known to occur
Seabirds		
Ardenna tenuirostris Short-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

Scientific Name	Behaviour	Presence
Sterna dougallii		
Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis		
Little Tern [82850]	Resting	Known to occur
Sternula nereis		
Fairy Tern [82949]	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]	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 is 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 on the contents of this report.

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 point locations and environmental data layers.

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 when time permits.

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 breeding sites; and
- 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.

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appendix b.3—hydrocarbon social EMBA

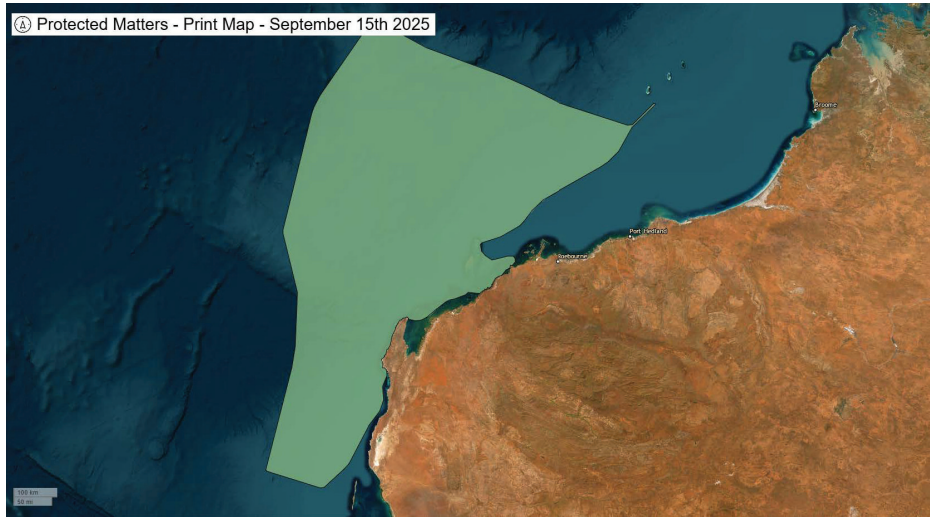
EPBC Act Protected Matters Report

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: 15-Sep-2025

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements



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:	2
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	63
Listed Migratory Species:	69

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:	2
Listed Marine Species:	119
Whales and Other Cetaceans:	33
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	13
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:	39
Regional Forest Agreements:	None
Nationally Important Wetlands:	2
EPBC Act Referrals:	222
Key Ecological Features (Marine):	7
Biologically Important Areas:	40
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
Murujuga Cultural Landscape	WA	Declared property
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

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
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

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		
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	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

Scientific Name	Threatened Category	Presence Text
Pezoporus occidentalis Night Parrot [59350]	Critically 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
Phaethon rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	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 likely to occur within area
Sternula albifrons Little Tern [82849]	Vulnerable	Breeding 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
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
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area
CRUSTACEAN		
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Milyeringa justitia Barrow Cave Gudgeon [86867]	Endangered	Species or species habitat known to occur within area
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
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 Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	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
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 likely to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]	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
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Sousa sahulensis		
Australian Humpback Dolphin [87942]	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 Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Sea Snake, 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
Liasis olivaceus barroni		
Pilbara Olive Python [66699]	Vulnerable	Species or species habitat likely to 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	Congregation or aggregation known 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
Centrophorus uyato Little Gulper Shark [68446]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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
null		
Balaenoptera omurai Omura's Whale [87136]		Species or species habitat likely to occur within area
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]		Species or species habitat 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
Phaethon rubricauda Red-tailed Tropicbird [994]		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]	Vulnerable	Breeding known to 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		
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
Carcharias taurus		
Grey Nurse Shark [64469]		Congregation or aggregation known 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
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		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
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]		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
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]	Vulnerable	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	Species or species habitat known to occur within area
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	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

Scientific Name	Threatened Category	Presence Text
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]	Vulnerable	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		
Hirundo rustica Barn Swallow [662]		Species or species habitat likely 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
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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

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]	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
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]	Endangered	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 - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Unknown	
Commonwealth Land - [52236]	WA
Commonwealth Land - [50385]	WA
Commonwealth Land - [51104]	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
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
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]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	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 likely 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 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 ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may 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 likely 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]	Vulnerable	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
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

Scientific Name	Threatened Category	Presence Text
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
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
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]		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 as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]	Vulnerable	Breeding known to 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
Tringa nebularia		
Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area overfly marine area
Fish		
Acentronura larsonae		
Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
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 galei Gale's Pipefish [66191]		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 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
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

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
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
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
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		

Scientific Name	Threatened Category	Presence Text
Aipysurus apraefrontalis Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Sea Snake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Sea Snake, Mjoberg's Sea Snake [1121]		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
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		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

Scientific Name	Threatened Category	Presence Text
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Port Darwin Sea Snake, Black-ringed Mangrove Sea Snake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli MacDowell's Sea Snake, Small-headed Sea Snake, [75601]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hydrophis platura as Pelamis platurus Yellow-bellied Sea Snake [93746]		Species or species habitat may occur within area
Hydrophis stokesii as Astrotia stokesii Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to 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 omurai Omura's Whale [87136]		Species or species habitat likely 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 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 Australian Snubfin Dolphin [81322]	Vulnerable	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 Australian Humpback Dolphin [87942]	Vulnerable	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)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Ningaloo	Recreational Use Zone (IUCN IV)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles		[Resource Information]
Scientific Name	Behaviour	Presence
All year (Jun - Aug)		
Natator depressus		
Flatback Turtle [59257]	Nesting	Known to occur
Nov-Feb		
Caretta caretta		
Loggerhead Turtle [1763]	Nesting	Known to occur
Oct - Feb		
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Nesting	Known to occur
Oct - Mar		
Chelonia mydas		
Green Turtle [1765]	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
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Cape Range	National Park	WA
Cape Range (South)	National Park	WA
Great Sandy Island	Nature Reserve	WA
Great Sandy Island	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) 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
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
Nyingguulu (Ningaloo) Coastal Reserve	5(1)(h) Reserve	WA
Rocky Island	Nature Reserve	WA
Round Island	Nature Reserve	WA
Rowley Shoals	Marine Park	WA
Serrurier Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA
Thevenard Island	Nature 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 WA40322	5(1)(h) Reserve	WA
Unnamed WA40877	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Victor Island	Nature Reserve	WA
Weld Island	Nature Reserve	WA

Nationally Important Wetlands	[Resource Information]
Wetland Name	State
Cape Range Subterranean Waterways	WA
Exmouth Gulf East	WA

EPBC Act Referrals	[Resource Information]		
Title of referral	Reference	Referral Outcome	Assessment Status
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778		Completed
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081		Completed
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092		Completed
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260		Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033		Completed
Gorgon Gas Development	2003/1294		Post-Approval
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693		Post-Approval
Offshore Dredge Spoil Disposal - Mardie Project	2024/10054		Referral Decision
Optimised Mardie Project ? Additional Triodia Grassland Habitat Clearing	2024/10094		Referral Decision
Optimised Mardie Solar Salt Project	2022/9169		Post-Approval
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Balmoral South Iron Ore Mine	2008/4236	Controlled Action	Post-Approval
Binowee Iron Ore Project	2001/366	Controlled Action	Proposed Decision
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 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
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 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

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	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
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	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
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
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
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
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
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	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
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
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
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
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
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	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
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
Onslow Water Supply Infrastructure Upgrade Project, Onslow, WA	2014/7329	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	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
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
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
WA-295-P Kerr-McGee Exploration Wells	2001/152	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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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 sesmic survey	2006/2781	Not Controlled Action (Particular Manner)	Post-Approval
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
Agrippina 3D Seismic Marine Survey	2009/5212	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
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
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
Decommissioning of the Legendre facilities	2010/5681	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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
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

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
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 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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	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 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
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	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
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
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
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	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
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

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
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
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	2010/5715	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Undertake a three dimensional marine seismic survey	2010/5679	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 Manner)	Post-Approval
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

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
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
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
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas [Resource Information]

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]	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]	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

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
Seabirds		
Ardenna tenuirostris Short-tailed Shearwater [84292]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
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
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sternula nereis Fairy Tern [82949]	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]	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 is 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 on the contents of this report.

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 point locations and environmental data layers.

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 when time permits.

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 breeding sites; and
- 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.

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appendix c oil spill modelling reports

appendix c.1—WTR vessel collision (MDO)

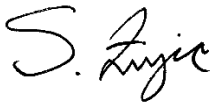
GREATER GORGON – WEST TRYAL ROCKS

Oil Spill Modelling

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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
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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating oil 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
g/m^2	Grams per square meter (unit of surface area density)
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.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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

SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia. RPS was commissioned via Xodus on behalf of Chevron to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,500 m^3 surface release of marine diesel oil (MDO) over 24 hours resulting from a containment loss following a vessel collision.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running per scenario 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Hydrocarbon Properties

Marine Diesel Oil Properties

The MDO has an API of 37.60, a density of 829 kg/m^3 (at 25ºC) and a low viscosity value of 4.0 cP. When exposed to the atmosphere at local temperatures, about 6.0% of the MDO volatile components should evaporate within the first 12 hours (BP < 180°C); a further 34.6% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (54.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 5.0% of the MDO is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

Key Findings

- 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) threshold for floating condensate was 167.0 northeast (summer), 59.6 km south-southwest (winter) and 17.6 km north-northeast (summer), respectively.

- Excluding the receptors that the release location resides within, the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate floating oil thresholds. The probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 16–22% and 3–4%,whilst the probabilities of low and moderate exposure to the Continental Slope Demersal Fish Communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before exposure at the low threshold for the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore above the low threshold was 35.1 m3. No high (≥ 1,000 g/m2) shoreline threshold accumulation was predicted in the modelling results.

- In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed to dissolved hydrocarbons at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs, the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the Humpback Whale - Migration BIA.

- In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs (that the release location resides within, the highest probabilities of exposure for the low threshold were predicted for the Humpback Whale - Migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).

- During all 3 seasons, 3 AMPs were predicted to be exposed at the low entrained hydrocarbon threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the WTR field, Xodus on behalf of Chevron had commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,500 m^3 surface release of marine diesel oil (MDO) over 24 hours resulting from a containment loss following a vessel collision.

The release location is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 West Tryal Rocks release location.

Location	Latitude	Longitude	Depth (mLAT)
WTR Well 5	20.23666° S	115.04357° E	150

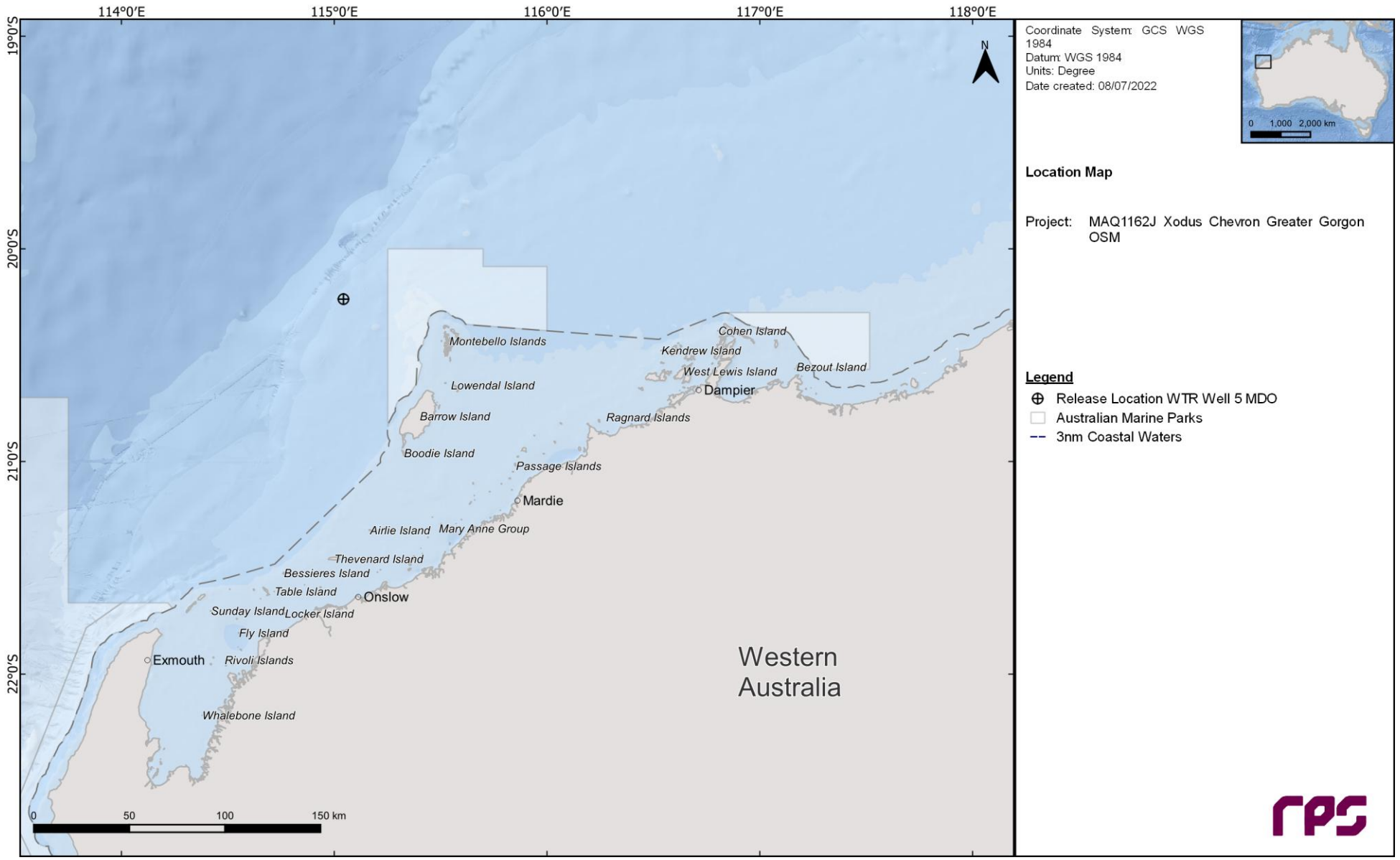


Figure 1.1 West Tryal Rocks hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. For each scenario run 100 simulations per season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds for each scenario; and

5. From the 300 simulations modelled per scenario, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:

    a. Largest swept area of floating hydrocarbon above 10 g/m^2

    b. Largest swept area of floating hydrocarbon above 50 g/m^2

    c. Largest volume of oil ashore

    d. Longest length of shoreline with accumulation above 100 g/m^2

    e. Largest area of entrained hydrocarbons above 100 ppb

    f. Largest area of dissolved hydrocarbons above 50 ppb

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

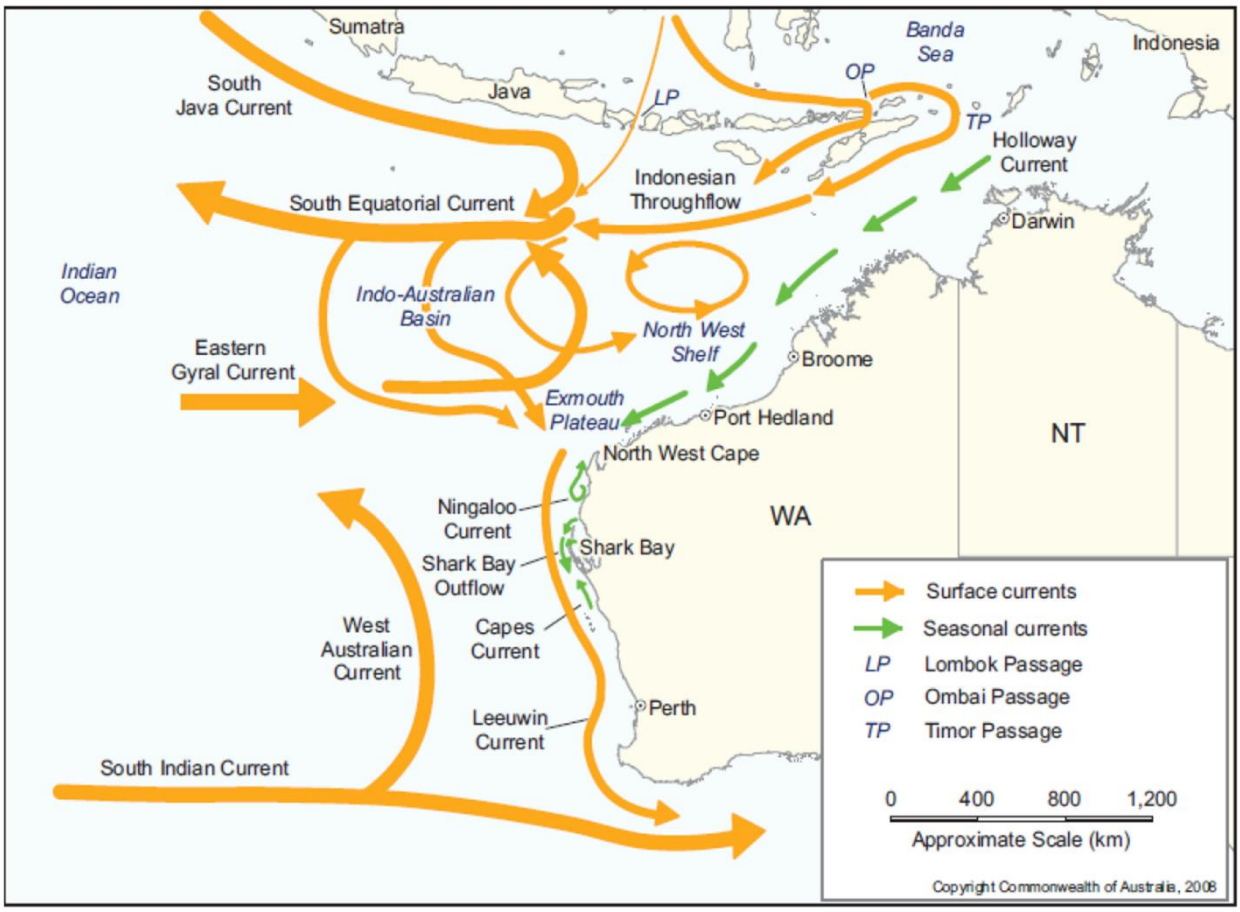


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

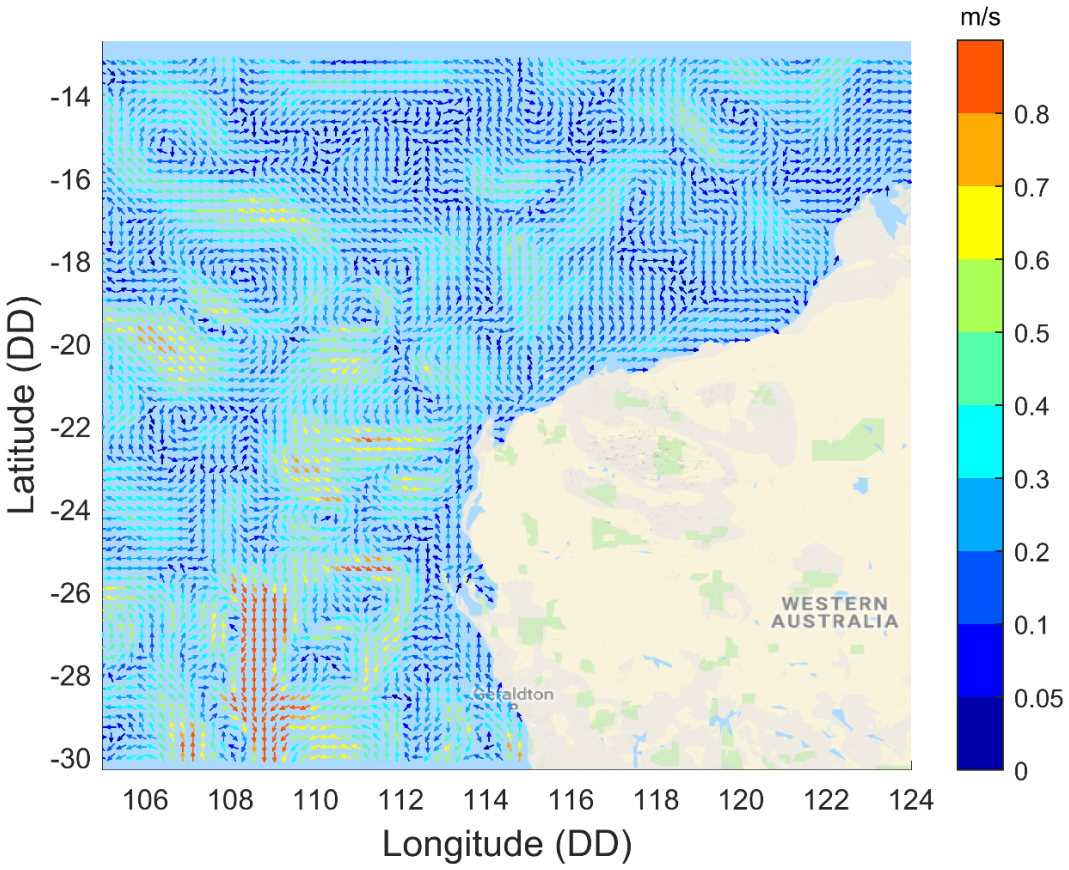


Figure 3.2 Typical ocean current circulation pattern during the summer months.

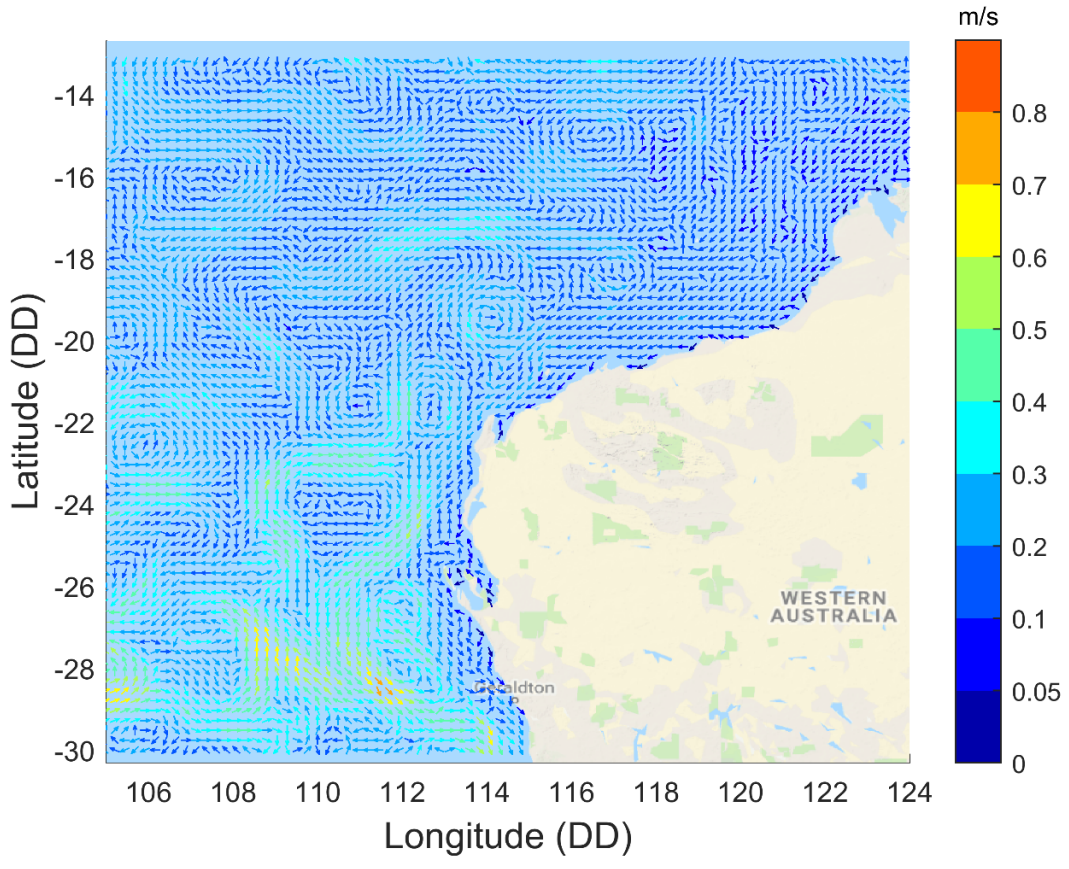


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

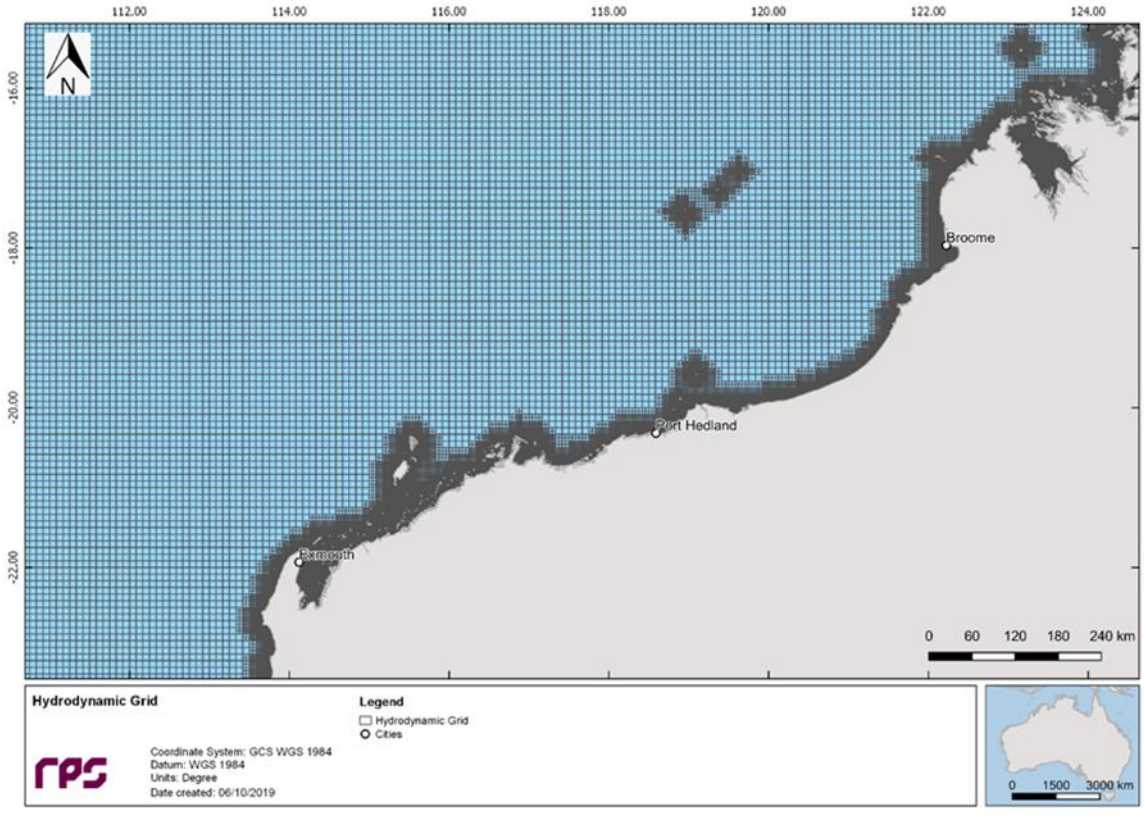


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

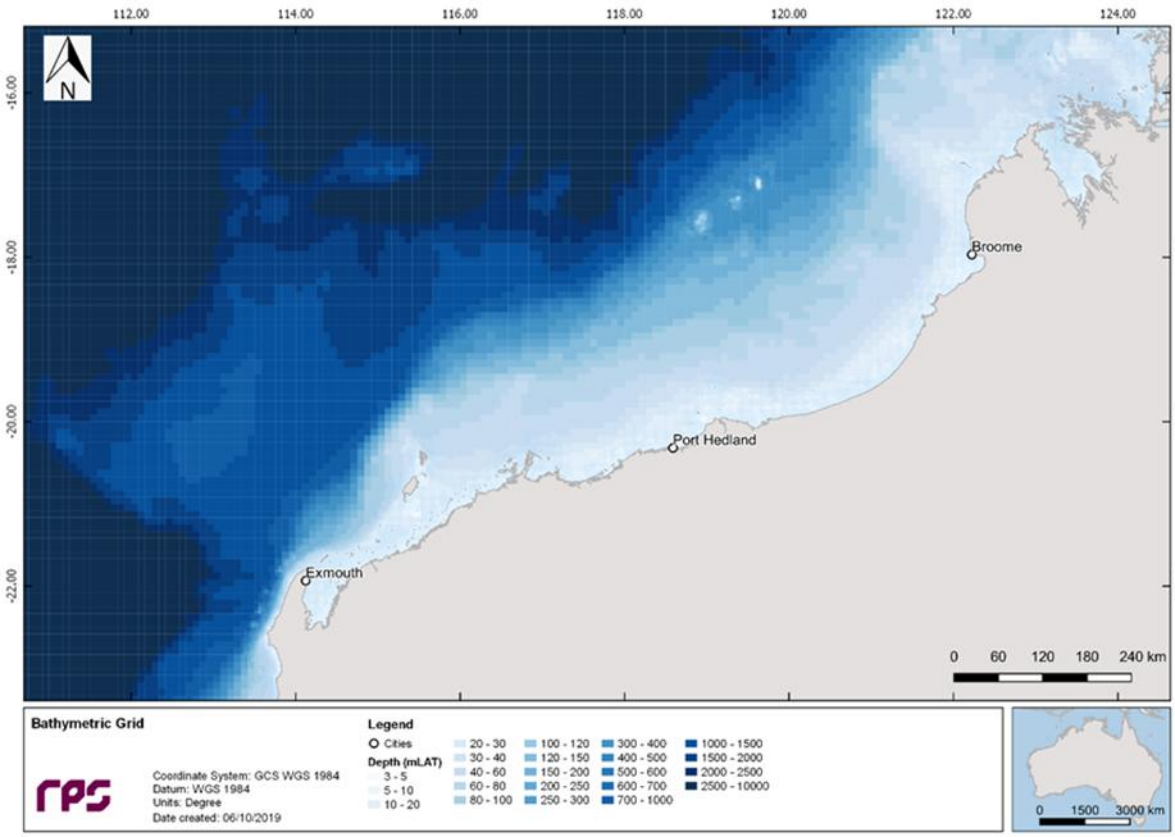


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.26 m/s (May). Additionally, the maximums ranged between 0.54 m/s (November) and 2.18 m/s (March). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.23	1.93	Northeast and Southwest
	February	0.21	1.07	Northeast and Southwest
	March	0.22	2.18	Southwest
Transitional	April	0.24	1.20	Southwest
Winter	May	0.26	0.95	Southwest
	June	0.26	0.90	Southwest
	July	0.21	1.08	Southwest
Transitional	August	0.19	0.78	Southwest
Summer	September	0.19	1.03	Northeast and Southwest
	October	0.18	0.63	Northeast and Southwest
	November	0.16	0.54	Variable
	December	0.20	0.80	Southwest
Minimum		**0.16**	**0.54**	
Maximum		**0.26**	**2.18**	

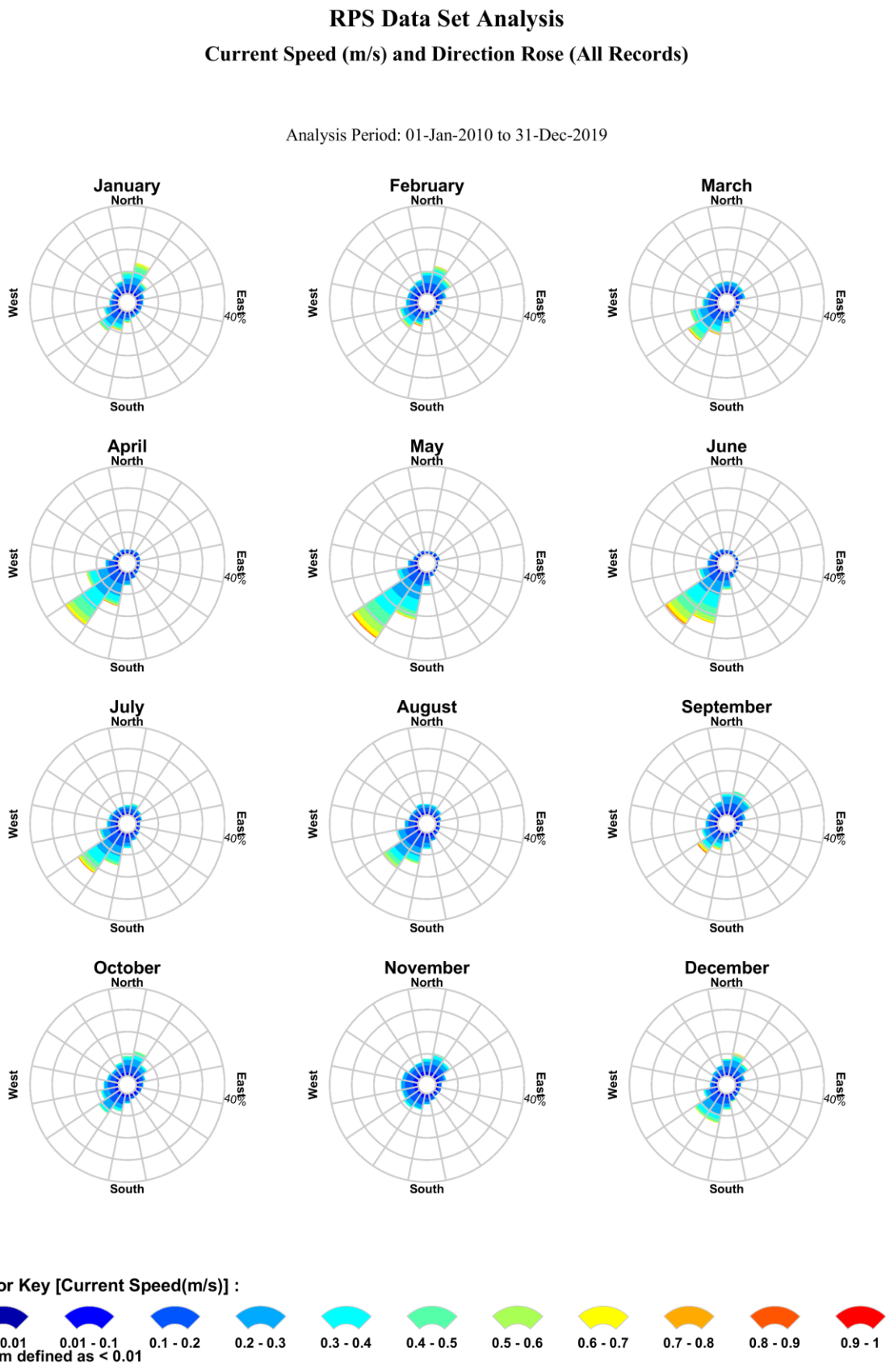


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

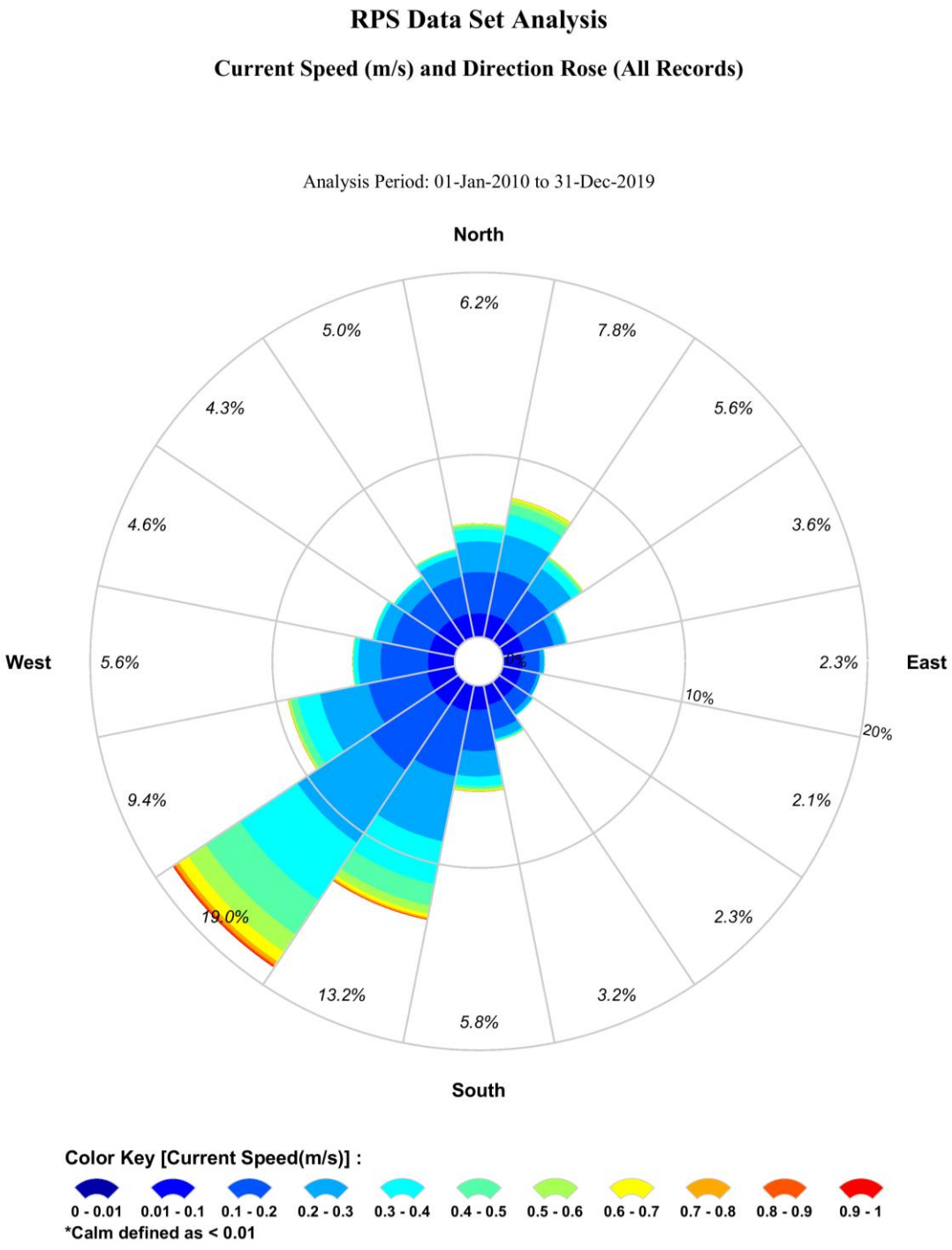


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 49 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

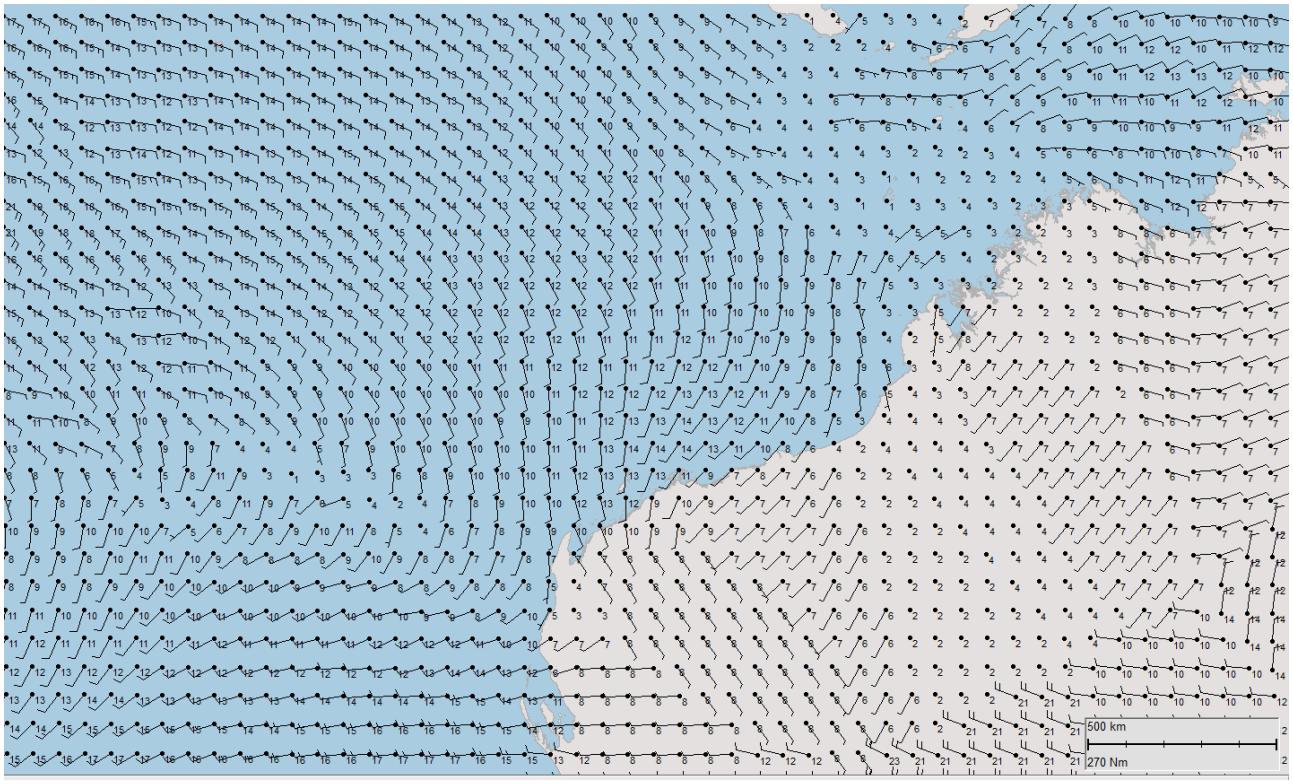


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	41	Southwest
	February	11	46	Southwest
	March	10	35	Southwest
Transitional	April	10	38	Variable
Winter	May	12	40	East
	June	14	31	East
	July	13	49	East to South
Transitional	August	11	31	South
Summer	September	12	27	South-Southwest
	October	13	28	Southwest
	November	13	25	Southwest
	December	12	29	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**49**	

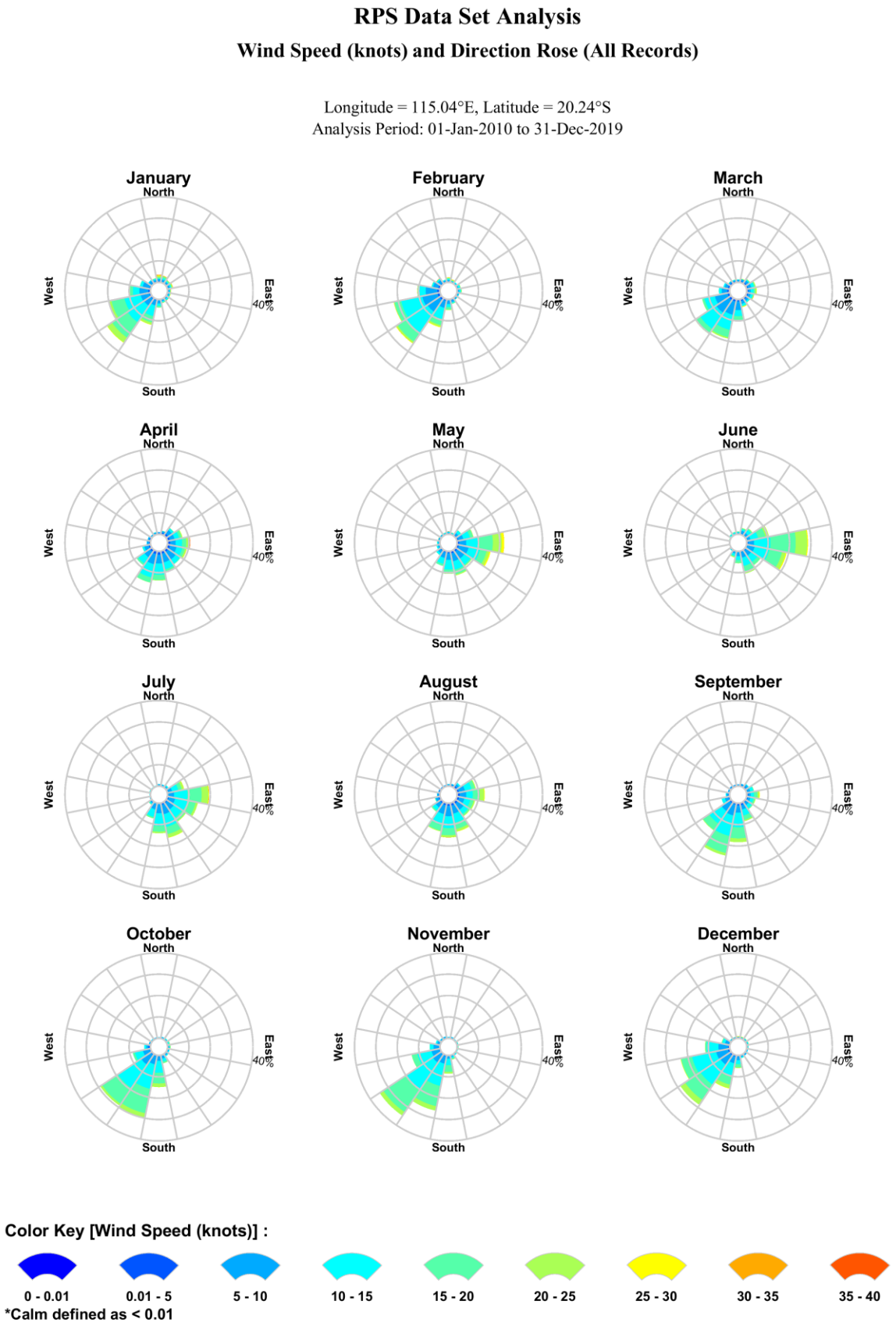


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

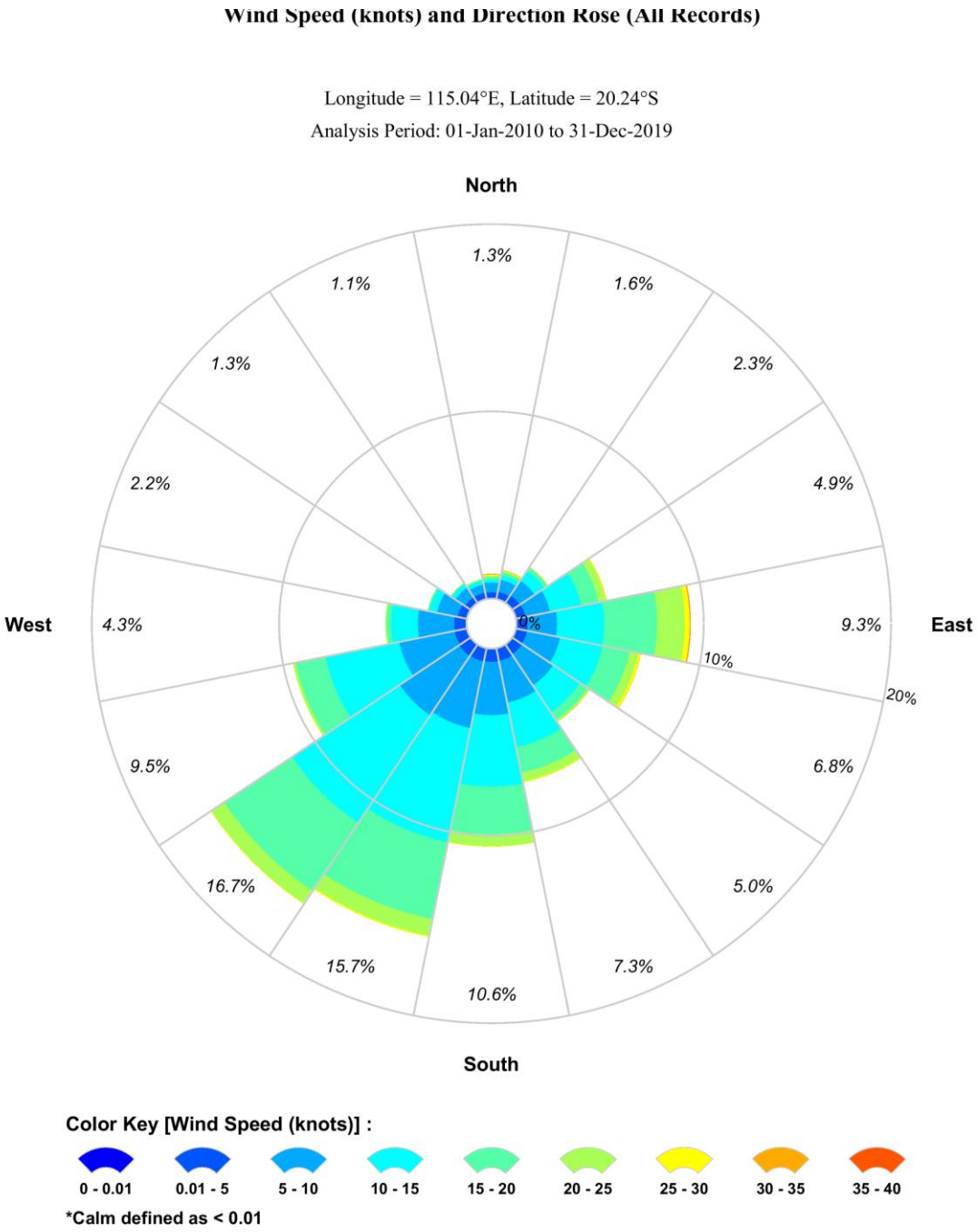


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.2°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.3 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.7	27.9	27.0	25.3	24.5	24.2	25.0	27.3	27.0
Salinity (psu)	35.1	34.9	35.0	35.1	35.2	35.3	34.9	34.8	34.9	34.9	34.6	34.9

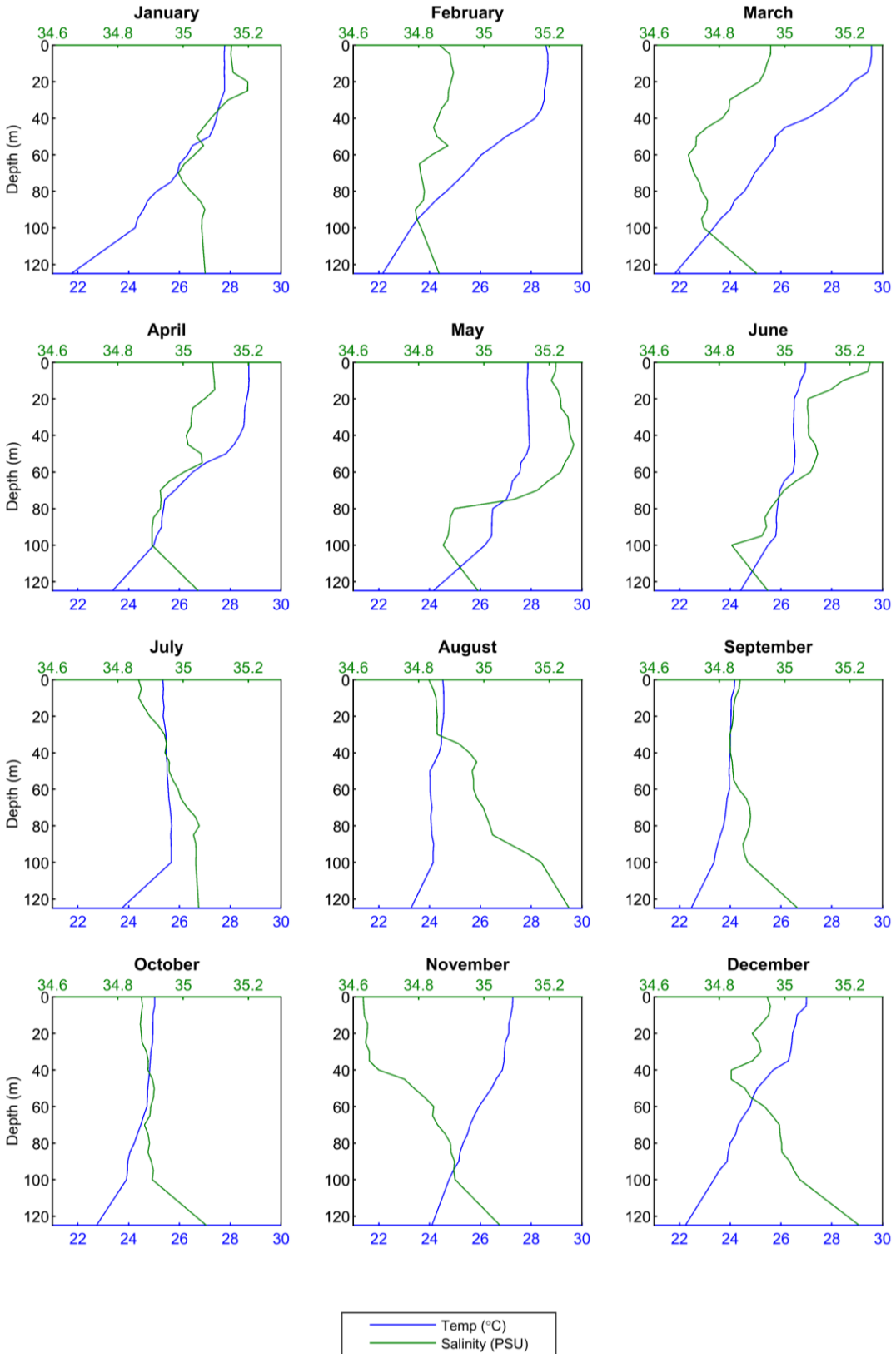


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

6.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 6.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

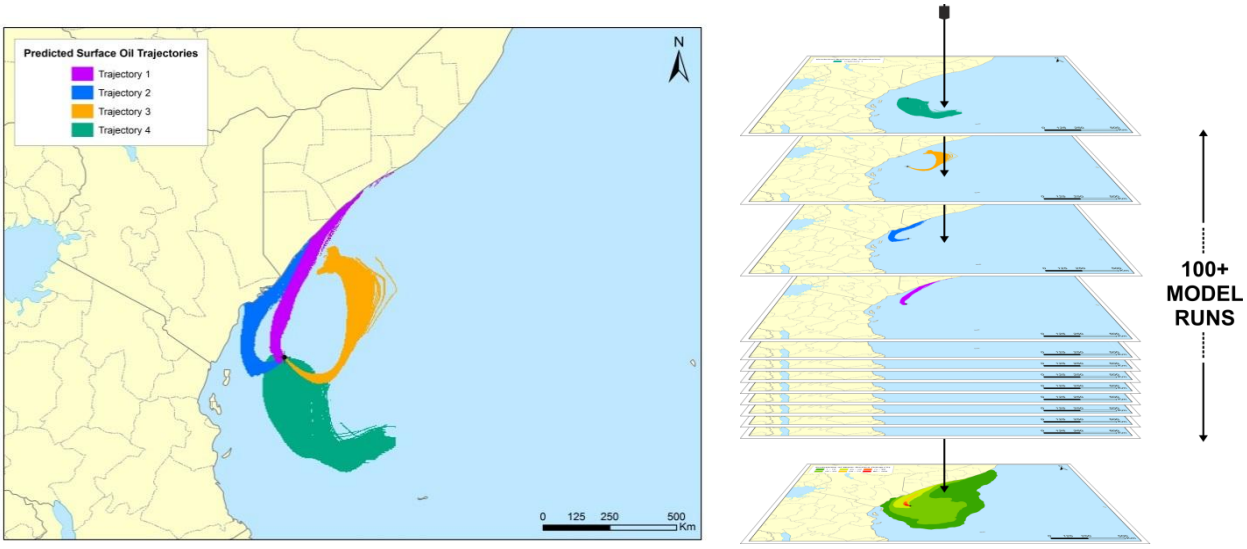


Figure 6.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

6.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 6.2.1 to 6.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

6.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 6.1). Figure 6.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 6.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 6.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 6.1 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

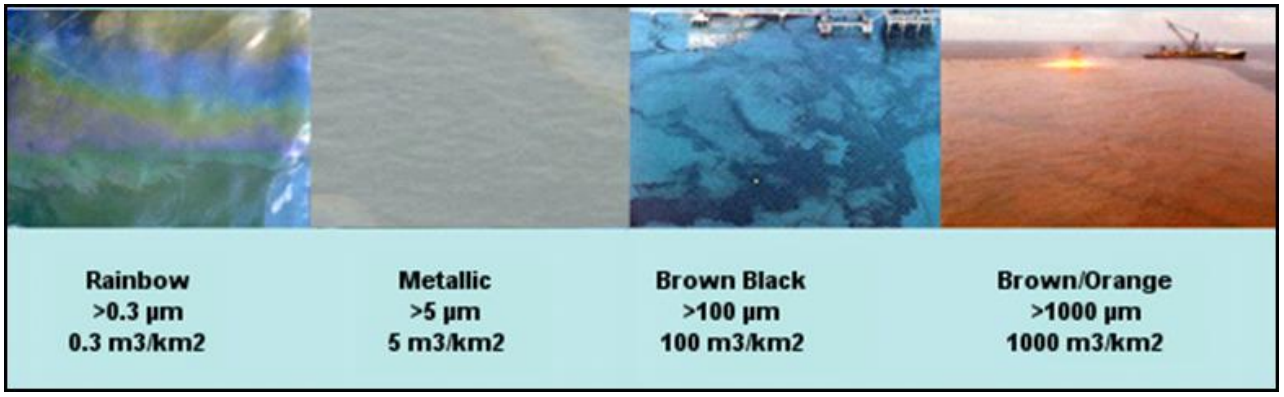


Figure 6.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 6.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

6.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 6.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 6.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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.

6.2.3 In-water Exposure 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.

6.2.3.1 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 & Di Toro, 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 6.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

6.2.3.2 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 & ARMCANZ (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.

This exposure zone 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 6.4), 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 6.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

7 HYDROCARBON PROPERTIES

7.1 Marine Diesel Oil Properties

The marine diesel oil (MDO) physical properties and boiling point distributions are presented in Table 7.1 and Table 7.2, respectively.

The MDO has an API of 37.60, a density of 829 kg/m^3 (at 25ºC) and a low viscosity value of 4.0 cP. When exposed to the atmosphere at local temperatures, about 6.0% of the MDO volatile components should evaporate within the first 12 hours (BP < 180°C); a further 34.6% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (54.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 5.0% of the MDO is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

The oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015) guidelines. The classification is based on the specific gravity of hydrocarbons in combination with relevant boiling point ranges.

The actual fate of released oil in the marine environment will depend greatly on the amount of oil that remains on the surface or is entrained in the water column.

Table 7.1 Physical properties of marine diesel oil.

Characteristic	Marine Diesel Oil
Density (kg/m^3)	829 (at 25°C)
API	37.60
Dynamic viscosity (cP)	4.0 (at 25°C)
Pour point (°C)	-14
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 7.2 Boiling point ranges of marine diesel oil.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Marine Diesel Oil	% of total	6.0	34.6	54.4	5.0

7.2 Marine Diesel Oil Weathering Characteristics

7.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this diesel when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the diesel reaches the surface.

7.2.2 Results

The mass balance forecast for the calm-wind case (Figure 7.1) shows that 36.1% of the diesel is predicted to evaporate within 24 hours. Majority of the remaining diesel on the water surface will weather at a slower rate due to being comprised of the longer-chain compounds with higher boiling points. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 7.2), where the winds are of greater strength on average, entrainment of diesel into the water column is predicted to increase. Approximately 24 hours after the spill, 80.5% of the diesel is forecast to have entrained and a further 15.0% is forecast to have evaporated, leaving only a small proportion floating on the water surface (<1%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and diesel droplets in the water column occurs at an approximate rate of 2.90% per day with an accumulated total of 20.3% after 7 days, in comparison to a rate of 0.37% per day and an accumulated total of 2.60% after 7 days in the constant-wind case. Given the proportion of entrained MDO and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

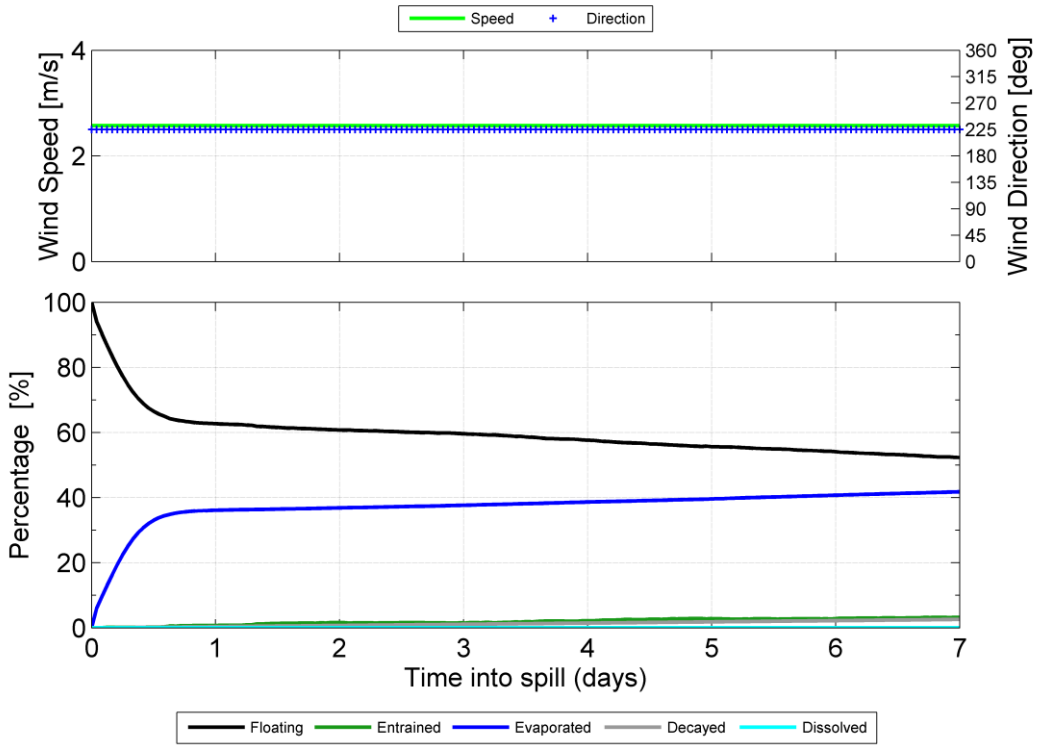


Figure 7.1 Proportional mass balance plot representing the weathering of marine diesel oil spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

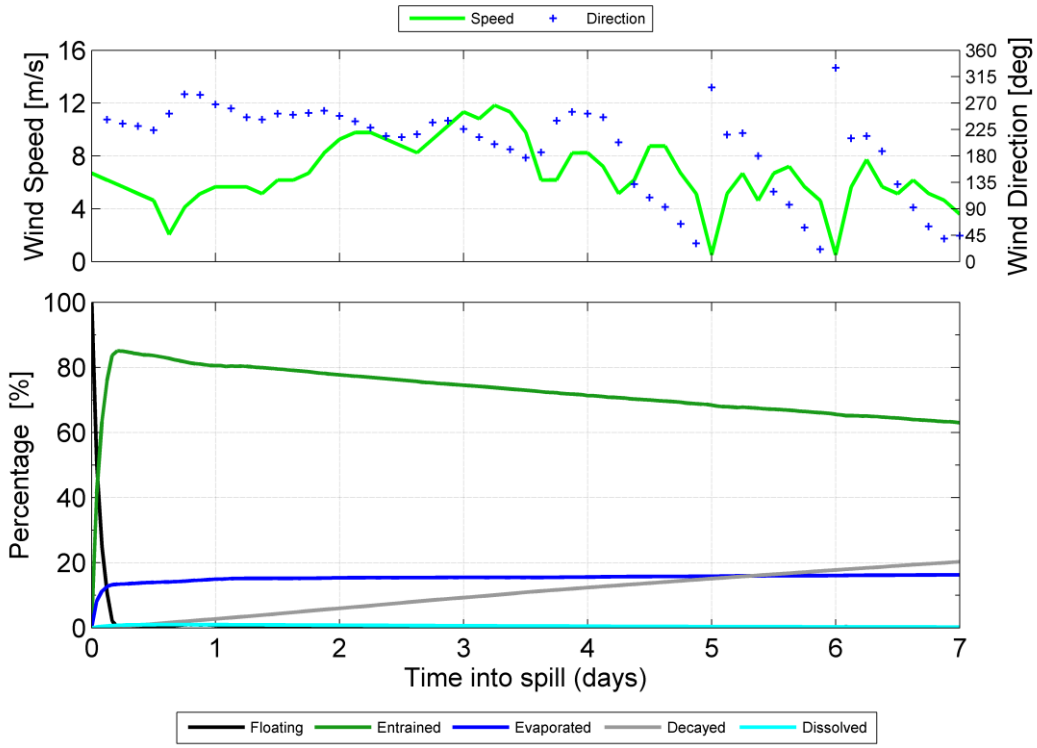


Figure 7.2 Proportional mass balance plot representing the weathering of marine diesel oil spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

8 MODEL SETTINGS

Table 8.1 provides a summary of the oil spill model settings.

Table 8.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	WTR Well 5
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	1,500 [238.5]
Condensate type	MDO
Release type (depth)	Surface
Release duration (days)	1
Simulation length (days)	60
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

9 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

9.1 Stochastic Analysis

9.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***probability of oil exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before oil exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

9.2 Deterministic Trajectories

The deterministic results for both scenarios are based on the following criteria:

a. Largest volume of oil ashore;

b. Minimum time before shoreline accumulation above 10 g/m^2;

c. Longest length of shoreline accumulation above 10 g/m^2;

d. Largest swept area of floating oil above 1 g/m2;

e. Largest area of entrained hydrocarbons above 10 ppb; and

f. Largest area of dissolved hydrocarbons above 10 ppb.

9.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 9.1 to Figure 9.11). Receptor categories (see Table 9.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 9.2 summarises the receptors that the location resides within.

Table 9.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
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 Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 9.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Flatback Turtle - Internesting Buffer	BIA	✓
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Whale Shark - Foraging	BIA	✓
Offshore Area	IAA	✓
Pilbara (offshore)	IMCRA	✓
Ancient coastline at 125 m depth contour	KEF	✓

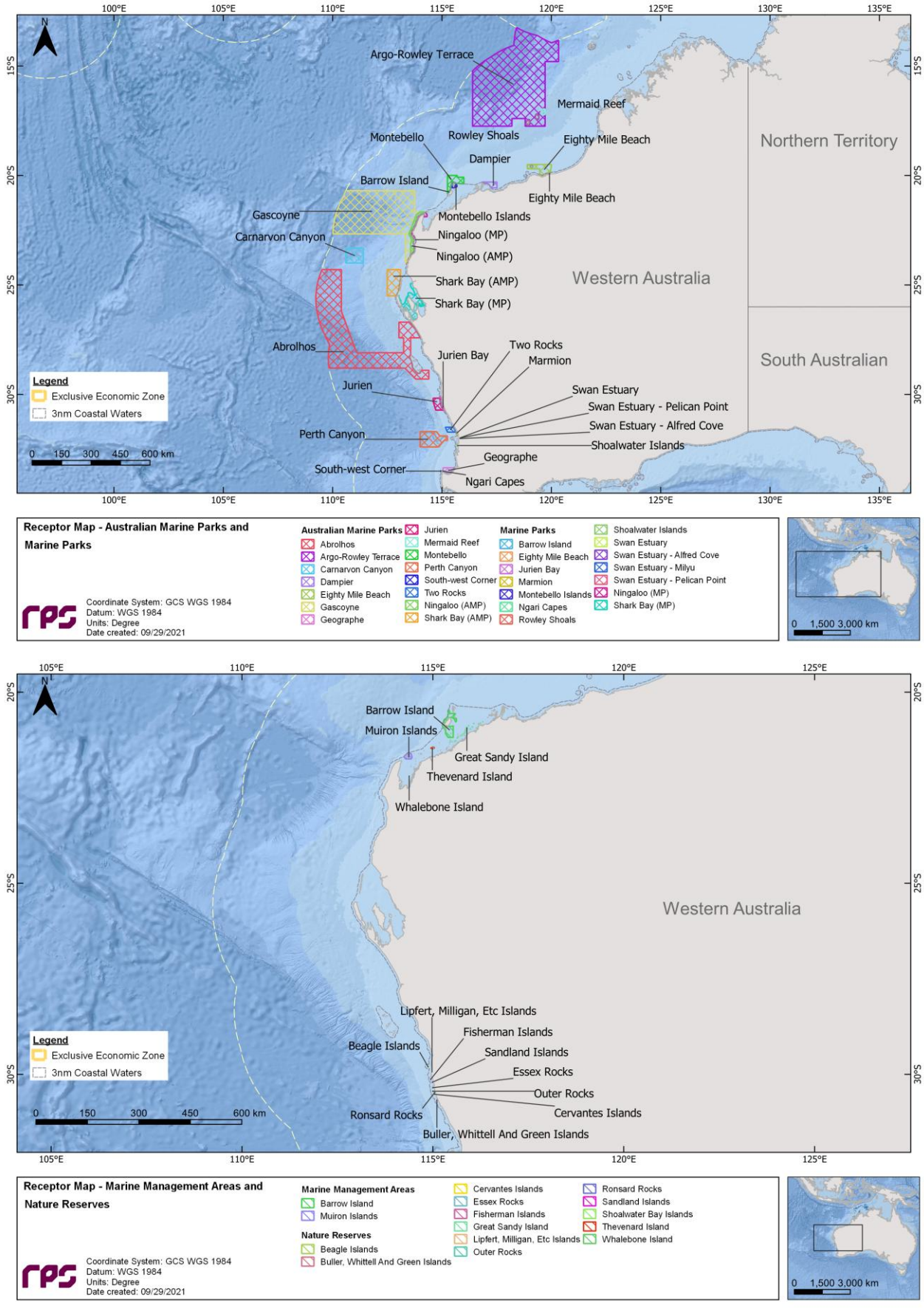


Figure 9.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

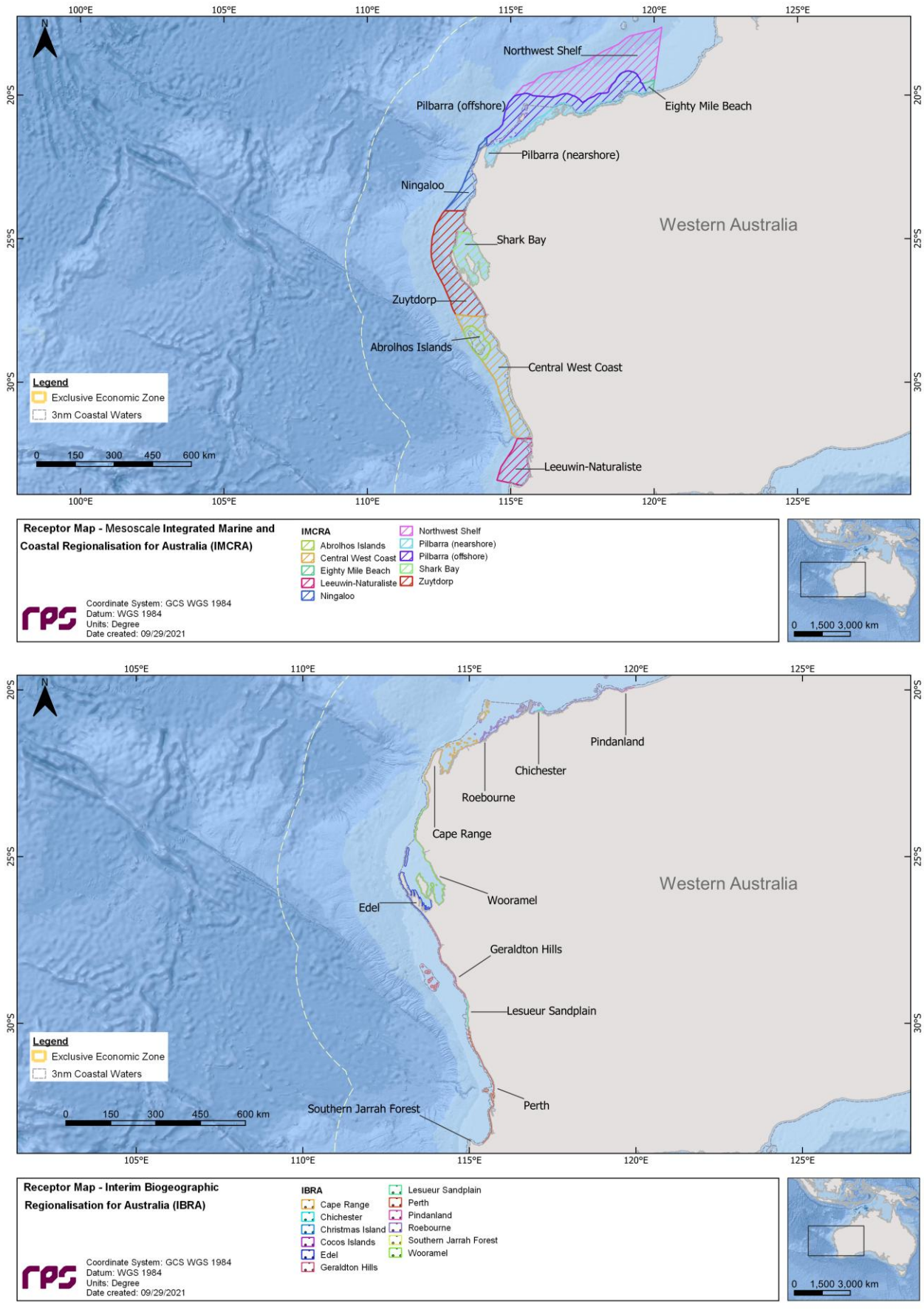


Figure 9.2 Receptor maps for Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

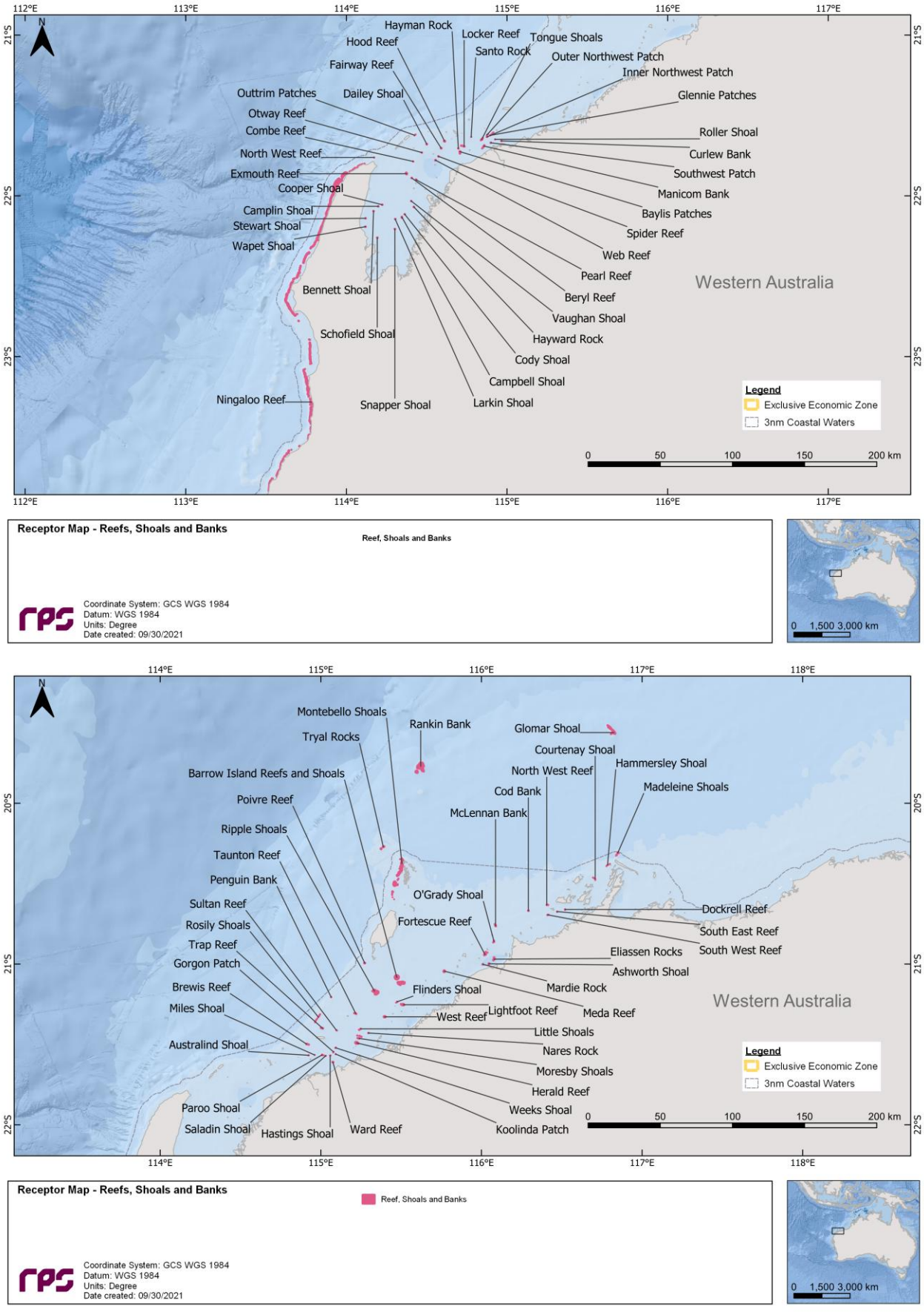


Figure 9.3 Receptor maps for Reefs, Shoals and Banks (RSB).

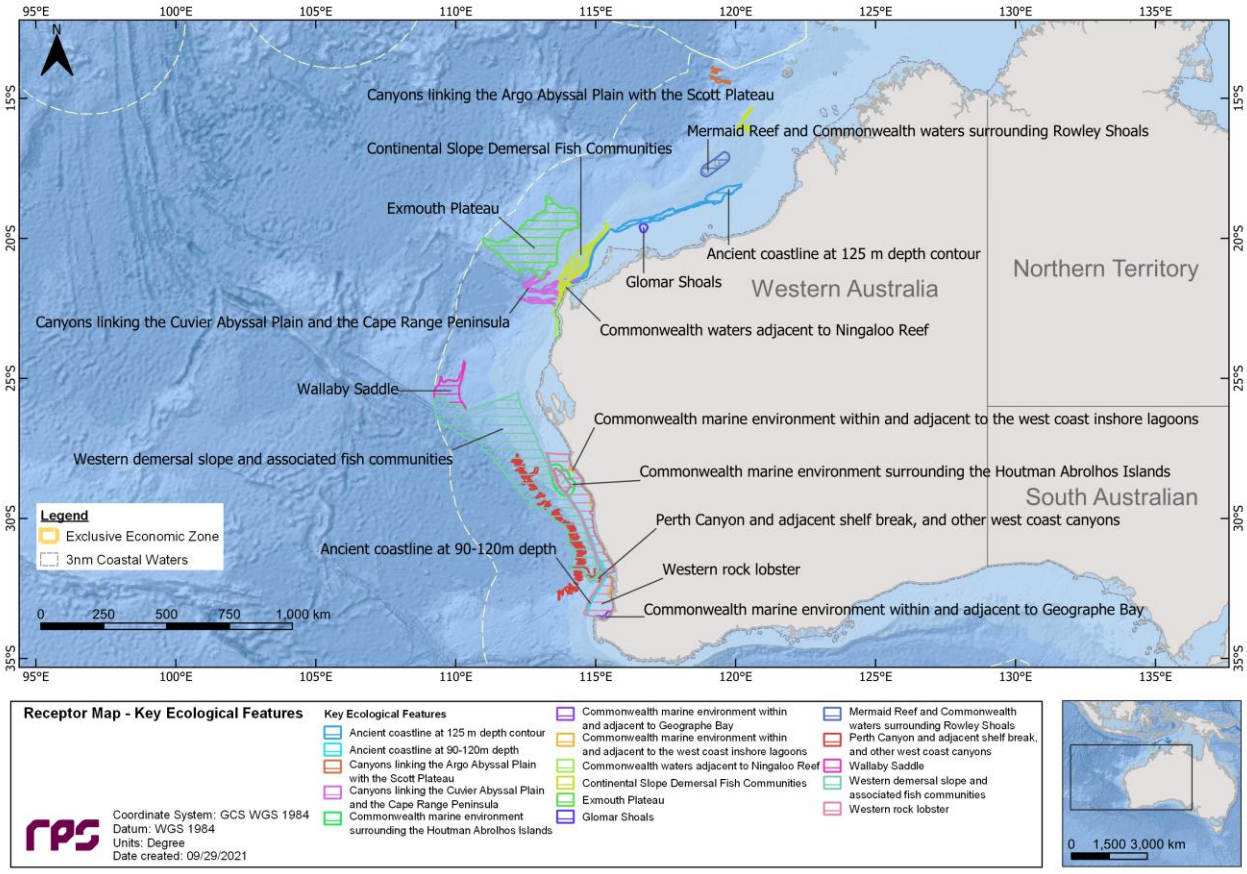


Figure 9.4 Receptor maps for Key Ecological Features (KEFs).

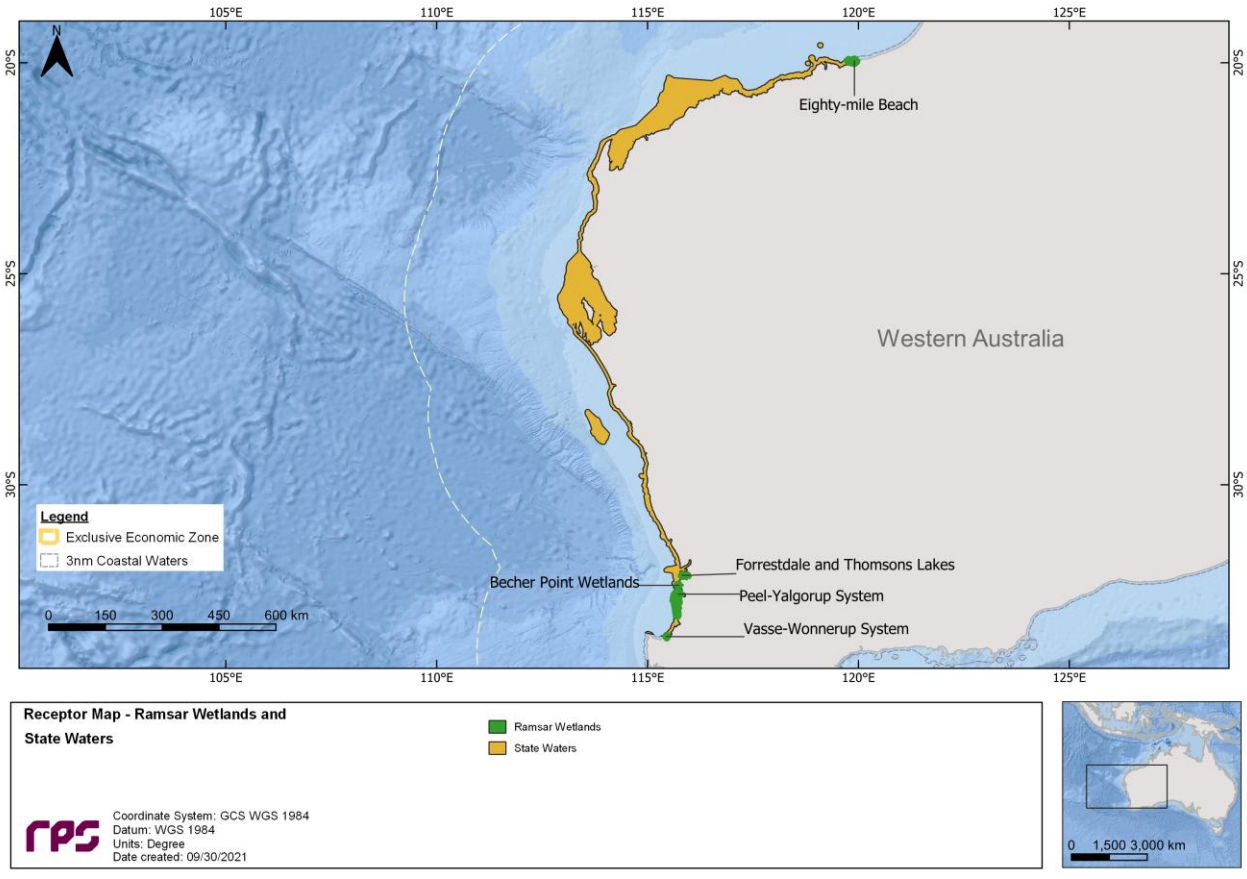


Figure 9.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

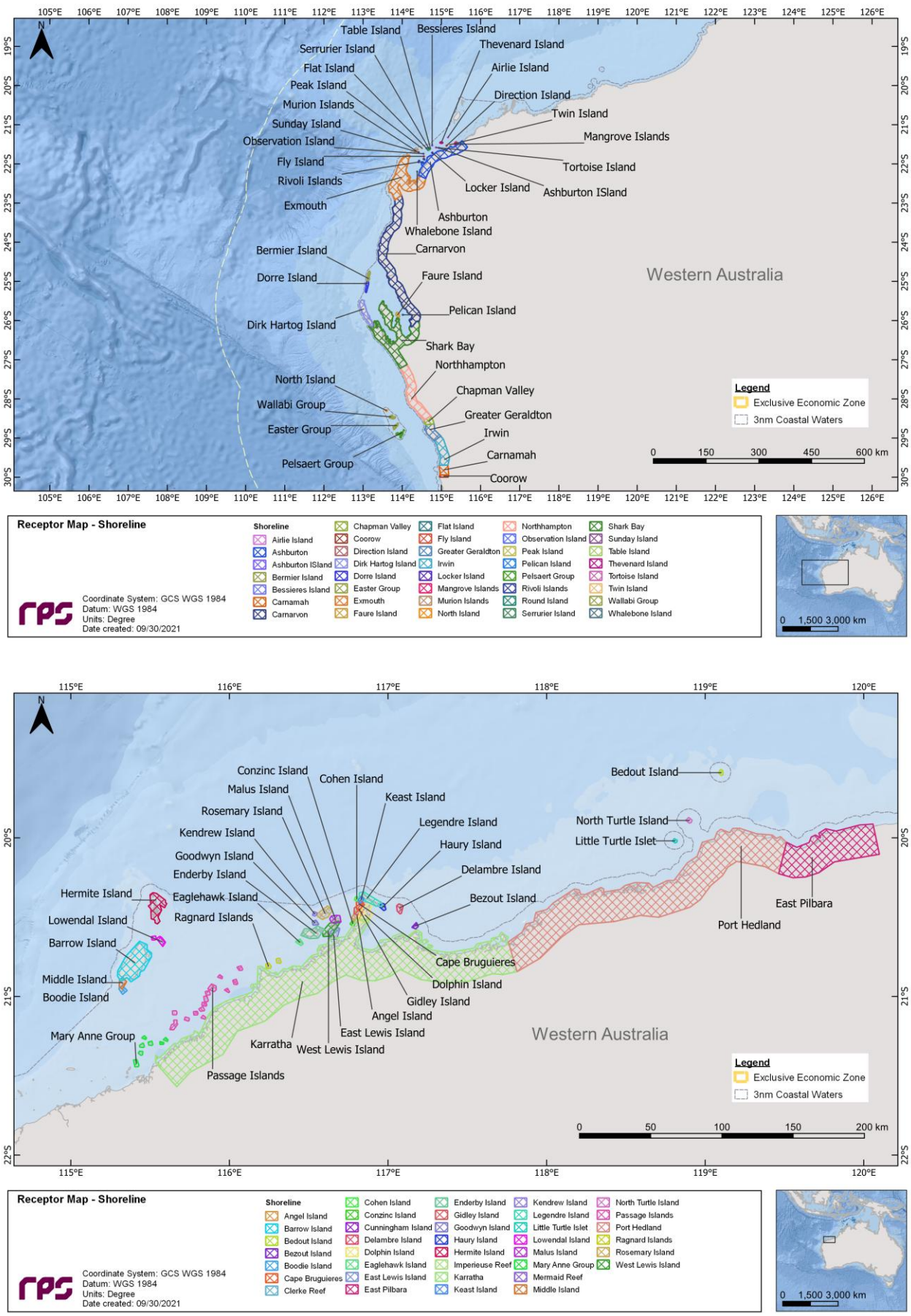


Figure 9.6 Receptor maps for Shorelines (1 of 2).

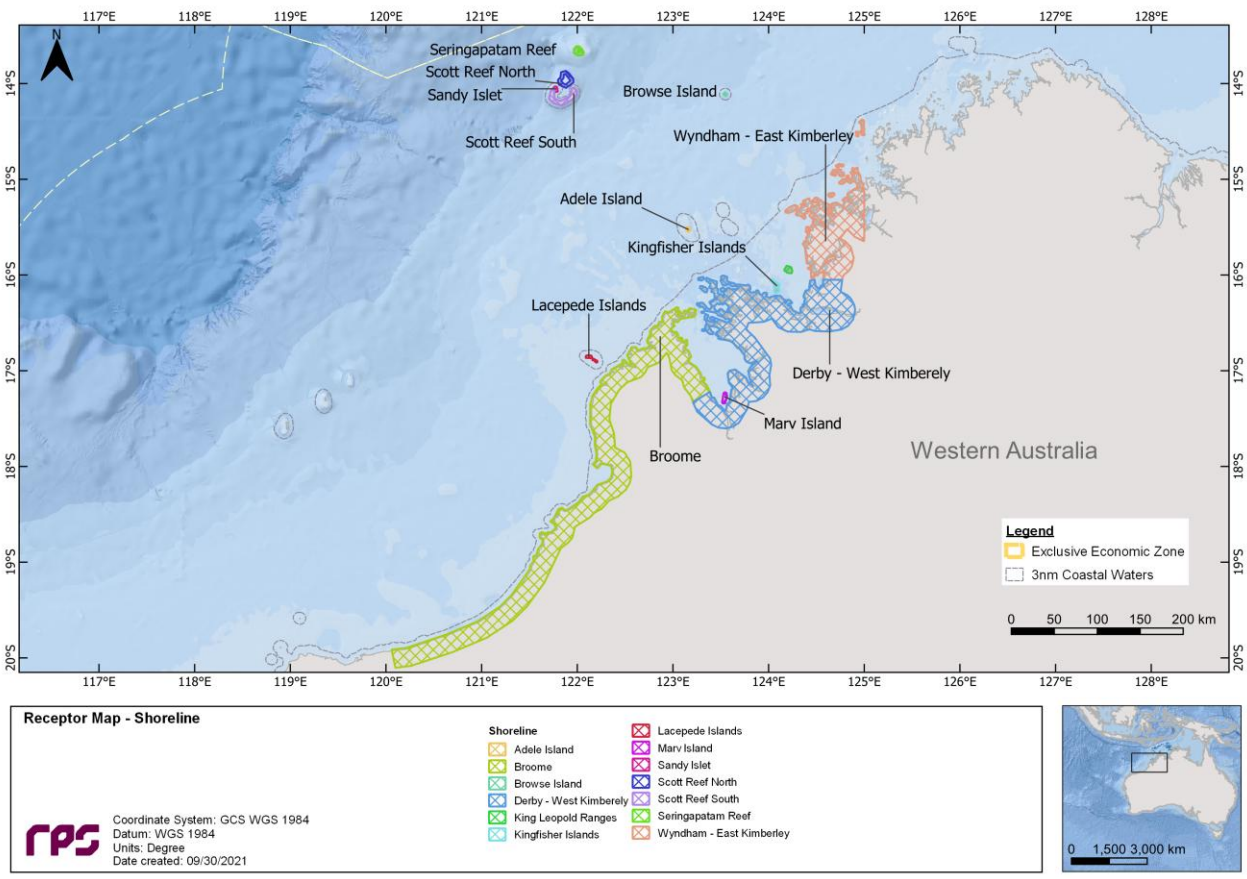


Figure 9.7 Receptor maps for Shorelines (2 of 2).

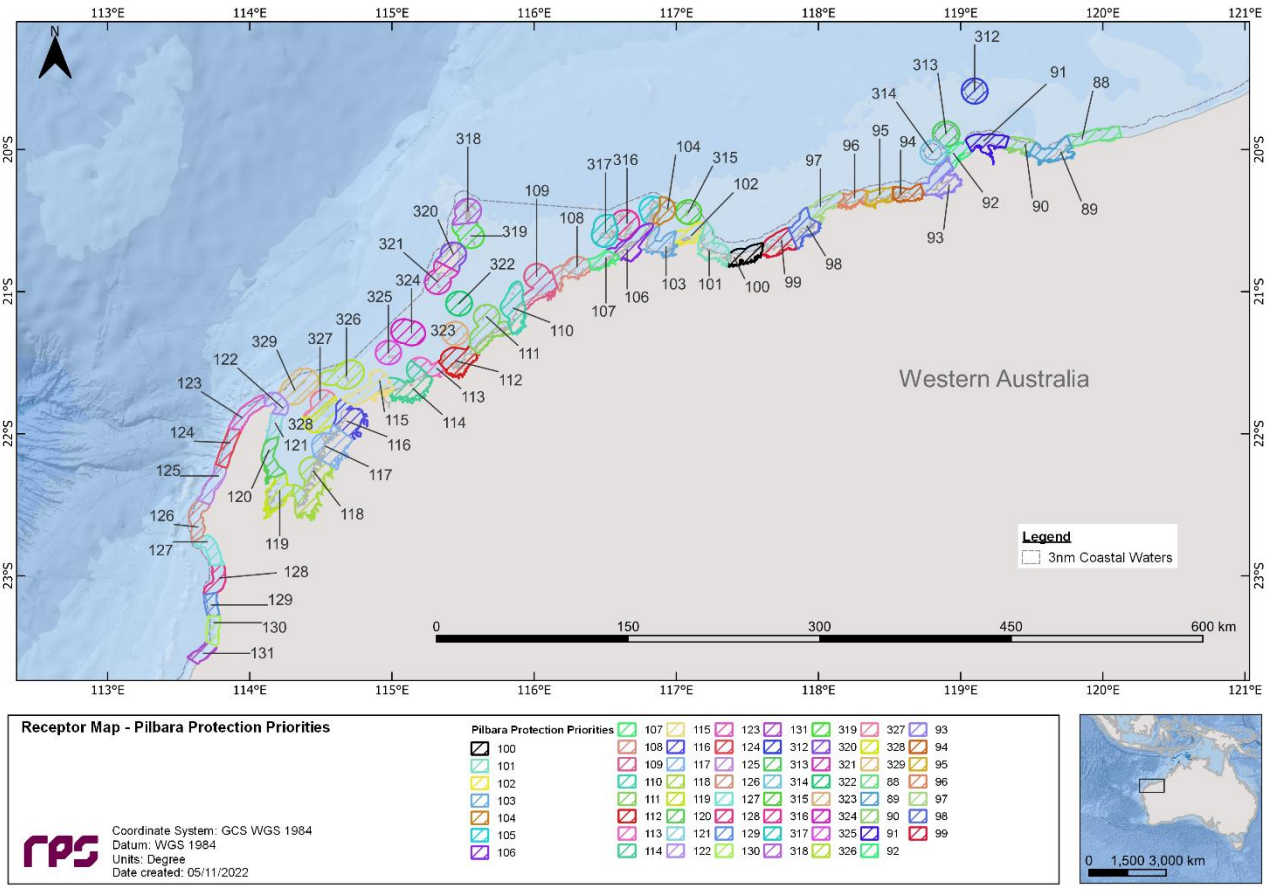


Figure 9.8 Receptor maps for Pilbara Protection Priorities Shorelines.

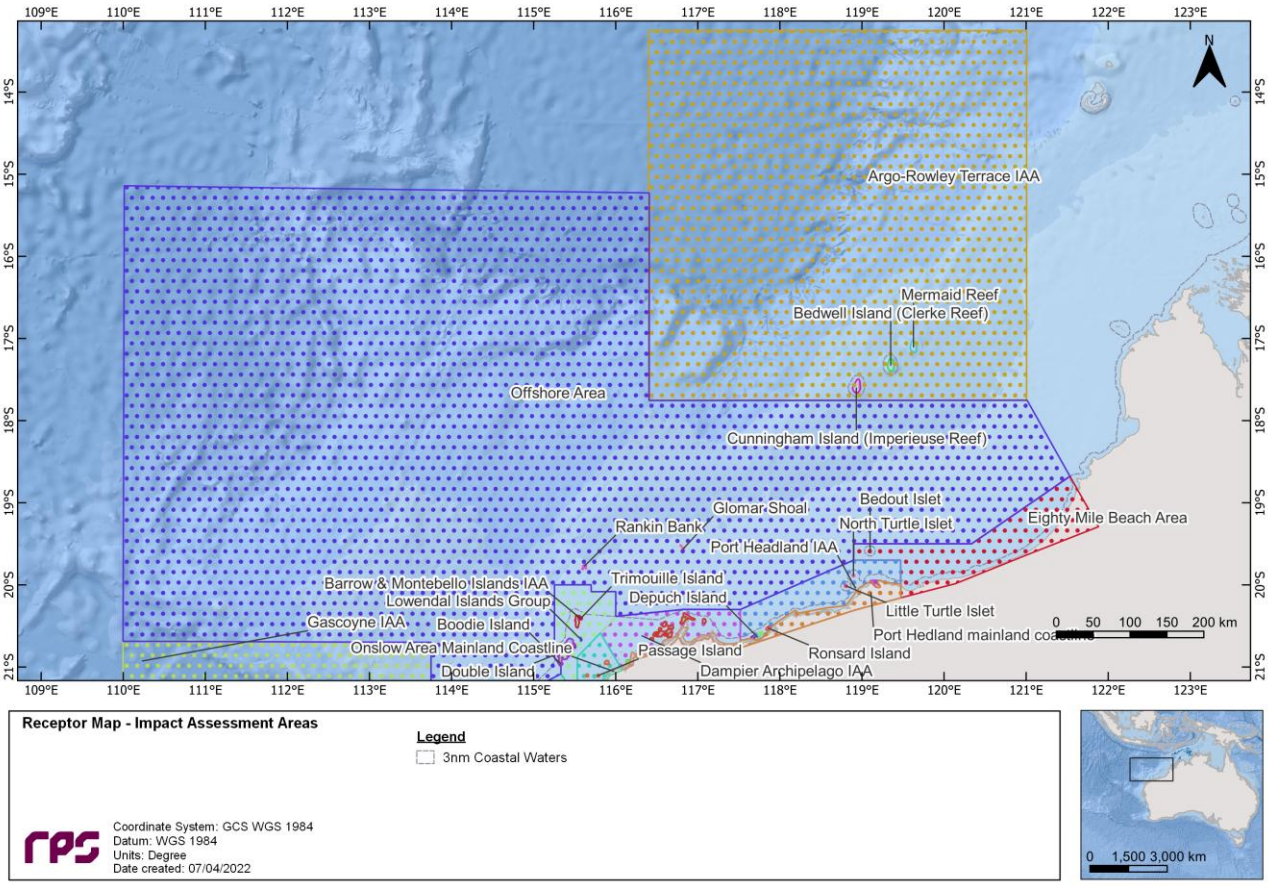


Figure 9.9 Receptor maps for Impact Assessment Areas (1 of 3).

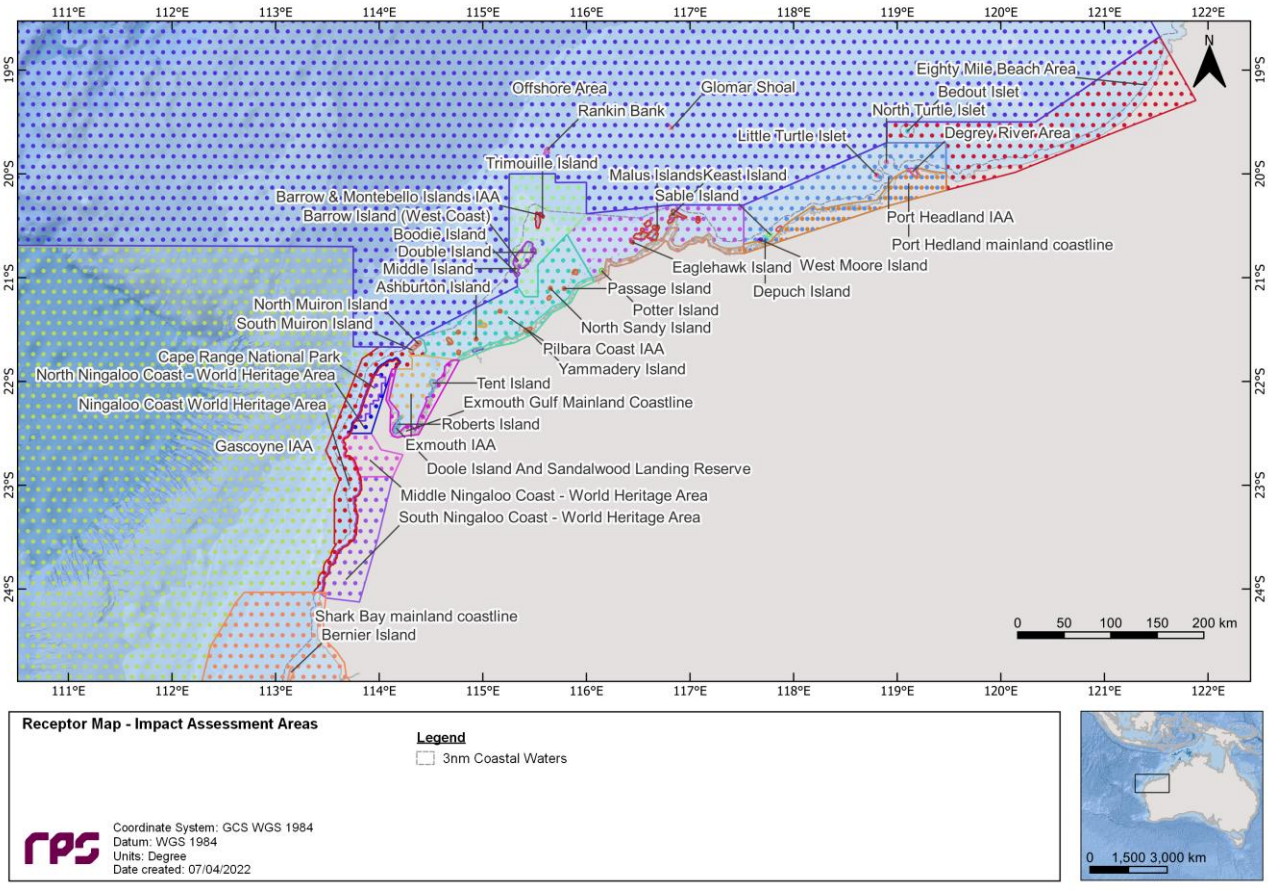


Figure 9.10 Receptor maps for Impact Assessment Areas (2 of 3).

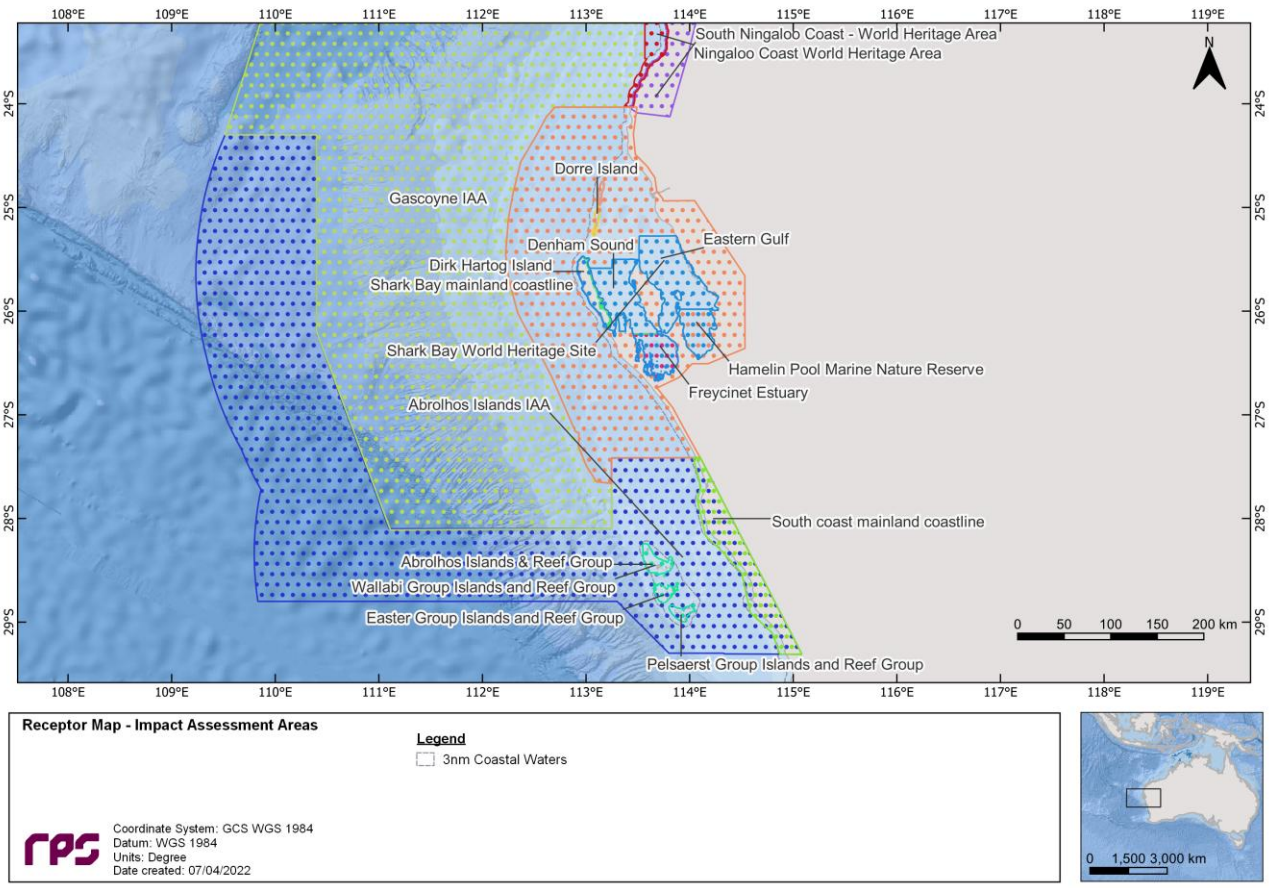


Figure 9.11 Receptor maps for Impact Assessment Areas (3 of 3).

10 RESULTS: WEST TRYAL ROCKS VESSEL COLLISION

This scenario examined a 1,500 m^3 surface release of MDO over 24 hours, from a vessel collision. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 60 days.

Section 10.1 presents the seasonal (or stochastic) analysis results, while Section 10.2 presents the deterministic results.

10.1 Stochastic Analysis

10.1.1 Floating MDO Exposure

Table 10.1 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 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold was 167.0 northeast (summer), 59.6 km south-southwest (winter) and 17.6 km north-northeast (summer), respectively.

Table 10.2 summarises the potential floating oil exposure to individual receptors during each season.

The Offshore Area IAA, Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging BIAs, Pilbara (offshore) IMCRA, and the Ancient coastline at 125 m depth contour KEF, which the release location resides within (see Section 10.3), and the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. With the exception of the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF, the probabilities for the low and moderate thresholds was 100% for all seasons for these receptors. The probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 16–22% and 3–4%, whilst the probabilities of low and moderate exposure to the Continental Slope Demersal Fish Communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before low exposure for the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.

Figure 10.1 to Figure 10.3 present the zones of floating oil exposure for each season.

Table 10.1 Maximum distances and directions travelled from the release location to floating oil exposure for each season and threshold, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating oil exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	167.0	52.1	17.6
	Max. distance from release site (km) (99th percentile)	154.0	43.4	17.1
	Direction	Northeast	South	North-northeast
Transitional	Max. distance from release site (km)	134.4	46.6	17.3
	Max. distance from release site (km) (99th percentile)	91.6	43.7	16.7
	Direction	West-northwest	South-southwest	South-southwest
Winter	Max. distance from release site (km)	158.6	59.6	9.8
	Max. distance from release site (km) (99th percentile)	86.3	53.3	9.5
	Direction	South-southwest	South-southwest	North

Table 10.2 Summary of the potential floating oil exposure to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	3	-	-	1.96	-	-	4	-	-	3.33	-	-	1	-	-	4.88	-	-
BIA	Flatback Turtle - Internesting Buffer*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Flatback Turtle - Nesting	10	2	-	1.08	1.5	-	8	-	-	0.71	-	-	14	-	-	1.17	-	-
	Green Turtle - Internesting Buffer	1	-	-	3.08	-	-	-	-	-	-	-	-	4	-	-	2.58	-	-
	Hawksbill Turtle - Internesting Buffer	1	-	-	3.04	-	-	-	-	-	-	-	-	2	-	-	2.58	-	-
	Humpback Whale - Migration	16	3	-	0.71	0.79	-	19	4	-	0.83	0.88	-	22	3	-	0.54	0.88	-
	Loggerhead Turtle - Internesting Buffer	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6.92	-	-
	Pygmy Blue Whale - Distribution*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Wedge-tailed Shearwater - Breeding*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Whale Shark - Foraging*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
IAA	Barrow & Montebello Islands	3	-	-	1.96	-	-	4	-	-	3.33	-	-	1	-	-	4.88	-	-
	Offshore Area*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
IMCRA	Northwest Shelf	9	1	-	1.04	1.58	-	8	-	-	1.25	-	-	-	-	-	-	-	-
	Pilbara (offshore)	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
KEF	Ancient coastline at 125 m depth contour*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Continental Slope Demersal Fish Communities	35	4	-	0.79	0.88	-	54	13	2	0.38	0.58	1.75	37	6	-	0.71	1.58	-
	Exmouth Plateau	-	-	-	-	-	-	1	-	-	7.04	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

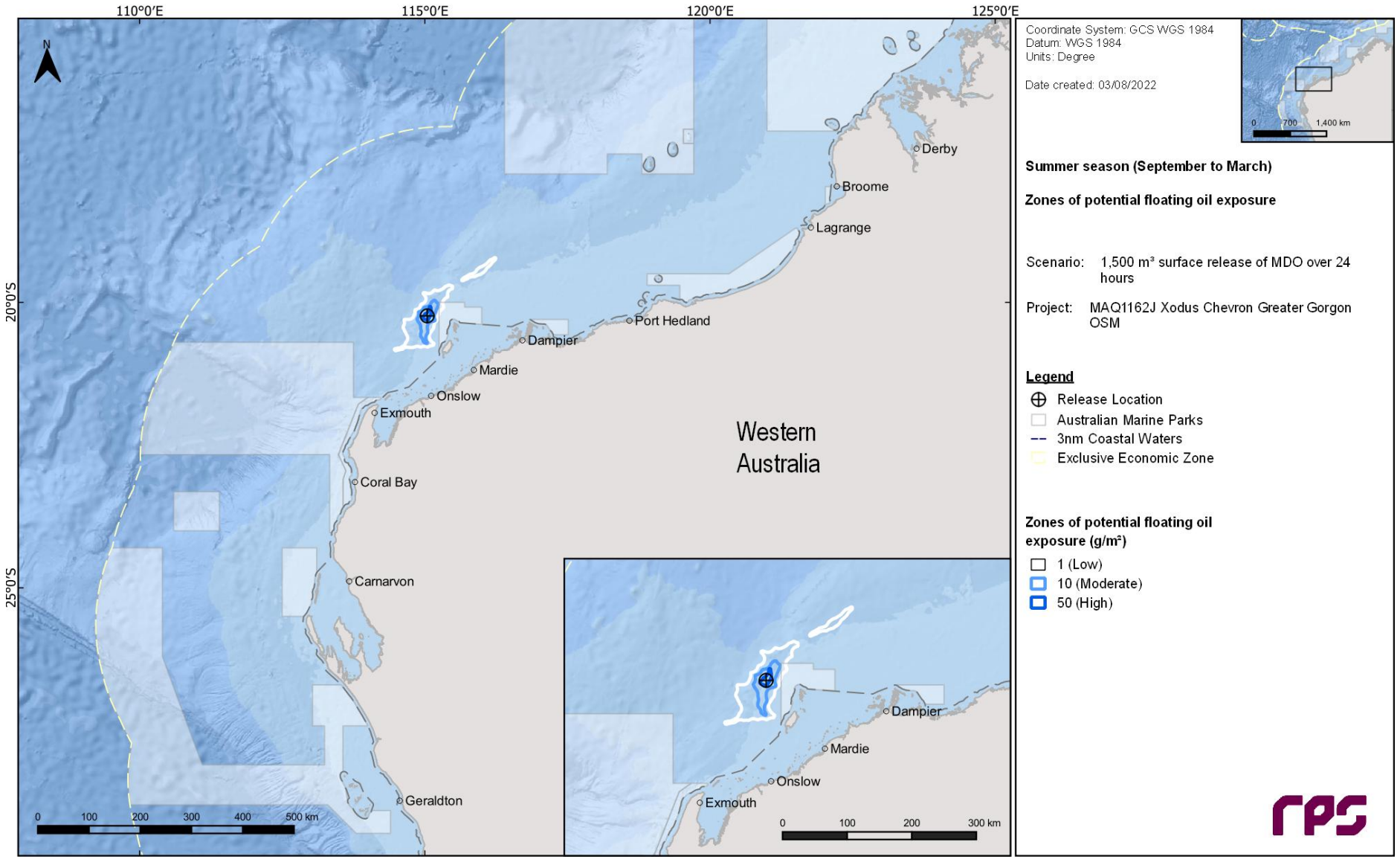


Figure 10.1 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

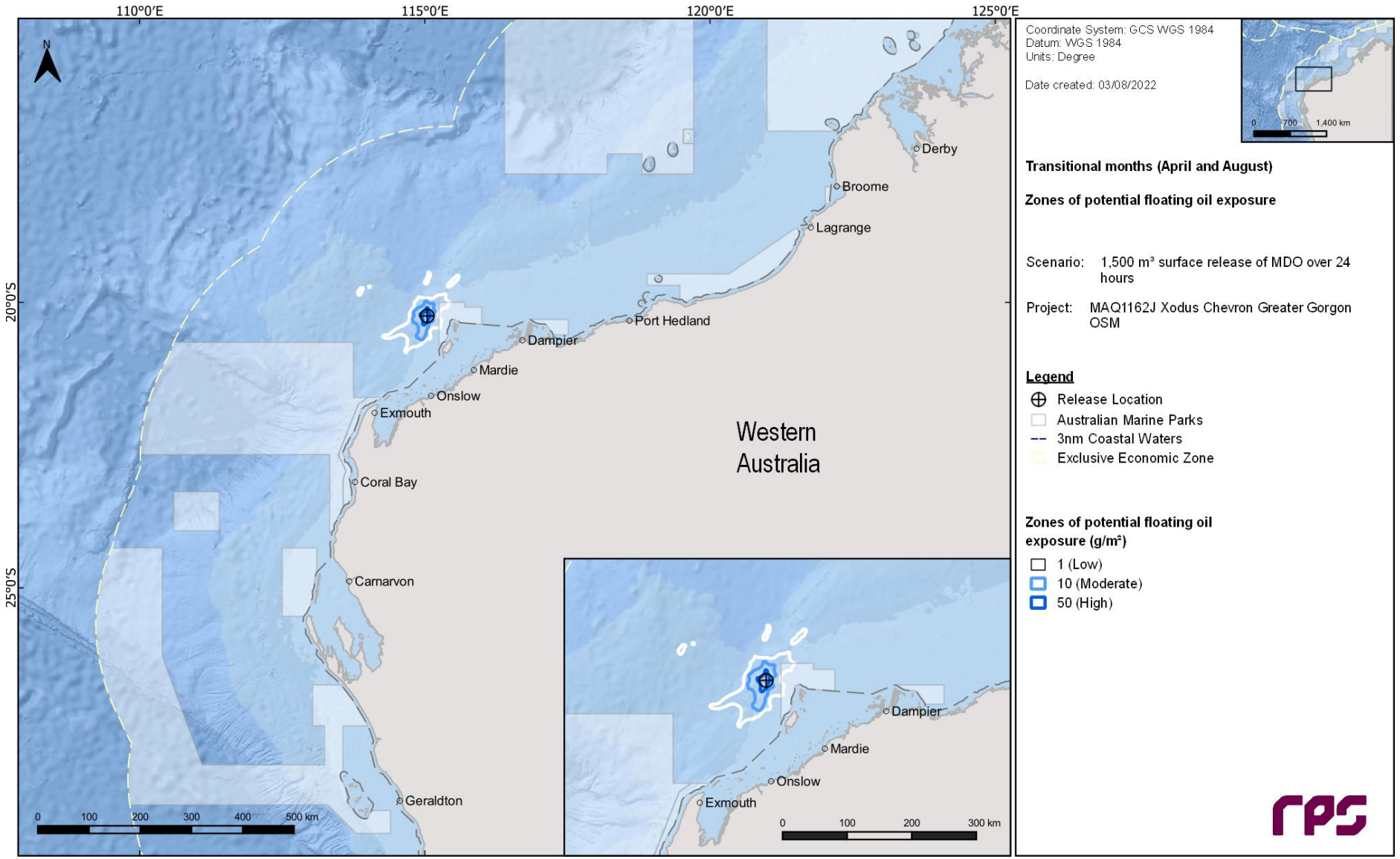


Figure 10.2 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

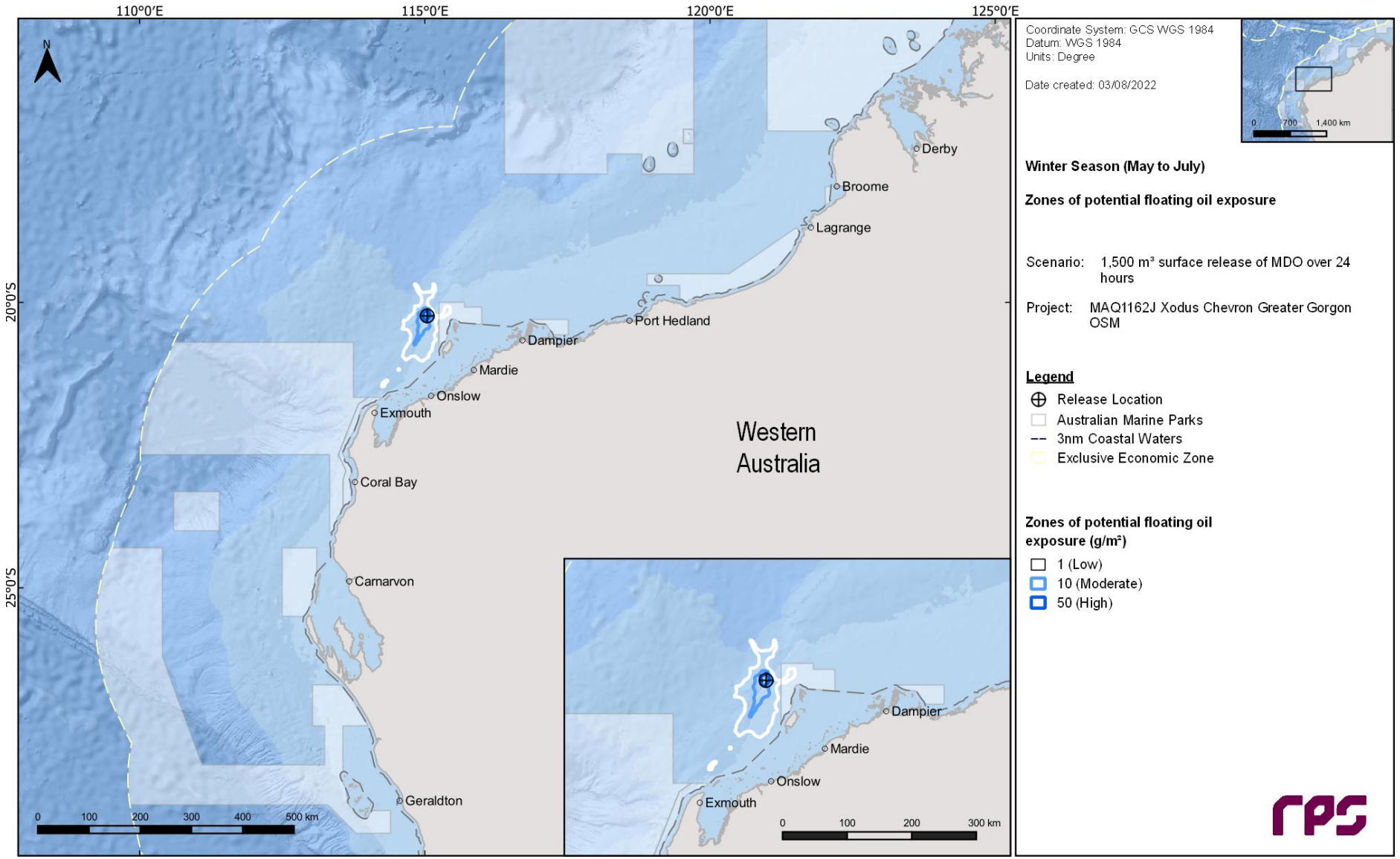


Figure 10.3 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

10.1.2 Shoreline Accumulation

Table 10.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore was 35.1 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 10.4 to Table 10.6summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, 23 shoreline receptors were predicted to record oil accumulation at, or above, the low threshold with the greatest probability predicted for Ningaloo Coast World Heritage Area IAA (4%). In comparison, during transitional and winter conditions, 9 and 22 shoreline receptors, respectively, were predicted to record accumulation. During transitional conditions the greatest probability for low threshold accumulation was 3% predicted for South Muiron Island and Ningaloo Coast World Heritage Area IAA, and the Muiron Islands IAA and shoreline. Additionally, during the winter conditions the greatest probability for low threshold accumulation was 7% and was predicted for the Ningaloo Coast World Heritage Area IAA.

The maximum potential shoreline accumulation is presented for each season in Figure 10.4 to Figure 10.6.

Table 10.3 Summary of oil accumulation across all shorelines for each season and threshold, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	6	4	9
Absolute minimum time for visible oil to shore (days)	8.04	16.33	6.50
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	35.1	1.7	7.2
Average volume of hydrocarbons ashore (m^3) above the low threshold	1.9	< 0.1	0.2
Maximum length of the shoreline at **10 g/m^2** (km)	51.0	6	14
Average shoreline length (km) at **10 g/m^2** (km)	21.7	4.3	6.2
Maximum length of the shoreline at **100 g/m^2** (km)	24	-	2
Average shoreline length (km) at **100 g/m^2** (km)	6.5	-	2
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 10.4 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	2	2	-	10.92	14.29	-	17	177	< 0.1	1.5	14.4	1.4	-	15.4	1.9	-
	South Muiron Island	2	1	-	9.08	12.92	-	6	224	< 0.1	0.6	4.8	1	-	6.7	1	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	3	-	-	8.54	-	-	9	69	< 0.1	0.5	3.5	-	-	5.8	-	-
	Boodie Island	2	-	-	9	-	-	25	73	< 0.1	0.4	3.4	-	-	3.8	-	-
	Middle Island	2	2	-	8.04	12.42	-	85	348	< 0.1	2.5	6.7	4.8	-	6.7	5.8	-
	Middle Ningaloo Coast - World Heritage Area	1	1	-	10.38	12.46	-	271	271	1.2	1.2	23.1	3.8	-	23.1	3.8	-
	North Ningaloo Coast - World Heritage Area	1	1	-	10.25	14.38	-	280	280	1.5	1.5	14.4	7.7	-	14.4	7.7	-
	Cape Range National Park	1	-	-	10.58	-	-	67	67	0.4	0.4	13.5	-	-	13.5	-	-
	Ningaloo Coast World Heritage Area	4	2	-	8.54	12.46	-	11	280	< 0.1	2	13	3.8	-	29.8	6.7	-
	Barrow & Montebello Islands IAA	2	2	-	8.04	12.42	-	11	348	< 0.1	4.3	24.5	6.3	-	25	7.7	-
	Pilbara Coast IAA	2	-	-	13.17	-	-	2	15	< 0.1	< 0.1	1.4	-	-	1.9	-	-
	Barrow Island Group	2	2	-	8.04	12.42	-	28	348	< 0.1	4.3	24.5	6.3	-	25	7.7	-
	Pilbara Coast Islands Group	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Muiron Islands	3	1	-	8.54	12.92	-	7	224	< 0.1	1.1	6.7	1	-	12.5	1	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	2	2	-	10.63	12.42	-	19	242	< 0.1	1.9	16.4	2.4	-	17.3	2.9	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	2	1	-	8.04	17.42	-	34	147	< 0.1	0.7	4.3	1	-	4.8	1	-
	Exmouth	1	1	-	10.25	12.46	-	280	280	35	35	51	24	-	51	24	-
	Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	2	2	-	8.04	12.42	-	77	348	< 0.1	2.7	8.7	4.8	-	8.7	5.8	-
	Murion Islands	3	1	-	8.54	12.92	-	7	224	< 0.1	1.1	6.7	1	-	12.5	1	-
	Peak Island	1	-	-	13.17	-	-	15	15	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Sunday Island	1	-	-	13.92	-	-	15	15	< 0.1	< 0.1	1.9	-	-	1.9	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 10.5 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	3	-	-	18.54	-	-	3	19	< 0.1	< 0.1	1.3	-	-	1.9	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	2	-	-	17.54	-	-	4	21	< 0.1	< 0.1	3.4	-	-	3.8	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.8	-	-	5.8	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	16.33	-	-	3	34	< 0.1	0.1	2.4	-	-	3.8	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.5	-	-	5.8	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flat Island	2	-	-	16.33	-	-	7	34	< 0.1	< 0.1	1.9	-	-	2.9	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.5	-	-	5.8	-	-
	Peak Island	1	-	-	16.71	-	-	14	14	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sunday Island	1	-	-	17.71	-	-	16	16	< 0.1	< 0.1	1	-	-	1	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 10.6 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	1	1	-	9.42	12.5	-	185	185	0.4	0.4	5.8	1	-	5.8	1	-
	Thevenard Island	1	-	-	11.08	-	-	20	20	< 0.1	< 0.1	1	-	-	1	-	-
	Serrurier Island	2	-	-	9.58	-	-	4	71	< 0.1	0.2	2.9	-	-	3.8	-	-
	Bessieres Island	1	-	-	8.92	-	-	44	44	< 0.1	0.1	2.9	-	-	2.9	-	-
	Airlie Island	1	-	-	10.54	-	-	35	35	< 0.1	0.1	2.9	-	-	2.9	-	-
	North Muiron Island	4	1	-	6.5	14.04	-	4	106	< 0.1	0.2	2.4	1	-	3.8	1	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	3	-	-	12.29	-	-	3	27	< 0.1	0.2	5.8	-	-	12.5	-	-
	Ningaloo Coast World Heritage Area	7	1	-	6.5	12.5	-	4	185	< 0.1	0.7	4.3	1.9	-	11.5	1.9	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	8.92	-	-	3	71	< 0.1	0.5	9.6	-	-	13.5	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	2	-	-	8.92	-	-	4	71	< 0.1	0.3	5.8	-	-	6.7	-	-
	Muiron Islands	4	1	-	6.5	12.5	-	4	185	< 0.1	0.7	3.8	1.9	-	9.6	1.9	-
Shoreline	Airlie Island	1	-	-	10.54	-	-	35	35	0.1	0.1	2.9	-	-	2.9	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	8.92	-	-	44	44	0.1	0.1	2.9	-	-	2.9	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	3	-	-	12.29	-	-	3	27	< 0.1	0.2	5.8	-	-	12.5	-	-
	Flat Island	1	-	-	9.5	-	-	32	32	0.1	0.1	3.8	-	-	3.8	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	4	1	-	6.5	12.5	-	4	185	< 0.1	0.7	3.8	1.9	-	9.6	1.9	-
	Peak Island	1	-	-	12.08	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	1	-	-	12.04	-	-	13	13	< 0.1	< 0.1	1	-	-	1	-	-
	Serrurier Island	2	-	-	9.58	-	-	4	71	< 0.1	0.2	2.9	-	-	3.8	-	-
	Sunday Island	1	-	-	11.88	-	-	20	20	< 0.1	1.9	1.9	-	-	1.9	-	-
	Table Island	1	-	-	11.46	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Thevenard Island	1	-	-	11.08	-	-	20	20	< 0.1	< 0.1	1	-	-	1	-	-

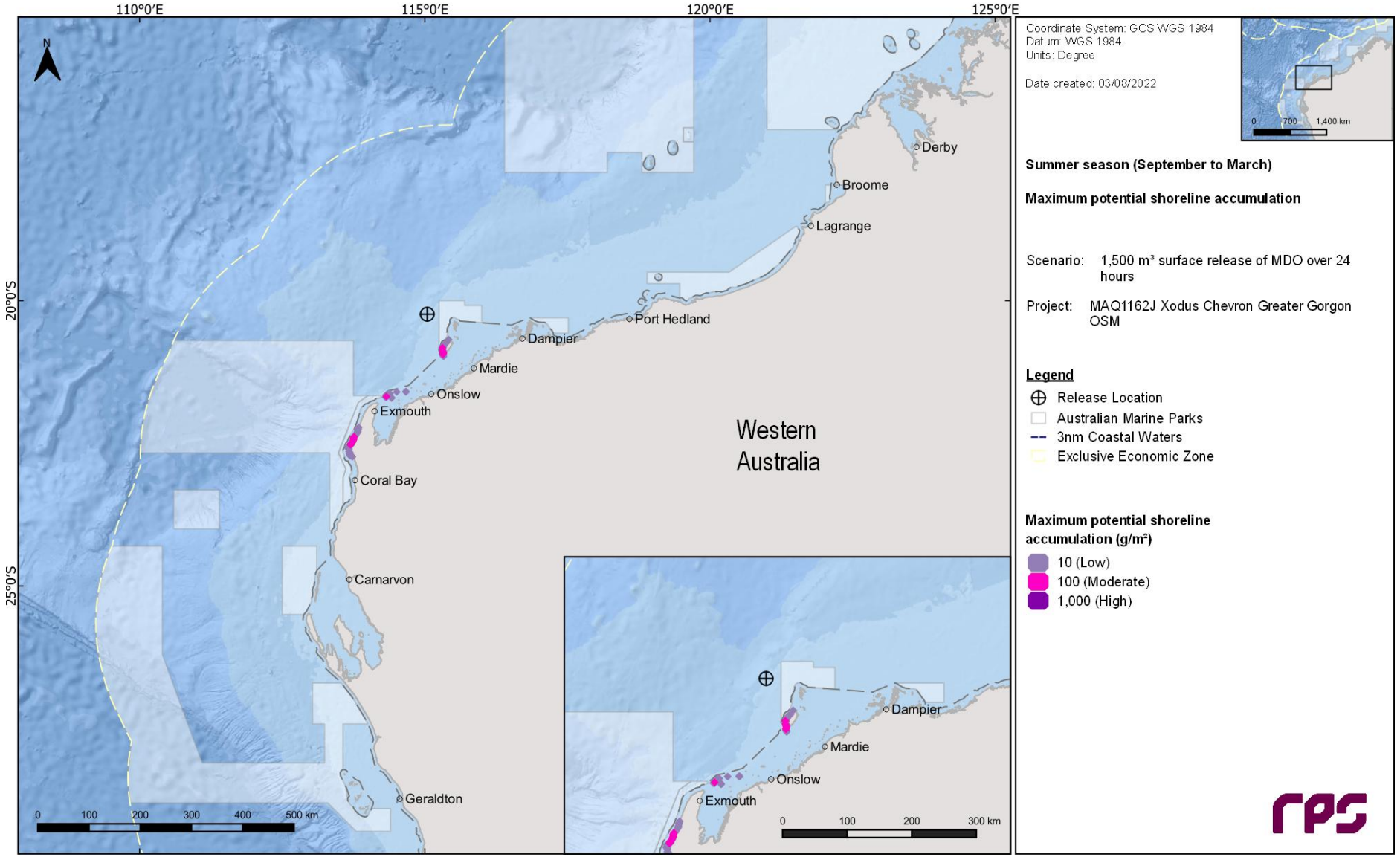


Figure 10.4 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

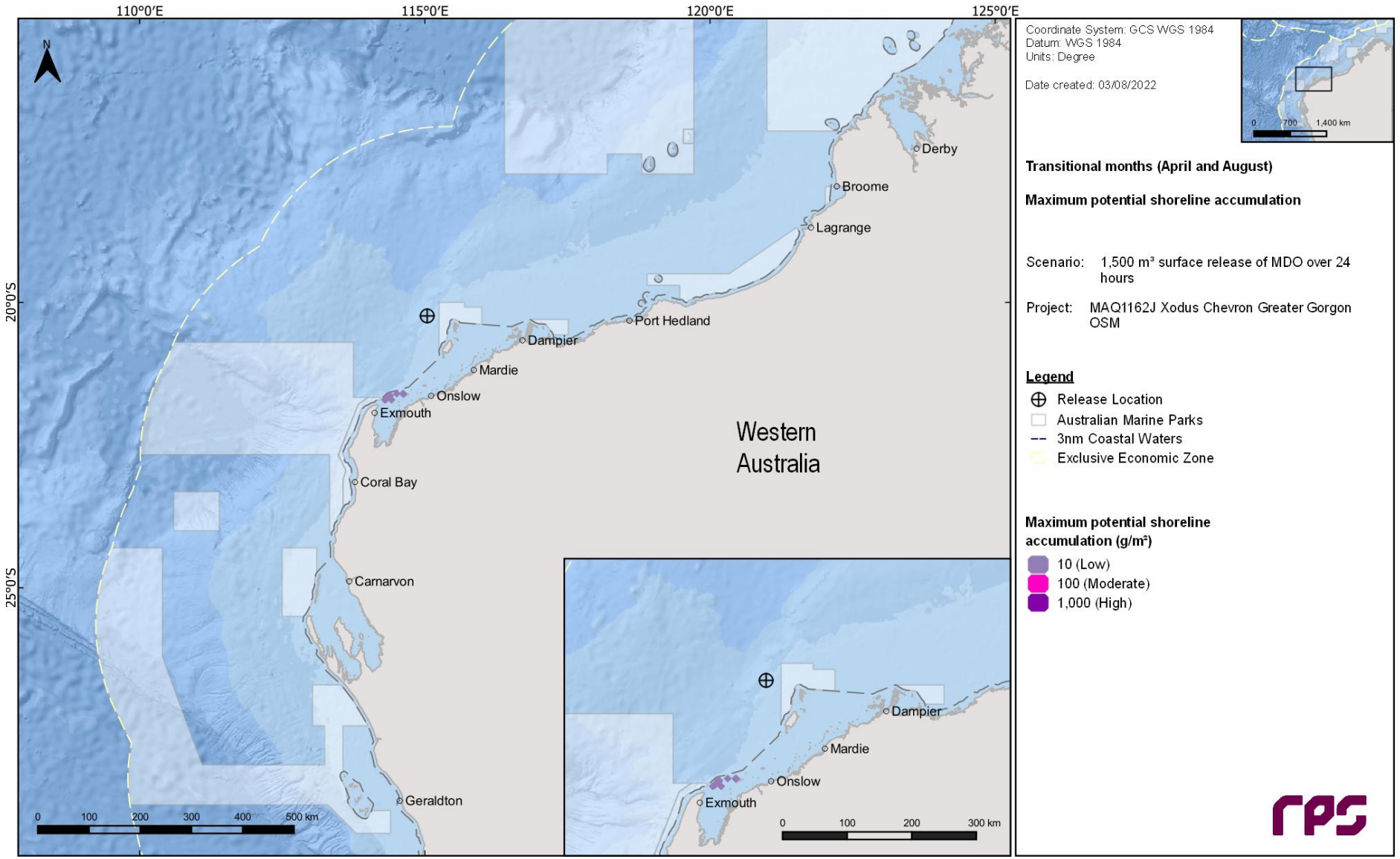


Figure 10.5 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

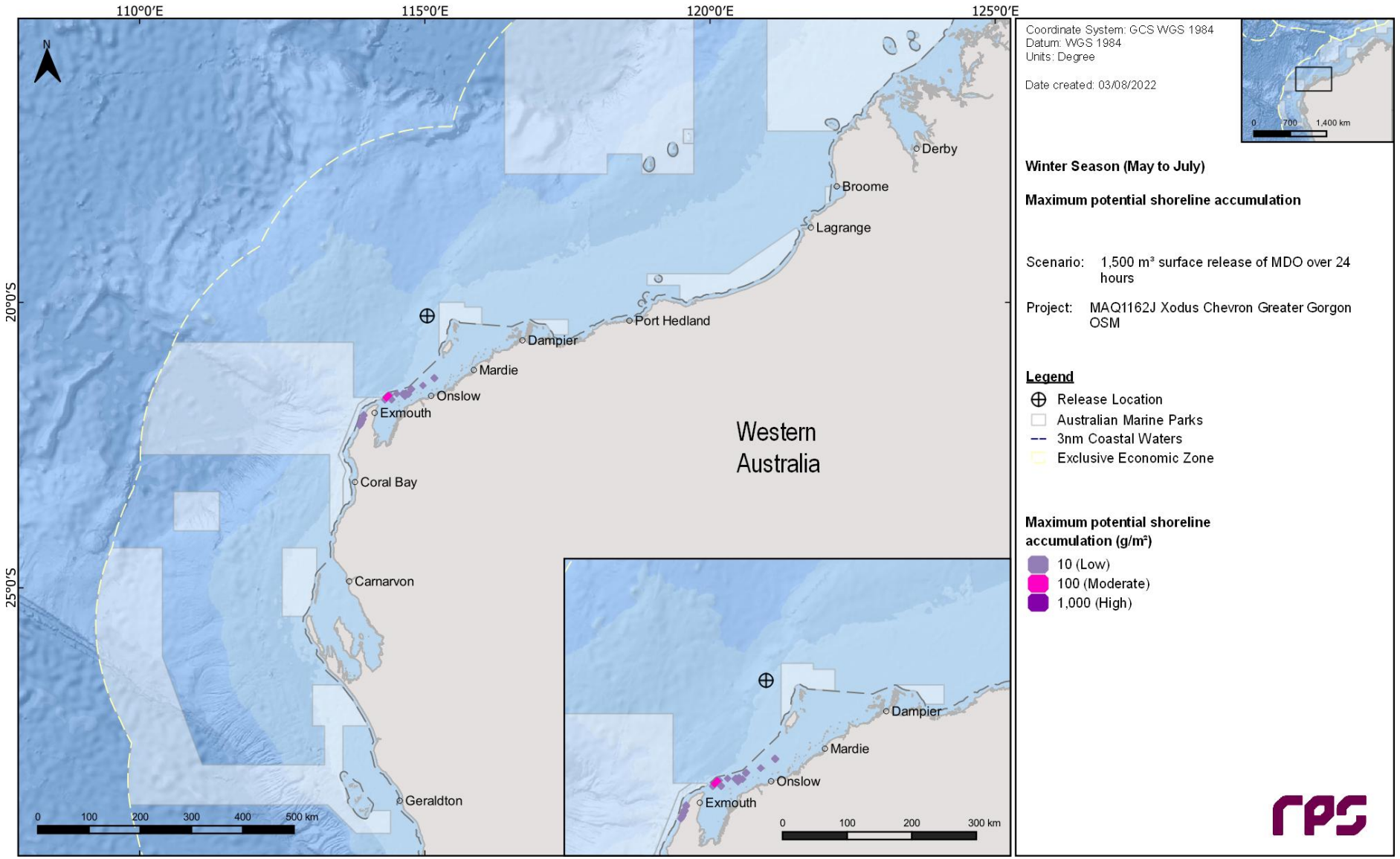


Figure 10.6 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

10.1.3 Water Column Exposure

10.1.3.1 Dissolved Hydrocarbons

Table 10.7 summarises the seasonal probability of exposure to individual receptors from dissolved hydrocarbons in the 0-10 m depth layer, at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥ 400 ppb) exposure thresholds.

In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) , the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the Humpback Whale - Migration BIA.

A total of 3, 2 and 2 AMPs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively with the highest probability predicted at the Montebello AMP of 3% during summer and transitional.

Additionally, 4, 3 and 4 IAAs and 2, 3 and 3 IMCRAs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively.

Furthermore, 4 (summer) and 3 (transitional) and 5 (winter) KEFs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold.

Figure 10.7 to Figure 10.9 presents the zones of potential instantaneous dissolved hydrocarbon exposure for the 0-10 m depth layer for the summer, transitional and winter periods, respectively.

Table 10.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a vessel collision at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer				Transitional				Winter			
		Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)		
			Low	Moderate	High		Low	Moderate	High		Low	Moderate	High
AMP	Gascoyne	16	1	-	-	14	1	-	-	17	1	-	-
	Montebello	31	3	-	-	53	3	1	-	8	-	-	-
	Ningaloo	4	-	-	-	5	-	-	-	12	1	-	-
BIA	Fairy Tern - Breeding	11	1	-	-	5	-	-	-	9	-	-	-
	Flatback Turtle - Internesting Buffer*	144	71	35	-	132	75	25	-	138	84	29	-
	Flatback Turtle - Nesting	50	2	1	-	32	2	-	-	43	3	-	-
	Green Turtle - Internesting Buffer	44	1	-	-	32	1	-	-	26	1	-	-
	Green Turtle - Nesting	44	1	-	-	32	1	-	-	26	1	-	-
	Hawksbill Turtle - Internesting Buffer	44	1	-	-	32	1	-	-	26	1	-	-
	Hawksbill Turtle - Nesting	44	1	-	-	32	1	-	-	26	1	-	-
	Humpback Whale - Migration	55	6	1	-	52	6	1	-	82	14	1	-
	Lesser Crested Tern - Breeding	20	1	-	-	6	-	-	-	9	-	-	-
	Loggerhead Turtle - Internesting Buffer	6	-	-	-	14	1	-	-	13	1	-	-
	Loggerhead Turtle - Nesting	5	-	-	-	14	1	-	-	12	1	-	-
	Pygmy Blue Whale - Distribution*	144	71	35	-	132	75	25	-	138	84	29	-
	Pygmy Blue Whale - Foraging	12	1	-	-	10	-	-	-	11	1	-	-
	Roseate Tern - Breeding	34	1	-	-	5	-	-	-	17	1	-	-
	Wedge-tailed Shearwater - Breeding*	144	71	35	-	132	75	25	-	138	84	29	-
	Whale Shark - Foraging*	144	71	35	-	132	75	25	-	138	84	29	-
IAA	Gascoyne	16	1	-	-	14	1	-	-	17	1	-	-
	Ningaloo Coast World Heritage Area	4	-	-	-	5	-	-	-	12	1	-	-
	Barrow & Montebello Islands	31	3	-	-	53	3	1	-	8	-	-	-
	Pilbara Coast	16	1	-	-	5	-	-	-	14	1	-	-
	Offshore Area*	144	71	35	-	132	75	25	-	138	84	29	-
IMCRA	Ningaloo	8	-	-	-	10	1	-	-	12	1	-	-
	Northwest Shelf	45	4	-	-	44	2	-	-	19	2	-	-
	Pilbara (offshore)*	144	71	35	-	132	75	25	-	138	84	29	-
KEF	Ancient coastline at 125 m depth contour*	144	71	35	-	132	75	25	-	138	84	29	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	16	1	-	-	13	1	-	-	14	1	-	-
	Commonwealth waters adjacent to Ningaloo Reef	4	-	-	-	5	-	-	-	12	1	-	-
	Continental Slope Demersal Fish Communities	64	9	1	-	60	9	1	-	97	9	1	-
State waters	Western Australia	20	1	-	-	5	-	-	-	12	1	-	-

*The release location resides within the receptor boundaries.

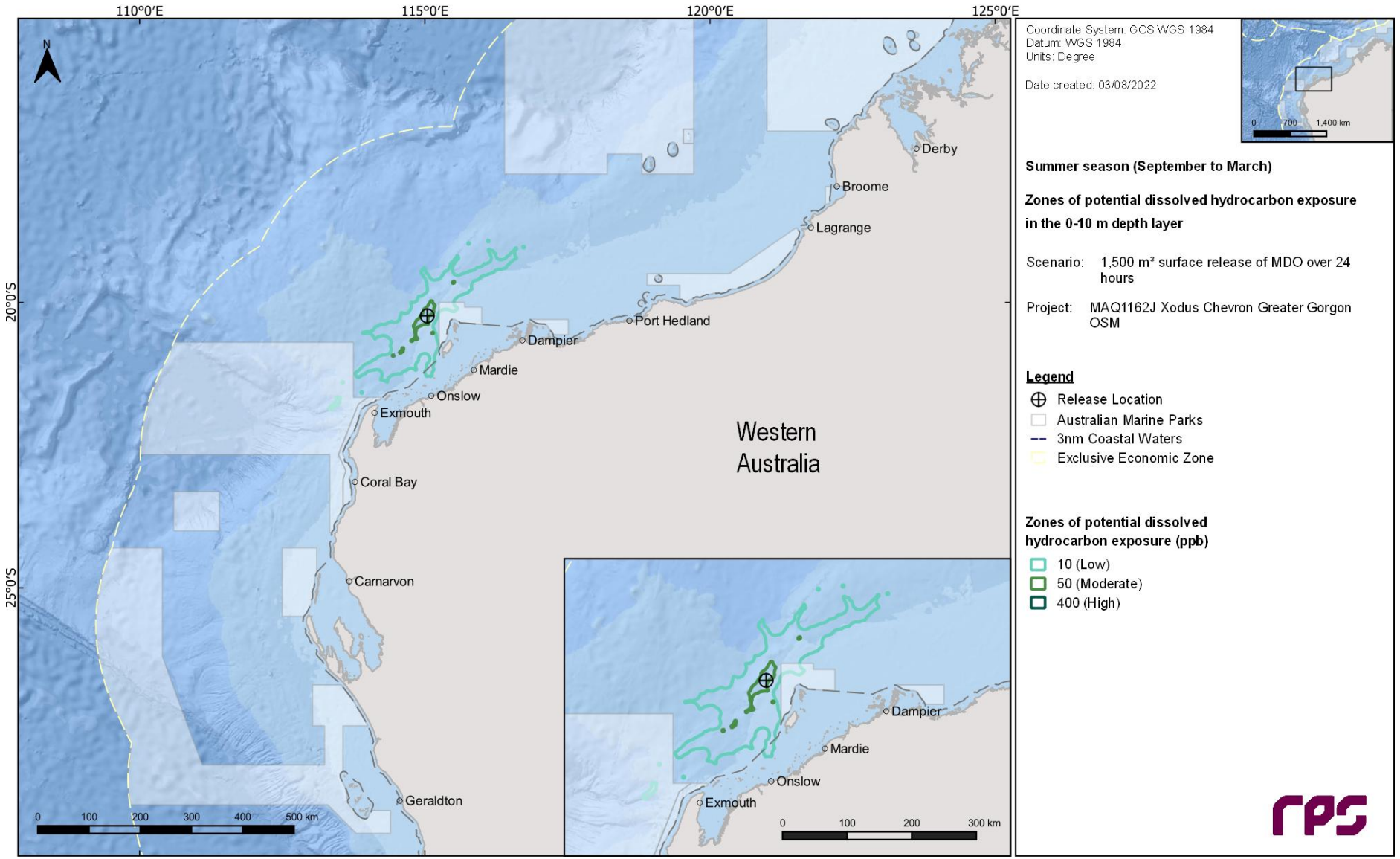


Figure 10.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

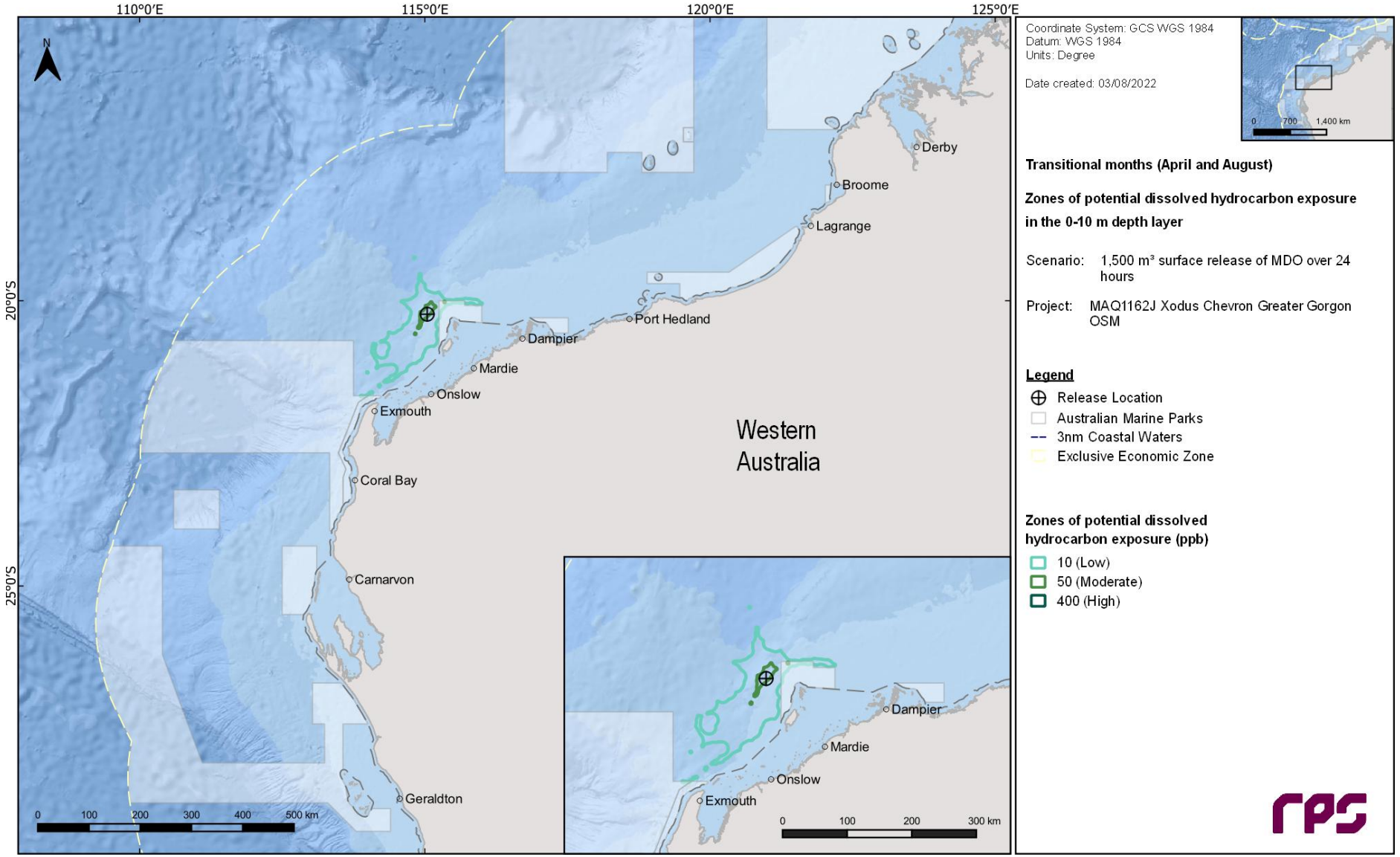


Figure 10.8 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

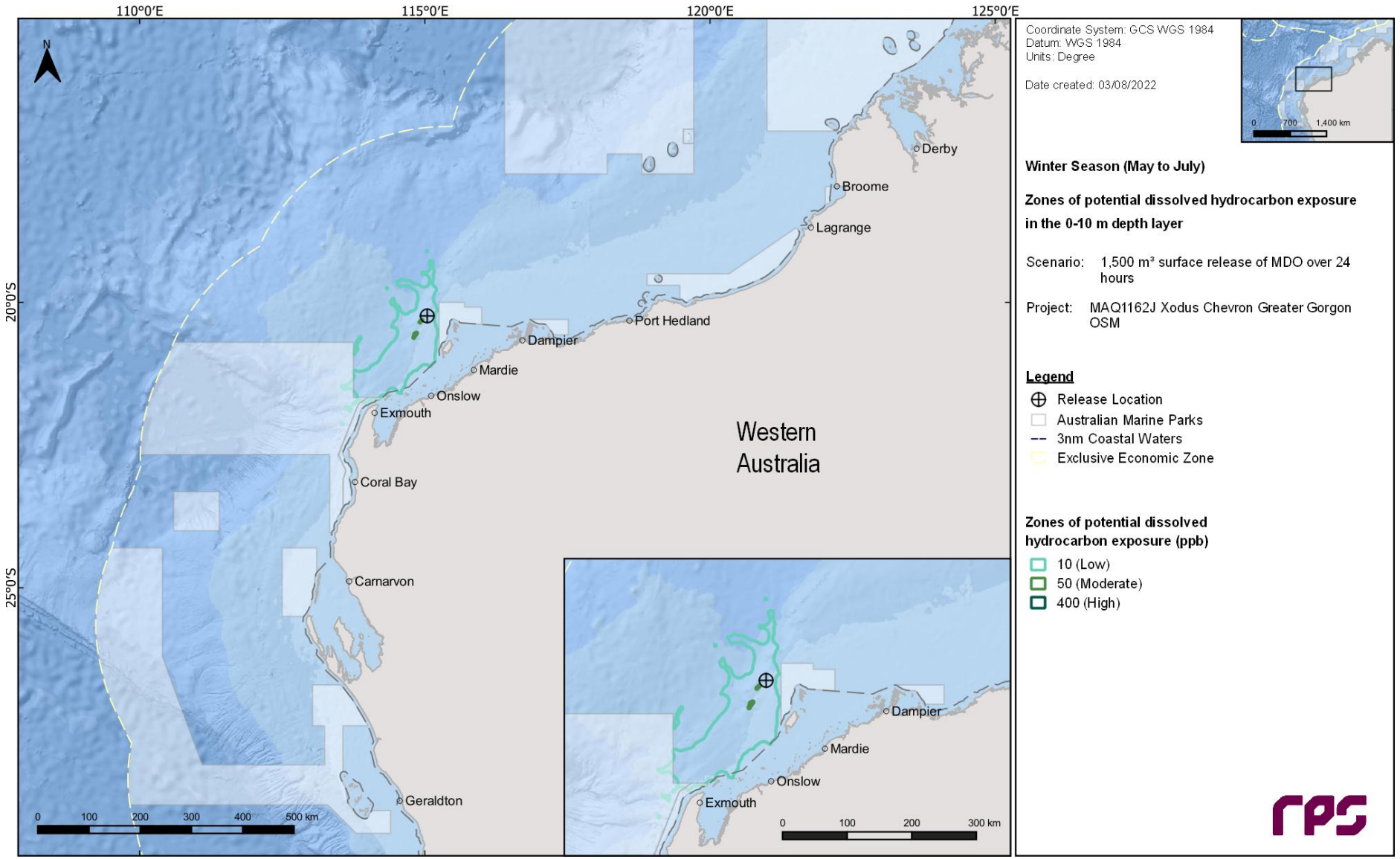


Figure 10.9 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

10.1.3.2 Entrained Hydrocarbons

Table 10.8 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) , the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Humpback Whale - Migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).

During all 3 seasons, 3 AMPs were predicted to be exposed at the low threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 8, 5 and 6 KEFs were predicted to be exposed by entrained hydrocarbons at the low threshold, respectively. Probabilities of exposure ranged between 1–100%, 13–95% and 12–100%, for summer, transitional and winter, respectively. Excluding the KEF that the release location resides within (Ancient coastline at 125 m depth contour), the KEF with the greatest probability of low exposure for each season was the Continental Slope Demersal Fish Communities KEF (58%, 54% and 68% for summer, transitional and winter, respectively).

Additionally, 24, 22 and 24 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore IAA, the probabilities for each season ranged between 1–21%, 1–22% and 1–37% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, 17, 22 and 23 RBS receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter, respectively. The maximum probabilities for low threshold exposure during summer, transitional and winter were predicted for Rankin Bank (17%), Rankin Bank (8%) and Outtrim Patches (13%), respectively.

Figure 10.10 to Figure 10.12 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

Table 10.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a vessel collision at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
AMP	Abrolhos	17	1	-	-	-	-	13	2	-
	Argo-Rowley Terrace	13	1	-	17	1	-	-	-	-
	Carnarvon Canyon	-	-	-	10	1	-	31	3	-
	Gascoyne	324	21	3	384	22	5	283	37	8
	Montebello	1,171	19	11	611	11	7	645	8	2
	Ningaloo	329	6	2	87	13	-	311	29	6
	Shark Bay	-	-	-	-	-	-	34	4	-
BIA	Bridled Tern - Foraging	-	-	-	-	-	-	20	2	-
	Dugong - Breeding	209	3	1	72	10	-	225	22	2
	Dugong - Calving	209	3	1	72	10	-	225	22	2
	Dugong - Foraging	209	3	1	72	10	-	225	22	2
	Dugong - Nursing	209	3	1	72	10	-	225	22	2
	Fairy Tern - Breeding	219	5	1	251	11	2	187	26	3
	Flatback Turtle - Aggregation	21	1	-	-	-	-	-	-	-
	Flatback Turtle - Foraging	102	2	1	26	1	-	13	1	-
	Flatback Turtle - Internesting	21	1	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	19,061	100	97	13,629	95	90	13,131	100	97
	Flatback Turtle - Mating	102	2	1	26	1	-	13	1	-
	Flatback Turtle - Nesting	1,242	22	13	1,334	33	17	1,613	58	17
	Green Turtle - Aggregation	21	1	-	-	-	-	-	-	-
	Green Turtle - Basking	102	2	1	30	1	-	17	2	-
	Green Turtle - Foraging	102	2	1	26	1	-	14	1	-
	Green Turtle - Internesting	102	2	1	26	1	-	14	1	-
	Green Turtle - Internesting Buffer	511	12	5	445	20	3	818	29	10
	Green Turtle - Mating	102	2	1	30	1	-	14	2	-
	Green Turtle - Nesting	332	11	4	310	15	2	690	31	9
	Hawksbill Turtle - Foraging	102	2	1	26	1	-	17	1	-
	Hawksbill Turtle - Mating	102	2	1	26	1	-	13	1	-
	Hawksbill Turtle - Nesting	274	11	4	306	15	2	690	27	9
	Humpback Whale - Migration	1,819	42	24	1,607	59	39	2,117	71	42
	Humpback Whale - Resting	35	2	-	32	6	-	17	4	-
	Lesser Crested Tern - Breeding	223	8	3	275	11	2	216	17	4
	Little Tern - Resting	11	1	-	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	366	9	5	229	19	2	360	32	9
	Loggerhead Turtle - Nesting	333	7	2	95	14	-	311	31	6
	Pygmy Blue Whale - Distribution*	19,061	100	97	13,629	95	90	13,131	100	97
	Pygmy Blue Whale - Foraging	219	9	3	195	18	3	226	33	8
	Roseate Tern - Breeding	277	11	1	191	11	2	331	17	8

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
	Sooty Tern - Foraging	-	-	-	-	-	-	22	3	-
	Wedge-tailed Shearwater - Breeding*	19,061	100	97	13,629	95	90	13,131	100	97
	Wedge-tailed Shearwater - Foraging	-	-	-	-	-	-	21	2	-
	Whale Shark - Foraging*	19,061	100	97	13,629	95	90	13,131	100	97
	White-tailed Tropicbird - Breeding	30	1	-	12	1	-	-	-	-
IAA	Barrow Island (West Coast)	93	2	-	19	1	-	11	1	-
	South Muiron Island	139	4	1	47	6	-	80	12	-
	Thevenard Island	-	-	-	22	2	-	46	2	-
	Serrurier Island	23	2	-	64	6	-	69	4	-
	Bessieres Island	15	2	-	55	6	-	128	4	1
	Airlie Island	-	-	-	31	1	-	23	1	-
	Ashburton Island	-	-	-	-	-	-	10	1	-
	North Muiron Island	175	3	1	57	6	-	130	16	1
	Boodie Island	83	2	-	25	1	-	11	1	-
	Middle Island	99	2	-	18	1	-	-	-	-
	Rankin Bank	425	17	5	79	8	-	208	2	1
	Glomar Shoal	11	1	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	156	2	1	-	-	-	43	2	-
	North Ningaloo Coast - World Heritage Area	160	1	1	22	5	-	53	8	-
	Cape Range National Park	128	1	1	23	4	-	113	7	1
	Abrolhos Islands	17	1	-	4	-	-	13	2	-
	Gascoyne	324	21	3	384	22	5	283	37	8
	Ningaloo Coast World Heritage Area	329	6	2	87	13	-	311	29	6
	Argo-Rowley Terrace	16	1	-	17	1	-	-	-	-
	Barrow Island (East Coast)	46	2	-	-	-	-	-	-	-
	Barrow & Montebello Islands	1,171	19	11	611	11	7	645	8	2
	Pilbara Coast	158	6	2	254	10	2	181	19	2
	Exmouth	69	3	-	45	6	-	46	5	-
	Shark Bay mainland coastline	-	-	-	-	-	-	43	4	-
	Offshore Area*	19,061	100	97	13,629	95	90	13,131	100	97
	Barrow Island Group	99	2	-	25	1	-	11	1	-
	Pilbara Coast Islands Group	23	2	-	64	6	-	128	4	1
	Muiron Islands	175	4	1	57	6	-	130	16	1
IBRA	Cape Range	175	4	1	74	6	-	130	16	1
	Roebourne	99	2	-	29	1	-	22	1	-
IMCRA	Ningaloo	365	7	3	182	19	4	311	37	8
	Northwest Shelf	1,255	34	23	1,187	16	10	707	12	5
	Pilbara (nearshore)	50	2	-	36	6	-	37	4	-
	Pilbara (offshore)*	19,061	100	97	13,629	95	90	13,131	100	97
	Zuytdorp	-	-	-	-	-	-	43	4	-

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
KEF	Ancient coastline at 125 m depth contour*	19,061	100	97	13,629	95	90	13,131	100	97
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	365	14	5	303	26	7	356	45	13
	Commonwealth waters adjacent to Ningaloo Reef	329	6	2	87	13	-	311	29	6
	Continental Slope Demersal Fish Communities	2,828	58	39	3,732	54	36	2,964	68	44
	Exmouth Plateau	239	13	3	214	14	3	203	12	3
	Glomar Shoals	51	4	-	-	-	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	12	1	-	-	-	-	-	-	-
	Wallaby Saddle	16	1	-	-	-	-	-	-	-
	Western demersal slope and associated fish communities	-	-	-	-	-	-	22	3	-
MMA	Barrow Island	119	3	1	36	2	-	67	3	-
	Muiron Islands	175	6	2	60	9	-	185	21	2
MP	Barrow Island	34	2	-	22	2	-	48	3	-
	Montebello Islands	118	3	1	28	1	-	15	1	-
	Ningaloo	196	3	1	67	9	-	141	16	2
NR	Great Sandy Island	18	1	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	31	2	-
RSB	Australind Shoal	-	-	-	-	-	-	19	2	-
	Barrow Island Reefs and Shoals	22	1	-	-	-	-	-	-	-
	Brewis Reef	-	-	-	-	-	-	47	2	-
	Combe Reef	31	2	-	25	4	-	14	1	-
	Dailey Shoal	53	3	-	52	6	-	22	4	-
	Exmouth Reef	-	-	-	13	1	-	-	-	-
	Fairway Reef	11	1	-	37	3	-	11	1	-
	Glennie Patches	-	-	-	-	-	-	10	1	-
	Glomar Shoal	11	1	-	-	-	-	-	-	-
	Hayman Rock	-	-	-	14	1	-	-	-	-
	Hood Reef	17	2	-	46	6	-	15	2	-
	Locker Reef	-	-	-	13	1	-	-	-	-
	Miles Shoal	-	-	-	-	-	-	13	1	-
	Montebello Shoals	27	1	-	-	-	-	11	1	-
	Ningaloo Reef	160	2	1	37	6	-	122	10	1
	North West Reef	27	1	-	16	2	-	60	7	-
	Otway Reef	32	2	-	34	5	-	21	3	-
	Outtrim Patches	140	3	1	59	6	-	79	13	-
	Penguin Bank	48	3	-	82	3	-	86	9	-
	Poivre Reef	94	2	-	37	1	-	15	3	-
	Rankin Bank	451	17	5	79	8	-	212	2	1
	Ripple Shoals	19	1	-	18	1	-	-	-	-
	Rosily Shoals	25	2	-	92	4	-	68	8	-

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
	Santo Rock	-	-	-	13	1	-	41	1	-
	Spider Reef	-	-	-	22	2	-	-	-	-
	Sultan Reef	-	-	-	-	-	-	21	1	-
	Taunton Reef	-	-	-	15	1	-	17	1	-
	Tongue Shoals	-	-	-	-	-	-	12	1	-
	Trap Reef	-	-	-	11	1	-	46	2	-
	Tryal Rocks	130	6	2	73	2	-	242	1	1
	Web Reef	-	-	-	19	2	-	-	-	-
Nearshore Waters	Airlie Island	-	-	-	31	1	-	23	1	-
	Barrow Island	93	2	-	19	1	-	11	1	-
	Bessieres Island	15	2	-	55	6	-	128	4	1
	Boodie Island	80	2	-	24	1	-	11	1	-
	Exmouth	160	2	1	25	5	-	111	8	1
	Flat Island	34	2	-	74	6	-	35	6	-
	Fly Island	-	-	-	18	1	-	-	-	-
	Middle Island	99	2	-	19	1	-	-	-	-
	Montebello Islands	14	1	-	-	-	-	-	-	-
	Murion Islands	175	4	1	57	6	-	130	16	1
	Observation Island	13	1	-	30	3	-	-	-	-
	Peak Island	89	3	-	62	6	-	72	11	-
	Round Island	11	1	-	50	5	-	32	3	-
	Serrurier Island	23	2	-	64	6	-	69	4	-
	Sunday Island	75	3	-	54	6	-	43	9	-
	Table Island	-	-	-	46	4	-	73	3	-
	Thevenard Island	-	-	-	-	-	-	29	2	-
	Tortoise Island	-	-	-	-	-	-	59	2	-
State Waters	Western Australia State Waters	196	6	2	251	10	2	192	21	3

*The release location resides within the receptor boundaries.

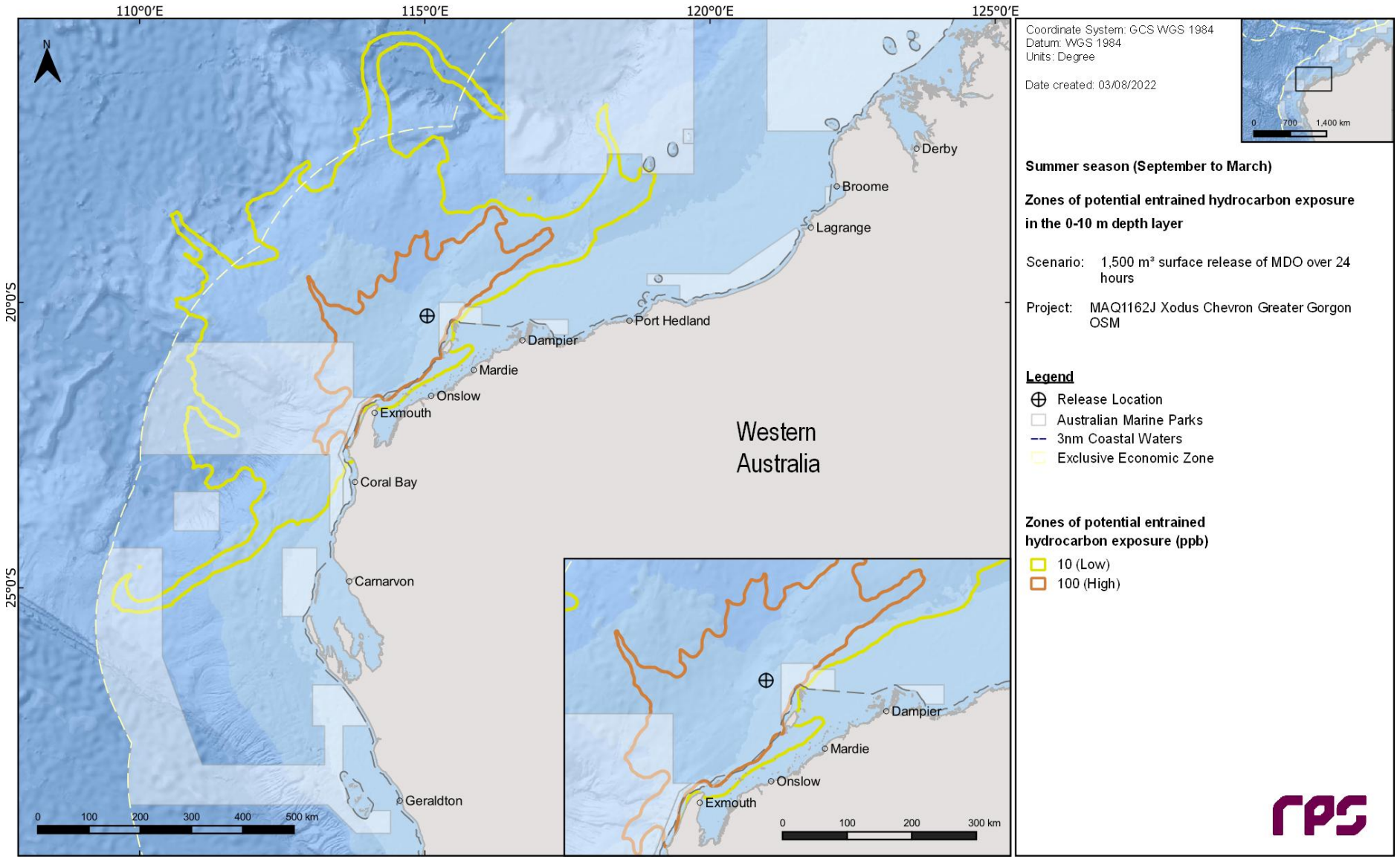


Figure 10.10 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

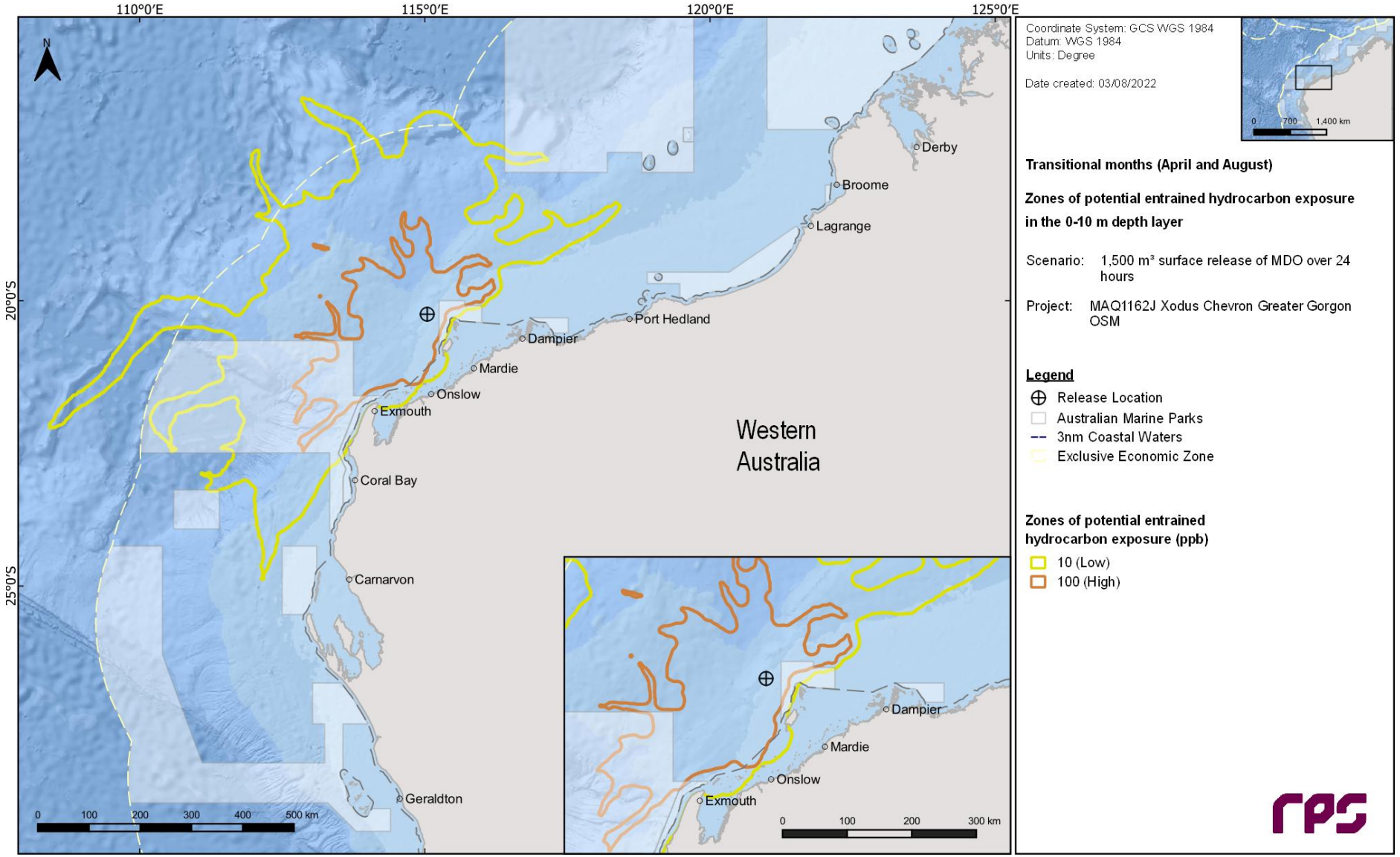


Figure 10.11 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

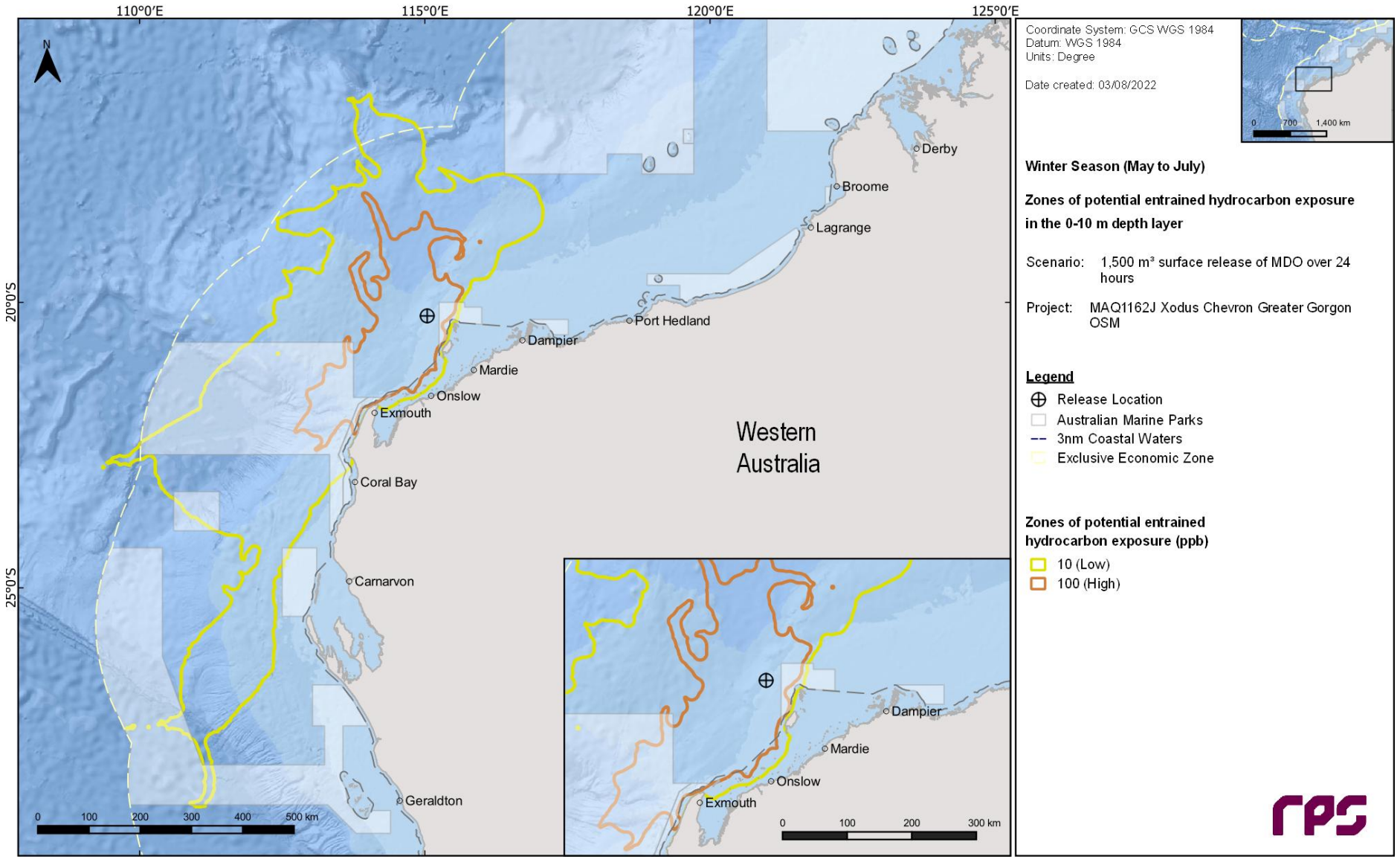


Figure 10.12 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

10.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating MDO above 10 g/m^2 (see Section 10.2.1), largest swept area of floating MDO above 50 g/m^2 (see Section 10.2.2), largest volume of oil ashore and longest length of shoreline accumulation above 100 g/m^2 (see Section 10.2.3), the largest area of entrained hydrocarbons above 100 ppb (see Section 10.2.4), and the largest area of dissolved hydrocarbons above 50 ppb (see Section 10.2.5).

Table 10.9 presents a summary of all deterministic analysis criteria and the corresponding floating oil, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Table 10.9 Summary of the deterministic analysis following a vessel collision at WTR Well 5.

Variable	Threshold	Deterministic Analysis Criteria					
		Largest swept area of floating MDO above 10 g/m^2	Largest swept area of floating MDO above 50 g/m^2	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb	Largest area of dissolved hydrocarbons above 50 ppb
Season		Winter	Transitional	Summer	Summer	Transitional	Winter
Run Number		60	64	41	41	31	96
Floating Oil (km^2)	1 g/m^2	912	181	122	122	36	54
	10 g/m^2	**256**	96	61	61	15	3
	50 g/m^2	8	**38**	14	14	4	0
Shoreline Length (km)	10 g/m^2	0	0	51	51	0	0
	100 g/m^2	0	0	24	**24**	0	0
	1,000 g/m^2	0	0	0	0	0	0
Minimum Time (days)		0	0	10.25	10.25	0	0
Maximum Volume (m^3)		0	0	**35**	35	0	0
Entrained Area (km^2)	10 ppb	15,905	22,528	7,741	7,741	23,157	10,363
	100 ppb	1,181	2,749	4,150	4,150	**6,049**	1,792
Dissolved Area (km^2)	10 ppb	0	0	0	0	204	413
	50 ppb	0	0	0	0	2	**60**
	400 ppb	0	0	0	0	0	0
Start Date		31 May 20111	28 August 2019	21 January 2012	21 January 2012	16 April 2015	20 May 2011

10.2.1 Deterministic Case: Largest swept area of floating oil above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating oil above 10 g/m^2 (moderate threshold) was identified as run number 60 during the winter period.

Figure 10.13 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 10.14 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating oil over the 60-day simulation.

Figure 10.15 presents the fates and weathering for the corresponding simulation and Table 10.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 60-day simulation.

Table 10.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest swept area of floating oil above 10 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	900	1	0
Entrained (m^3)	488	4	62
Dissolved (m^3)	1	4	0
Evaporation (m^3)	1,057	58	1,057
Decay (m^3)	371	60	371
Ashore (m^3)	0	0	0

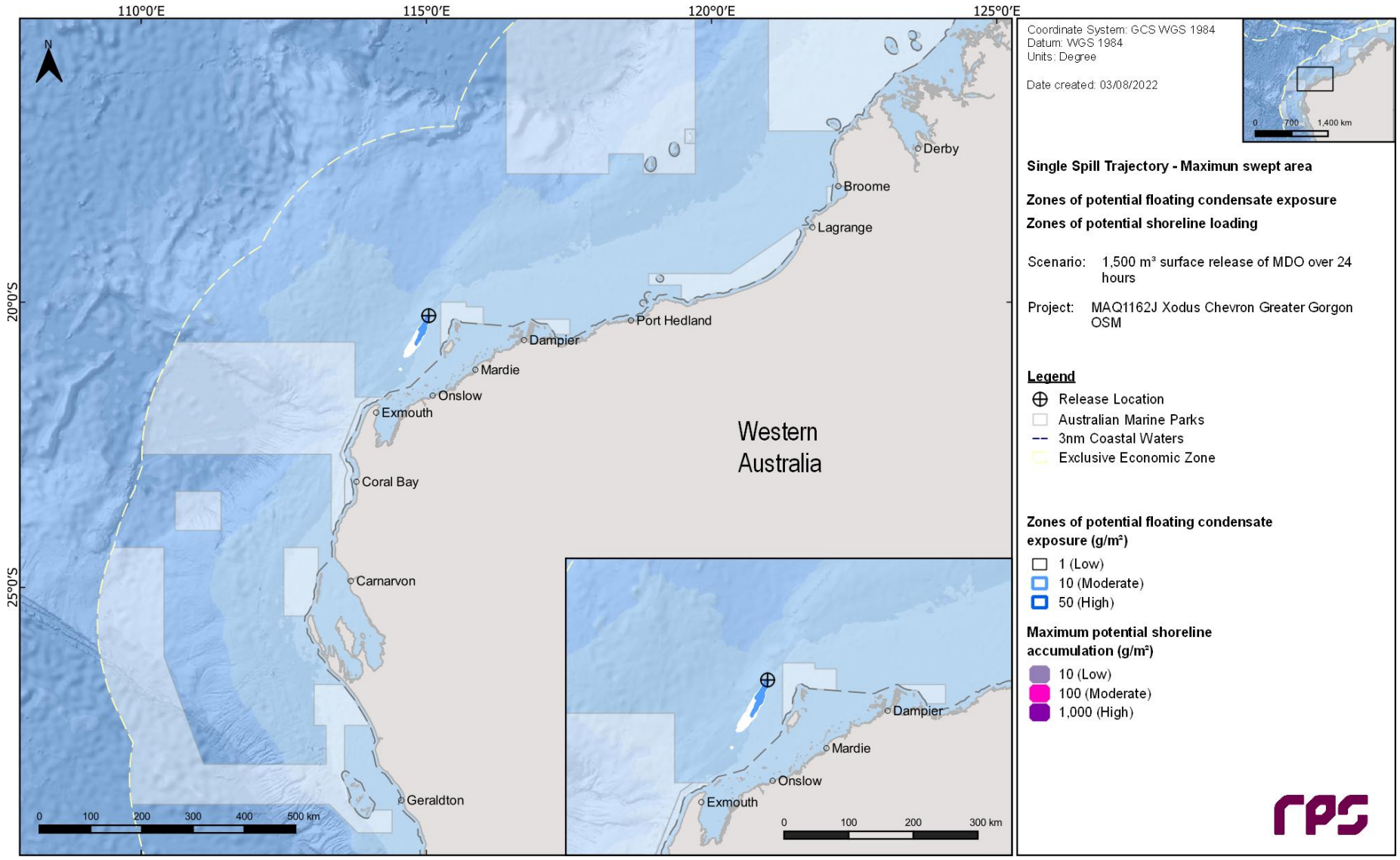


Figure 10.13 Zones of potential floating oil exposure and shoreline accumulation over the entire 60 days, for the simulation with the largest swept area of floating oil above 10 g/m² following a vessel collision at WTR Well 5.

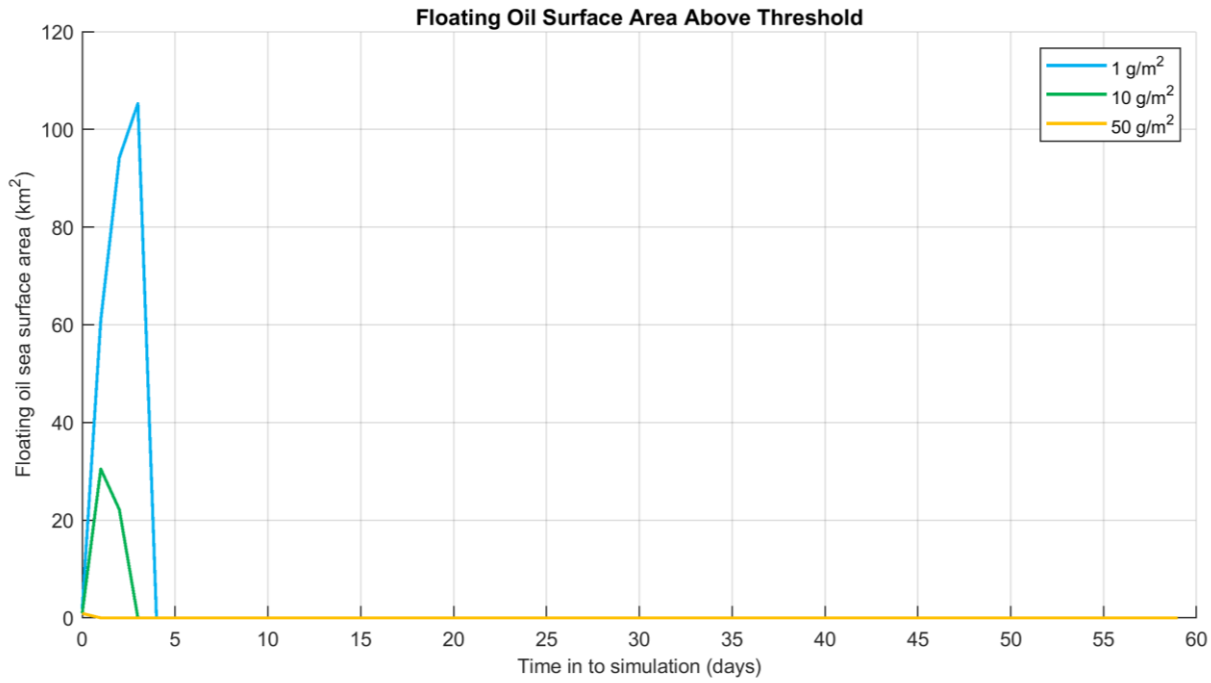


Figure 10.14 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating oil above 10 g/m^2 following a LOWC at WTR Well 5.

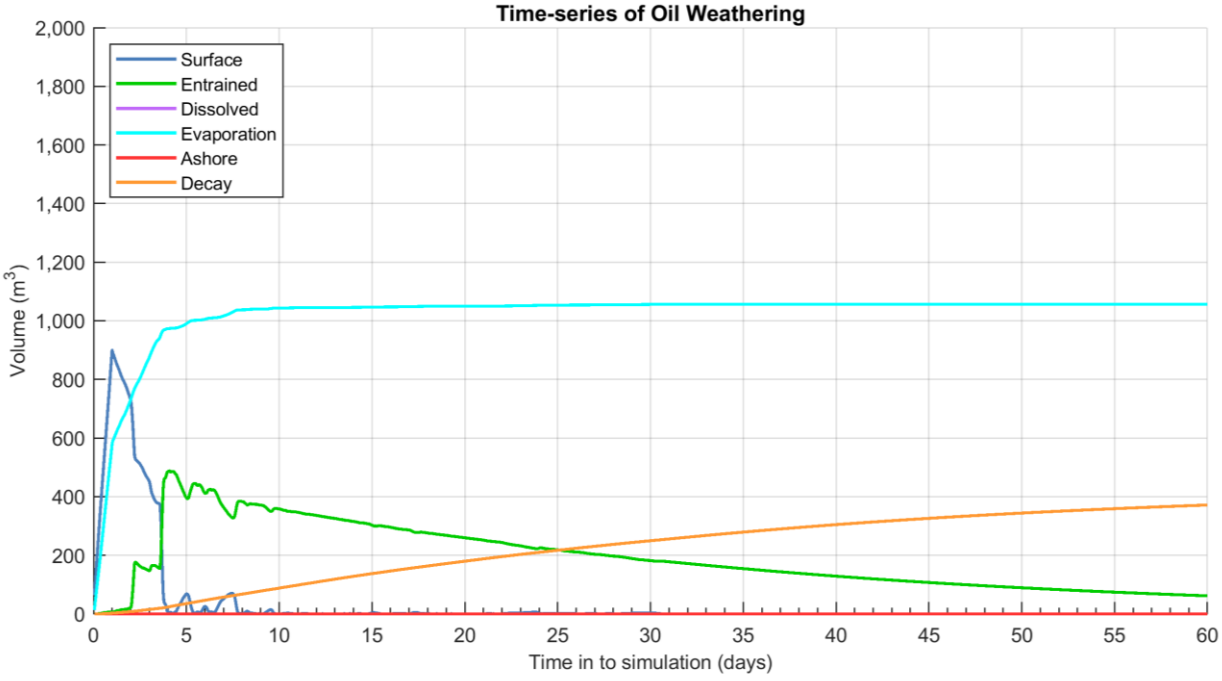


Figure 10.15 Predicted weathering and fates for the simulation with the largest swept area of floating oil above 10 g/m^2 following a vessel collision at WTR Well 5.

10.2.2 Deterministic Case: Largest swept area of floating oil above 50 g/m^2

The deterministic simulation that resulted in the largest swept area of floating oil above 50 g/m^2 (high threshold) was identified as run number 64 during the transitional period.

Figure 10.16 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 10.17 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating oil over the 60-day simulation.

Figure 10.18 presents the fates and weathering for the corresponding simulation and Table 10.11 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 60-day simulation.

Table 10.11 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest swept area of floating oil above 50 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	932	1	0
Entrained (m^3)	745	3	83
Dissolved (m^3)	1	5	0
Evaporation (m^3)	866	59	866
Decay (m^3)	553	60	553
Ashore (m^3)	0	0	0

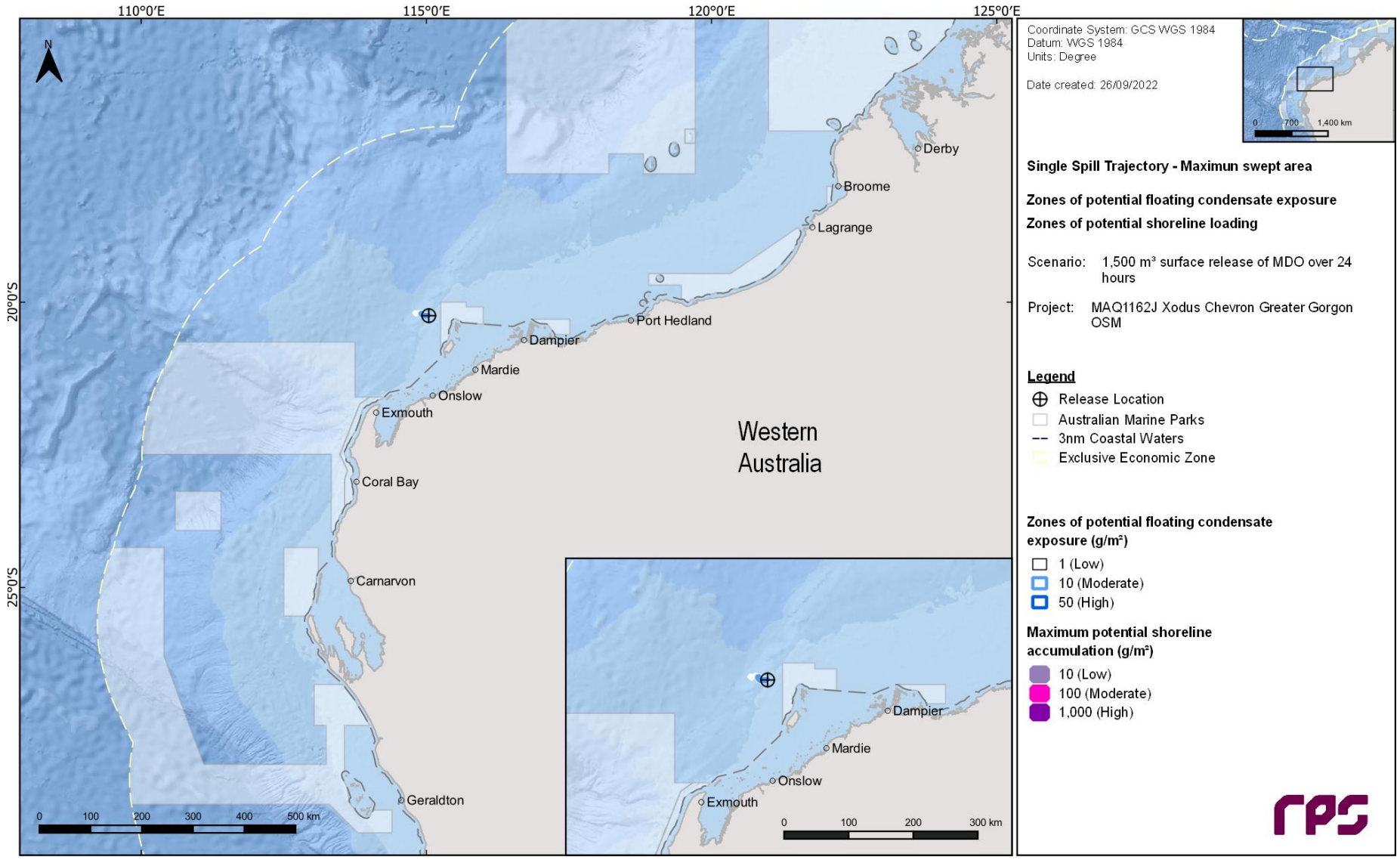


Figure 10.16 Zones of potential floating oil exposure and shoreline accumulation over the entire 60 days, for the simulation with the largest swept area of floating oil above 50 g/m² following a vessel collision at WTR Well 5.

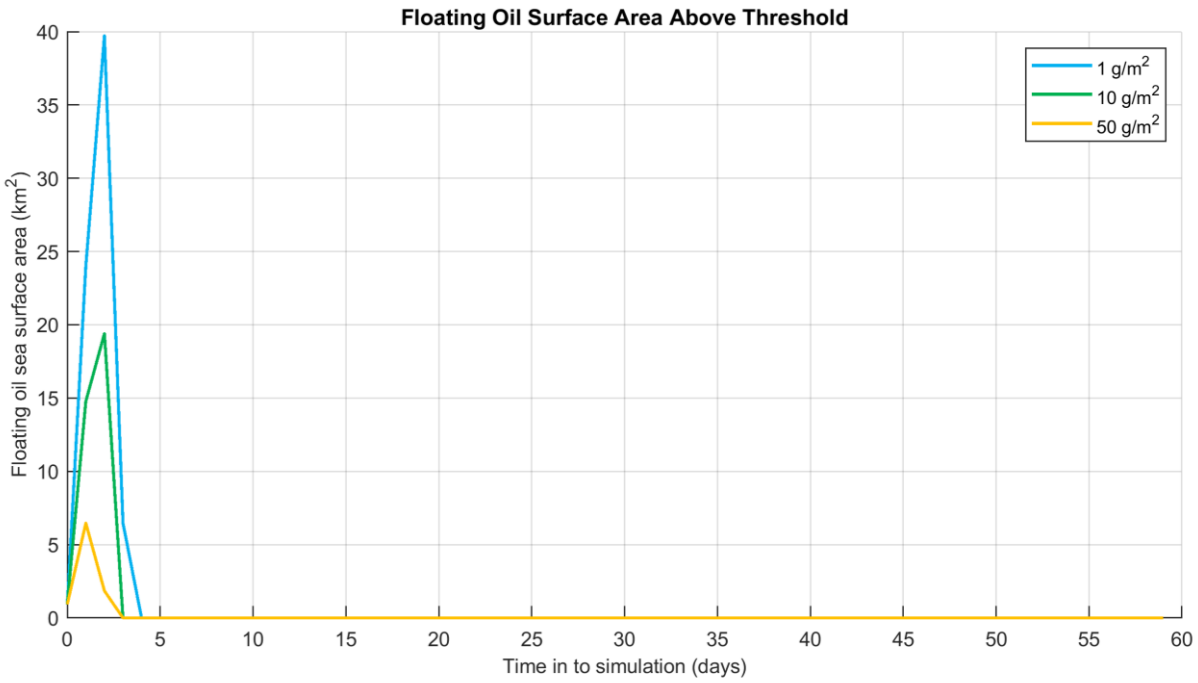


Figure 10.17 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating oil above 50 g/m^2 following a LOWC at WTR Well 5.

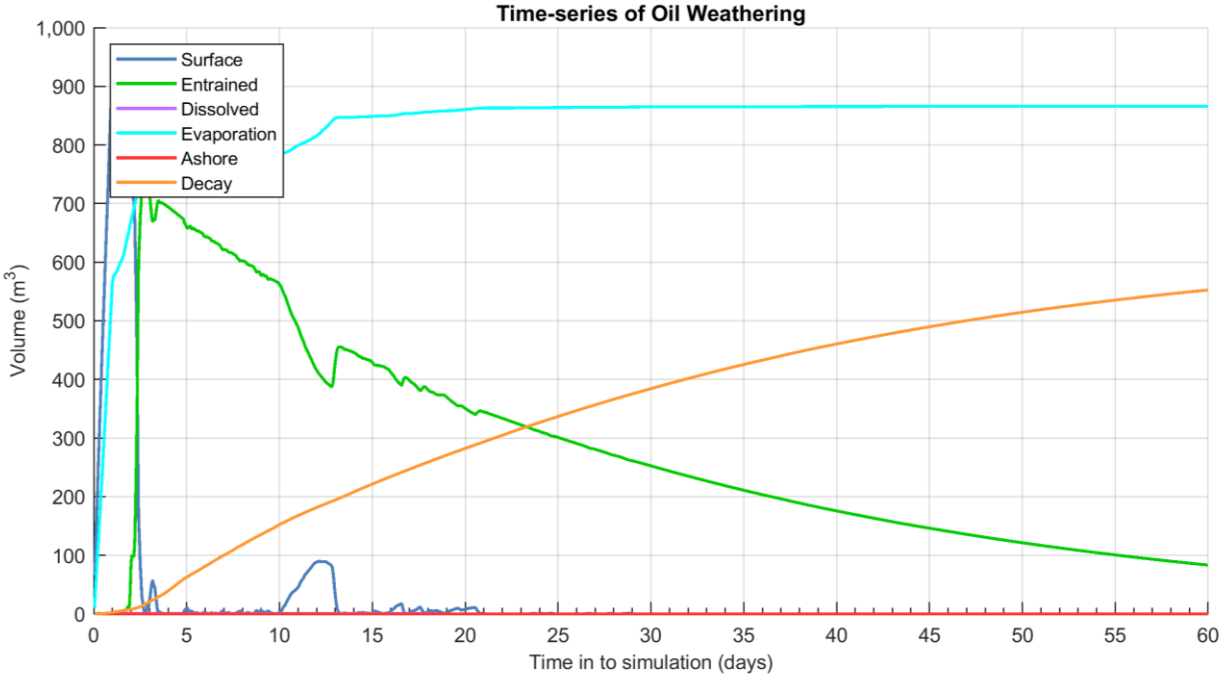


Figure 10.18 Predicted weathering and fates for the simulation with the largest swept area of floating oil above 50 g/m^2 following a vessel collision at WTR Well 5.

10.2.3 Deterministic Case: Largest volume of oil ashore and longest length of shoreline accumulation above 100 g/m^2

The deterministic simulation that resulted in the largest volume of oil ashore and the longest length of shoreline accumulation above 100 g/m^2 (moderate threshold) was identified as run number 41 during the summer period.

Figure 10.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 10.20 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 60-day simulation

Figure 10.21 displays the time series of length of shoreline oil accumulation at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 60-day simulation.

Figure 10.22 presents the fates and weathering graph for the corresponding single spill trajectory and Table 10.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 10.12 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation that resulted in the largest volume of oil ashore and the longest length of shoreline accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	738	1	<1
Entrained (m^3)	854	2	106
Dissolved (m^3)	1	5	-
Evaporation (m^3)	703	60	706
Decay (m^3)	679	60	684
Ashore (m^3)	35	17	3

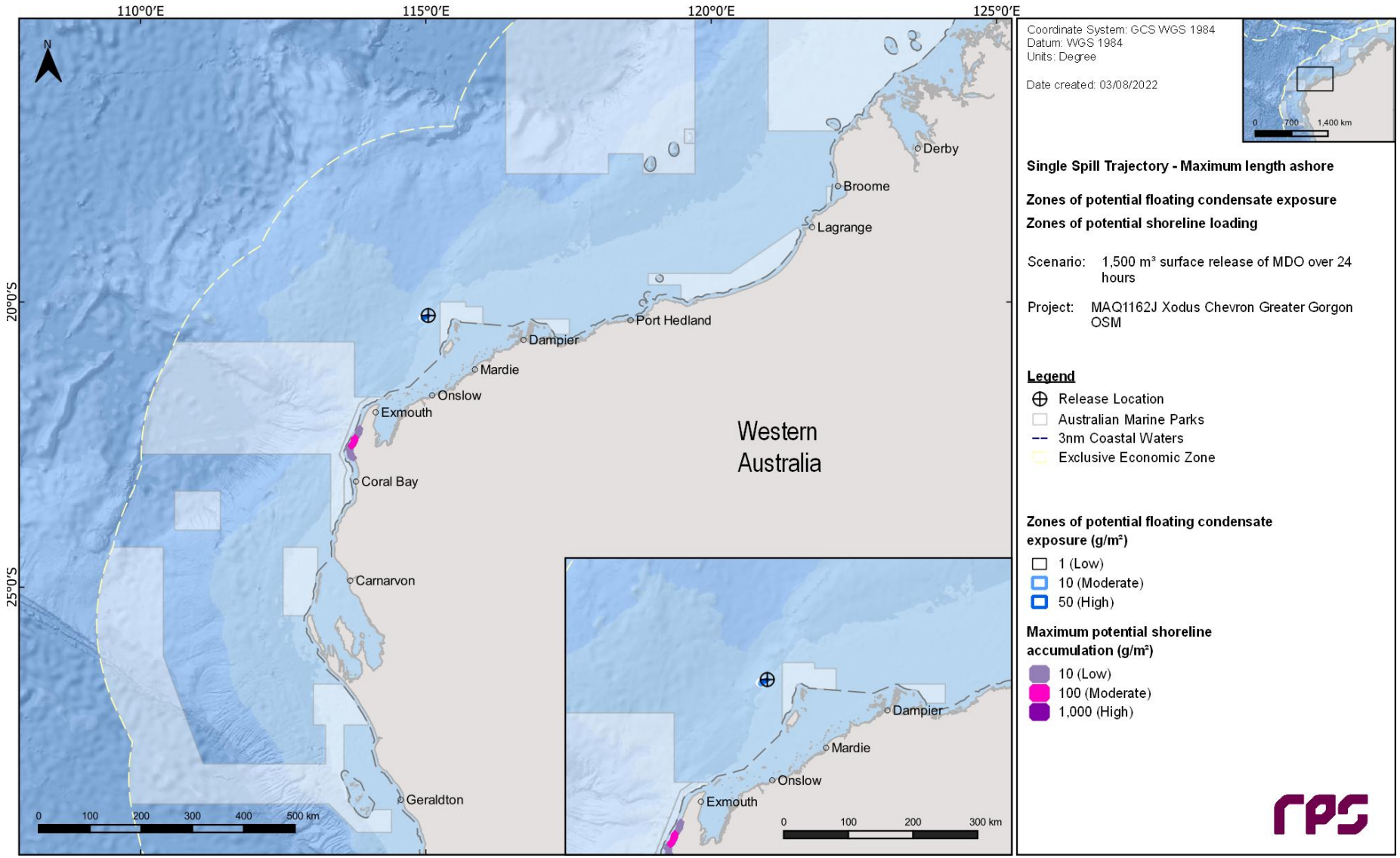


Figure 10.19 Zones of potential floating oil exposure over the entire 60 days, for the simulation with the largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m² following a vessel collision at WTR Well 5.

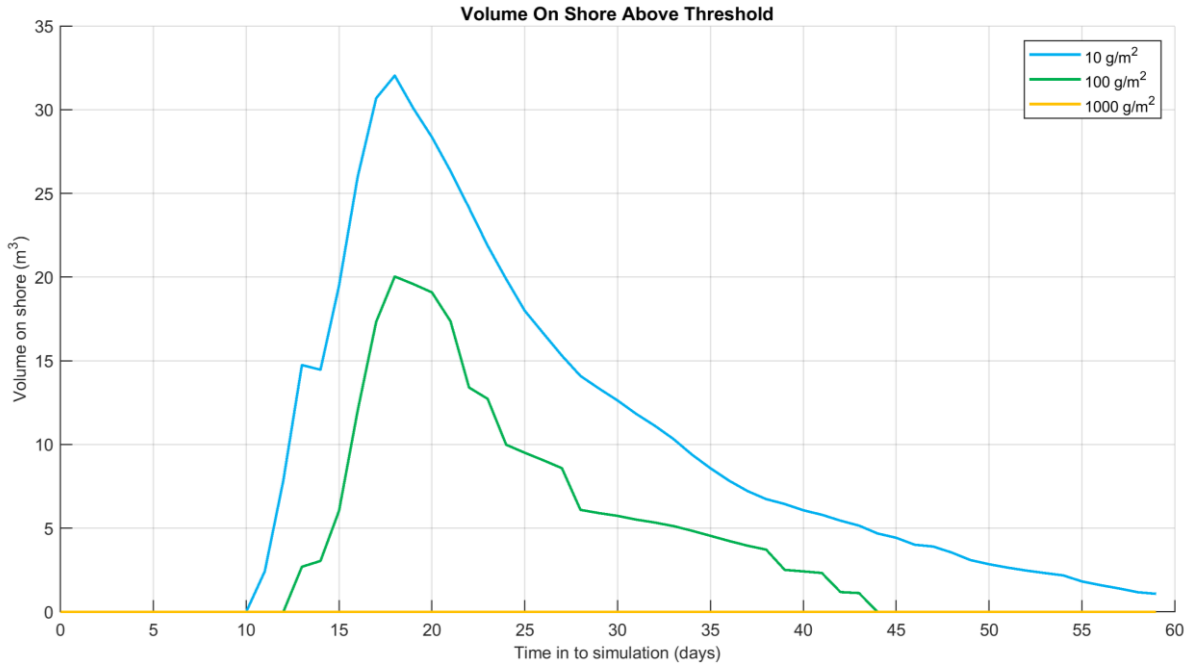


Figure 10.20 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore and the longest length of shoreline with accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

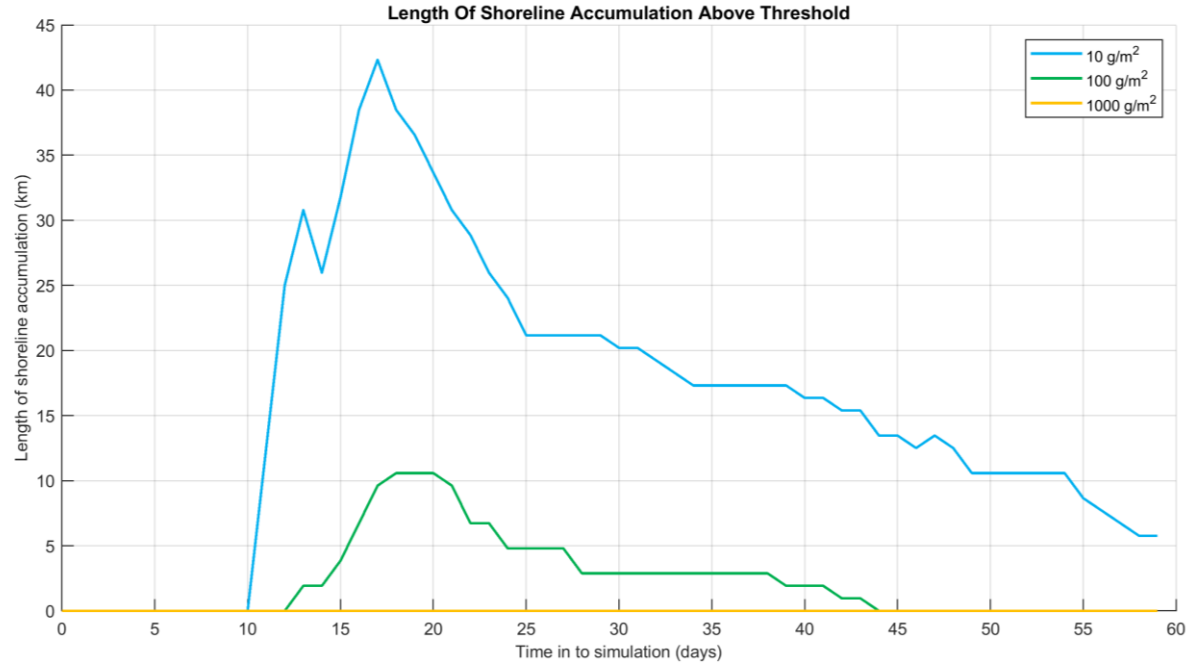


Figure 10.21 Time series of the length of shoreline at each thresholds for the simulation with the largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

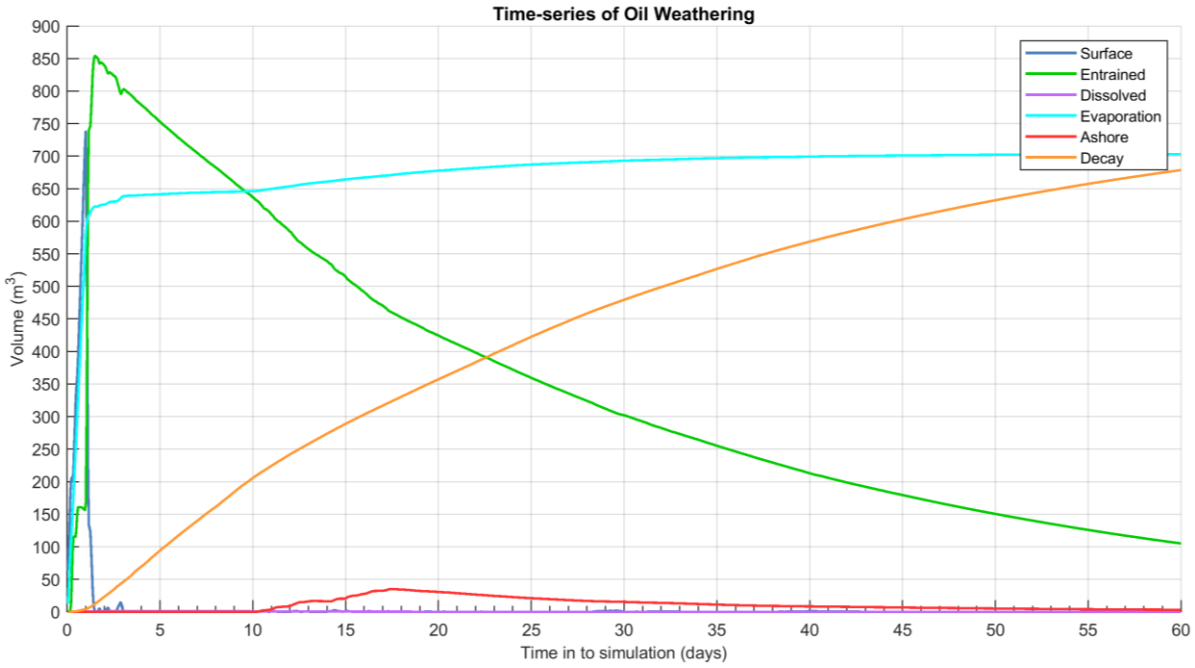


Figure 10.22 Predicted weathering and fates for the simulation that resulted largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

10.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 31 during transitional period.

Figure 10.23 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 60-day simulation.

Figure 10.24 displays the time series of the area of entrained hydrocarbons at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds over the 60-day simulation.

Figure 10.25 presents the fates and weathering for the corresponding single spill trajectory and Table 10.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 10.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	247	0	0
Entrained (m^3)	954	1	104
Dissolved (m^3)	3	2	0
Evaporation (m^3)	656	60	656
Decay (m^3)	727	60	727
Ashore (m^3)	0	0	0

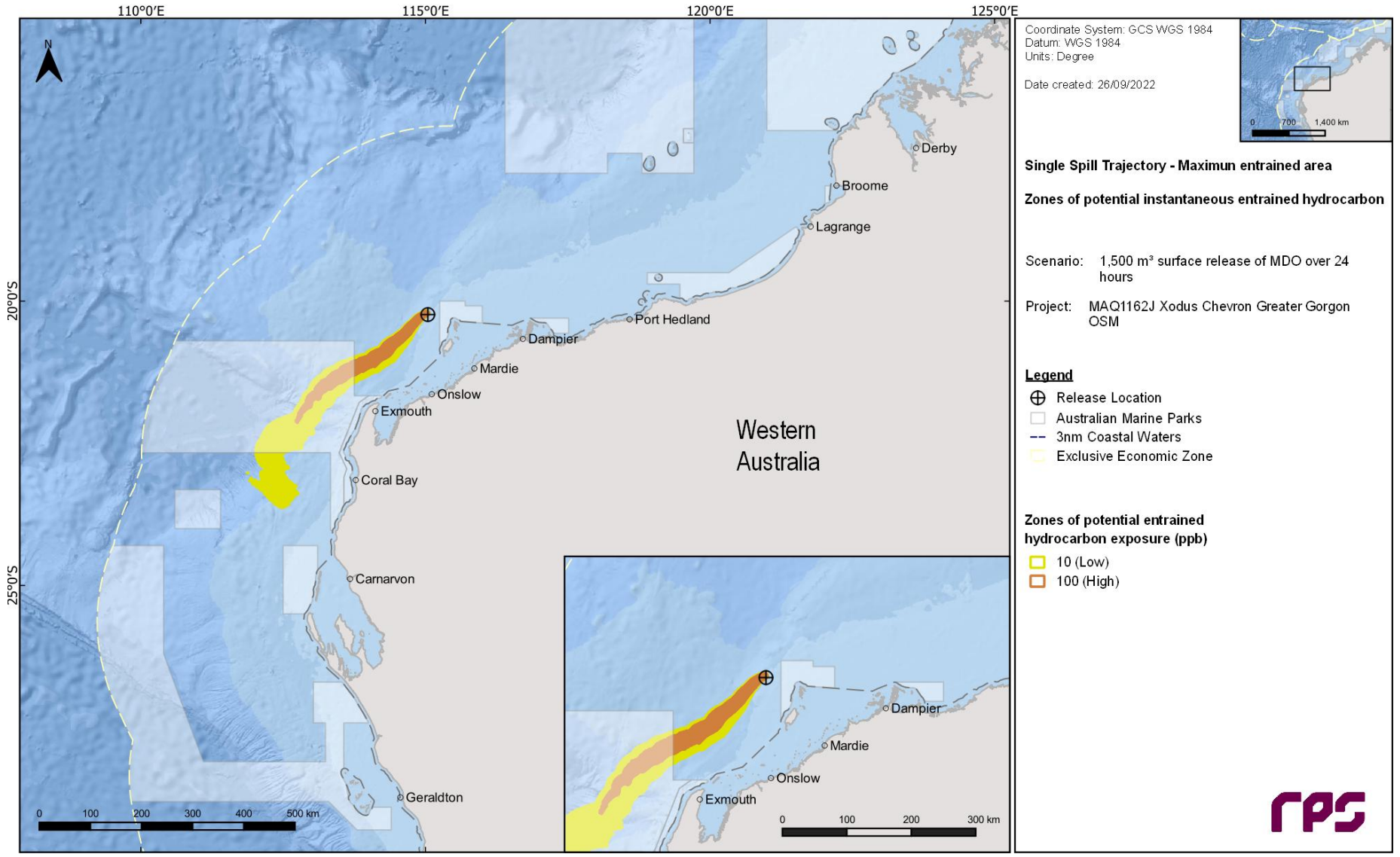


Figure 10.23 Zones of potential entrained hydrocarbon exposure over the entire 60 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

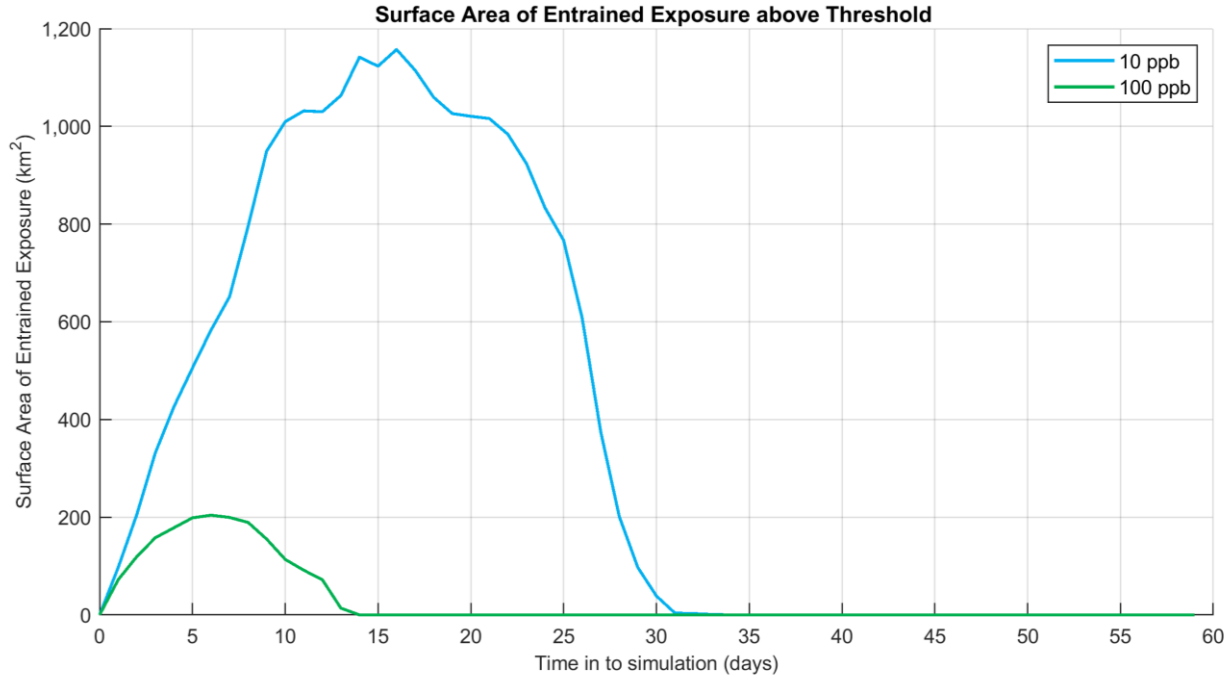


Figure 10.24 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

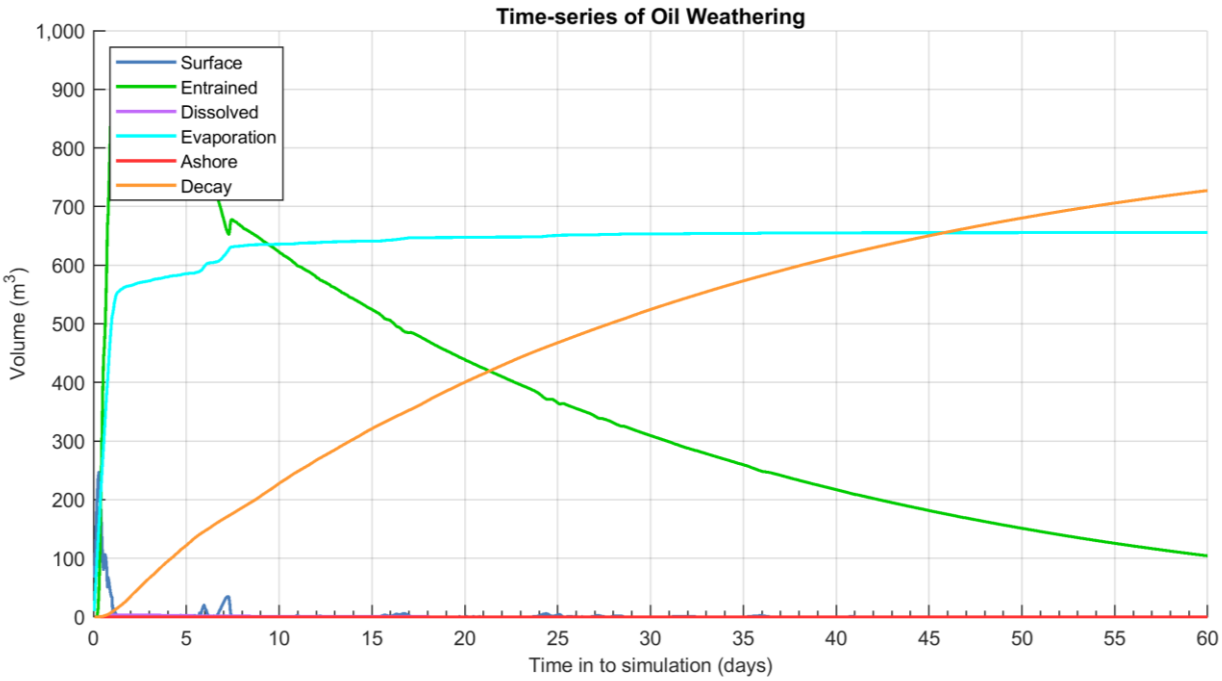


Figure 10.25 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

10.2.5 Deterministic Case: Largest area of dissolved hydrocarbons above 50 ppb

The deterministic simulation that resulted in the largest area of dissolved hydrocarbons above 50 ppb (moderate threshold) was identified as run number 96 during the winter period.

Figure 10.26 presents the extent of the predicted dissolved hydrocarbon exposure zones over the entire 60-day simulation.

Figure 10.27 displays the time series of the area of dissolved hydrocarbons at the low (≥ 10 ppb), moderate (≥50 ppb) and high (≥ 100 ppb) thresholds over the 60-day simulation.

Figure 10.28 presents the fates and weathering for the corresponding single spill trajectory and Table 10.14 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 10.14 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	78	0	0
Entrained (m^3)	1,049	1	84
Dissolved (m^3)	8	1	0
Evaporation (m^3)	789	51	789
Decay (m^3)	617	60	617
Ashore (m^3)	0	0	0

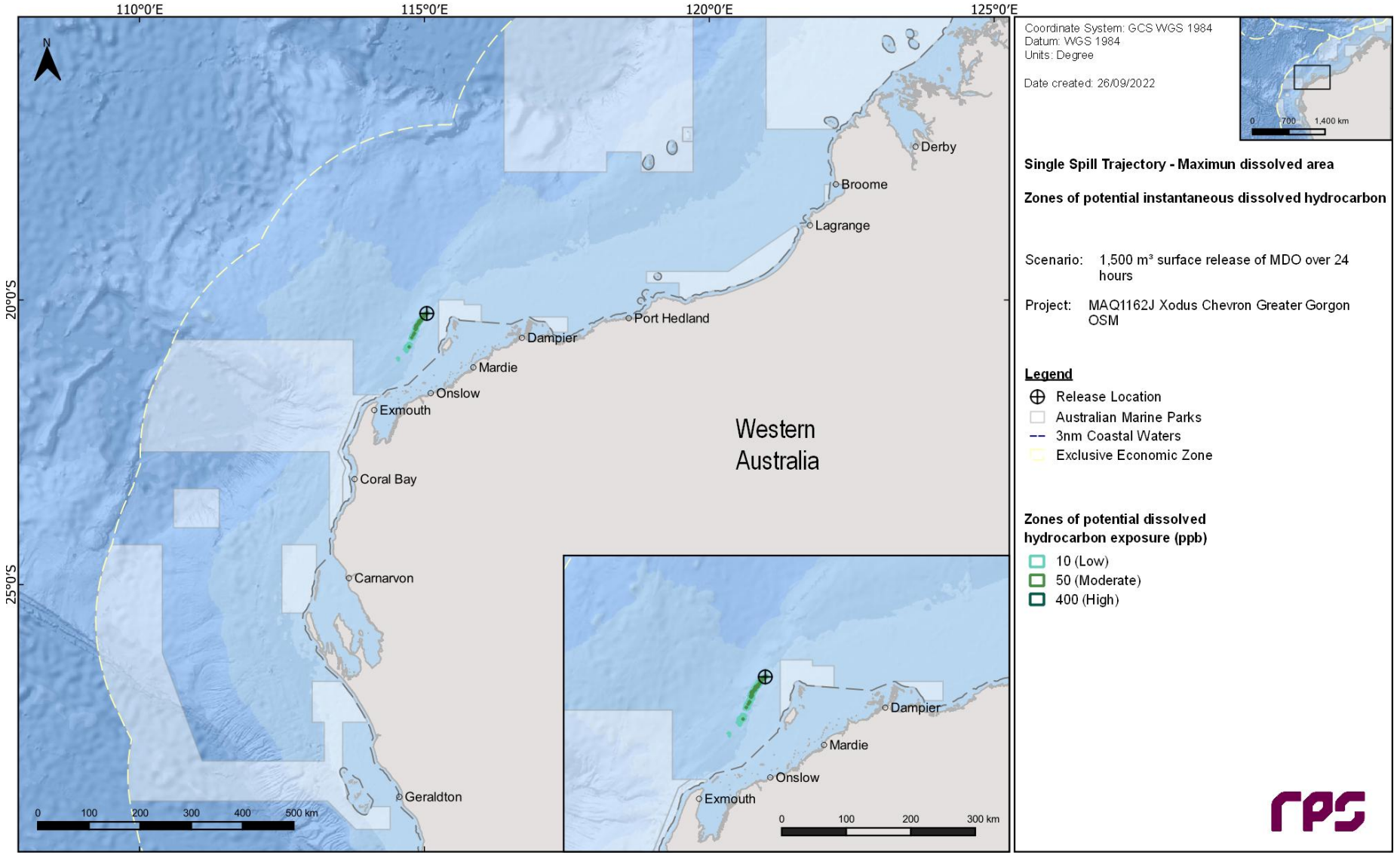


Figure 10.26 Zones of potential dissolved hydrocarbon exposure over the entire 60 days, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

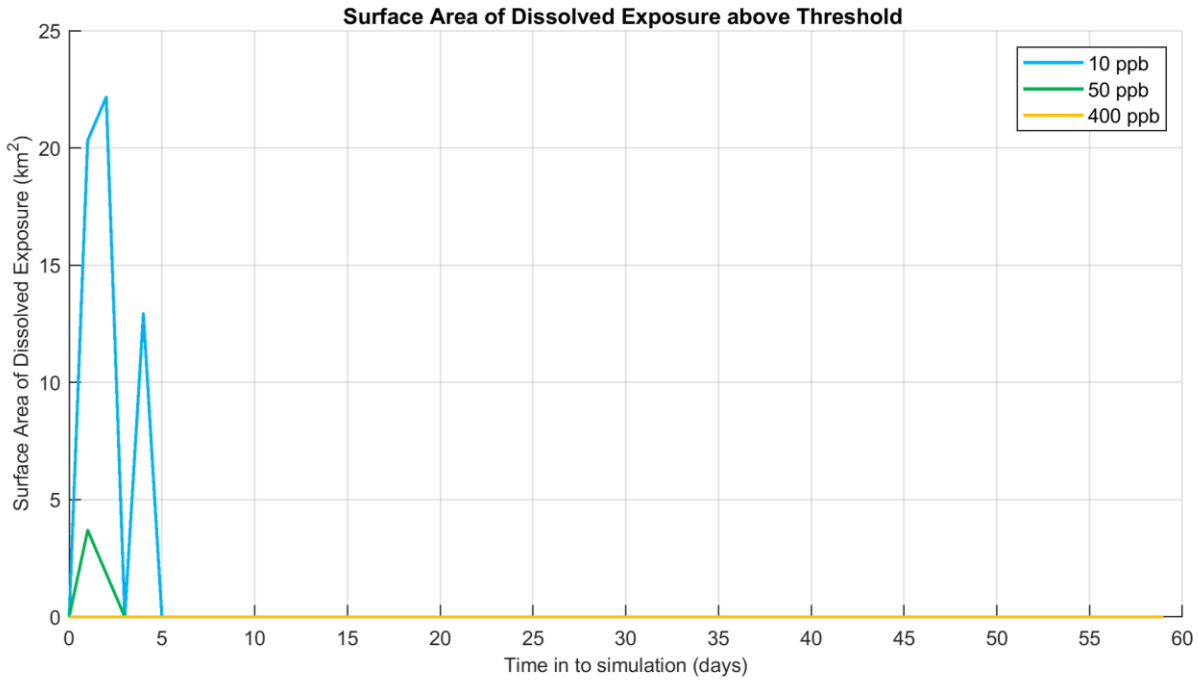


Figure 10.27 Time series of the area of dissolved hydrocarbons for each threshold, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

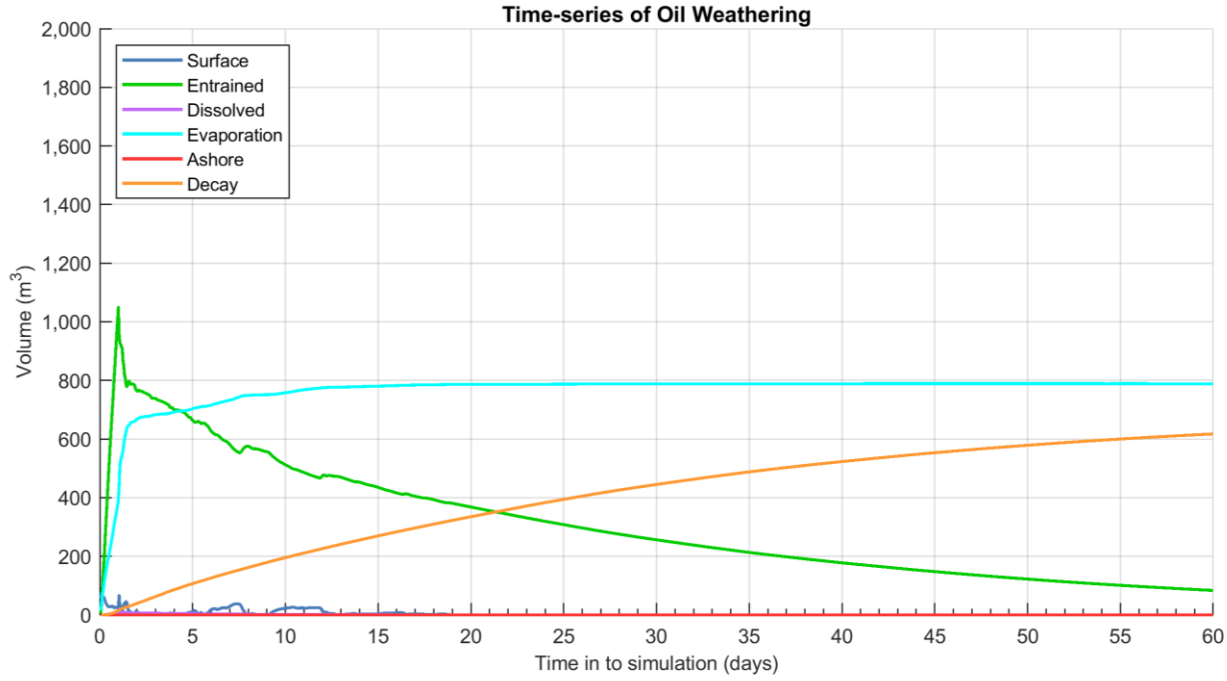


Figure 10.28 Predicted weathering and fates graph for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

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appendix c.2—WTR LOWC (condensate)

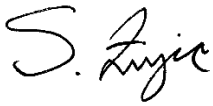
GREATER GORGON – WEST TRYAL ROCKS

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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
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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating oil 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
g/m^2	Grams per square meter (unit of surface area density)
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.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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

SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia. RPS was commissioned to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following two hypothetical scenario:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 90 days (totalling 387,180 stb or 61,555 m^3) resulting from a loss of well control (LOWC);

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running per scenario 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Hydrocarbon Properties

Condensate Properties

West Tryal Rocks condensate has an API of 41.2, a density of 817 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle. The soluble aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble.

Key Findings

Loss of Well Control

- 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) threshold was 251.7 West-southwest (summer), 45.9 km North-northwest (transitional) and 5.2 km West-northwest (transitional) and West-southwest (winter), respectively.

- Other than the receptors that the release location resides within (Section 10.3), the Montebello AMP, Flatback Turtle - Nesting and Humpback Whale - Migration BIAs, Barrow & Montebello Islands IAA and the Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. Accordingly, the probabilities for the low and moderate thresholds was 100% for all seasons for the receptors that the release location resides within. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting ranged between 91–95% and 17–25%, whilst the probabilities of low and moderate exposure at Humpback Whale - Migration ranged between 97–100% and 6–32%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 1.08 days and 0.71 days during summer conditions, respectively.

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 59%, while the minimum time before shoreline accumulation was 6.5 days and the maximum volume of oil ashore was 128 m^3. No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

- During summer conditions, 82 shoreline receptors were predicted to record condensate accumulation at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (38%). In comparison, during transitional and winter conditions, 40 and 42 shoreline receptors, respectively, were predicted to record accumulation, with the greatest probability during transitional season occurring at the Ningaloo Coast World Heritage Area IAA and the Muiron Islands (30%) and at the Ningaloo Coast World Heritage Area IAA only during winter (30%).

- In the surface (0-10 m) depth layer, a total of 14, 20, and 10 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging), the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 7% for Humpback Whale - Migration during summer, 12% Humpback Whale - Migration during transitional, and 4% for Flatback Turtle – Nesting and Humpback Whale - Migration during winter conditions.

- In the surface (0-10 m) depth layer, a total of 44, 39 and 40 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter respectively. Excluding the 4 BIAs that the release location resides within, the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Flatback Turtle - Nesting (98% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

- During summer, 9 AMPs were predicted to be exposed at the low threshold, compared to 7 AMPs during transitional and winter periods. The highest probabilities predicted were at the Gascoyne AMP (96% summer, 100% transitional and 98% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the WTR field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the two following hypothetical scenarios:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 90 days (totalling 387,180 stb or 61,555 m^3) resulting from a loss of well control (LOWC);

The release location is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 West Tryal Rocks release location.

Location	Latitude	Longitude	Depth (mLAT)
WTR Well 5	20.23666° S	115.04357° E	150

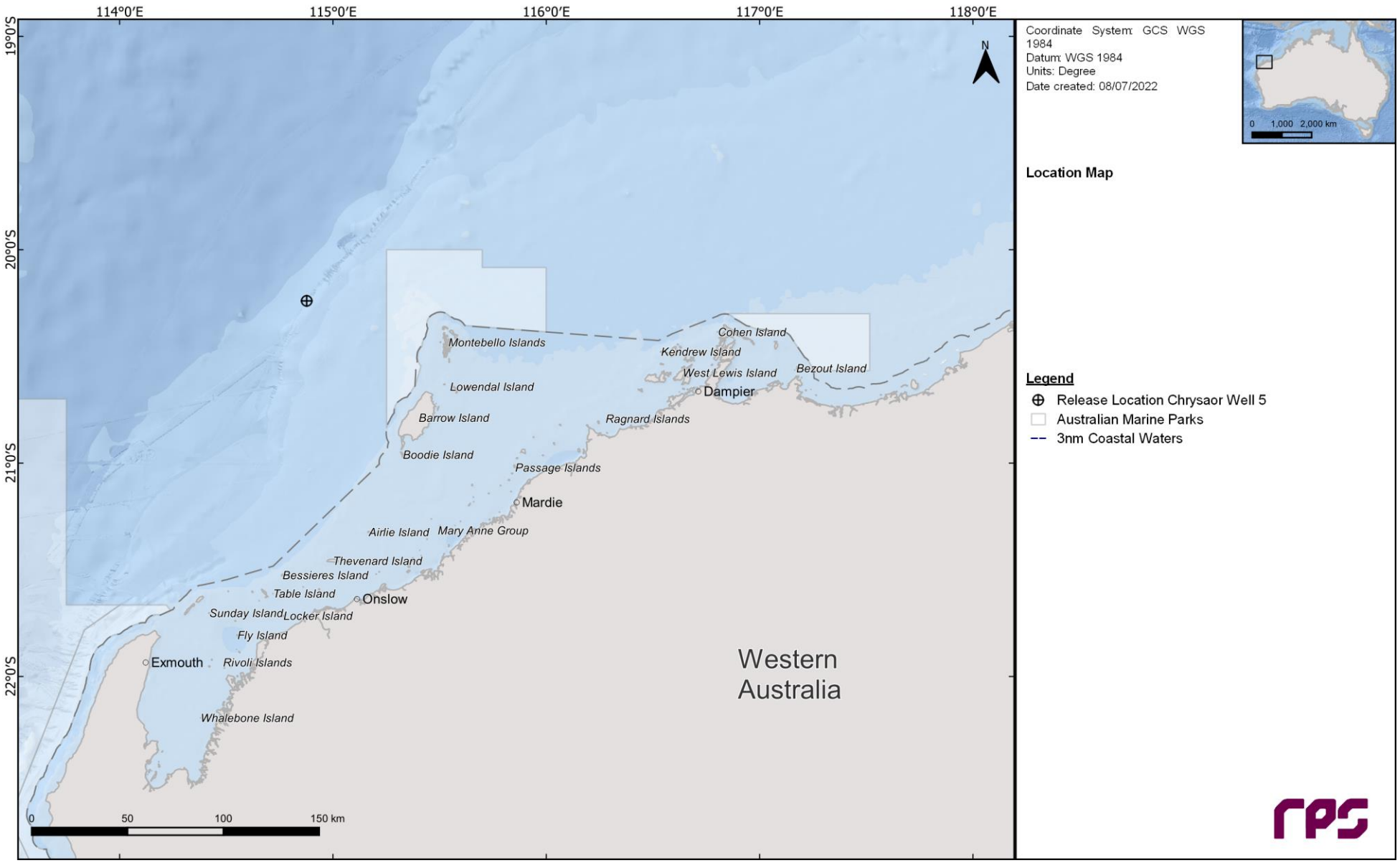


Figure 1.1 West Tryal Rocks hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. For each scenario run 100 simulations per season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds for each scenario; and

5. From the 300 simulations modelled per scenario, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:

    a. Largest swept area of floating hydrocarbon above 10 g/m^2

    b. Largest swept area of floating hydrocarbon above 50 g/m^2

    c. Largest volume of oil ashore

    d. Longest length of shoreline with accumulation above 100 g/m^2

    e. Largest area of entrained hydrocarbons above 100 ppb

    f. Largest area of dissolved hydrocarbons above 50 ppb

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

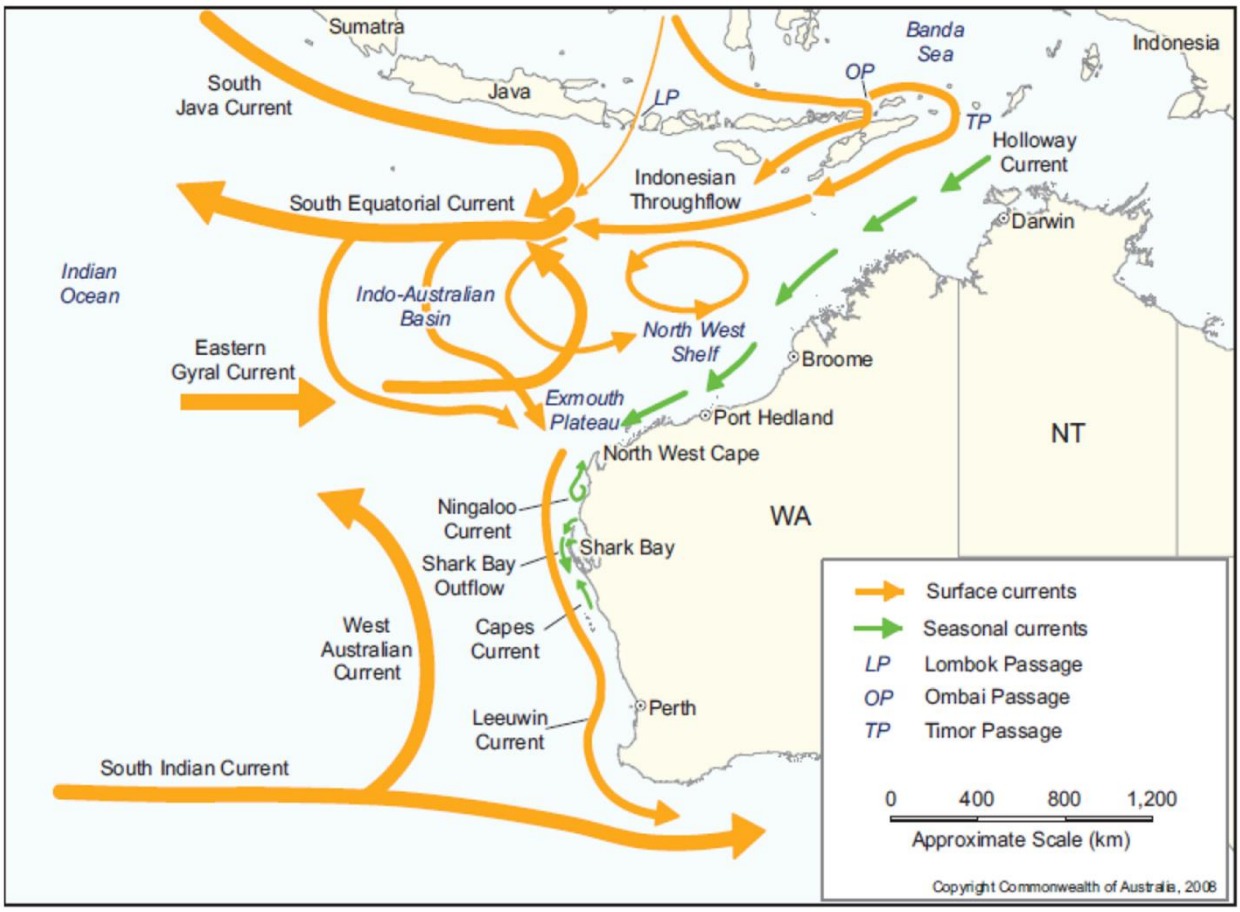


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

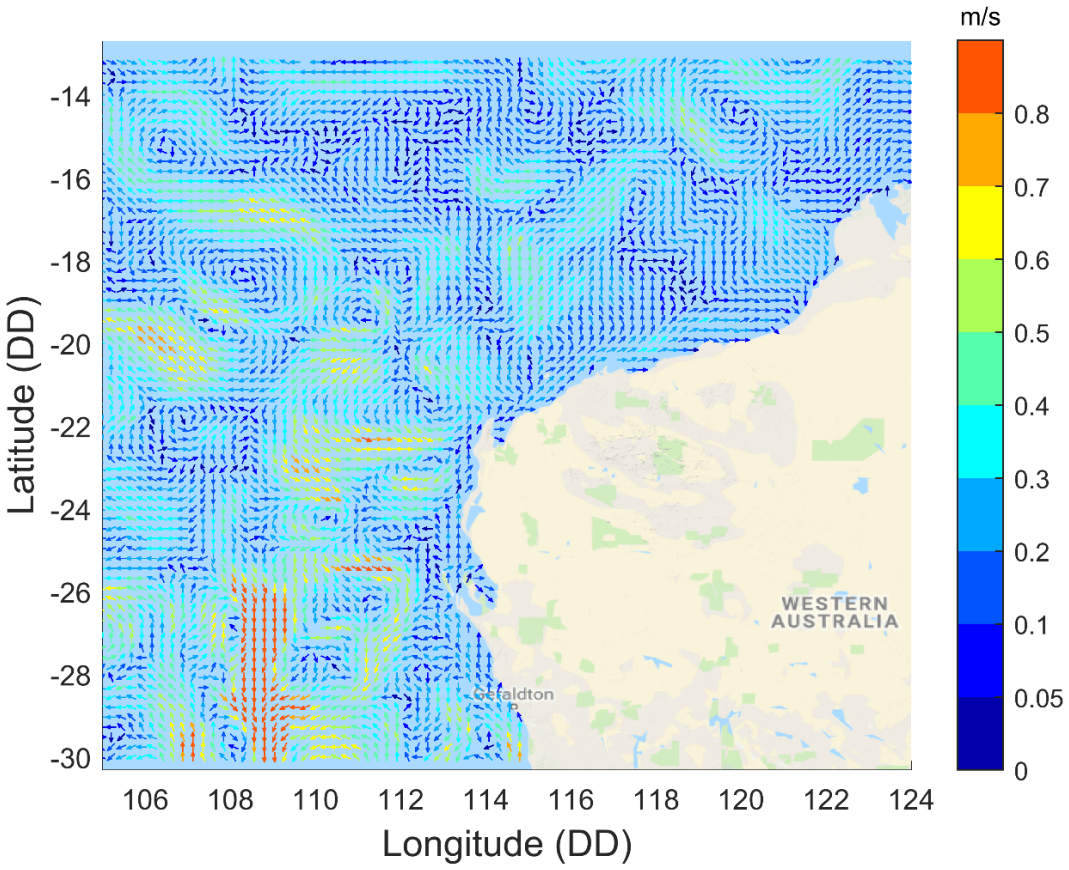


Figure 3.2 Typical ocean current circulation pattern during the summer months.

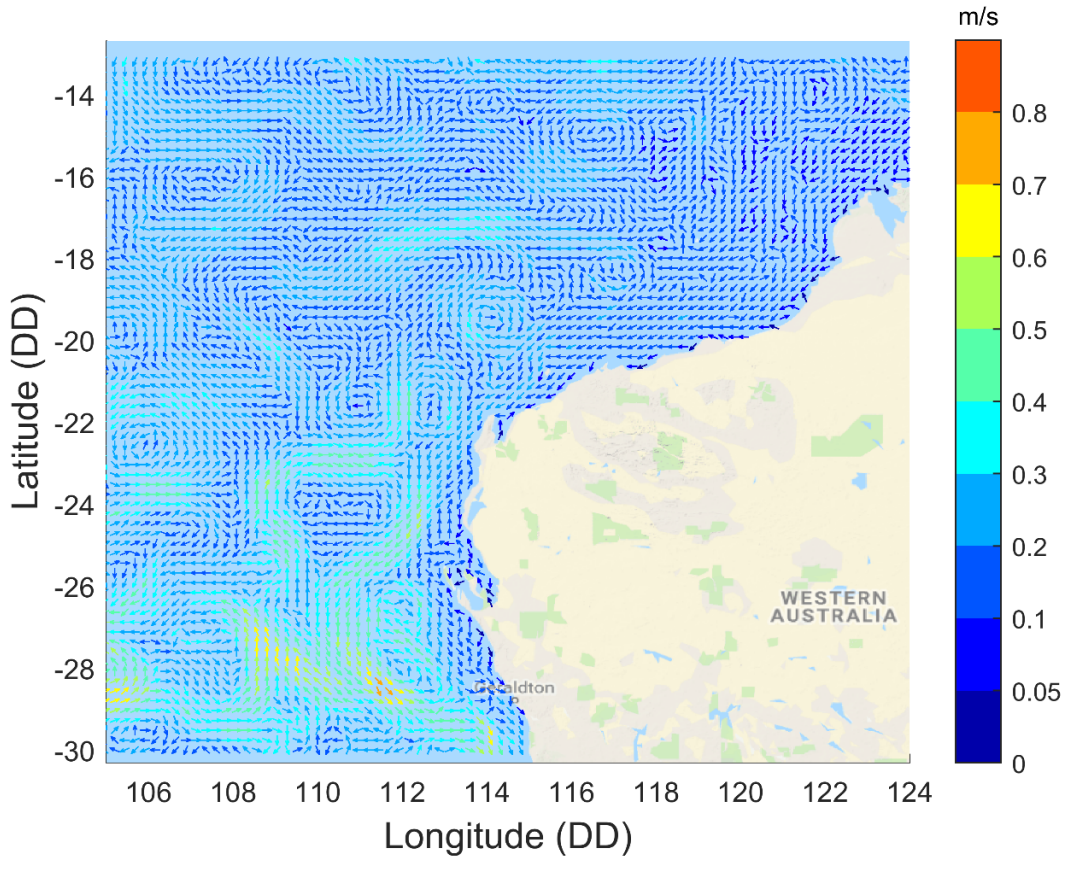


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

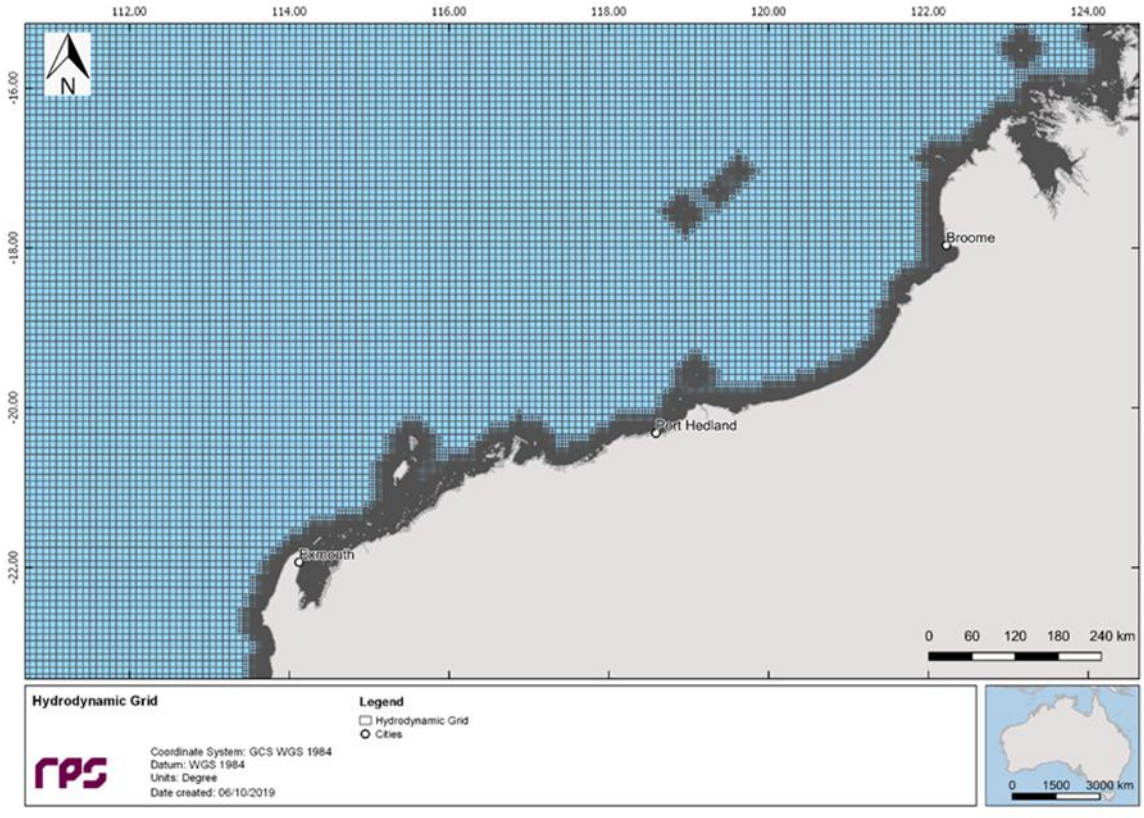


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

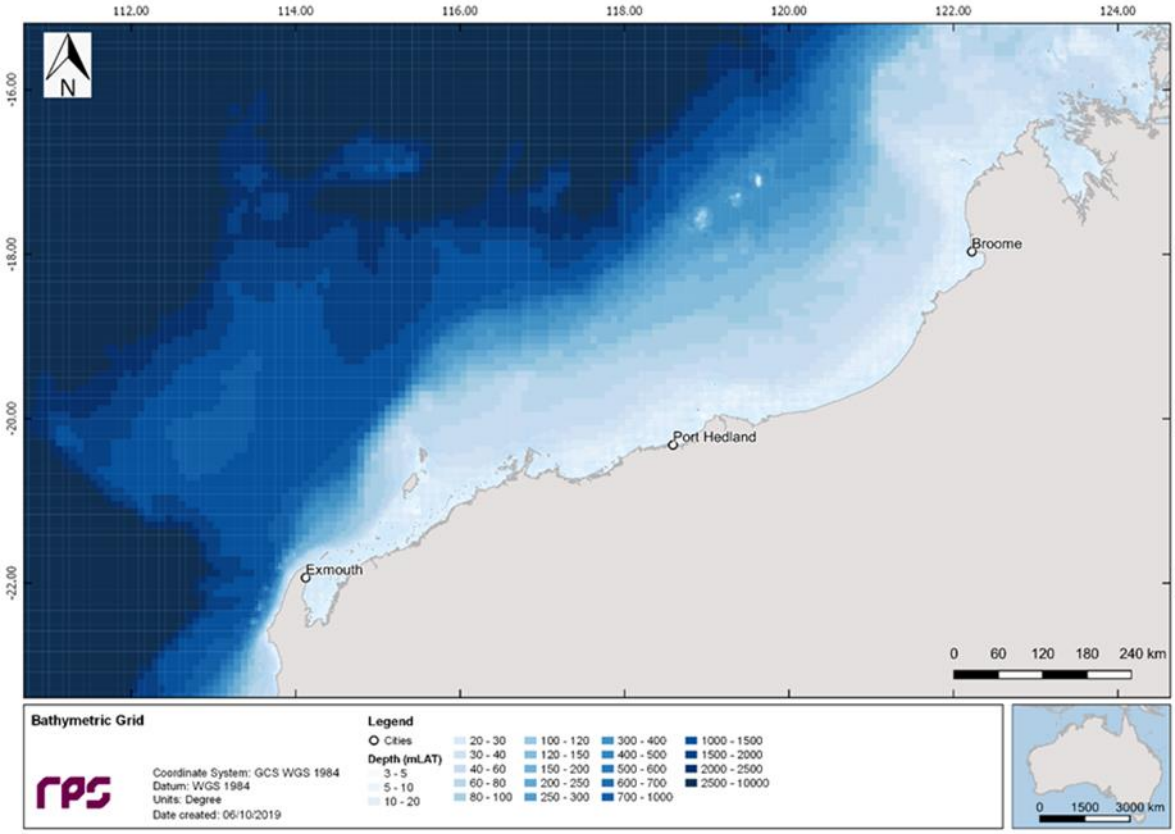


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.26 m/s (May). Additionally, the maximums ranged between 0.54 m/s (November) and 2.18 m/s (March). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.23	1.93	Northeast and Southwest
	February	0.21	1.07	Northeast and Southwest
	March	0.22	2.18	Southwest
Transitional	April	0.24	1.20	Southwest
Winter	May	0.26	0.95	Southwest
	June	0.26	0.90	Southwest
	July	0.21	1.08	Southwest
Transitional	August	0.19	0.78	Southwest
Summer	September	0.19	1.03	Northeast and Southwest
	October	0.18	0.63	Northeast and Southwest
	November	0.16	0.54	Variable
	December	0.20	0.80	Southwest
Minimum		**0.16**	**0.54**	
Maximum		**0.26**	**2.18**	

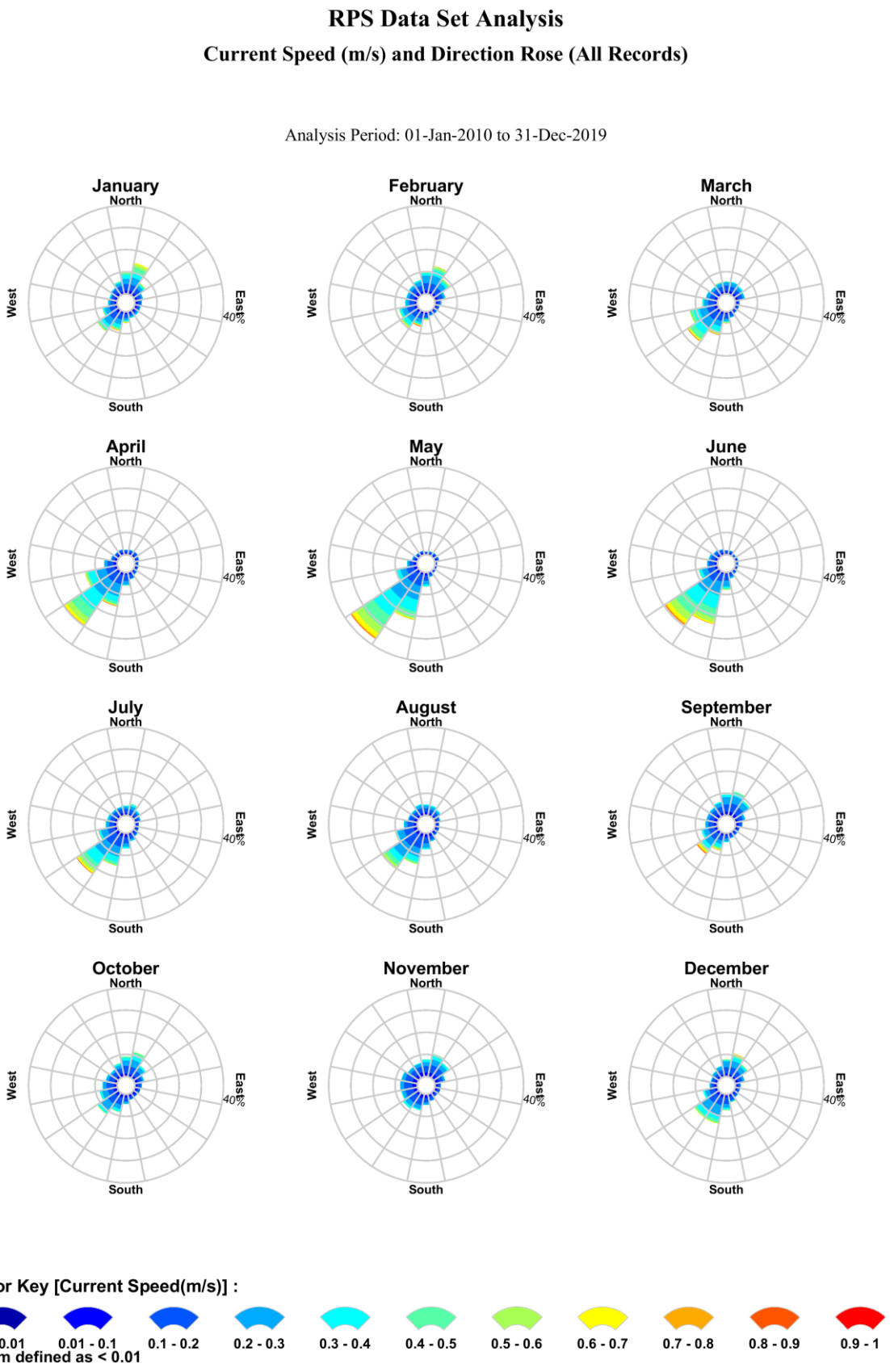


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

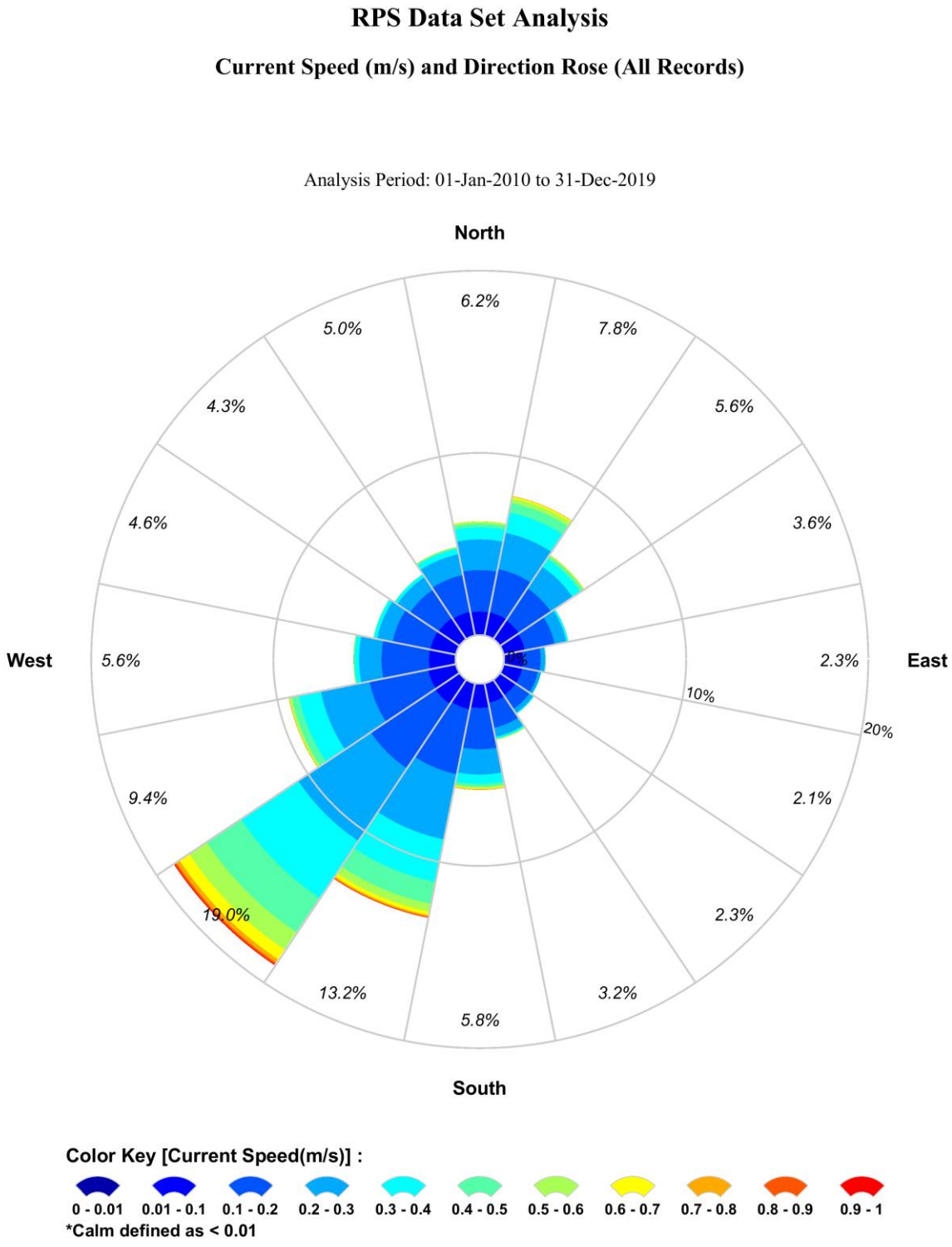


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 49 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

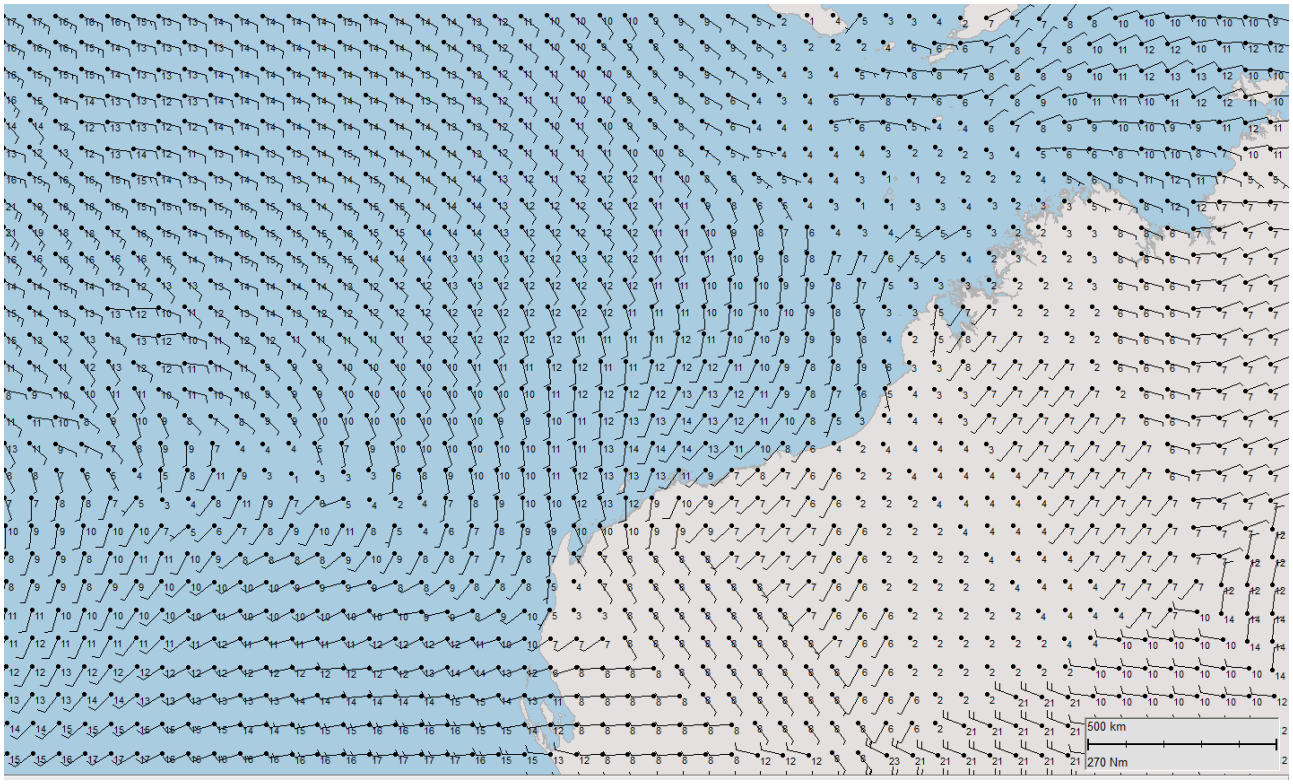


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	41	Southwest
	February	11	46	Southwest
	March	10	35	Southwest
Transitional	April	10	38	Variable
Winter	May	12	40	East
	June	14	31	East
	July	13	49	East to South
Transitional	August	11	31	South
Summer	September	12	27	South-Southwest
	October	13	28	Southwest
	November	13	25	Southwest
	December	12	29	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**49**	

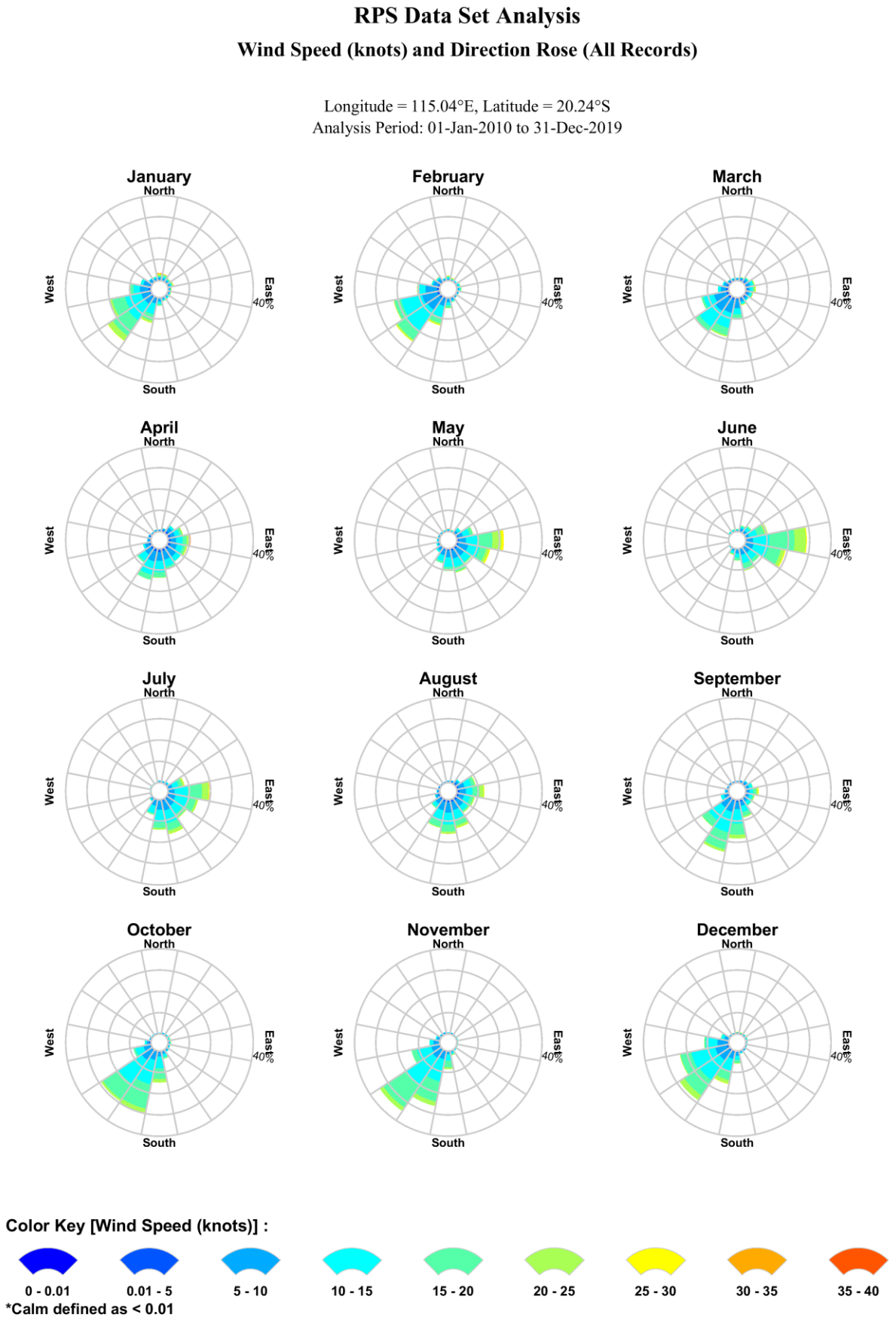


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

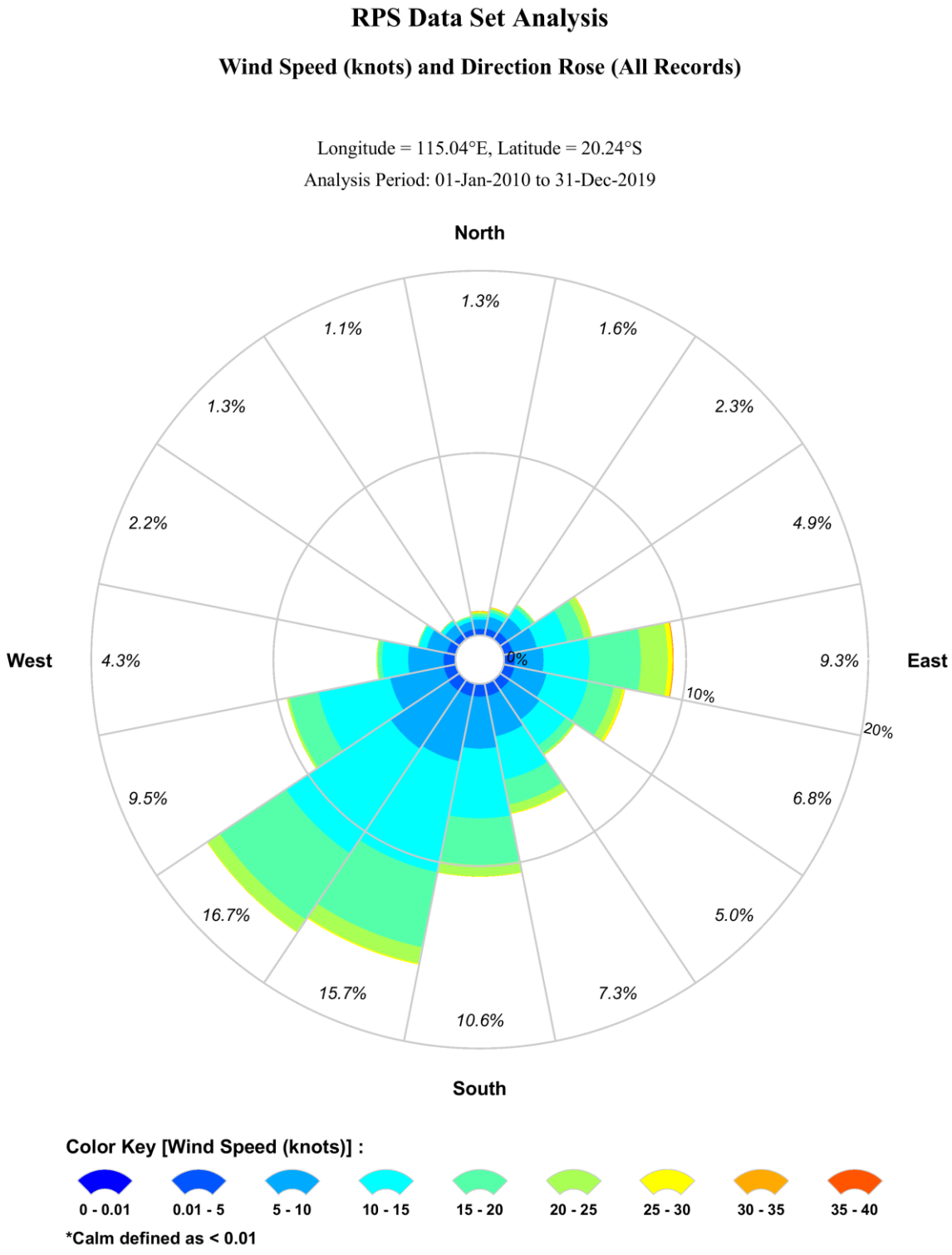


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.2°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.3 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.7	27.9	27.0	25.3	24.5	24.2	25.0	27.3	27.0
Salinity (psu)	35.1	34.9	35.0	35.1	35.2	35.3	34.9	34.8	34.9	34.9	34.6	34.9

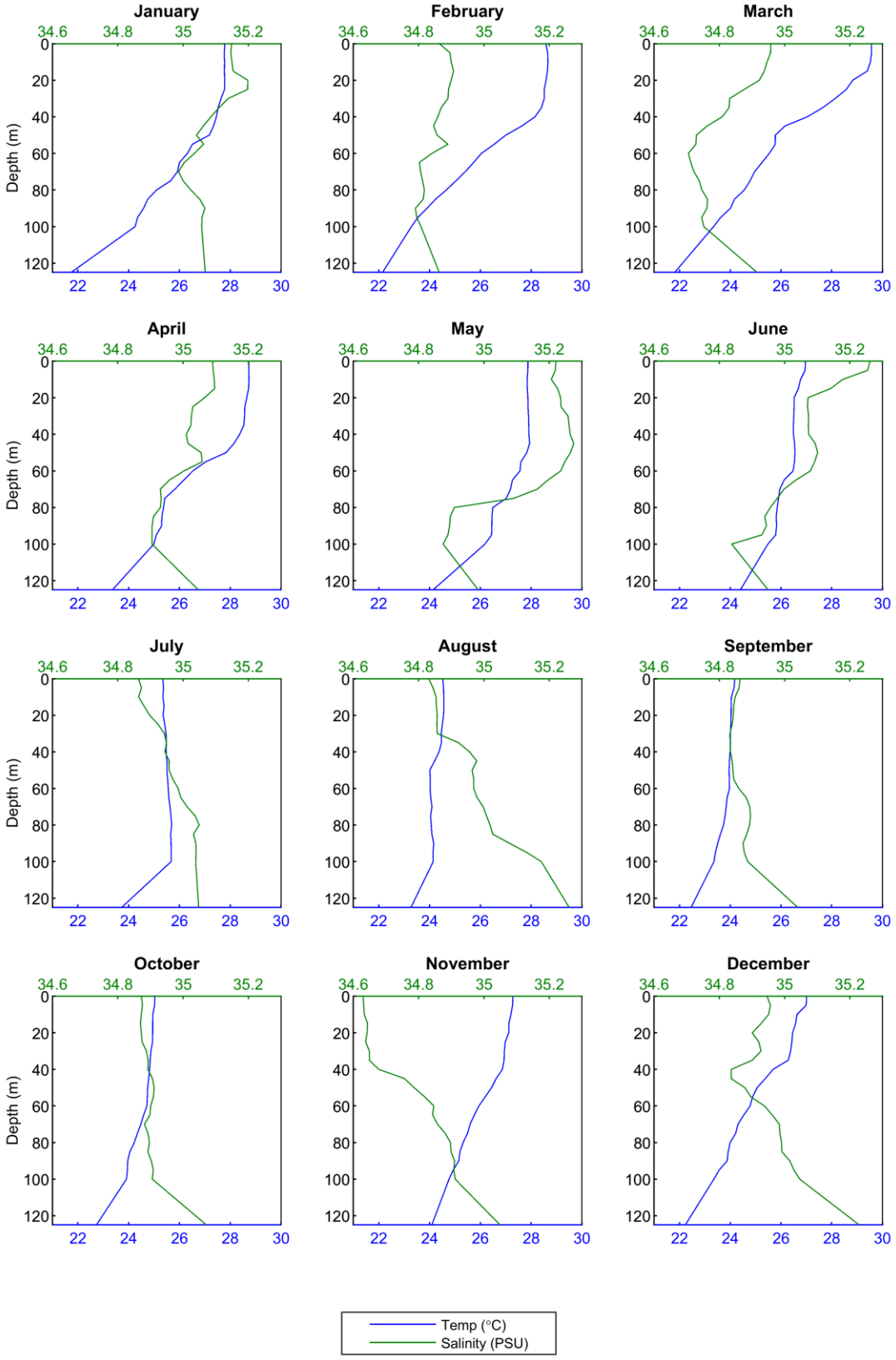


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

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).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of less than 1 m below mean sea level. The modelling predicted droplets ranging in size from 175 to 756 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	WTR Well 5
Water depth (m)	150
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	4,302
Gas rate (MMscf/day)	310
Gas to condensate ratio (scf/bbl)	72,060
Formation water flow rate (stb/day)	0
Operating pressure (psia)	6,220
Key results	
Plume execution depth (m BMSL)	<1
Droplet sizes (µm)	175 to 756

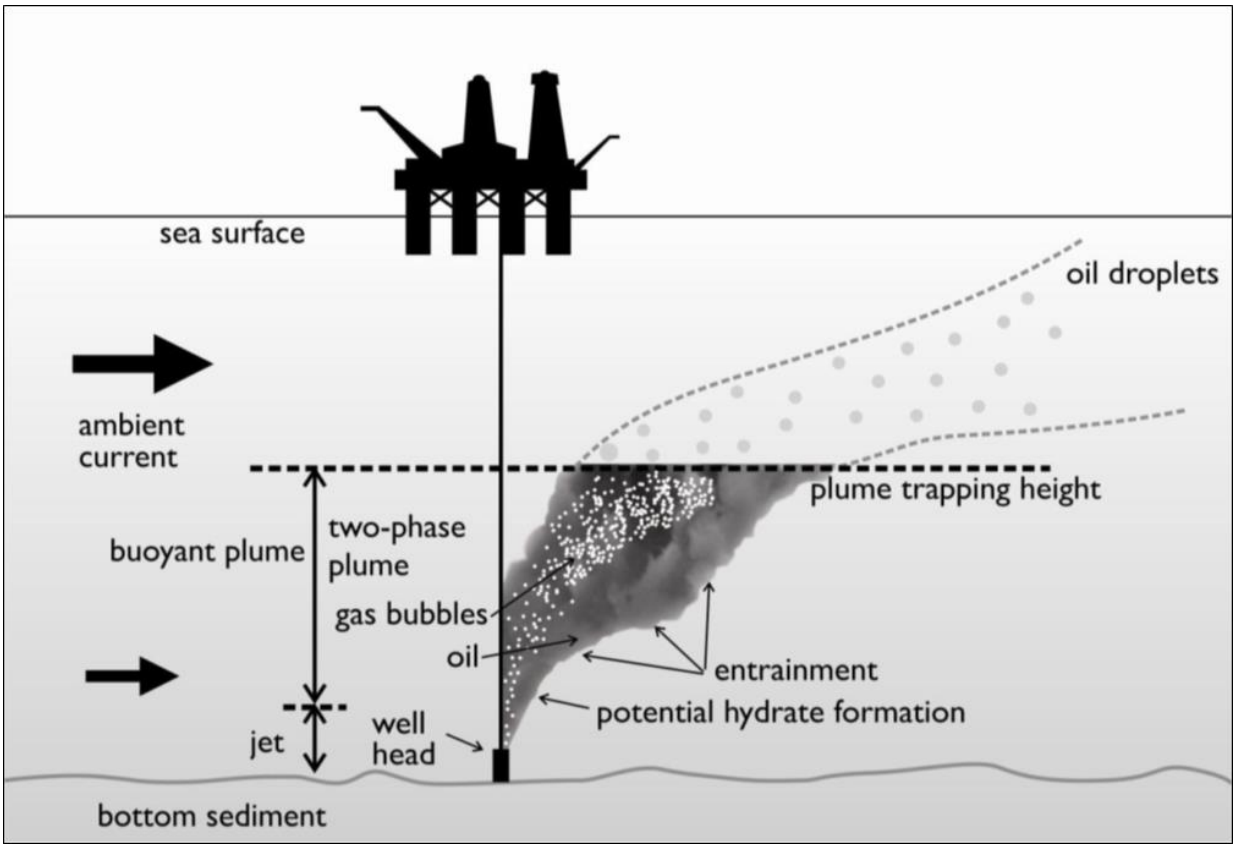


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

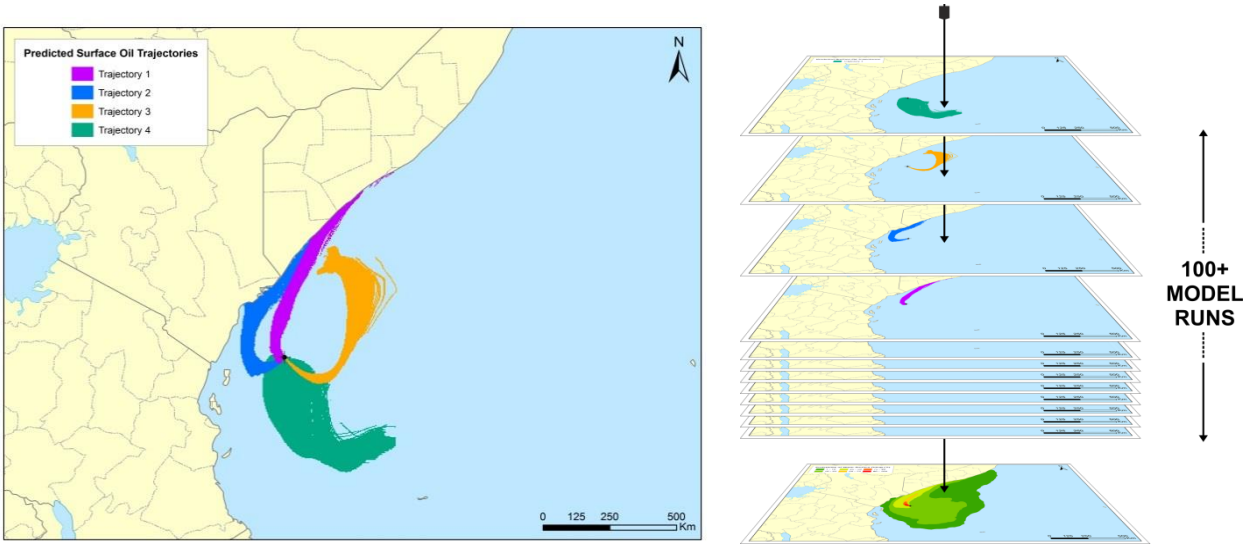


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 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

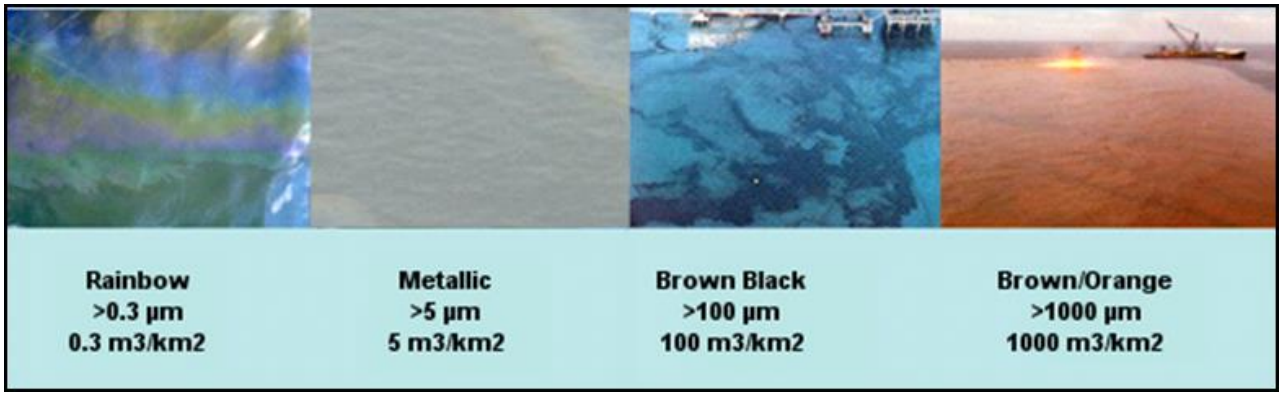


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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 In-water Exposure 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 & Di Toro, 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 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on 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 & ARMCANZ (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.

This exposure zone 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 7.4), 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 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 HYDROCARBON PROPERTIES

8.1 Condensate Properties

West Tryal Rocks condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

West Tryal Rocks condensate has an API of 41.2, a density of 789 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble, aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble. The process of evaporation will be greater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of West Tryal Rocks condensate.

Characteristic	West Tryal Rocks Condensate
Density (kg/m^3)	817 (at 15°C)
API	41.2
Dynamic viscosity (cP)	5.9 (at 15°C)
Pour point (°C)	0
Surface tension (dyne/cm)	23
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of West Tryal Rocks condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
West Tryal Rocks Condensate	% of total	31.1	29.9	19.4	19.6
	% of aromatics	3.2	0.0	0.0	0.0

8.2 Condensate Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 61.1% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of West Tryal Rocks condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 51.6% of the condensate mass is forecast to have entrained and a further 45.1% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (1.5%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of 1.66% per day with an accumulated total of 11.6% after 7 days, in comparison to a rate of 0.22% per day and an accumulated total of 1.59% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

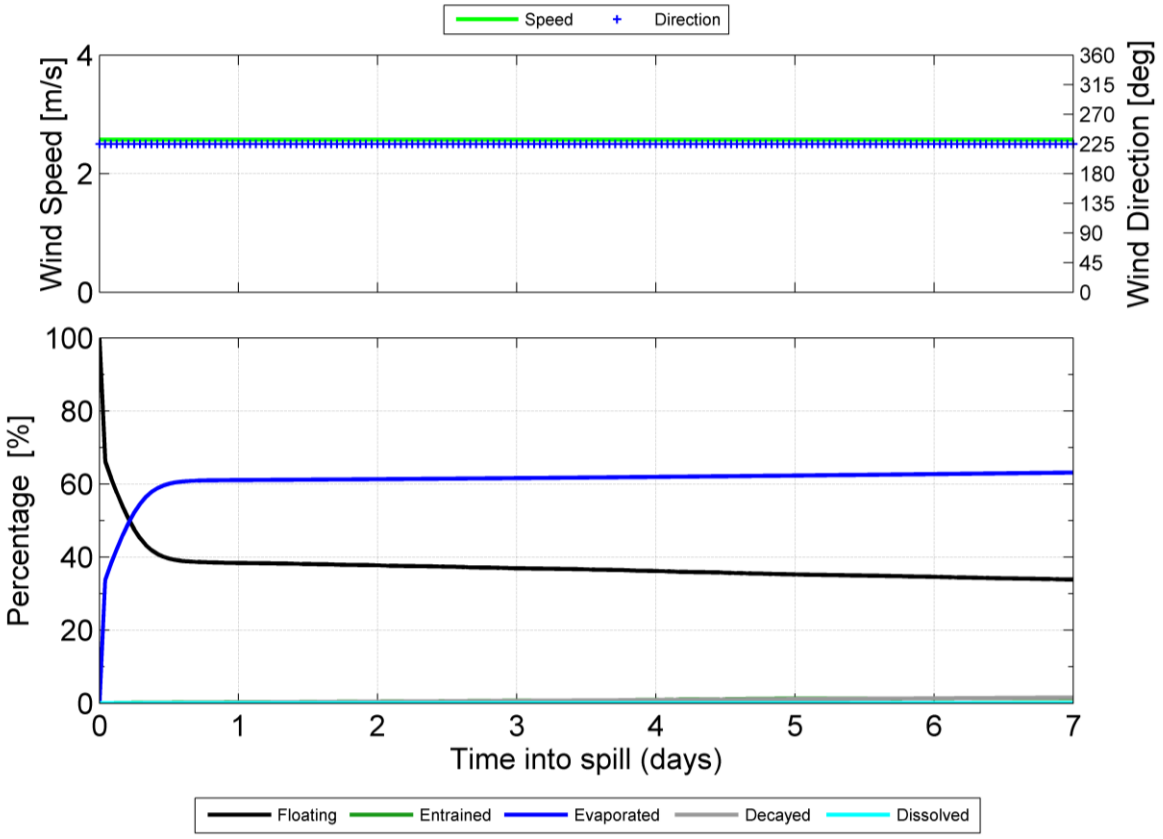


Figure 8.1 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

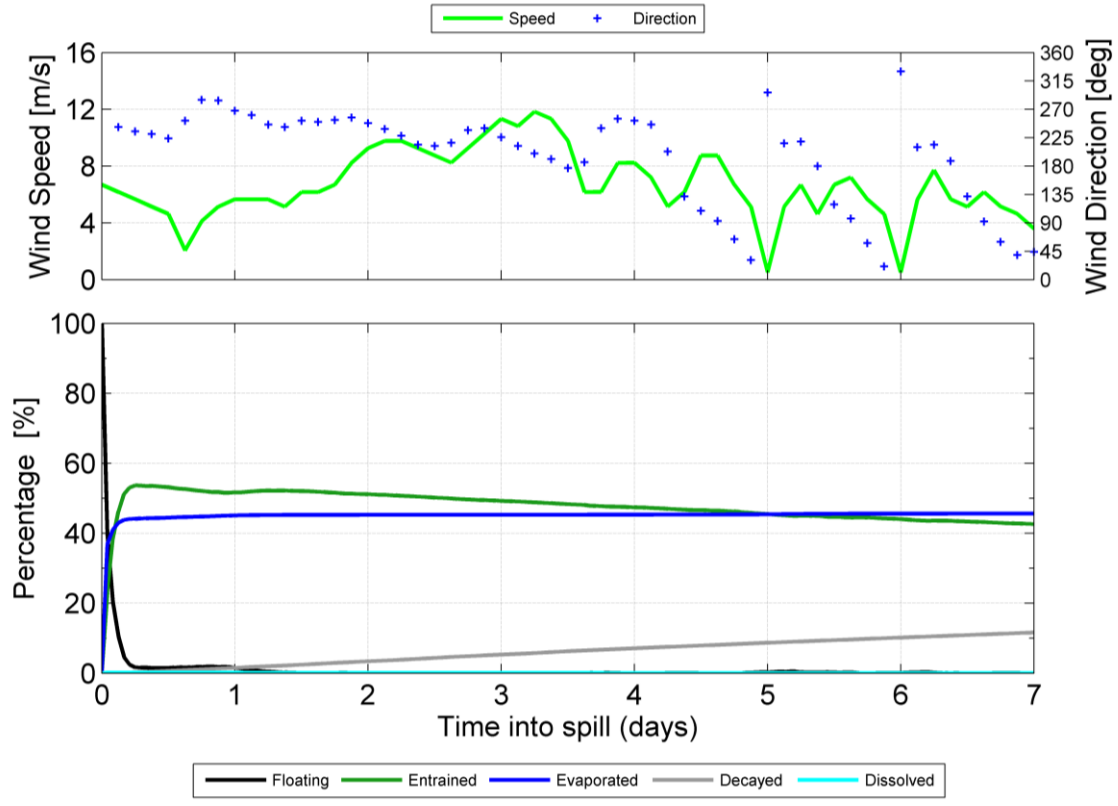


Figure 8.2 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario 1
Location	WTR Well 5
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	61,555 [387,180]
Condensate type	West Tryal Rocks condensate
Release type (depth)	Subsea (150 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***probability of oil exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before oil exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results for both scenarios are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline with accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.11). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
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 Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Flatback Turtle - Internesting Buffer	BIA	✓
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Whale Shark - Foraging	BIA	✓
Offshore Area	IAA	✓
Pilbara (offshore)	IMCRA	✓
Ancient coastline at 125 m depth contour	KEF	✓

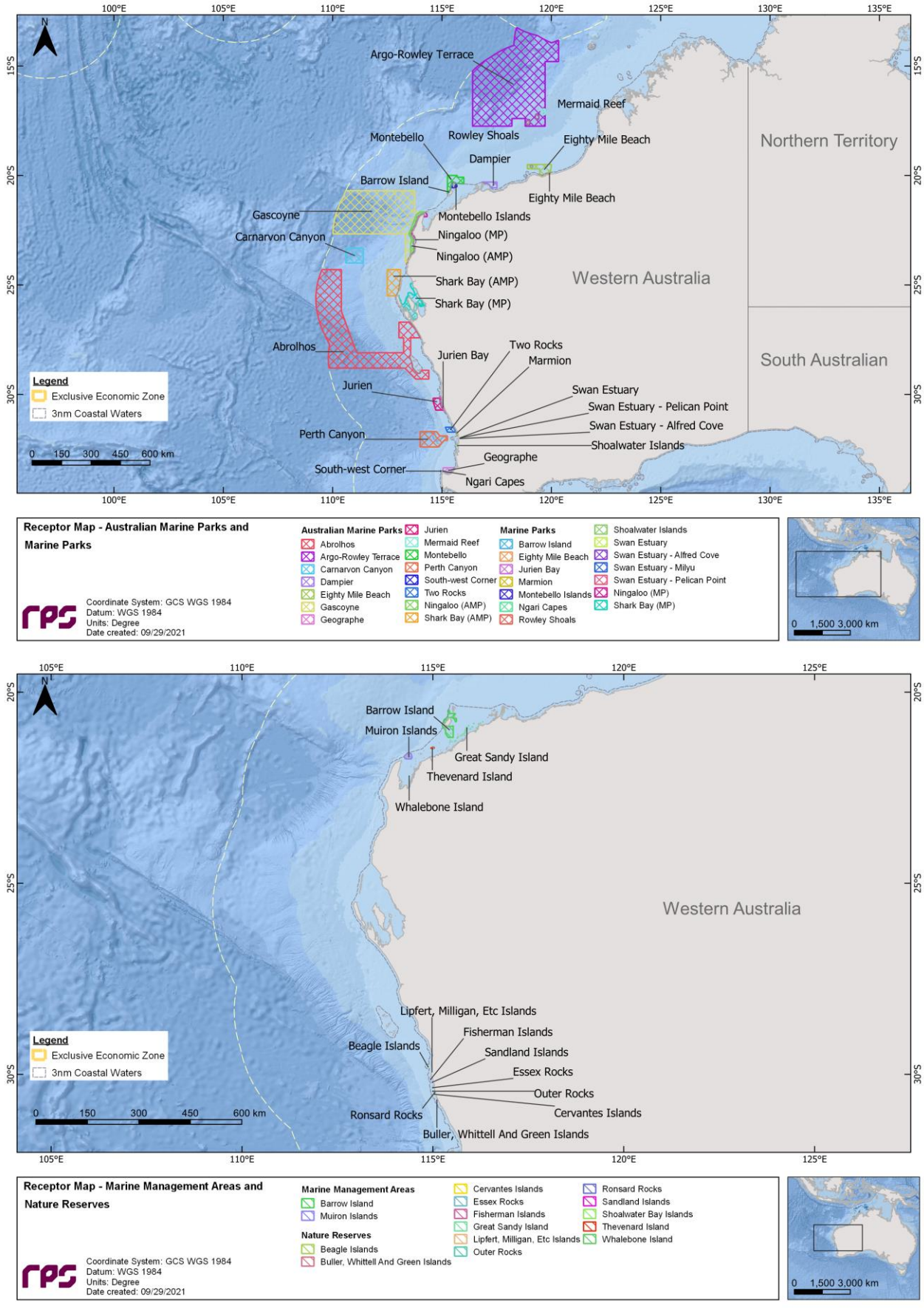


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

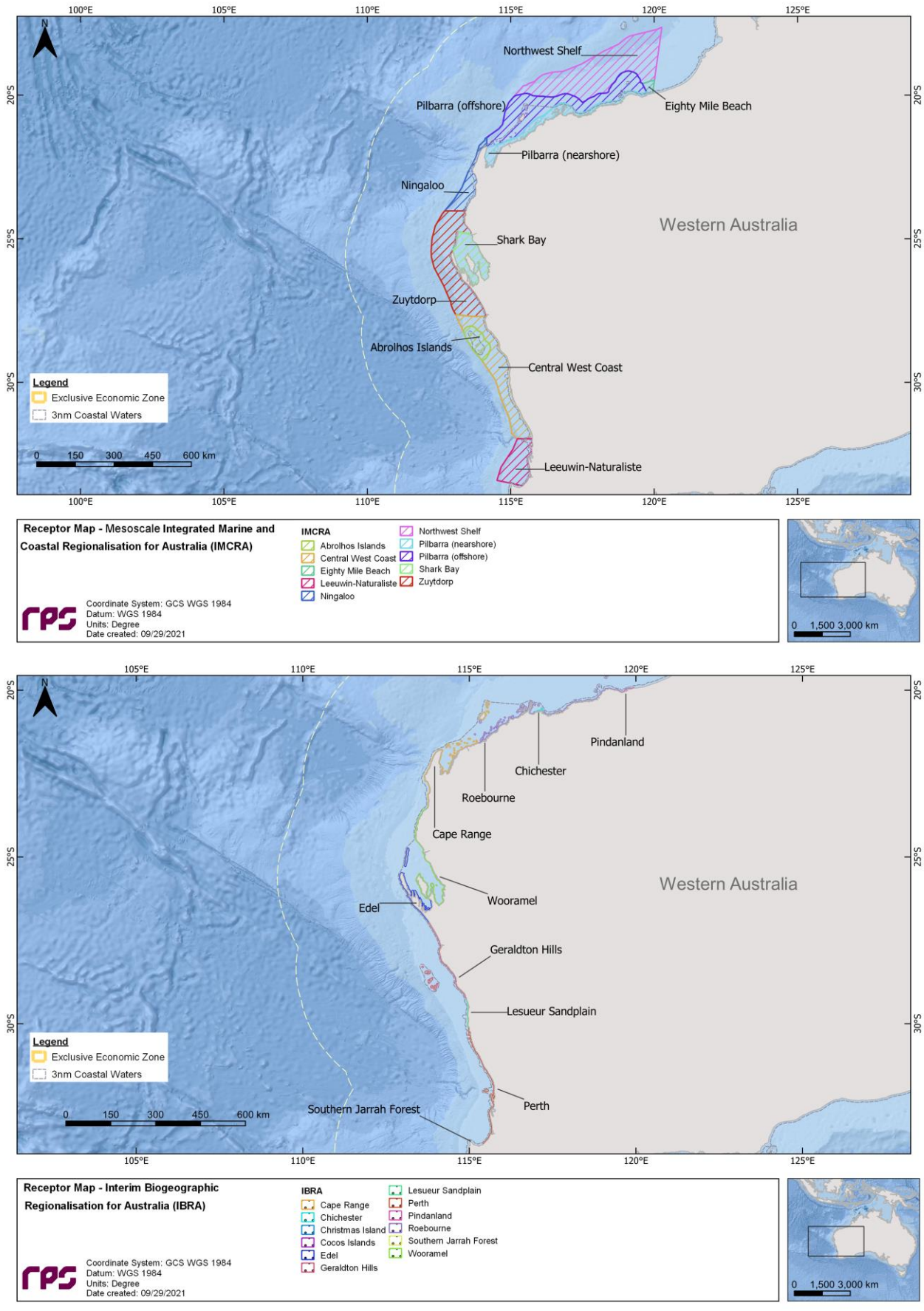


Figure 10.2 Receptor maps for Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

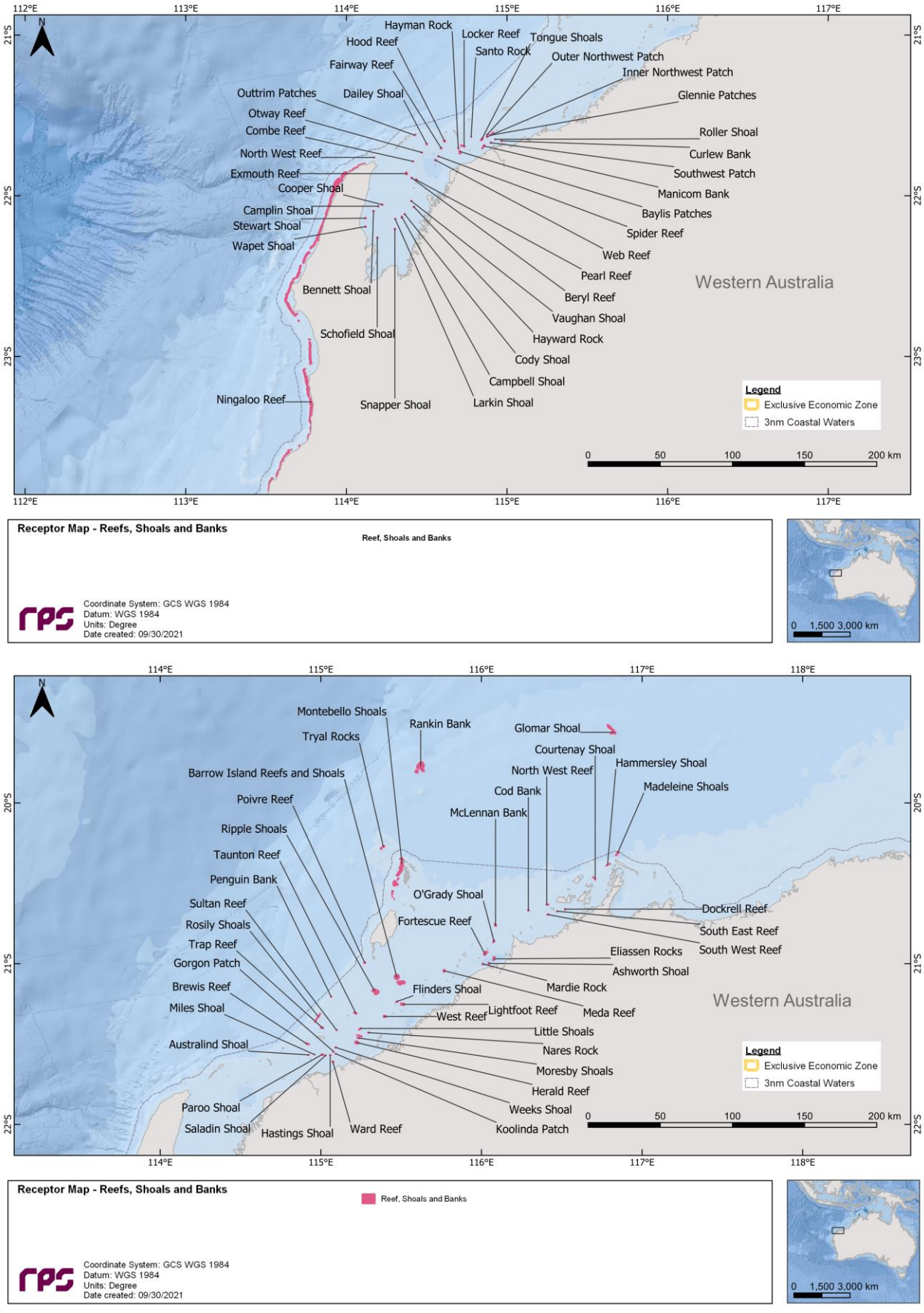


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

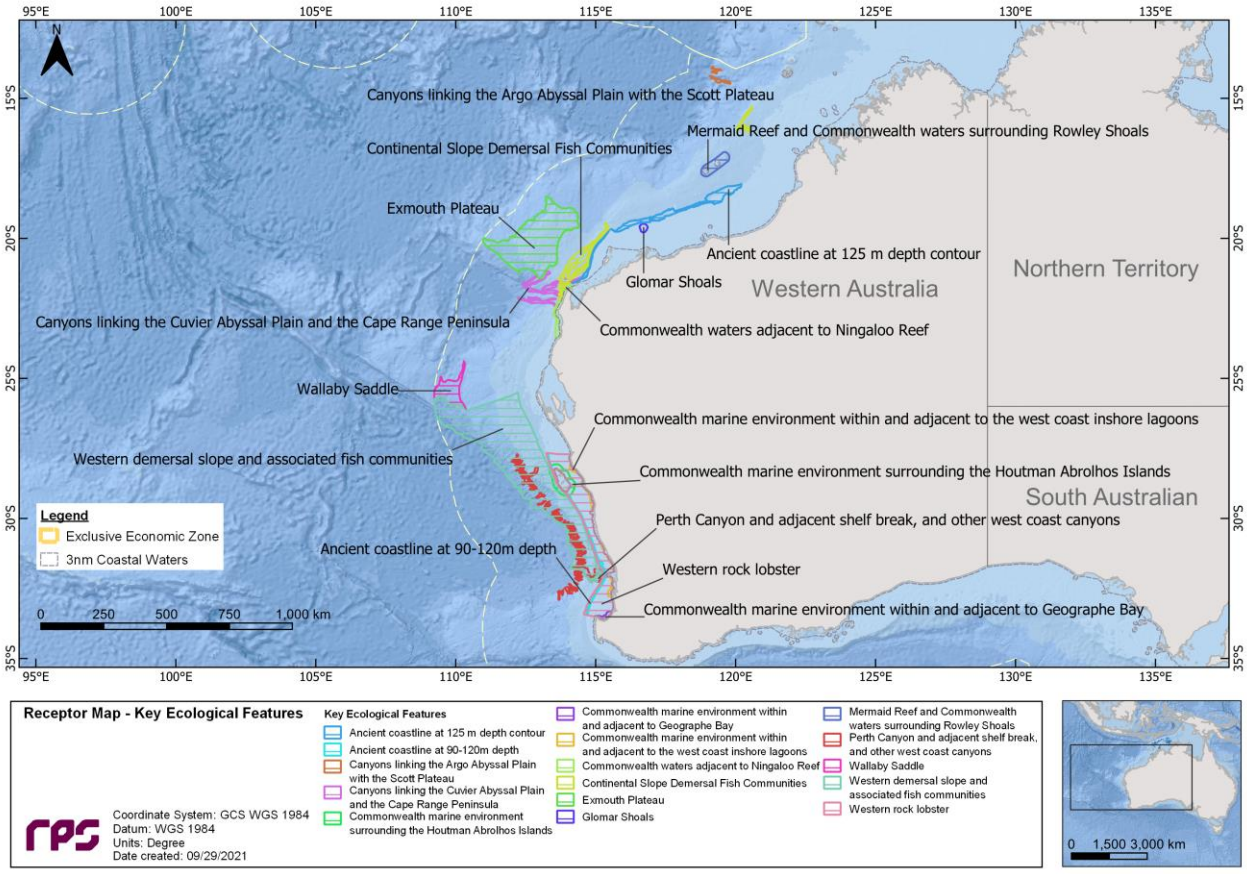


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

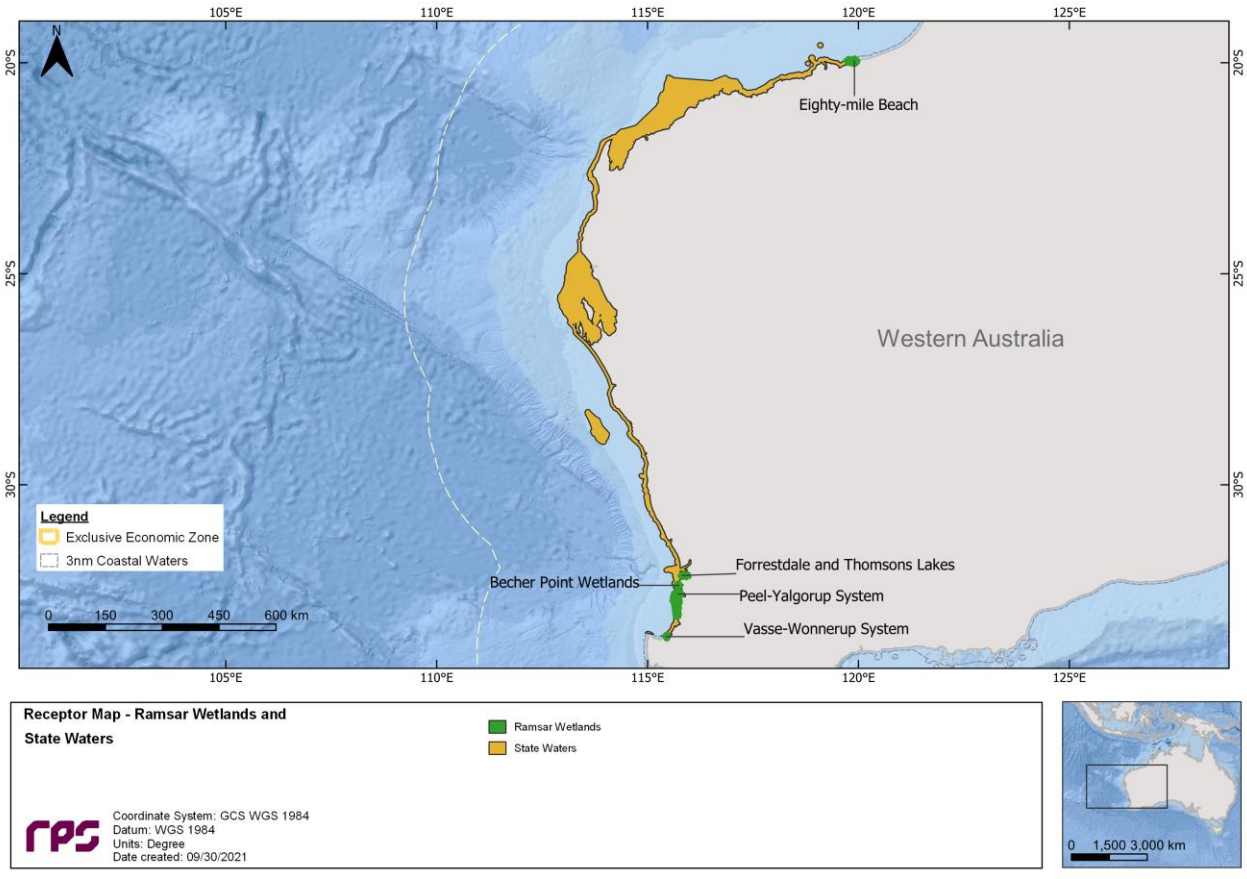


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

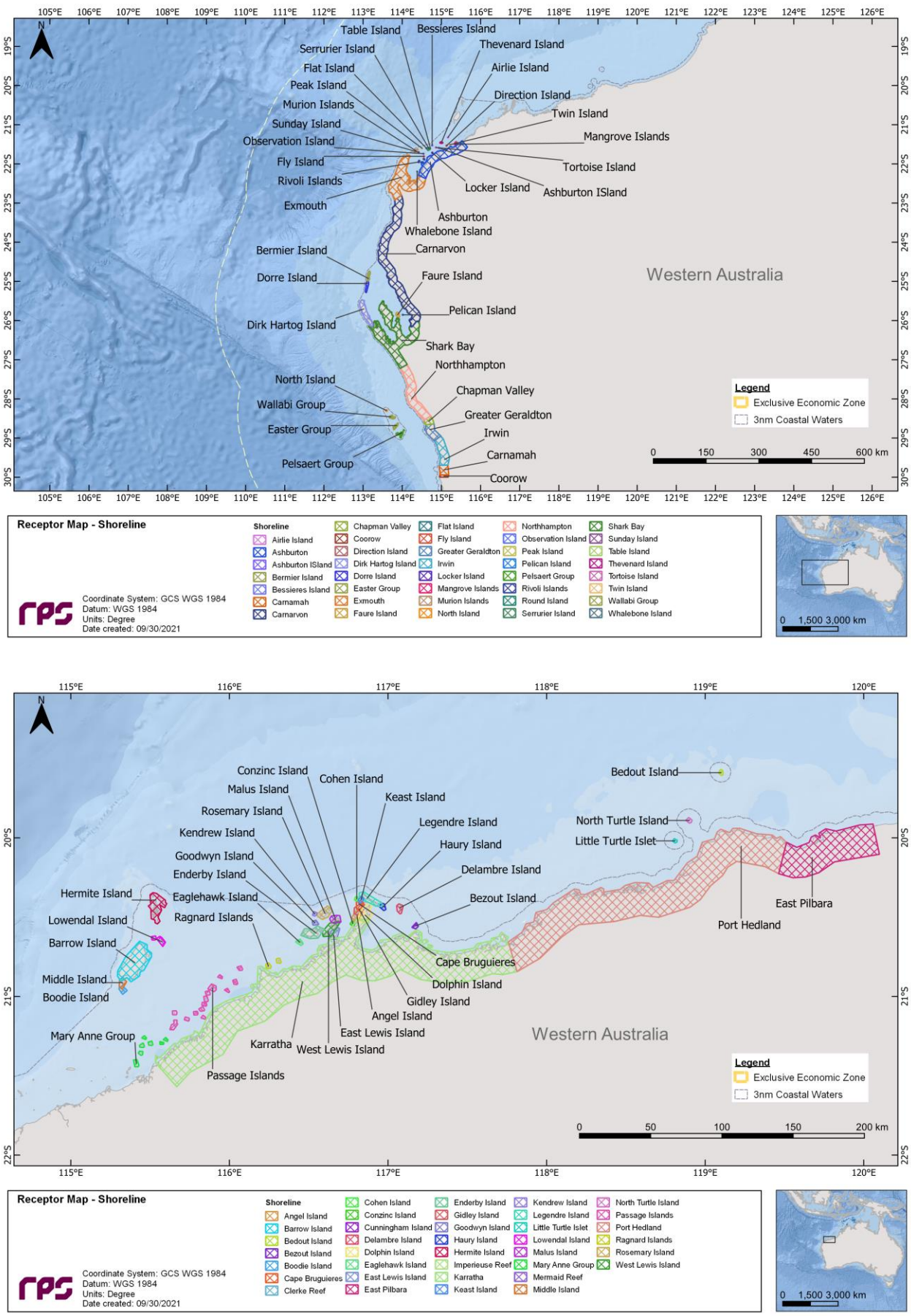


Figure 10.6 Receptor maps for Shorelines (1 of 2).

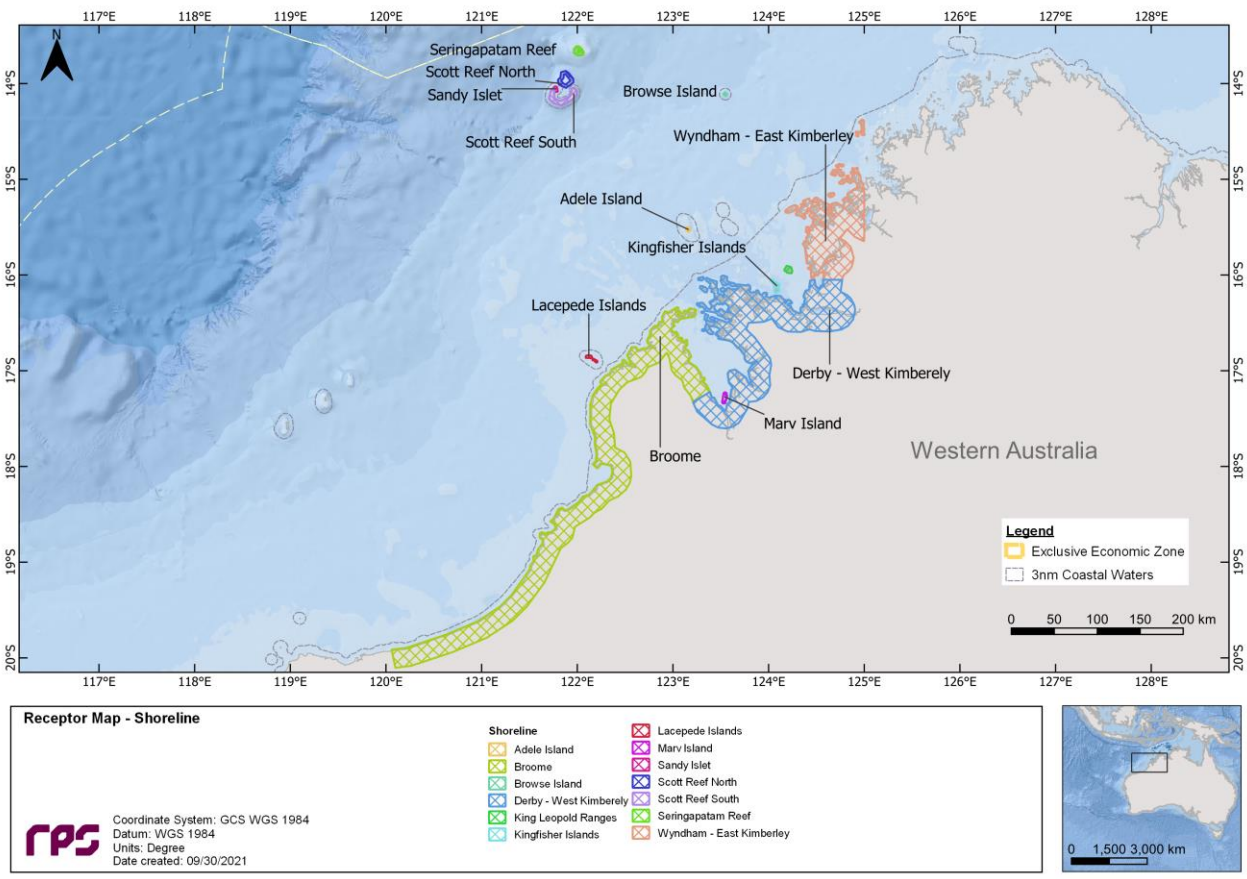


Figure 10.7 Receptor maps for Shorelines (2 of 2).

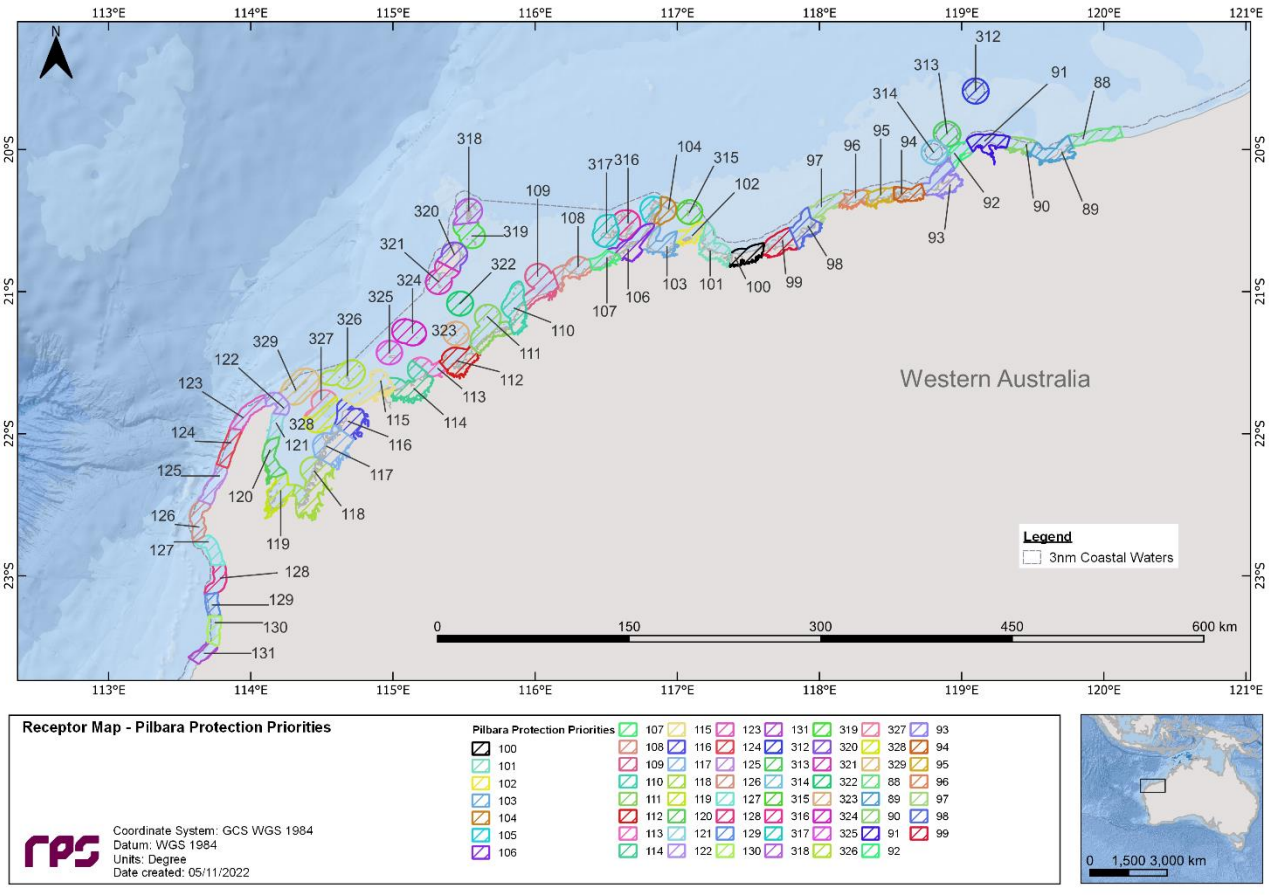


Figure 10.8 Receptor maps for Pilbara Protection Priorities Shorelines.

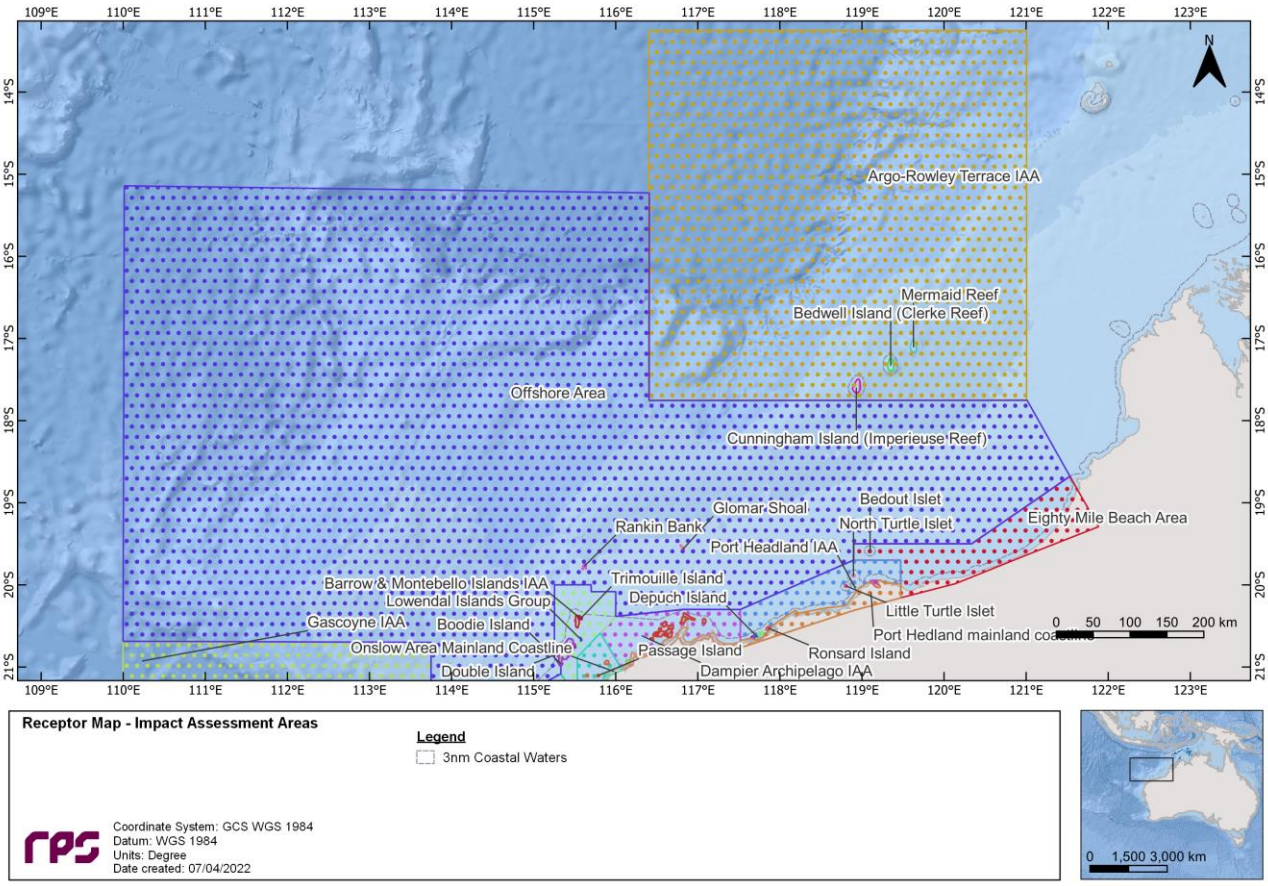


Figure 10.9 Receptor maps for Impact Assessment Areas (1 of 3).

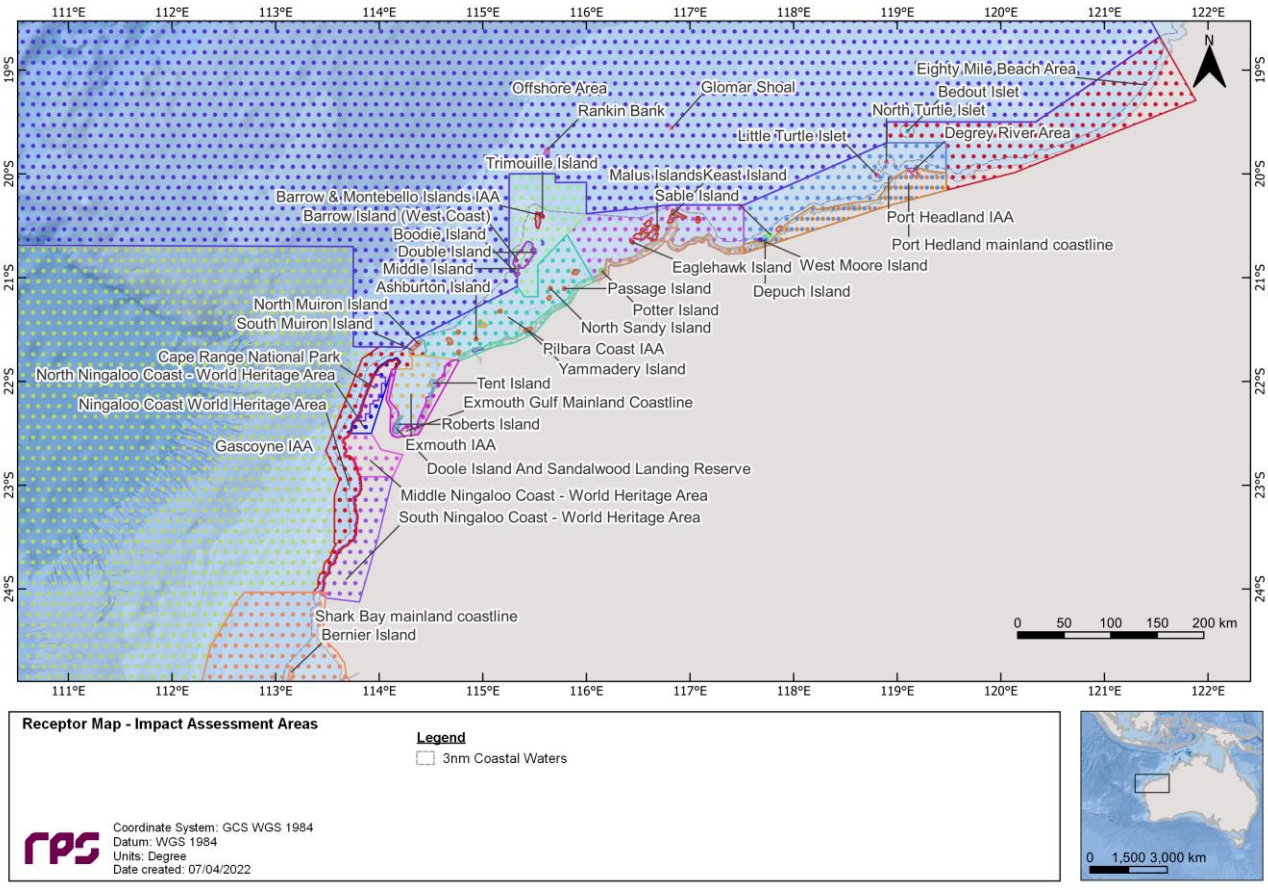


Figure 10.10 Receptor maps for Impact Assessment Areas (2 of 3).

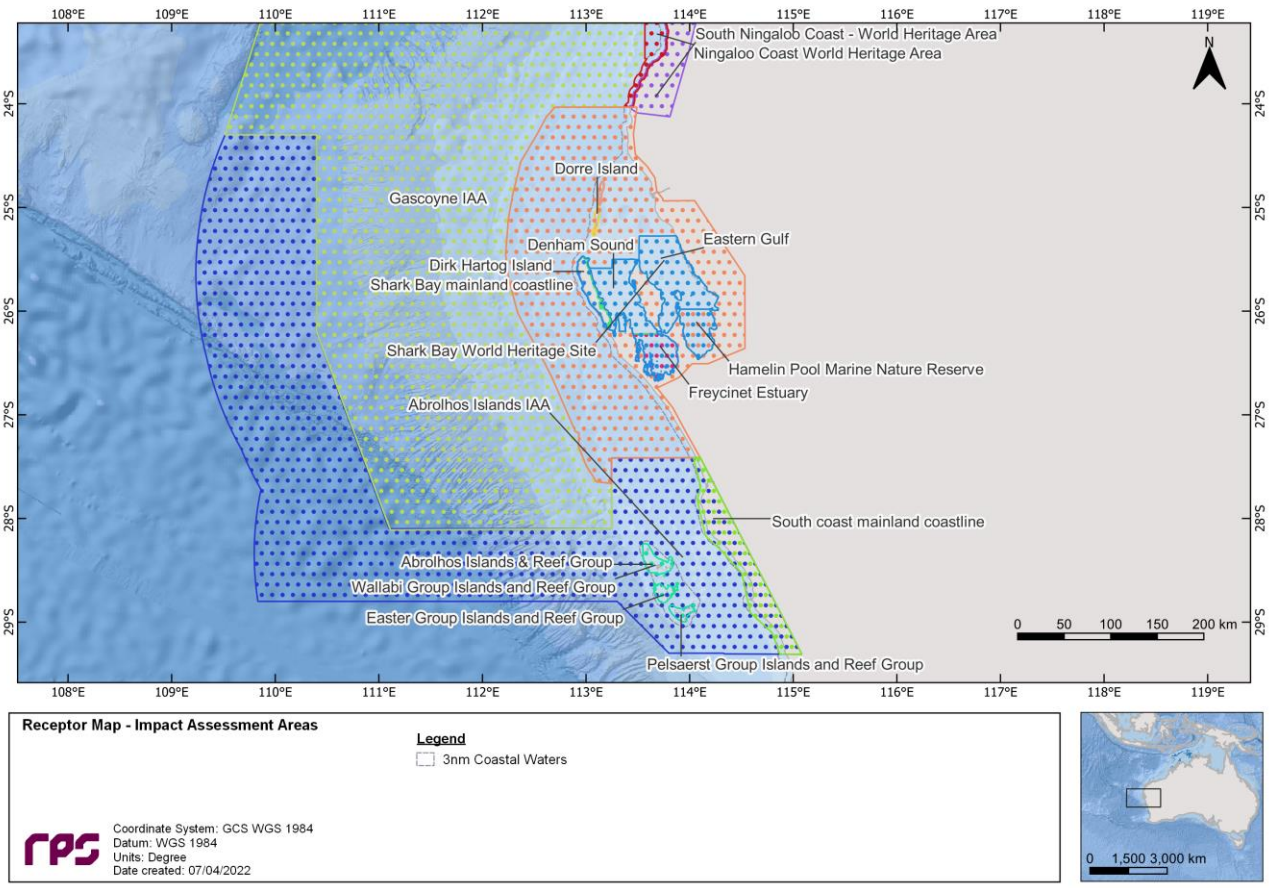


Figure 10.11 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: WEST TRYAL ROCKS LOSS OF WELL CONTROL

This scenario examined a 387,180 bbl (or 61,555 m^3) subsea release of condensate over 90 days, from a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season.

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) threshold was 251.7 West-southwest (summer), 45.9 km North-northwest (transitional) and 5.2 km West-northwest (transitional) and West-southwest (winter), respectively.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging BIAs, Pilbara (offshore) IMCRA, and the Ancient coastline at 125 m depth contour KEF, which the release location resides within (see Section 10.3), and the Montebello AMP, Flatback Turtle - Nesting and Humpback Whale - Migration BIAs, Barrow & Montebello Islands IAA and the Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low and moderate thresholds was 100% for all seasons for the receptors which the release location resides within. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting BIA ranged between 91–95% and 17–25%, whilst the probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 97–100% and 6–32%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 1.08 days and 0.71 days during summer conditions, respectively. Furthermore, the probability of exposure at the low threshold for the Montebello AMP and Continental Slope Demersal Fish Communities KEF was 77%, 60% and 59% during summer, transitional and winter conditions and 100%, 100% and 100% during summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure Montebello AMP and Continental Slope Demersal Fish Communities KEF was 1.21 days (winter) and 0.46 days (transitional and winter).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	251.7	45.9	4.9
	Max. distance from release site (km) (99th percentile)	107.5	39.1	4.9
	Direction	West-southwest	North-northwest	North
Transitional	Max. distance from release site (km)	177.1	42.8	5.2
	Max. distance from release site (km) (99th percentile)	127.7	37.5	5.2
	Direction	North	Northeast	West-northwest
Winter	Max. distance from release site (km)	169.7	43.5	5.2
	Max. distance from release site (km) (99th percentile)	114	37.1	5.2
	Direction	Northeast	Northeast	West-southwest

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	77	11	-	1.63	6.67	-	60	11	-	2.17	53.33	-	59	13	-	1.21	22.21	-
	Dugong - Breeding	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Calving	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Foraging	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Nursing	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fairy Tern - Breeding	12	-	-	7.25	-	-	1	-	-	79.21	-	-	-	-	-	-	-	-
	Flatback Turtle - Aggregation	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Foraging	6	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Flatback Turtle - Mating	6	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Nesting	91	25	-	1.08	6.54	-	95	17	-	2	3	-	91	22	-	1.71	20.75	-
	Green Turtle - Aggregation	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Foraging	8	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Internesting	8	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BIA	Green Turtle - Internesting Buffer	31	-	-	4.08	-	-	35	-	-	6.5	-	-	21	-	-	5.29	-	-
	Green Turtle - Mating	7	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Nesting	24	-	-	4.08	-	-	13	-	-	41.08	-	-	6	-	-	38.96	-	-
	Hawksbill Turtle - Foraging	2	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	30	-	-	4.08	-	-	33	-	-	7.13	-	-	21	-	-	5.29	-	-
	Hawksbill Turtle - Mating	2	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hawksbill Turtle - Nesting	24	-	-	4.08	-	-	13	-	-	41.08	-	-	6	-	-	38.96	-	-
	Humpback Whale - Migration	97	32	-	0.71	5.96	-	100	18	-	0.79	14.21	-	100	6	-	0.83	17.25	-
	Lesser Crested Tern - Breeding	11	-	-	5.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	16	-	-	5.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Nesting	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pygmy Blue Whale – Distribution*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Roseate Tern - Breeding	8	-	-	7.25	-	-	2	-	-	76.75	-	-	-	-	-	-	-	-
	Wedge-tailed Shearwater – Breeding*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Whale Shark – Foraging*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
EEZ	Australian Exclusive Economic Zone *	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Airlie Island	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	77	11	-	1.63	6.67	-	60	11	-	2.17	53.33	-	59	13	-	1.21	22.21	-
	Barrow Island Group	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IAA	Boodie Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Offshore Area*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
	Pilbara Coast IAA	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rankin Bank	2	-	-	48.96	-	-	5	-	-	75.13	-	-	6	-	-	42.29	-	-
IBRA	Cape Range	2	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Roebourne	3	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMCRA	Ningaloo	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Northwest Shelf	75	7	-	0.92	7.5	-	69	13	-	1.83	5.17	-	83	10	-	1.25	2.71	-
	Pilbara (offshore)*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
KEF	Ancient coastline at 125 m depth contour*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Continental Slope Demersal Fish Communities	100	53	-	0.67	2.83	-	100	46	-	0.46	3	-	100	61	-	0.46	3.04	-
MMA	Barrow Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MP	Montebello Islands	7	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RSB	Montebello Shoals	5	-	-	33.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Reef	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rankin Bank	2	-	-	48.96	-	-	5	-	-	75.13	-	-	6	-	-	42.29	-	-
	Tryal Rocks	5	-	-	48.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nearshore Waters	Airlie Island	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands	1	-	-	92.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
State Waters	Western Australia State Waters	9	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

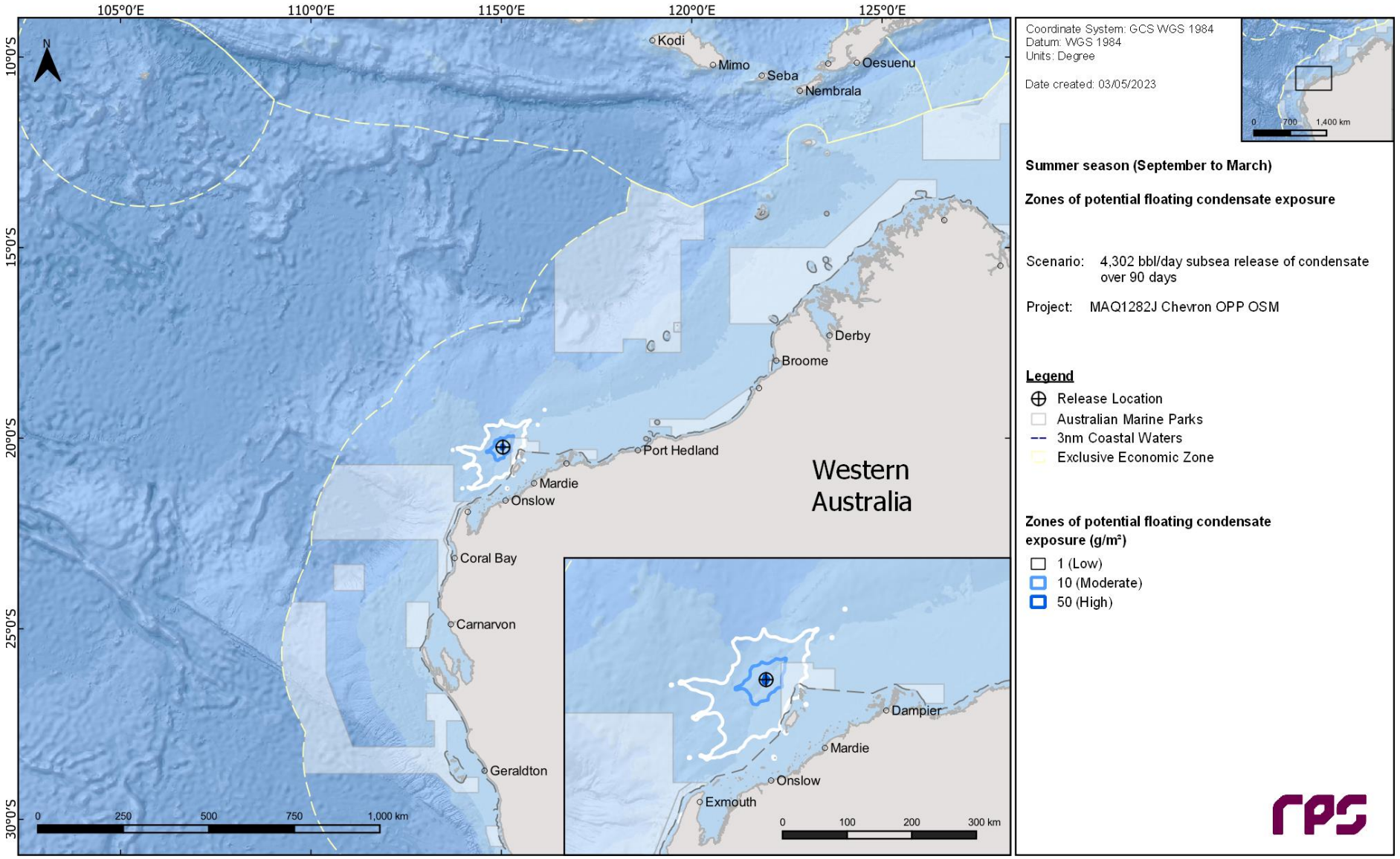


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

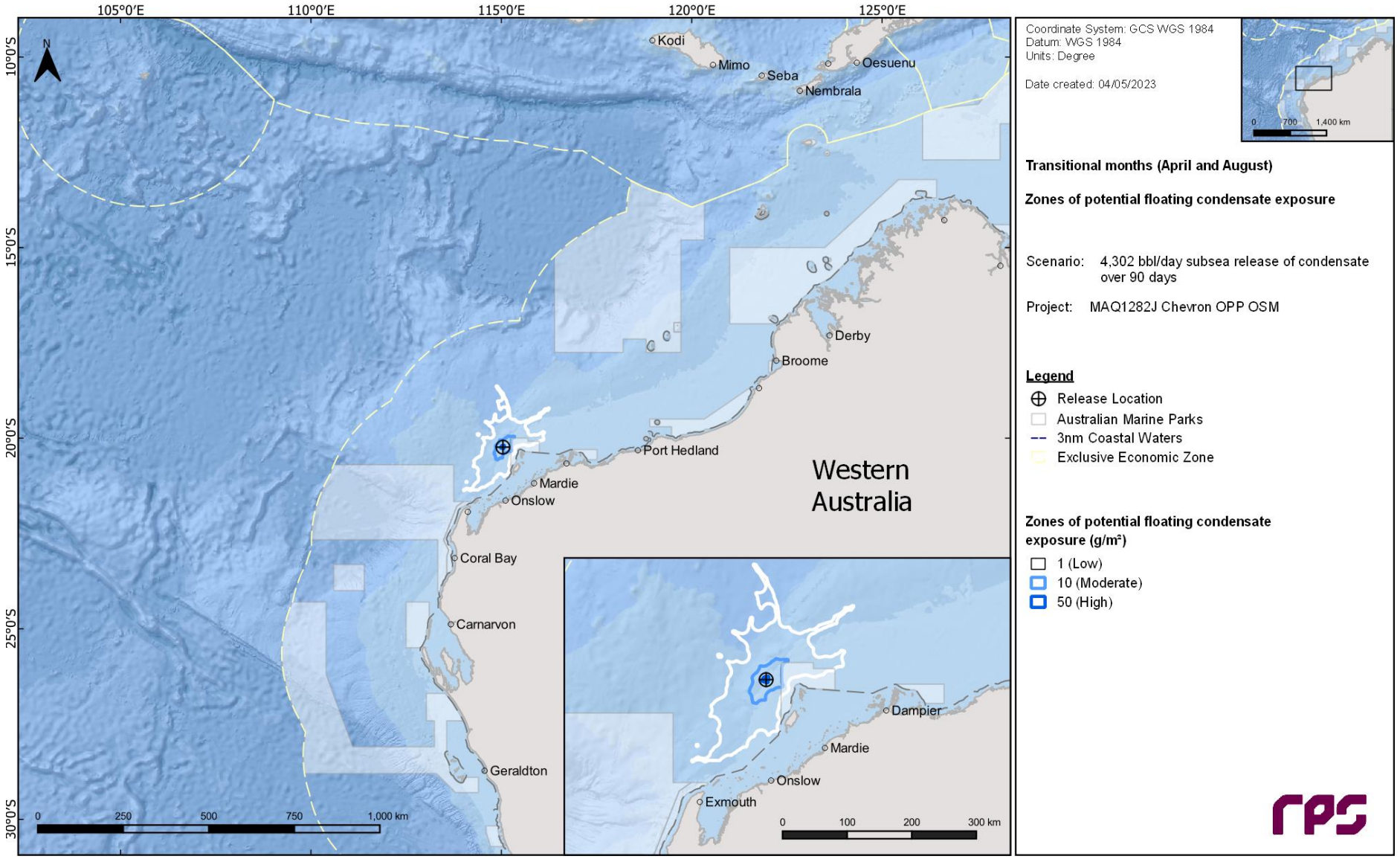


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

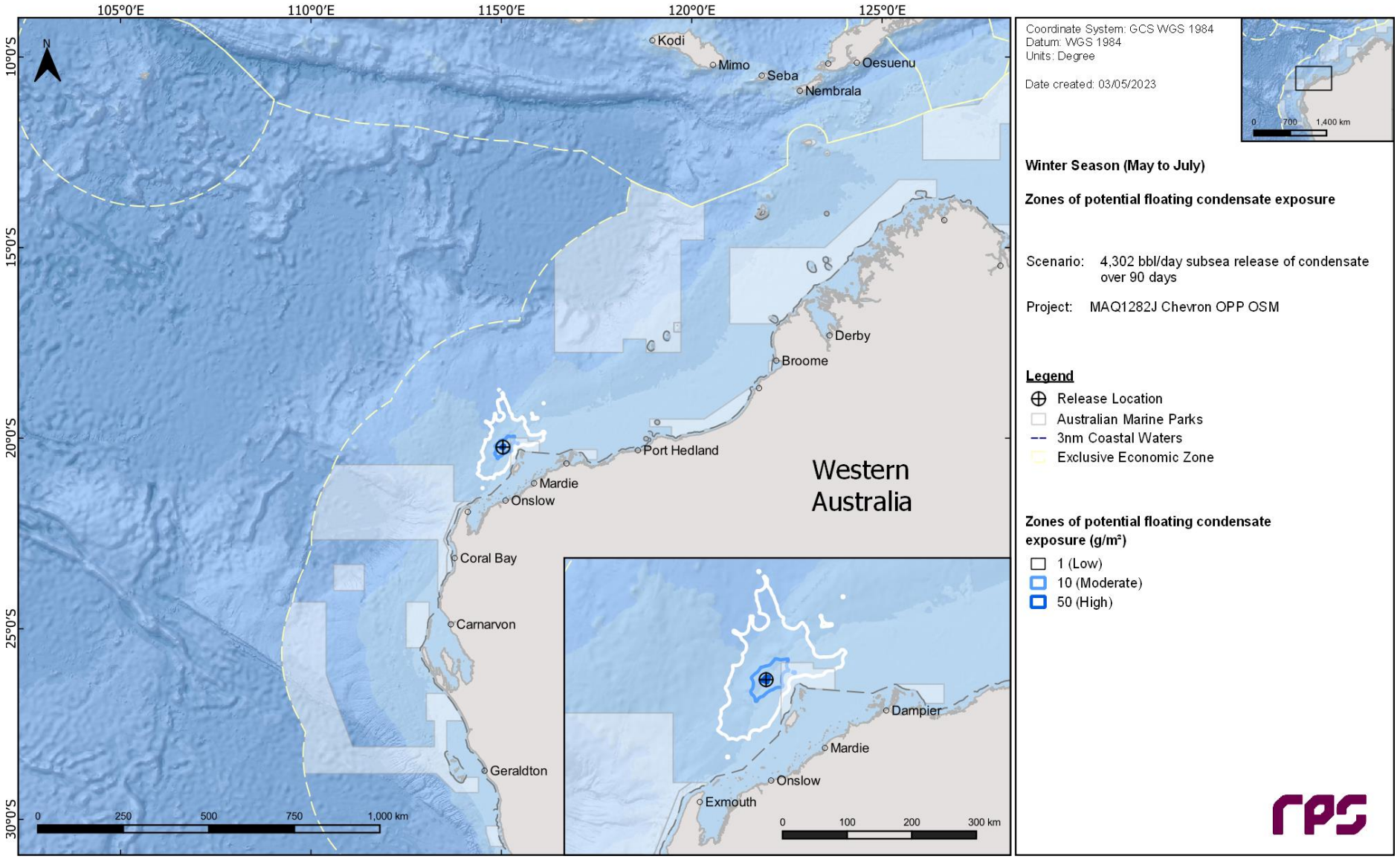


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 59%, while the minimum time before shoreline accumulation was 6.5 days and the maximum volume of oil ashore was 128 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, 82 shoreline receptors were predicted to record condensate accumulation at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (38%). In comparison, during transitional and winter conditions, 40 and 42 shoreline receptors, respectively, were predicted to record accumulation, with the greatest probability during transitional season occurring at the Ningaloo Coast World Heritage Area IAA and the Muiron Islands (30%) and at the Ningaloo Coast World Heritage Area IAA only during winter (30%).

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.6.

Table 11.3 Summary of oil accumulation across all shorelines for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	59	38	45
Absolute minimum time for visible oil to shore (days)	6.5	7.75	10.79
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	128	27.5	4.8
Average volume of hydrocarbons ashore (m^3) above the low threshold	27.1	3.2	1.6
Maximum length of the shoreline at **10 g/m^2** (km)	155	39	13
Average shoreline length (km) at **10 g/m^2** (km)	47.2	9.2	4.9
Maximum length of the shoreline at **100 g/m^2** (km)	38	7	-
Average shoreline length (km) at **100 g/m^2** (km)	12.6	4.7	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	26	15	-	7.63	8.5	-	35	507	14.4	53	18.8	7.8	-	31.7	19.2	-
	South Muiron Island	23	-	-	26.58	-	-	9	95	0.8	5.9	2.6	-	-	10.6	-	-
	Thevenard Island	13	-	-	11.54	-	-	9	32	0.6	1.6	2.4	-	-	5.8	-	-
	Serrurier Island	23	-	-	10.13	-	-	11	62	1.1	2.9	4.7	-	-	9.6	-	-
	Bessieres Island	13	-	-	15.17	-	-	11	56	0.4	1.7	1.5	-	-	3.8	-	-
	Locker Island	2	-	-	16.08	-	-	8	19	0.1	0.3	1	-	-	1	-	-
	Airlie Island	13	3	-	11.79	81.04	-	57	402	2	9.3	2.1	1.9	-	2.9	1.9	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	23	-	-	9	-	-	10	62	0.7	2.6	2.6	-	-	5.8	-	-
	Great Sandy Island	12	-	-	17.63	-	-	16	77	0.7	2.7	2	-	-	3.8	-	-
	North Sandy Island	9	-	-	13	-	-	17	50	0.4	1	1.5	-	-	1.9	-	-
	Passage Island	3	-	-	33.88	-	-	11	39	0.1	0.5	1	-	-	1	-	-
	Sholl Island	11	-	-	14.67	-	-	11	45	0.8	1.4	3.1	-	-	5.8	-	-
	Eaglehawk Island	2	-	-	92.46	-	-	8	13	0.1	0.2	1	-	-	1	-	-
	Enderby Island	2	-	-	92.79	-	-	5	13	0.2	0.5	1.4	-	-	1.9	-	-
	Rosemary Island	3	-	-	90.04	-	-	7	19	0.3	1	1.9	-	-	2.9	-	-
	Goodwyn Island	1	-	-	34.79	-	-	6	11	< 0.1	0.1	1	-	-	1	-	-
	Malus Islands	2	-	-	91.33	-	-	7	14	0.2	0.5	1	-	-	1	-	-
	Boodie Island	21	10	-	7.04	9.88	-	75	853	5.8	18.7	3.9	2.9	-	6.7	3.8	-
	Middle Island	23	11	-	7.13	8.17	-	86	706	8.3	23.4	6.1	3.8	-	7.7	5.8	-
	Double Island	2	-	-	67.08	-	-	7	17	0.1	0.4	1	-	-	1	-	-
	Bedwell Island (Clerke Reef)	2	-	-	82.5	-	-	10	13	0.2	0.2	1	-	-	1	-	-
	Cunningham Island (Imperieuse Reef)	2	-	-	88.29	-	-	4	14	0.2	0.6	1	-	-	1	-	-
	South Ningaloo Coast - World Heritage Area	1	-	-	68.25	-	-	6	16	0.4	0.8	1	-	-	1	-	-
	Middle Ningaloo Coast - World Heritage Area	16	-	-	11	-	-	8	60	2	5.2	6.7	-	-	14.4	-	-
	North Ningaloo Coast - World Heritage Area	25	4	-	10.33	11.08	-	10	172	2.7	9.4	9.2	1	-	26	1	-
	Cape Range National Park	21	3	-	10.25	10.54	-	11	256	4.7	36.5	12.1	4.2	-	44.2	6.7	-
	Ningaloo Coast World Heritage Area	35	6	-	9	10.54	-	12	256	5.8	29.9	14.1	2.4	-	39.4	5.8	-
	Argo-Rowley Terrace IAA	3	-	-	82.5	-	-	4	14	0.3	0.9	1.3	-	-	1.9	-	-
	Dampier Archipelago IAA	10	-	-	16.08	-	-	6	27	1.3	5.1	3.7	-	-	13.5	-	-
	Abutilon Island	4	-	-	32.33	-	-	12	37	0.1	0.4	1	-	-	1	-	-
	Varanus Island	14	-	-	9.33	-	-	11	44	0.4	0.9	1.6	-	-	2.9	-	-
	Trimouille Island	14	2	-	14.71	15.21	-	11	168	0.8	6.1	2.5	1.4	-	7.7	1.9	-
	Hermite Island	34	8	-	6.5	24.29	-	23	178	4.8	15.1	10	2.3	-	17.3	3.8	-
	Barrow & Montebello Islands IAA	38	17	-	6.5	7.67	-	27	853	27.8	124.6	37.4	14.3	-	83.7	36.6	-
	Pilbara Coast IAA	32	3	-	9.17	81.04	-	12	402	5.4	26.4	15	2.6	-	43.3	2.9	-
	Exmouth IAA	9	-	-	15.13	-	-	6	29	0.4	1	1	-	-	1	-	-
	Onslow Area Mainland Coastline	9	-	-	26.17	-	-	6	40	1.2	4.6	5	-	-	13.5	-	-
	Dampier mainland coastline	3	-	-	89.5	-	-	6	27	0.4	1.8	2.6	-	-	4.8	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Shoreline	Dampier Archipelago Island Group	4	-	-	34.79	-	-	6	19	0.6	2	3.4	-	-	5.8	-	-
	Lowendal Islands Group	15	-	-	9.33	-	-	11	44	0.4	1.3	1.7	-	-	3.8	-	-
	Montebello Islands Group	34	10	-	6.5	15.21	-	20	178	5.3	16	11	2.1	-	22.1	3.8	-
	Barrow Island Group	28	16	-	7.04	8.17	-	43	853	24.7	94.3	25.5	11.8	-	45.2	28.9	-
	Pilbara Mainland Coast	9	-	-	26.17	-	-	6	40	1.2	4.6	5	-	-	13.5	-	-
	Pilbara Coast Islands Group	27	3	-	10.13	81.04	-	15	402	3.2	13.2	8.6	1.9	-	22.1	1.9	-
	Exmouth Gulf Mainland Coastline	5	-	-	15.13	-	-	6	29	0.3	0.7	1	-	-	1	-	-
	Muiron Islands	29	-	-	9	-	-	9	95	1.4	8.5	4.1	-	-	15.4	-	-
	Airlie Island	13	3	-	11.79	81.04	-	57	402	2	9.3	2.1	1.9	-	2.9	1.9	-
	Ashburton	7	-	-	15.13	-	-	6	29	0.4	0.8	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	26	15	-	7.63	8.5	-	37	706	16.4	61.8	20.1	8.3	-	33.7	20.2	-
	Bessieres Island	13	-	-	15.17	-	-	11	56	0.4	1.7	1.5	-	-	3.8	-	-
	Boodie Island	22	11	-	7.04	8.63	-	78	853	7	22.6	4.6	3.3	-	7.7	4.8	-
	Carnarvon	1	-	-	68.25	-	-	6	16	0.4	0.8	1	-	-	1	-	-
	Clerke Reef	2	-	-	82.5	-	-	10	13	0.2	0.2	1	-	-	1	-	-
	Cunningham Island	1	-	-	88.29	-	-	4	10	0.2	0.4	1	-	-	1	-	-
	Direction Island	3	-	-	32.58	-	-	13	32	0.2	0.4	1	-	-	1	-	-
	Eaglehawk Island	2	-	-	92.46	-	-	8	13	0.1	0.2	1	-	-	1	-	-
	Enderby Island	2	-	-	92.79	-	-	5	13	0.2	0.5	1.4	-	-	1.9	-	-
	Exmouth	26	6	-	10.25	10.54	-	10	256	7.5	46.4	22.7	2.7	-	63.5	7.7	-
	Flat Island	18	-	-	10.42	-	-	12	45	0.4	1.3	2	-	-	2.9	-	-
	Fly Island	3	-	-	24.25	-	-	7	14	0.1	0.3	1	-	-	1	-	-
	Goodwyn Island	1	-	-	34.79	-	-	6	11	< 0.1	0.1	1	-	-	1	-	-
	Imperieuse Reef	1	-	-	90.88	-	-	5	14	0.2	0.5	1	-	-	1	-	-
	Karratha	7	-	-	26.17	-	-	6	40	1.4	6.7	7.8	-	-	20.2	-	-
	Kendrew Island	1	-	-	92.13	-	-	8	13	< 0.1	0.2	1	-	-	1	-	-
	Locker Island	2	-	-	16.08	-	-	8	19	0.1	0.3	1	-	-	1	-	-
	Lowendal Island	20	8	-	7.63	32.13	-	19	224	2.3	7	5.4	1.3	-	9.6	1.9	-
	Malus Island	2	-	-	91.33	-	-	7	14	0.2	0.5	1	-	-	1	-	-
	Mary Anne Group	9	2	-	15.5	92.17	-	14	130	0.9	4.7	2.7	1	-	6.7	1	-
	Middle Island	24	11	-	7.08	8.17	-	86	706	10.4	32.6	7.4	5.1	-	9.6	7.7	-
	Montebello Islands	36	13	-	6.5	7.67	-	20	192	8.2	24.9	16.6	3.3	-	31.7	6.7	-
	Muiron Islands	29	-	-	9	-	-	9	95	1.4	8.5	4.1	-	-	15.4	-	-
	Observation Island	6	-	-	12.75	-	-	11	41	0.2	0.8	1.4	-	-	1.9	-	-
	Passage Islands	14	-	-	13	-	-	11	86	3.6	8.2	10.9	-	-	21.2	-	-
	Peak Island	14	-	-	9.17	-	-	13	40	0.2	0.5	1	-	-	1	-	-
	Rivoli Islands	1	-	-	66.83	-	-	6	17	0.1	0.2	1	-	-	1	-	-
	Rosemary Island	3	-	-	90.04	-	-	6	19	0.3	1	1.9	-	-	2.9	-	-
	Round Island	6	-	-	28.67	-	-	11	25	0.1	0.3	1	-	-	1	-	-
	Serrurier Island	23	-	-	10.13	-	-	11	62	1.1	2.9	4.7	-	-	9.6	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Sunday Island	14	-	-	18	-	-	12	49	0.2	1	1.2	-	-	1.9	-	-
	Table Island	7	-	-	22.04	-	-	11	27	0.1	0.3	1	-	-	1	-	-
	Thevenard Island	13	-	-	11.54	-	-	9	32	0.6	1.6	2.4	-	-	5.8	-	-
	Tortoise Island	6	-	-	10.96	-	-	10	18	0.1	0.2	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	5	3	-	78.54	80.67	-	20	158	2.5	6.5	7.1	1.6	-	8.7	1.9	-
	South Muiron Island	19	-	-	7.75	-	-	8	42	0.5	1.1	1.8	-	-	3.8	-	-
	Thevenard Island	9	-	-	21.04	-	-	7	22	0.3	0.6	1.1	-	-	1.9	-	-
	Serrurier Island	6	-	-	24.58	-	-	8	24	0.3	0.8	1.4	-	-	1.9	-	-
	Bessieres Island	4	1	-	11.13	23.75	-	13	121	0.5	2.3	2.4	1	-	2.9	1	-
	Locker Island	1	-	-	96.46	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Airlie Island	1	-	-	59.13	-	-	8	13	0.2	0.2	1	-	-	1	-	-
	Ashburton Island	1	-	-	97.13	-	-	9	14	0.1	0.2	1	-	-	1	-	-
	North Muiron Island	27	-	-	8.08	-	-	9	38	0.5	1.1	1.8	-	-	3.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	5	5	-	77.71	78.75	-	68	176	5	7.4	5.2	2.5	-	5.8	3.8	-
	Middle Island	5	5	-	77.79	78.63	-	61	221	5.1	8.3	6.7	1.7	-	6.7	1.9	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	10	-	-	43.96	-	-	8	35	0.7	1.3	2.6	-	-	3.8	-	-
	Cape Range National Park	7	-	-	43.79	-	-	6	41	0.4	0.9	1.4	-	-	1.9	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Shoreline	Ningaloo Coast World Heritage Area	30	-	-	7.75	-	-	8	42	1.1	2.5	3.6	-	-	8.7	-	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	5	-	-	80.75	-	-	8	58	1	3.8	9	-	-	11.5	-	-
	Barrow & Montebello Islands IAA	6	5	-	77.71	78.63	-	12	221	4.9	27.5	25.7	5.2	-	37.5	6.7	-
	Pilbara Coast IAA	19	1	-	11.13	23.75	-	9	121	0.9	3.1	3.3	1	-	6.7	1	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	5	-	-	80.75	-	-	8	58	1	3.9	9	-	-	11.5	-	-
	Barrow Island Group	5	5	-	77.71	78.63	-	28	221	7.8	22.2	19	5.2	-	20.2	6.7	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	11	1	-	11.13	23.75	-	11	121	0.6	2.5	1.9	1	-	3.8	1	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	30	-	-	7.75	-	-	8	42	0.9	2.2	2.8	-	-	6.7	-	-
	Airlie Island	1	-	-	59.13	-	-	8	13	0.2	0.2	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	1	-	-	97.13	-	-	9	14	0.1	0.2	1	-	-	1	-	-
	Barrow Island	5	5	-	77.79	78.63	-	24	221	3.7	10.4	9	2.5	-	10.6	3.8	-
	Bessieres Island	4	1	-	11.13	23.75	-	13	121	0.5	2.3	2.4	1	-	2.9	1	-
	Boodie Island	5	5	-	77.71	78.75	-	69	176	5.9	9.1	6.2	2.7	-	6.7	4.8	-
	Carnarvon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clerke Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	10	-	-	43.79	-	-	7	41	0.7	2	3.6	-	-	5.8	-	-
	Flat Island	9	-	-	28.42	-	-	8	25	0.3	0.7	1.5	-	-	2.9	-	-
	Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Locker Island	1	-	-	96.46	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Lowendal Island	2	-	-	85.38	-	-	5	15	0.1	0.3	1	-	-	1	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	5	5	-	77.75	78.63	-	58	221	6.3	11	8.7	2.1	-	8.7	2.9	-
	Montebello Islands	6	-	-	80.75	-	-	8	58	1.1	5	9.5	-	-	16.4	-	-
	Muiron Islands	30	-	-	7.75	-	-	8	42	0.9	2.2	2.8	-	-	6.7	-	-
	Observation Island	2	-	-	91.17	-	-	8	14	0.1	0.3	1	-	-	1	-	-
	Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peak Island	12	-	-	29.29	-	-	15	34	0.2	0.4	1	-	-	1	-	-
	Rivoli Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Round Island	4	-	-	85.33	-	-	21	40	0.3	0.5	1	-	-	1	-	-
	Serrurier Island	6	-	-	24.58	-	-	8	24	0.3	0.8	1.4	-	-	1.9	-	-
	Sunday Island	3	-	-	31.88	-	-	7	19	0.1	0.3	1	-	-	1	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	9	-	-	21.04	-	-	7	22	0.3	0.6	1.1	-	-	1.9	-	-
	Tortoise Island	1	-	-	96.13	-	-	7	11	< 0.1	0.1	1	-	-	1	-	-

Table 11.6 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	2	-	-	31.96	-	-	6	15	0.1	0.2	1	-	-	1	-	-
	South Muiron Island	17	-	-	16.08	-	-	7	26	0.4	1.2	2	-	-	3.8	-	-
	Thevenard Island	8	-	-	19.42	-	-	7	18	0.3	0.7	1.3	-	-	1.9	-	-
	Serrurier Island	10	-	-	19.29	-	-	7	38	0.3	1.1	1.6	-	-	2.9	-	-
	Bessieres Island	4	-	-	28.38	-	-	7	20	0.1	0.4	1	-	-	1	-	-
	Locker Island	1	-	-	59.92	-	-	8	12	< 0.1	0.1	1	-	-	1	-	-
	Airlie Island	1	-	-	40.33	-	-	7	17	0.1	0.2	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	25	-	-	10.79	-	-	9	32	0.4	1.4	1.8	-	-	4.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	3	-	-	39.96	-	-	9	27	0.2	0.3	1	-	-	1	-	-
	Middle Island	2	-	-	51.71	-	-	6	12	0.1	0.2	1	-	-	1	-	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	1	-	-	98.71	-	-	5	10	0.1	0.2	1	-	-	1	-	-
	Cunningham Island (Imperieuse Reef)	5	-	-	72.13	-	-	6	19	0.5	0.9	1.5	-	-	2.9	-	-
	South Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	11	-	-	33.54	-	-	6	23	0.6	1.2	1.9	-	-	3.8	-	-
	North Ningaloo Coast - World Heritage Area	7	-	-	18.79	-	-	8	34	0.6	1.6	2.6	-	-	3.8	-	-
	Cape Range National Park	5	-	-	18.5	-	-	6	20	0.3	1.2	1.3	-	-	1.9	-	-
	Ningaloo Coast World Heritage Area	30	-	-	10.79	-	-	7	34	0.9	3.2	3.8	-	-	9.6	-	-
	Argo-Rowley Terrace IAA	5	-	-	72.13	-	-	6	19	0.6	1	1.7	-	-	2.9	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	6	-	-	31.96	-	-	7	27	0.3	0.7	1.1	-	-	1.9	-	-
	Pilbara Coast IAA	17	-	-	19.29	-	-	7	43	0.7	2.7	3.9	-	-	10.6	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	6	-	-	31.96	-	-	7	27	0.3	0.7	1.1	-	-	1.9	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	11	-	-	19.29	-	-	7	38	0.4	1.5	2	-	-	3.8	-	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	29	-	-	10.79	-	-	8	32	0.6	2	2.8	-	-	5.8	-	-
Shoreline	Airlie Island	1	-	-	40.33	-	-	7	17	0.1	0.2	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	3	-	-	31.96	-	-	6	15	0.2	0.3	1	-	-	1	-	-
	Bessieres Island	4	-	-	28.38	-	-	7	20	0.1	0.4	1	-	-	1	-	-
	Boodie Island	3	-	-	39.96	-	-	9	27	0.2	0.3	1	-	-	1	-	-
	Carnarvon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clerke Reef	1	-	-	98.71	-	-	5	10	0.1	0.2	1	-	-	1	-	-
	Cunningham Island	1	-	-	95.58	-	-	5	11	0.2	0.3	1	-	-	1	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	17	-	-	18.5	-	-	6	34	0.8	2.5	2.7	-	-	4.8	-	-
Flat Island	8	-	-	21.29	-	-	9	25	0.3	0.7	1.4	-	-	2.9	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	5	-	-	72.13	-	-	7	19	0.4	0.8	1.5	-	-	2.9	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Locker Island	1	-	-	59.92	-	-	8	12	< 0.1	0.1	1	-	-	1	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	2	-	-	51.71	-	-	6	12	0.1	0.2	1	-	-	1	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	29	-	-	10.79	-	-	8	32	0.6	2	2.8	-	-	5.8	-	-
Observation Island	2	-	-	37.04	-	-	8	16	0.1	0.2	1	-	-	1	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	13	-	-	20.08	-	-	13	43	0.2	0.5	1	-	-	1	-	-
Rivoli Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	4	-	-	21.67	-	-	8	18	0.1	0.2	1	-	-	1	-	-
Serrurier Island	10	-	-	19.29	-	-	7	38	0.3	1.1	1.6	-	-	2.9	-	-
Sunday Island	4	-	-	22.83	-	-	8	18	0.1	0.3	1	-	-	1	-	-
Table Island	3	-	-	35.08	-	-	10	22	0.1	0.3	1	-	-	1	-	-
Thevenard Island	8	-	-	19.42	-	-	7	18	0.3	0.7	1.3	-	-	1.9	-	-
Tortoise Island	1	-	-	37.08	-	-	10	19	0.1	0.2	1	-	-	1	-	-

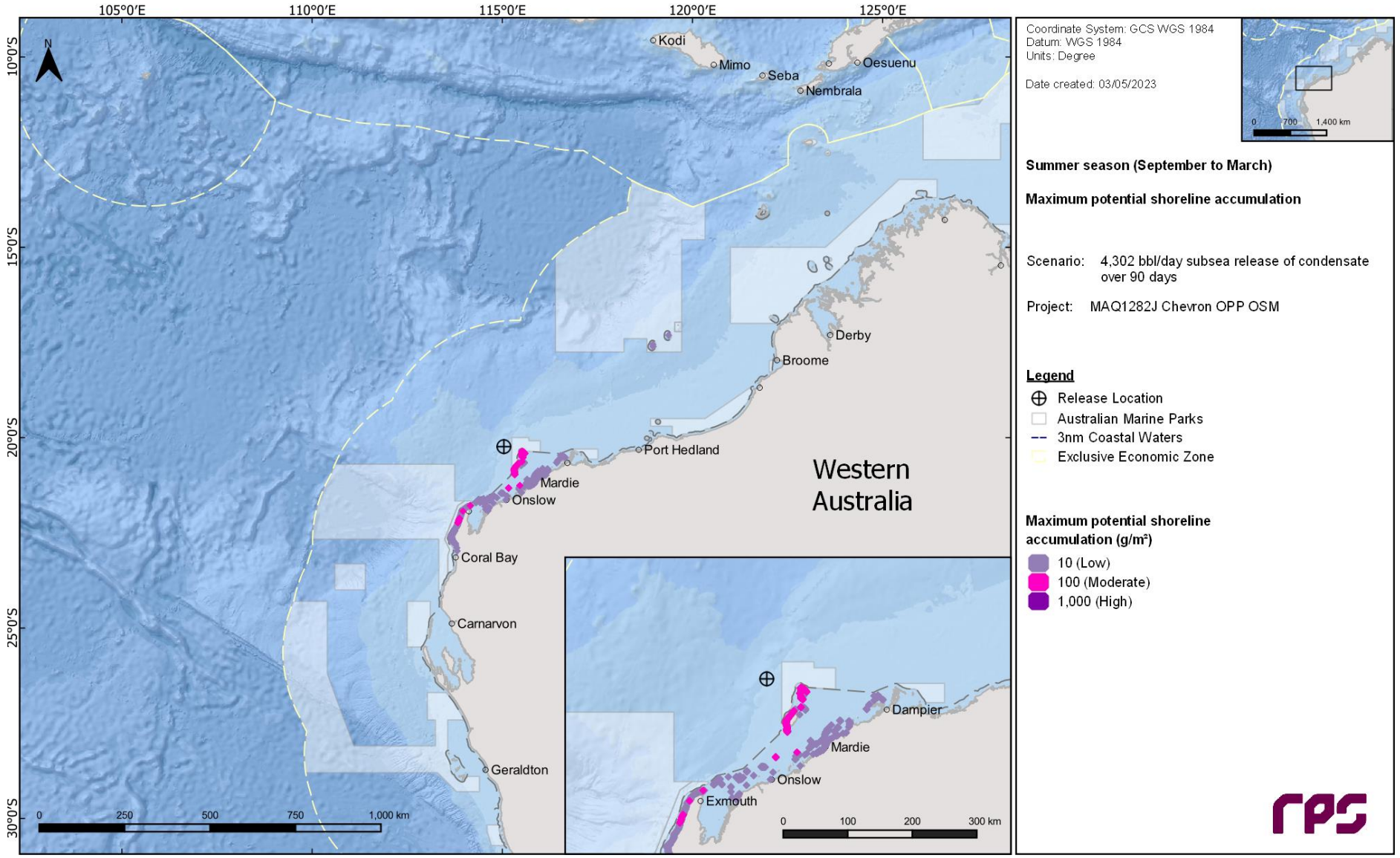


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

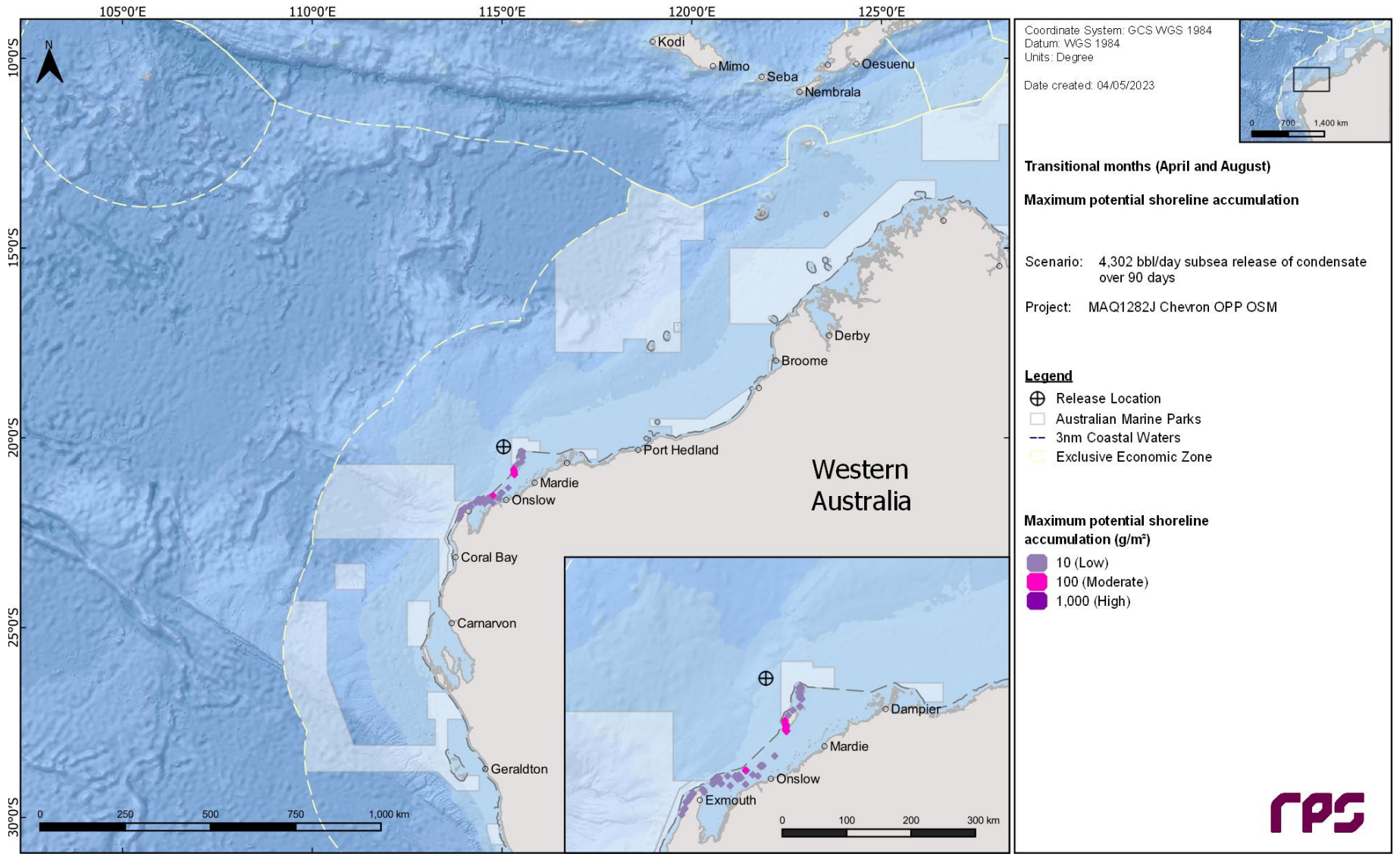


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

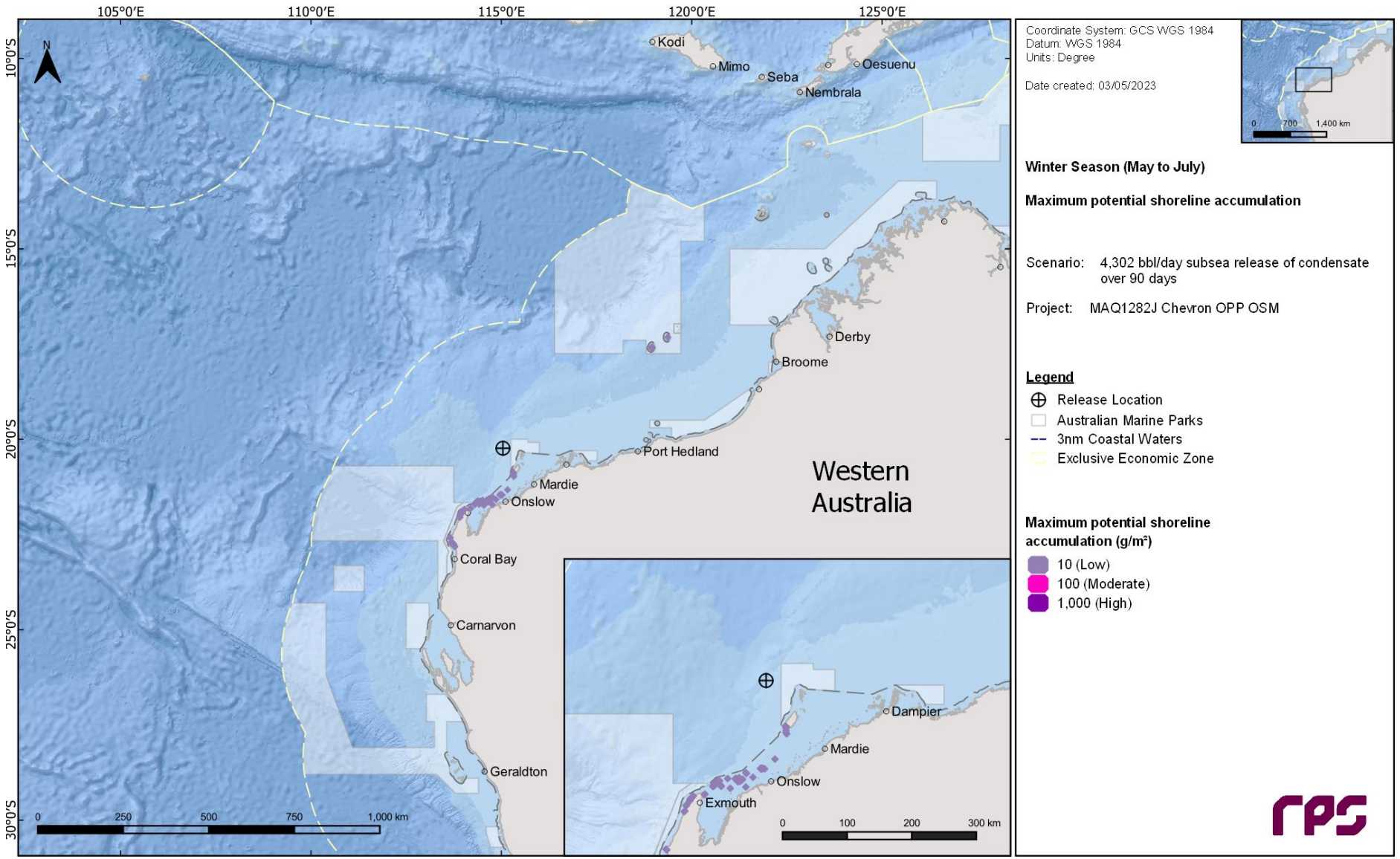


Figure 11.6 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.7 summarises the seasonal probability of exposure to individual receptors from dissolved hydrocarbons in the 0-10 m depth layer, at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥ 400 ppb) exposure thresholds.

In the surface (0-10 m) depth layer, a total of 14, 20, and 10 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) (see Section 10.3), the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 7% for Humpback Whale - Migration during summer, 12% Humpback Whale - Migration during transitional, and 4% for Flatback Turtle – Nesting and Humpback Whale - Migration during winter conditions.

A total of 2, 3 and 1 AMPs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively with the highest probability predicted at the Montebello AMP (3%) during transitional and winter.

Additionally, 3, 4 and 2 IAAs and 3, 3 and 2 IMCRAs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively.

Furthermore, 3 (summer), 4 (transitional) and 2 (winter) KEFs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold.

Figure 11.7 to Figure 11.9 presents the zones of potential instantaneous dissolved hydrocarbon exposure for the 0-10 m depth layer for the summer, transitional and winter periods, respectively.

The same maps for the 10-20 m depth layer are presented in Figure 11.10 to Figure 11.12.

Table 11.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

	Receptor	Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
AMP	Gascoyne	17.9	2	-	-	17.38	-	-	12.4	1	-	-	33.54	-	-	6.7	-	-	-	-	-	-
	Montebello	13.7	1	-	-	22.67	-	-	18	3	-	-	7.75	-	-	15.3	3	-	-	22.58	-	-
	Ningaloo	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
BIA	Dugong - Breeding	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Calving	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Foraging	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Nursing	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Fairy Tern - Breeding	7.7	-	-	-	-	-	-	16.7	1	-	-	65.83	-	-	6.2	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Flatback Turtle - Nesting	32.2	5	-	-	4.71	-	-	32.9	5	-	-	5.67	-	-	23.1	4	-	-	5.71	-	-
	Green Turtle - Internesting Buffer	20.1	1	-	-	5.25	-	-	17.6	1	-	-	51.17	-	-	10.5	1	-	-	81.71	-	-
	Green Turtle - Nesting	20.1	1	-	-	5.5	-	-	17.8	1	-	-	51.75	-	-	10.5	1	-	-	81.71	-	-
	Hawksbill Turtle - Internesting Buffer	20.3	1	-	-	5.25	-	-	17.8	2	-	-	41.46	-	-	10.5	1	-	-	81.71	-	-
	Hawksbill Turtle - Nesting	20.1	1	-	-	5.5	-	-	12.3	1	-	-	66.33	-	-	10.5	1	-	-	81.71	-	-
	Humpback Whale - Migration	56.3	7	1	-	4.71	68.42	-	54.5	12	1	-	2.63	68.46	-	42.3	4	-	-	3.79	-	-
	Lesser Crested Tern - Breeding	11.6	1	-	-	79.33	-	-	15.9	1	-	-	84.29	-	-	7.1	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	10.9	1	-	-	37.54	-	-	17.8	2	-	-	41.46	-	-	7.5	-	-	-	-	-	-
	Loggerhead Turtle - Nesting	9.8	-	-	-	-	-	-	17.8	1	-	-	51.75	-	-	7.4	-	-	-	-	-	-
	Pygmy Blue Whale – Distribution*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Pygmy Blue Whale - Foraging	17.9	2	-	-	40.67	-	-	10.2	1	-	-	33.67	-	-	6.4	-	-	-	-	-	-
	Roseate Tern - Breeding	12.5	1	-	-	78.71	-	-	10.2	1	-	-	41.46	-	-	9.4	-	-	-	-	-	-
	Wedge-tailed Shearwater – Breeding*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Whale Shark – Foraging*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
EEZ	Australian Exclusive Economic Zone*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
IAA	Barrow & Montebello Islands IAA	13.7	1	-	-	22.67	-	-	18	3	-	-	7.75	-	-	15.3	3	-	-	22.58	-	-
	Gascoyne IAA	17.9	2	-	-	17.38	-	-	12.4	1	-	-	33.54	-	-	6.7	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
	Offshore Area*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
IMCRA	Ningaloo	10.8	1	-	-	26.17	-	-	20	1	-	-	51.25	-	-	7.4	-	-	-	-	-	-
	Northwest Shelf	16.2	2	-	-	3.46	-	-	22.1	3	-	-	31.17	-	-	14.3	1	-	-	18.5	-	-
	Pilbara (offshore)*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
KEF	Ancient coastline at 125 m depth contour*	37.8	100	-	-	0.29	-	-	42.9	100	-	-	0.33	-	-	42.3	100	-	-	0.29	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	17.3	2	-	-	25.79	-	-	20	1	-	-	22.42	-	-	9	-	-	-	-	-	-

	Receptor	Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
	Commonwealth waters adjacent to Ningaloo Reef	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
	Continental Slope Demersal Fish Communities	45.8	11	-	-	1.75	68.42	-	49.2	14	-	-	2.5	-	-	40.4	21	-	-	3.79	-	-
MP	Ningaloo	5.2	-	-	-	-	-	-	12.3	1	-	-	66.29	-	-	5.4	-	-	-	-	-	-
State Waters	Western Australia State Waters	12.5	1	-	-	79	-	-	12.3	1	-	-	66.29	-	-	6.5	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

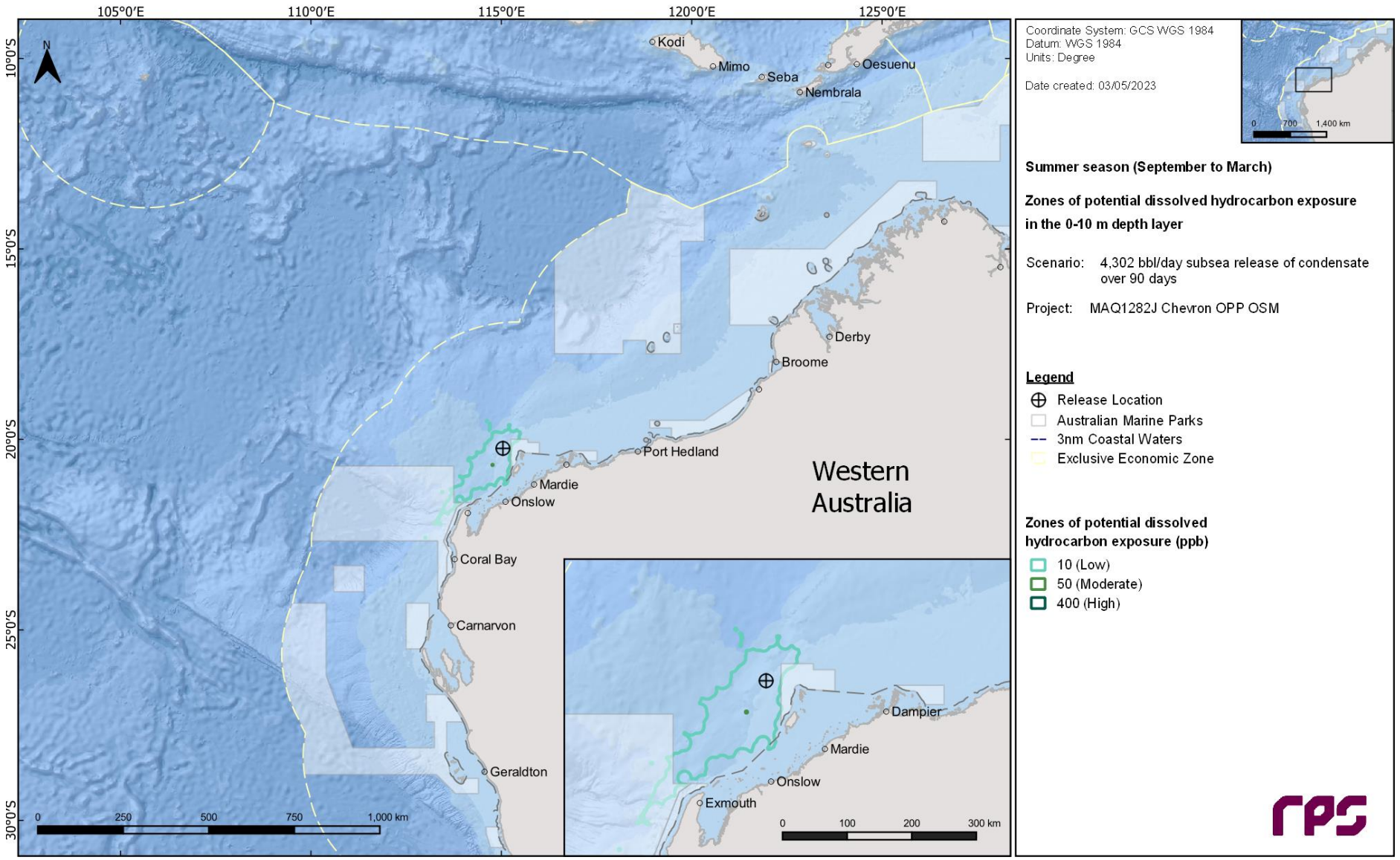


Figure 11.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

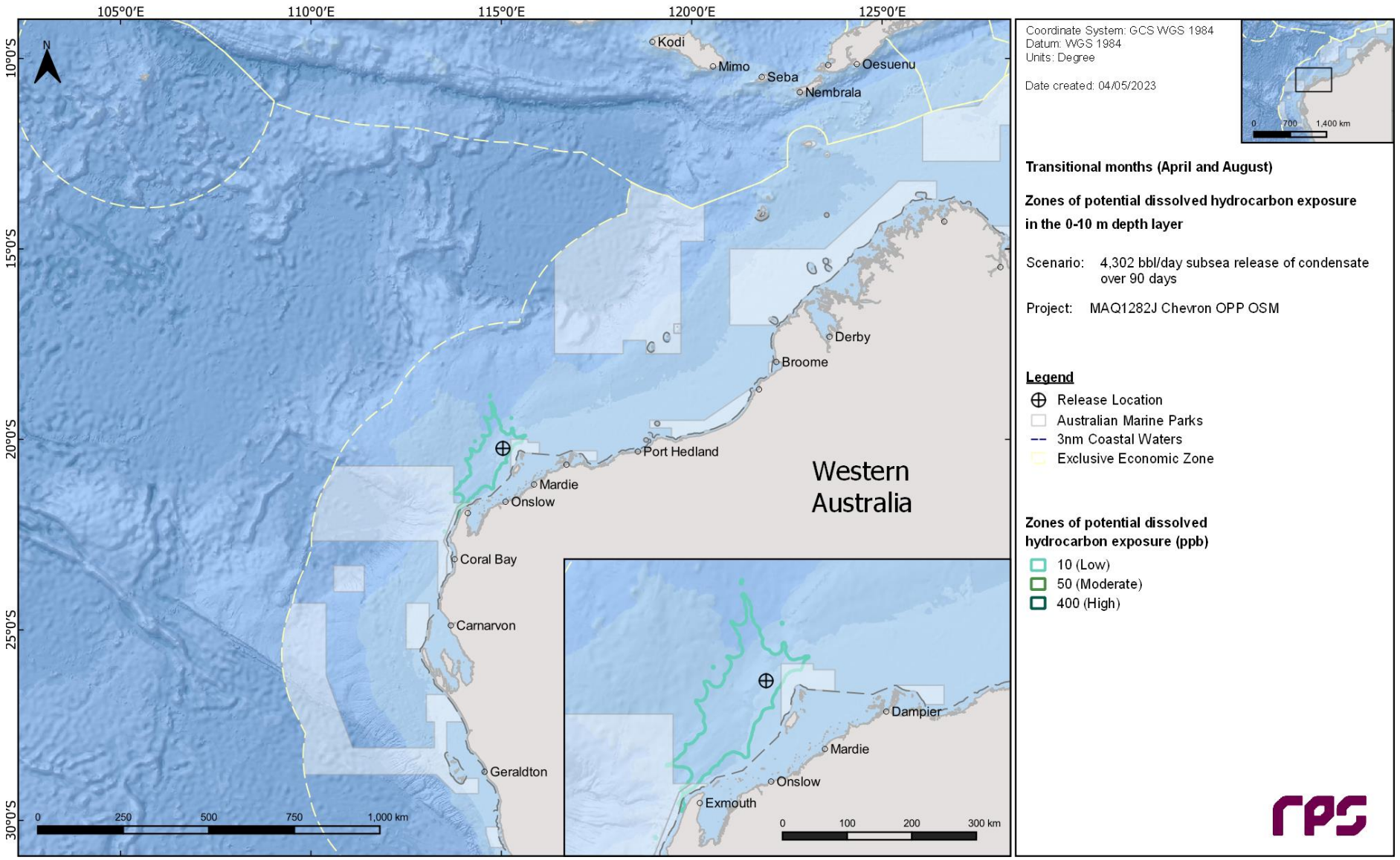


Figure 11.8 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

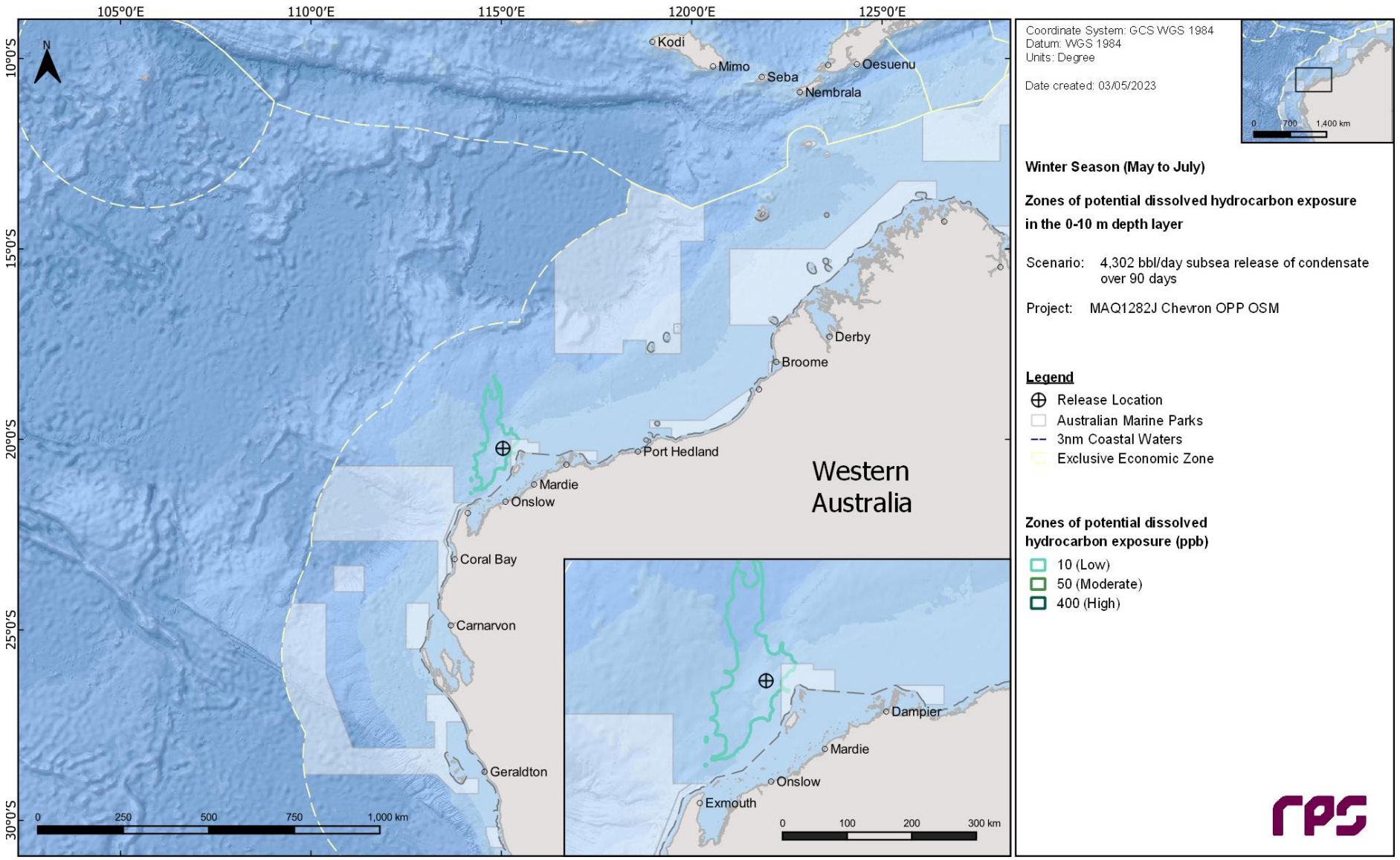


Figure 11.9 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

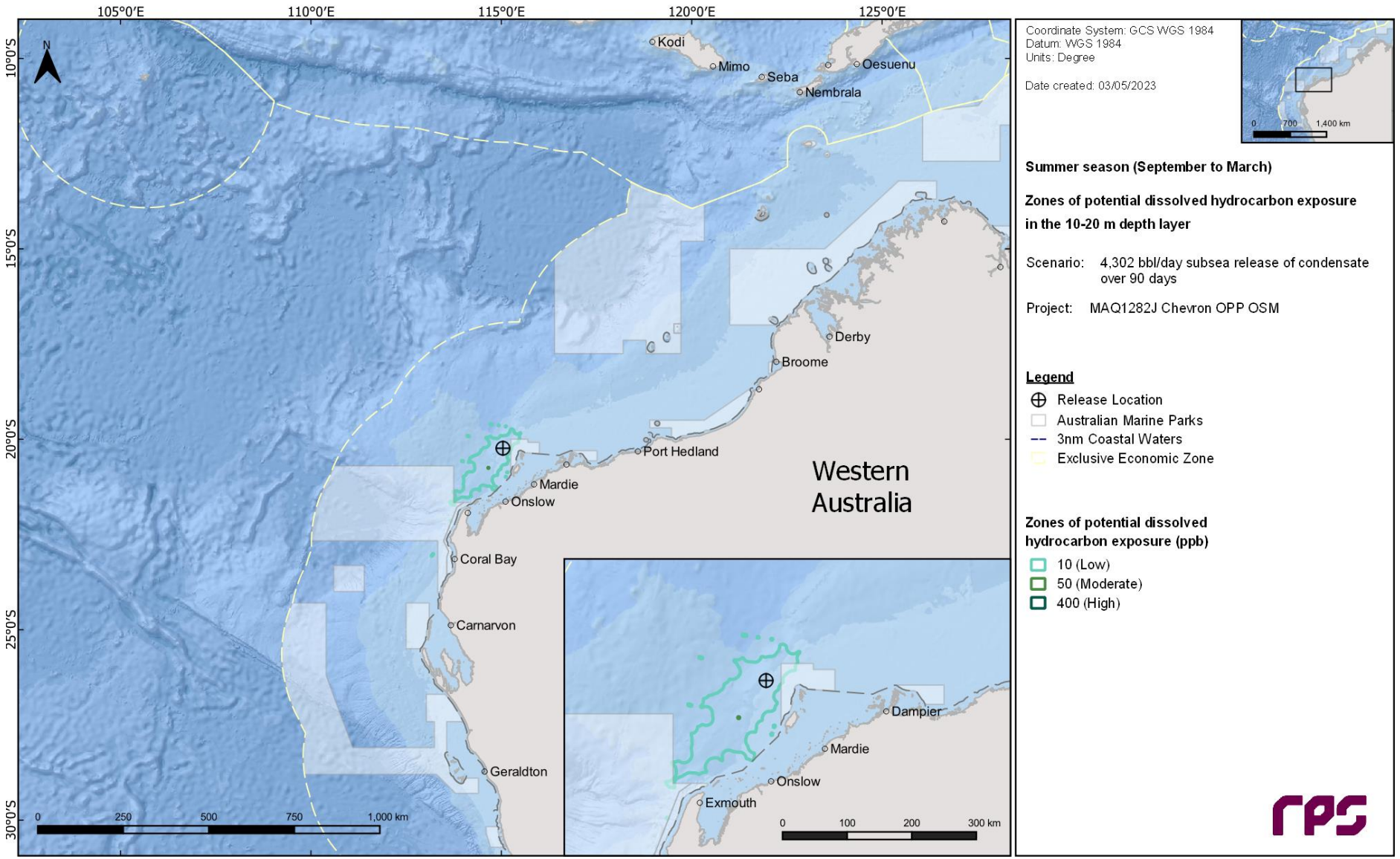


Figure 11.10 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

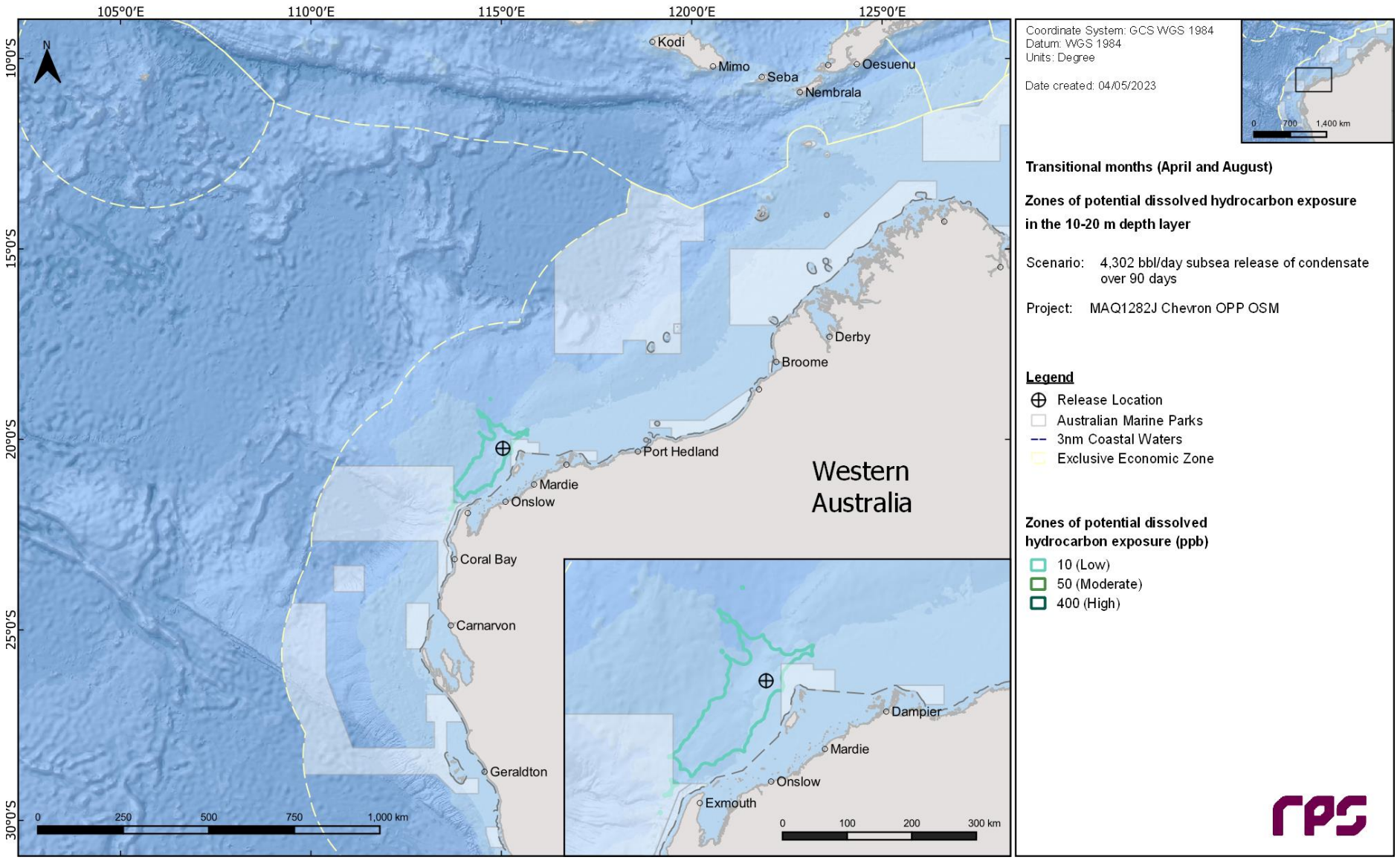


Figure 11.11 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

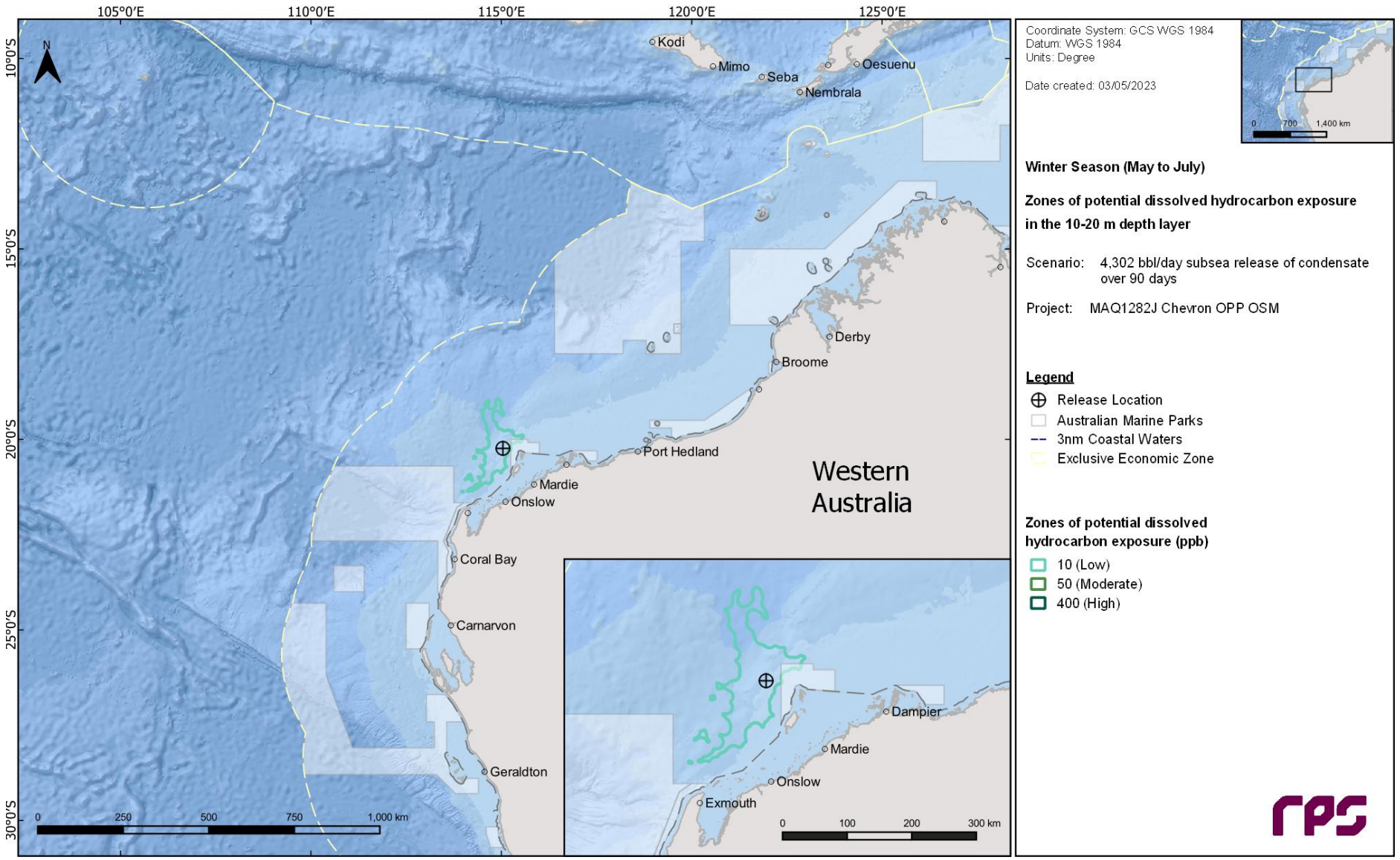


Figure 11.12 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.8 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

In the surface (0-10 m) depth layer, a total of 44, 39 and 40 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter respectively. Excluding the 4 BIAs (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) that the release location resides within (see Section 10.3), the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Flatback Turtle - Nesting (98% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

During summer, 9 AMPs were predicted to be exposed at the low threshold, compared to 7 AMPs during transitional and winter periods. The highest probabilities predicted were at the Gascoyne AMP (96% summer, 100% transitional and 98% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 9, 10 and 11 KEFs were predicted to be exposed by entrained hydrocarbons at the low threshold, respectively. Probabilities of exposure ranged between 9–100%, 4–100% and 2–100%, for summer, transitional and winter, respectively. Excluding the KEF that the release location resides within (Ancient coastline at 125 m depth contour), the KEF with the greatest probability of low exposure for each season was the Continental Slope Demersal Fish Communities KEF (100% during all seasons).

Additionally, 60, 35 and 32 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore IAA, the probabilities for each season ranged between 1–96%, 1–100% and 7–99% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during summer and transitional and at Barrow & Montebello Islands IAA during winter.

Furthermore, 70, 29 and 35 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter, respectively. The maximum probabilities for low threshold exposure were predicted for Rankin Bank (73% and 58% for summer and transitional respectively) and Rosily Shoals (73% for winter).

Figure 11.13 to Figure 11.15 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.16 to Figure 11.18.

Table 11.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	88.7	11	-	23.25	-	30.1	13	-	30.54	-	27.6	10	-	32.13	-
	Argo-Rowley Terrace	92.2	29	-	24.21	-	96.6	34	-	20.13	-	95.6	42	-	32	-
	Carnarvon Canyon	41.7	20	-	25.83	-	43.4	17	-	17.08	-	43.3	11	-	17.75	-
	Dampier	22.2	1	-	38.96	-	1.1	-	-	-	-	1.5	-	-	-	-
	Gascoyne	481.2	96	34	5.17	7.13	469.9	100	45	5.13	8.17	282.4	98	40	5	8.58
	Mermaid Reef	11.7	1	-	68.96	-	2.1	-	-	-	-	3.8	-	-	-	-
	Montebello	728.6	90	77	1.29	1.92	618.2	90	78	1.71	2.33	531.8	99	75	1	1.17
	Ningaloo	343.3	67	31	5.92	7.46	331.7	73	32	6.42	19.83	485.6	92	39	5.75	10.58
	Shark Bay	136	25	2	33.88	52.08	24.7	37	-	18.08	-	27.7	16	-	20.83	-
BIA	Bridled Tern - Foraging	41.2	15	-	40.67	-	28.1	19	-	28.13	-	26	7	-	23.58	-
	Dugong - Breeding	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Calving	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Foraging	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Nursing	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Fairy Tern - Breeding	969.9	57	31	4.08	5.79	331.7	68	24	6	10	498.5	91	34	6.04	6.96
	Flatback Turtle - Aggregation	116.3	26	5	8.63	32.17	113.9	6	3	37.63	81.17	16	8	-	31.79	-
	Flatback Turtle - Foraging	267	27	16	6.67	8.33	113.9	7	3	21	81.17	57.2	25	-	12.13	-
	Flatback Turtle - Internesting	116.3	26	5	8.63	32.17	113.9	6	3	37.63	81.17	16	8	-	31.79	-
	Flatback Turtle - Internesting Buffer*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Flatback Turtle - Mating	240	27	16	6.67	8	113.9	7	3	21	81.17	57.2	25	-	12.13	-
	Flatback Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Flatback Turtle - Nesting	1,143.40	98	85	0.58	1.17	1,225.20	100	98	1.13	1.46	1,155	100	100	1.17	1.29
	Green Turtle - Aggregation	116	26	5	8.63	32	113.9	6	3	38	81.17	16	8	-	31.79	-
	Green Turtle - Basking	243.6	29	16	6.67	8.33	73.5	7	-	21	-	65	30	-	11.75	-
	Green Turtle - Foraging	267	33	16	6.67	8.33	139.7	18	5	21	80.96	57.2	25	-	12.13	-
	Green Turtle - Internesting	243.6	33	16	6.67	8.33	139.7	18	5	21	80.96	57.2	25	-	12.13	-
	Green Turtle - Internesting Buffer	911.2	80	51	1.5	4.29	551.1	91	42	3.04	3.92	535.4	96	59	2.83	5.54
	Green Turtle - Mating	243.6	33	16	6.67	8.33	139.7	18	5	21	80.96	65	26	-	11.75	-
	Green Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Green Turtle - Nesting	982.8	80	38	1.63	5.08	552.3	86	38	3.83	8	518.1	96	39	3.08	5.83
	Hawksbill Turtle - Foraging	267	27	16	6.67	8.33	98.2	7	-	21	-	57.2	25	-	12.08	-
	Hawksbill Turtle - Internesting	62.9	21	-	12.96	-	11.9	3	-	80.96	-	11.8	2	-	44.71	-
	Hawksbill Turtle - Internesting Buffer	969.9	80	46	1.46	4.83	560.7	91	42	4.42	6.42	540.8	98	61	2.58	5.63
	Hawksbill Turtle - Mating	240	27	16	6.67	8.33	98.2	7	-	21	-	57.2	25	-	12.13	-
	Hawksbill Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Hawksbill Turtle - Nesting	982.8	80	38	1.63	5.08	552.3	86	38	3.83	7.96	518.1	96	38	3.08	5.83
	Humpback Whale - Migration	1,229.50	100	100	0.25	0.29	921.9	100	100	0.63	0.71	912	100	100	0.63	0.71

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Humpback Whale - Resting	112	37	3	9.33	41.71	134.7	36	3	18.83	30.46	111.8	55	1	14.75	27.63
	Lesser Crested Tern - Breeding	982.8	58	30	3.63	5.08	401.6	78	29	4.46	8.25	335.3	87	28	4.04	5.88
	Lesser Frigatebird - Breeding	10.1	1	-	69	-	5.3	-	-	-	-	6.8	-	-	-	-
	Little Shearwater - Foraging	15.3	3	-	88.13	-	20.9	5	-	54.58	-	20.5	3	-	40.79	-
	Little Tern - Resting	92.6	10	-	24.04	-	5.4	-	-	-	-	61.2	8	-	59.08	-
	Loggerhead Turtle - Internesting Buffer	423.6	72	35	4.75	5.29	331.7	86	42	3.75	3.92	512	94	52	5.17	9.63
	Loggerhead Turtle - Nesting	380.4	68	32	5.75	7.29	331.7	77	32	4.92	19.83	498.5	92	39	5.71	10.5
	Pygmy Blue Whale – Distribution*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Pygmy Blue Whale - Foraging	406	85	31	6.13	7	297	83	27	5	8.25	345.4	93	36	5.58	11
	Roseate Tern - Breeding	982.8	72	33	3.25	6.79	306.8	85	38	7	18.63	301.9	92	38	3.92	4.67
	Sooty Tern - Foraging	38.8	17	-	28.71	-	29	19	-	25.75	-	27.6	12	-	23.83	-
	Wedge-tailed Shearwater – Breeding*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Wedge-tailed Shearwater - Foraging	41	21	-	31.42	-	28.1	19	-	26	-	26.6	8	-	23.58	-
	Whale Shark – Foraging*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	White-faced Storm-petrel - Foraging	16	3	-	87.29	-	21.5	5	-	55	-	20.5	3	-	40.67	-
	White-tailed Tropicbird - Breeding	103.5	27	1	20.17	71.96	50.5	12	-	32.38	-	83.5	17	-	55.42	-
CP	Montebello Islands	74.3	19	-	14.63	-	73.9	5	-	80.54	-	11.2	3	-	46.71	-
	Australian Exclusive Economic Zone *	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
EEZ	Christmas Island Exclusive Economic Zone	12	2	-	38.83	-	16.1	1	-	58	-	18.3	4	-	82	-
	Indonesian Exclusive Economic Zone	13.1	3	-	36.08	-	20.4	7	-	50.58	-	23.4	6	-	63.58	-
	Abrolhos Islands IAA	88.7	11	-	23.25	-	30.1	13	-	30.54	-	27.6	10	-	32.13	-
	Abutilon Island	22	16	-	14.58	-	3	-	-	-	-	9.7	-	-	-	-
	Airlie Island	779.3	24	4	11.42	79.96	39.1	17	-	52.79	-	38	32	-	8.25	-
	Argo-Rowley Terrace IAA	92.2	29	-	24.21	-	96.6	34	-	20.13	-	95.6	42	-	32	-
	Ashburton Island	29.2	14	-	36.04	-	5.5	-	-	-	-	16.6	11	-	32.83	-
	Barrow & Montebello Islands IAA	728.6	90	77	1.29	1.92	618.2	90	78	1.71	2.33	531.8	99	75	1	1.17
	Barrow Island (East Coast)	118.3	21	5	9.42	33.17	11	1	-	25.33	-	20.6	8	-	13.63	-
	Barrow Island (West Coast)	217.2	25	11	7.21	11.96	44.6	7	-	22	-	43.8	18	-	12.13	-
	Barrow Island Group	234.1	25	12	7.21	8.38	44.6	7	-	22	-	64.9	18	-	12.13	-
IAA	Bedwell Island (Clerke Reef)	14.4	5	-	31.21	-	1.2	-	-	-	-	6.5	-	-	-	-
	Bessieres Island	249.1	42	9	9.33	37.29	364.7	56	5	9.04	10.04	63.1	68	-	12.04	-
	Boodie Island	223.2	25	12	7.29	8.38	20.5	6	-	22.71	-	64.9	17	-	12.75	-
	Cape Range National Park	246.3	38	7	8.75	9.75	107.7	43	1	15.5	103.96	346.1	53	12	12.29	19.25
	Cunningham Island (Imperieuse Reef)	66.5	8	-	28.21	-	1.6	-	-	-	-	61.2	8	-	60.25	-
	Dampier Archipelago IAA	237.6	15	3	15.5	90.08	5.8	-	-	-	-	5.6	-	-	-	-
	Dampier Archipelago Island Group	30.9	11	-	30.67	-	0.9	-	-	-	-	1.9	-	-	-	-
	Dampier mainland coastline	123.5	8	3	58	93.08	0.7	-	-	-	-	2.3	-	-	-	-
	Dirk Hartog Island	15.9	5	-	81.42	-	15.3	5	-	56.83	-	5.7	-	-	-	-
	Double Island	20.2	11	-	21.42	-	2.8	-	-	-	-	8.8	-	-	-	-

Receptor	Summer					Transitional					Winter				
	Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Eaglehawk Island	22.1	10	-	30.67	-	0.5	-	-	-	-	1.4	-	-	-	-
Enderby Island	20.9	10	-	30.67	-	0.8	-	-	-	-	1.6	-	-	-	-
Exmouth Gulf Mainland Coastline	20.3	21	-	31.42	-	18.6	19	-	34.88	-	27.5	20	-	25.42	-
Exmouth IAA	120.2	38	8	8.83	41.29	155.9	43	10	9.08	28.88	125.3	59	4	7.38	20.83
Gascoyne IAA	481.2	96	34	5.17	7.13	469.9	100	45	5.13	8.17	282.4	98	40	5	8.58
Glomar Shoal	135.2	11	2	13.04	13.75	10.3	1	-	85.63	-	2.7	-	-	-	-
Goodwyn Island	23.5	10	-	33.83	-	0.7	-	-	-	-	1.7	-	-	-	-
Great Sandy Island	186.3	13	3	21.38	86.25	2.4	-	-	-	-	9.7	-	-	-	-
Hermite Island	87.2	19	-	12.83	-	74.7	5	-	80.42	-	12.4	7	-	45.96	-
Legendre Island	11.2	1	-	40.21	-	0.9	-	-	-	-	1.4	-	-	-	-
Locker Island	22.7	16	-	33.08	-	11.2	3	-	35.25	-	7.1	-	-	-	-
Lowendal Islands Group	22	16	-	14.58	-	3	-	-	-	-	9.7	-	-	-	-
Malus Islands	23.4	10	-	36.75	-	0.6	-	-	-	-	1.6	-	-	-	-
Mermaid Reef	10.2	1	-	69.42	-	1.3	-	-	-	-	2.7	-	-	-	-
Middle Island	234.1	25	12	7.29	8.88	24	6	-	23.38	-	55.6	15	-	13.13	-
Middle Ningaloo Coast - World Heritage Area	158.8	34	9	9.17	11.83	73.4	36	-	26.92	-	54.6	30	-	20.38	-
Montebello Islands Group	87.2	19	-	12.83	-	74.7	5	-	80.42	-	12.4	7	-	45.96	-
Muiron Islands	221.6	46	18	7.75	39.58	170.3	59	12	6.92	22.21	398.6	73	22	6.08	17.5
Ningaloo Coast World Heritage Area	343.3	67	31	5.92	7.46	331.7	73	32	6.21	19.83	512	92	39	5.75	10.58
North Muiron Island	221.6	46	18	7.75	39.58	170.3	59	11	6.92	22.21	398.6	73	22	6.08	17.5
North Ningaloo Coast - World Heritage Area	251.4	42	9	8.75	11.38	261.6	44	9	15.83	42.92	256.6	57	18	12.04	17.63
North Sandy Island	156.7	13	3	18.83	87.83	1.6	-	-	-	-	6.4	-	-	-	-
Offshore Area*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
Onslow Area Mainland Coastline	123	6	3	36.42	88	2.9	-	-	-	-	6.2	-	-	-	-
Passage Island	97.4	4	-	62.42	-	0.9	-	-	-	-	3.2	-	-	-	-
Pilbara Coast IAA	969.9	50	24	4.21	10.42	512.1	78	23	4.46	8.25	510.4	84	28	5.46	8.67
Pilbara Coast Islands Group	779.3	43	12	9.29	37.29	364.7	56	5	9.04	10.04	63.1	68	-	8.25	-
Pilbara Mainland Coast	122.6	6	3	36.42	88.33	2.9	-	-	-	-	6.2	-	-	-	-
Potter Island	80.8	3	-	91.38	-	0.7	-	-	-	-	2.1	-	-	-	-
Rankin Bank	360.9	73	59	3.58	4.96	412.2	58	42	8.29	10.96	428.8	72	53	3.46	14.17
Rosemary Island	30.9	11	-	35.21	-	0.9	-	-	-	-	1.9	-	-	-	-
Serrurier Island	176	43	12	9.29	37.63	216.1	54	4	10.38	18.17	59.7	68	-	12.54	-
Shark Bay mainland coastline	136	25	2	14.63	51.63	32	39	-	17.42	-	27.3	16	-	20.54	-
Shark Bay World Heritage Site	15.9	5	-	81.42	-	15.3	5	-	56.83	-	5.7	-	-	-	-
Sholl Island	196.6	13	3	18.79	89.33	0.8	-	-	-	-	3	-	-	-	-
South Muiron Island	173.2	42	14	7.92	40.42	160.7	55	12	7.88	29.08	252	72	18	6.63	17.75
South Ningaloo Coast - World Heritage Area	45	14	-	14.54	-	24.2	5	-	50.5	-	28.9	14	-	30.17	-
Thevenard Island	461.6	37	4	11.38	79.67	106.8	37	2	10.83	19	54.7	43	-	10	-
Trimouille Island	39.5	17	-	15.67	-	16.8	5	-	81.42	-	9.1	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	West Lewis Island	16.9	8	-	36.75	-	0.5	-	-	-	-	1.2	-	-	-	-
	Yammadery Island	30.8	3	-	64.96	-	1.6	-	-	-	-	3.3	-	-	-	-
IBRA	Cape Range	251.4	46	18	7.21	9.79	358.3	59	12	5.5	10.38	398.6	73	22	6.08	17.38
	Edel	15.9	5	-	81.29	-	15.6	5	-	56.83	-	6.8	-	-	-	-
	Roebourne	779.3	25	12	7.29	8.38	33.6	17	-	22.71	-	57.2	31	-	8.29	-
	Wooramel	13.6	4	-	34.38	-	5.8	-	-	-	-	4.8	-	-	-	-
IMCRA	Ningaloo	423.9	72	33	5.54	6.38	331.7	86	32	4.42	9.04	498.5	96	41	5.04	6.83
	Northwest Shelf	1,009.20	95	89	0.54	0.63	1,094.80	93	89	0.63	1.63	1,034.50	100	96	1.08	1.17
	Pilbara (nearshore)	378	41	8	8.88	40	165.6	43	4	7	27.92	117.9	57	1	9.25	27.67
	Pilbara (offshore)*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Zuytdorp	136	26	2	14.63	52	32	40	-	17	-	27.3	16	-	20.54	-
KEF	Ancient coastline at 125 m depth contour*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	5	-	-	-	-	18.4	7	-	49	-	17.5	5	-	90.42	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	433.1	96	43	2.79	6.38	382.6	91	53	3.75	3.92	519.9	100	51	4.38	6.92
	Commonwealth waters adjacent to Ningaloo Reef	343.3	67	31	5.92	7.46	331.7	73	32	6.42	19.83	485.6	92	39	5.75	10.58
	Continental Slope Demersal Fish Communities	1,511	100	100	0.38	0.42	1,350.90	100	100	0.33	0.42	1,256.80	100	100	0.42	0.5
	Exmouth Plateau	387	90	22	7	10	383.7	100	27	7	10.13	383.8	94	19	5.75	7.29
	Glomar Shoals	328.1	21	7	11.71	12.13	21.5	11	-	53	-	17.8	2	-	73.92	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	90.4	11	-	24.08	-	2.9	-	-	-	-	61.2	8	-	58.92	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	9.5	-	-	-	-	15.3	4	-	55.54	-	15.1	3	-	41.79	-
	Wallaby Saddle	84.9	9	-	23.92	-	15.6	5	-	46.29	-	15.2	5	-	36.79	-
	Western demersal slope and associated fish communities	41.2	21	-	28.71	-	28.1	19	-	25.63	-	26.6	12	-	23.58	-
MMA	Barrow Island	639.4	43	17	5.79	6.67	142.5	24	5	10.96	79.04	69.2	39	-	10.96	-
	Muiron Islands	222.9	48	18	7.33	39.38	190.9	61	19	6.21	22.21	512	73	31	5.83	16.21
MP	Barrow Island	124.3	33	10	6.21	9.38	91.9	18	-	22.96	-	39.5	39	-	11.04	-
	Montebello Islands	157.8	38	13	7.96	10	151.5	25	5	9.63	80.42	19.3	28	-	14.5	-
	Ningaloo	271.5	49	21	7.88	8.33	276.9	55	21	8.21	23.42	498.5	67	34	6.25	15.17
	Rowley Shoals	84.2	9	-	26.75	-	1.6	-	-	-	-	61.2	8	-	59.42	-
NR	Great Sandy Island	542.2	18	3	12.42	83.13	2	-	-	-	-	9.2	-	-	-	-
	Thevenard Island	149.4	25	2	11.42	80	55	27	-	17.92	-	43.1	33	-	10.79	-
RSB	Ashworth Shoal	93.6	3	-	91.88	-	0.8	-	-	-	-	2	-	-	-	-
	Australind Shoal	32.4	19	-	24.29	-	8.8	-	-	-	-	20.7	11	-	32.83	-
	Barrow Island Reefs and Shoals	561.8	19	3	11.88	83.08	2.3	-	-	-	-	11.7	2	-	36.33	-
	Baylis Patches	25.8	18	-	20.79	-	24.2	3	-	27.88	-	7	-	-	-	-
	Beryl Reef	33	10	-	29.79	-	44.2	6	-	23	-	31.4	13	-	22.96	-
	Brewis Reef	96.4	27	-	11	-	102.2	26	1	10.54	24.33	49.1	35	-	11.88	-
	Clerke Reef	15.3	5	-	31.21	-	1.2	-	-	-	-	7.6	-	-	-	-

Receptor	Summer					Transitional					Winter				
	Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Cod Bank	60.3	13	-	27.67	-	0.7	-	-	-	-	1.7	-	-	-	-
Combe Reef	78.5	36	-	10.33	-	125.5	24	3	21.38	29.96	39.4	37	-	18.17	-
Courtenay Shoal	17.1	8	-	37.71	-	0.6	-	-	-	-	1.2	-	-	-	-
Curlew Bank	11.6	1	-	99.75	-	1.2	-	-	-	-	4.9	-	-	-	-
Dailey Shoal	164.1	42	11	9.33	39.25	191.9	46	4	6.13	28.04	48	62	-	12.96	-
Eliassen Rocks	88.5	3	-	90.92	-	0.7	-	-	-	-	2.7	-	-	-	-
Exmouth Reef	46.7	31	-	10	-	93	17	-	22.42	-	47.7	24	-	19.29	-
Fairway Reef	96.3	37	-	10.5	-	144.1	37	3	7.04	27.88	25	40	-	14.33	-
Flinders Shoal	264.2	19	3	21.33	83.17	2.2	-	-	-	-	11.9	2	-	49.21	-
Fortescue Reef	133.9	7	2	49.79	94.13	0.7	-	-	-	-	2.6	-	-	-	-
Glennie Patches	23.5	16	-	35.38	-	6.6	-	-	-	-	14.1	7	-	33.38	-
Glomar Shoal	136	11	2	13.04	13.75	10.5	1	-	85.63	-	2.7	-	-	-	-
Gorgon Patch	45.7	6	-	41.75	-	1.7	-	-	-	-	8.2	-	-	-	-
Hammersley Shoal	13.7	4	-	52.92	-	0.8	-	-	-	-	1.2	-	-	-	-
Hastings Shoal	38.7	3	-	66.08	-	1.7	-	-	-	-	7.4	-	-	-	-
Hayman Rock	31	28	-	20.75	-	36.8	5	-	21.92	-	9.9	-	-	-	-
Herald Reef	41.7	10	-	42.29	-	1.5	-	-	-	-	5.4	-	-	-	-
Hood Reef	140.1	40	8	10.33	38.63	182.1	47	4	6.54	27.42	29.4	58	-	12.92	-
Imperieuse Reef	66.5	8	-	28.21	-	1.6	-	-	-	-	61.2	8	-	60.25	-
Inner Northwest Patch	21.8	17	-	35.42	-	5.7	-	-	-	-	7.5	-	-	-	-
Koolinda Patch	40.8	3	-	66.21	-	1.3	-	-	-	-	5	-	-	-	-
Lightfoot Reef	243.1	15	3	21.46	84.13	2.6	-	-	-	-	10.2	1	-	100.54	-
Little Shoals	45.4	18	-	29	-	2.4	-	-	-	-	8.6	-	-	-	-
Locker Reef	36.5	28	-	20.33	-	34.7	5	-	21.46	-	8.3	-	-	-	-
Madeleine Shoals	22	1	-	39	-	0.9	-	-	-	-	1.3	-	-	-	-
Manicom Bank	18.8	14	-	36.04	-	5.2	-	-	-	-	6.6	-	-	-	-
Mardie Rock	102.6	3	1	90.92	97.21	1	-	-	-	-	2.7	-	-	-	-
McLennan Bank	179.4	13	3	24.83	91.25	0.9	-	-	-	-	2	-	-	-	-
Meda Reef	132.8	13	3	20.38	88.92	0.8	-	-	-	-	2.5	-	-	-	-
Mermaid Reef	10.3	1	-	69.42	-	1.3	-	-	-	-	3	-	-	-	-
Miles Shoal	33.8	13	-	36.5	-	5.3	-	-	-	-	16.1	11	-	33.71	-
Montebello Shoals	125.7	29	2	8.42	52	114.9	11	5	79.88	81.5	16	7	-	35.25	-
Moresby Shoals	45	14	-	38.33	-	2.2	-	-	-	-	6	-	-	-	-
Nares Rock	46.4	14	-	33.04	-	2.2	-	-	-	-	6.1	-	-	-	-
Ningaloo Reef	261	42	13	8.46	9	276.9	45	12	15	42.88	376.8	59	18	6.63	17.54
North West Reef	26.3	11	-	29.33	-	0.6	-	-	-	-	1.6	-	-	-	-
North West Reef	152.8	39	9	8.92	41.13	154.8	36	9	16.17	44.96	161.2	58	18	14.54	18.33
O'Grady Shoal	193.4	11	3	48.88	91.33	0.7	-	-	-	-	2.3	-	-	-	-
Otway Reef	130.2	40	8	10.33	40.75	160.6	40	4	8.67	28.83	26.7	55	-	13.79	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Outtrim Patches	204	45	15	7.83	39.42	161.3	57	5	6.21	24.58	273.1	70	14	6.33	17.5
	Paroo Shoal	38.2	11	-	37.08	-	3.5	-	-	-	-	13.4	8	-	35.71	-
	Pearl Reef	23.6	7	-	30.33	-	34.3	3	-	29.96	-	18.8	13	-	23.46	-
	Penguin Bank	905.2	42	11	7.67	36.42	159.5	40	10	14.33	32.08	155.8	70	6	7.13	27.42
	Poivre Reef	220.6	34	12	7.21	7.33	27.7	10	-	14.92	-	62.5	35	-	12.38	-
	Rankin Bank	360.9	73	59	3.58	4.04	421.7	58	42	7.83	10.96	428.8	72	53	3.42	14.17
	Ripple Shoals	535.4	21	3	8.96	81.17	8.8	-	-	-	-	53	17	-	10.67	-
	Roller Shoal	16.5	1	-	99.13	-	2.1	-	-	-	-	5.2	-	-	-	-
	Rosily Shoals	880.9	42	6	7.17	79.13	160.7	51	9	10.54	18.88	112.5	73	3	8.5	27.88
	Saladin Shoal	41.5	7	-	66.63	-	2.9	-	-	-	-	11.3	4	-	41.83	-
	Santo Rock	45	21	-	24.33	-	33.3	12	-	18.54	-	17.2	14	-	14.75	-
	South East Reef	14.6	8	-	32.75	-	0.4	-	-	-	-	1.2	-	-	-	-
	South West Reef	25.9	10	-	30.79	-	0.5	-	-	-	-	1.2	-	-	-	-
	Southwest Patch	14.3	2	-	37.5	-	3.1	-	-	-	-	7.2	-	-	-	-
	Spider Reef	62.8	31	-	12.54	-	96.8	15	-	20.29	-	19.4	17	-	14.67	-
	Sultan Reef	225.9	20	3	15.67	80.08	28.1	8	-	53.33	-	27.8	14	-	8.83	-
	Taunton Reef	586.9	23	3	12.38	80.13	26.8	9	-	53.29	-	26	11	-	8.83	-
	Tongue Shoals	26.8	17	-	17.58	-	10.7	2	-	27.92	-	9.7	-	-	-	-
	Trap Reef	624.3	35	3	11.38	79.58	62.7	29	-	18	-	52.1	36	-	9.58	-
	Tryal Rocks	376.2	55	19	4.29	10.54	155.7	46	13	5.83	41.67	147	52	11	5.58	20.38
	Ward Reef	24.6	2	-	95.96	-	1.2	-	-	-	-	5.1	-	-	-	-
	Web Reef	48.6	26	-	12.42	-	90.3	11	-	20.38	-	18.9	13	-	21.75	-
	Weeks Shoal	45.3	10	-	39.33	-	1.9	-	-	-	-	10.6	1	-	90.58	-
	West Reef	89.9	15	-	30.42	-	2.2	-	-	-	-	9.8	-	-	-	-
Nearshore Waters	Airlie Island	779.3	24	4	11.42	79.96	39.1	17	-	52.79	-	38	32	-	8.25	-
	Ashburton	39.2	7	-	52.96	-	14.4	3	-	29.96	-	8.1	-	-	-	-
	Ashburton Island	29.2	12	-	36.04	-	4.6	-	-	-	-	14.3	11	-	32.83	-
	Barrow Island	217.2	25	11	7.21	11.96	44.5	7	-	22	-	43.8	18	-	12.13	-
	Bessieres Island	249.1	42	9	9.33	37.29	364.7	56	5	9.04	10.04	63.1	68	-	12.04	-
	Boodie Island	223.2	25	12	7.29	8.38	20.5	6	-	22.71	-	57.2	17	-	12.75	-
	Carnarvon	45	16	-	14.38	-	25.3	5	-	50.63	-	28.9	14	-	30	-
	Clerke Reef	11.6	1	-	72.63	-	1.1	-	-	-	-	5.4	-	-	-	-
	Cohen Island	13.7	3	-	93.13	-	0.8	-	-	-	-	1.2	-	-	-	-
	Cunningham Island	63.4	6	-	28.25	-	1.3	-	-	-	-	52.4	8	-	61.25	-
	Direction Island	42.1	10	-	42.25	-	1.4	-	-	-	-	5.3	-	-	-	-
	Dirk Hartog Island	15.9	5	-	81.33	-	15.6	5	-	56.83	-	5.7	-	-	-	-
	Eaglehawk Island	24.4	10	-	30.17	-	0.5	-	-	-	-	1.6	-	-	-	-
	Enderby Island	21.8	10	-	29.67	-	0.8	-	-	-	-	1.7	-	-	-	-
	Exmouth	251.4	43	9	8.67	9.79	261.6	44	9	15.46	42.92	357.5	57	18	12.04	17.63

Receptor		Summer					Transitional					Winter				
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			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Flat Island	200.9	43	10	9.17	37.71	235.8	53	4	6.5	18.63	63.4	62	-	9.33	-
	Fly Island	37.7	27	-	12.46	-	81.4	11	-	20.83	-	18.5	12	-	21.21	-
	Goodwyn Island	24.4	10	-	33.83	-	0.7	-	-	-	-	1.7	-	-	-	-
	Imperieuse Reef	66.5	6	-	28.21	-	1.6	-	-	-	-	55.9	8	-	60.63	-
	Karratha	166.2	11	3	47.75	88.38	1.9	-	-	-	-	5.6	-	-	-	-
	Kendrew Island	27.1	11	-	35	-	1.1	-	-	-	-	2	-	-	-	-
	Legendre Island	11.6	1	-	40.08	-	0.9	-	-	-	-	1.7	-	-	-	-
	Locker Island	22.7	16	-	33.08	-	11.2	3	-	35.25	-	7.1	-	-	-	-
	Lowendal Island	46.2	20	-	12.96	-	9.2	-	-	-	-	11.4	1	-	61.04	-
	Malus Island	23.4	10	-	36.75	-	0.7	-	-	-	-	1.6	-	-	-	-
	Mangrove Islands	39.5	3	-	61.79	-	2.2	-	-	-	-	5.6	-	-	-	-
	Mary Anne Group	247.4	18	3	21.46	83.17	2.6	-	-	-	-	10.6	1	-	46.71	-
	Middle Island	234.1	25	12	7.29	8.88	24	6	-	23.38	-	55.6	16	-	13.13	-
	Montebello Islands	105	26	2	8.5	52.13	112.7	5	1	80.38	97.63	13.8	7	-	38.79	-
	Muiron Islands	221.6	46	18	7.75	39.67	170.3	59	12	6.92	22.21	398.6	73	22	6.08	17.54
	Observation Island	109.1	40	6	11.33	42.79	142.8	37	4	20	28.38	25	42	-	13.71	-
	Passage Islands	220.8	13	3	18.75	86.25	2.4	-	-	-	-	9.7	-	-	-	-
	Peak Island	191	45	14	8.21	38.46	220.9	54	4	5.5	27.54	166.6	68	12	7.75	17.33
	Ragnard Islands	130.5	10	3	47.29	93.58	0.7	-	-	-	-	1.4	-	-	-	-
	Rivoli Islands	22.1	7	-	30.38	-	39.4	8	-	29.46	-	15.9	12	-	23.5	-
	Rosemary Island	31.6	11	-	35.21	-	0.9	-	-	-	-	2.3	-	-	-	-
	Round Island	109.5	41	8	10.38	38.71	152.4	46	4	7.54	27.29	34.8	57	-	13.17	-
	Serrurier Island	170.7	43	12	9.33	37.63	205.2	54	4	10.46	18.17	59.7	67	-	12.58	-
	Sunday Island	147.3	43	11	8.42	40.29	182.8	46	4	7.17	28.75	71.7	66	-	9.83	-
	Table Island	143.5	36	1	9.92	99.29	137.5	45	3	10.67	18.58	47.9	51	-	13.96	-
	Thevenard Island	149.4	25	2	11.42	80	48.6	26	-	17.96	-	40.2	33	-	10.79	-
	Tortoise Island	54.7	22	-	10.92	-	52.4	13	-	18	-	33.4	26	-	14.25	-
	Twin Island	43.9	9	-	44.83	-	1.6	-	-	-	-	5.6	-	-	-	-
	West Lewis Island	17.2	8	-	36.75	-	0.7	-	-	-	-	1.2	-	-	-	-
State Waters	Western Australia State Waters	982.8	49	24	4.13	6.83	398.7	61	21	4.92	9	512	80	34	4.83	8.04

*The release location resides within the receptor boundaries.

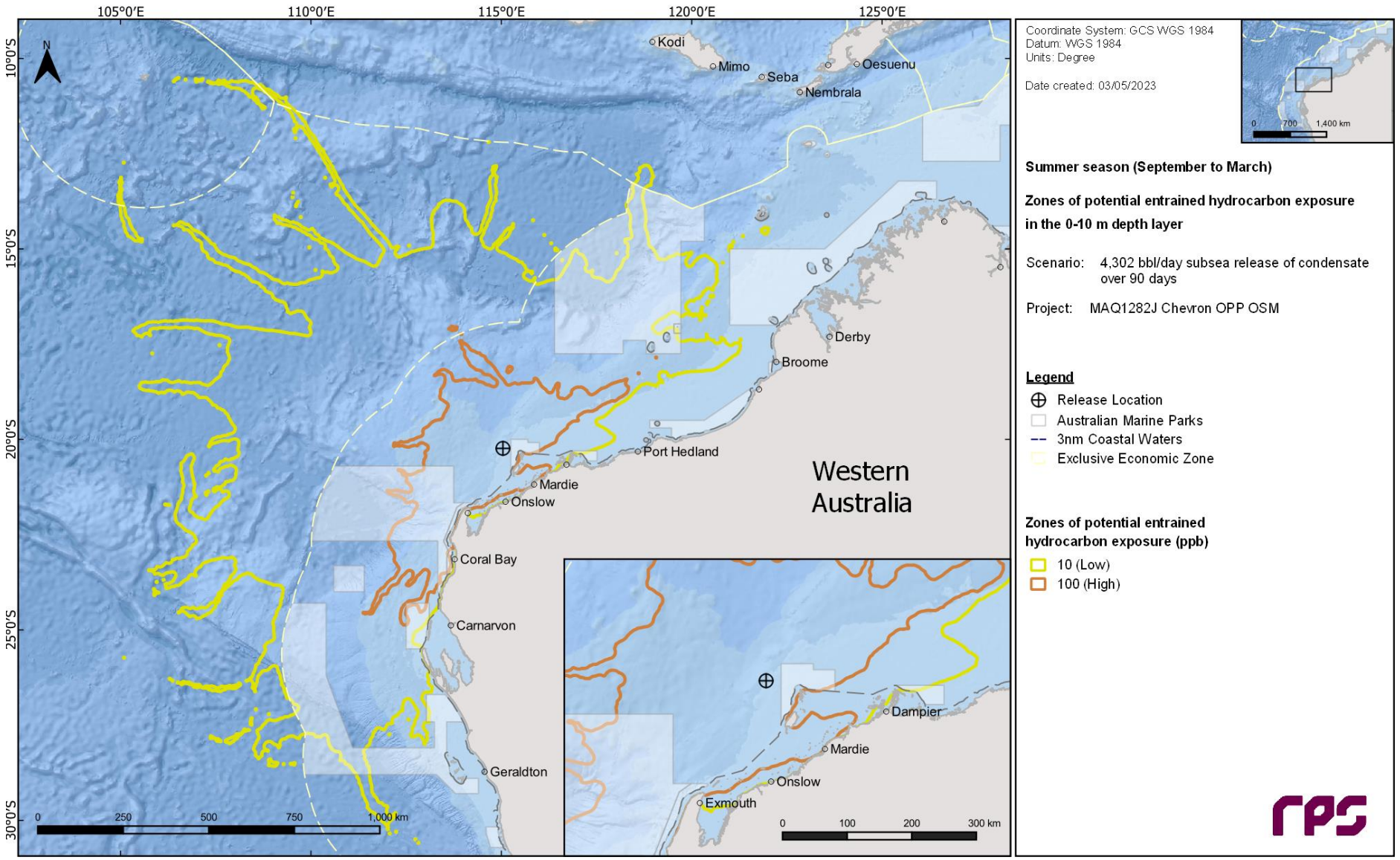


Figure 11.13 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

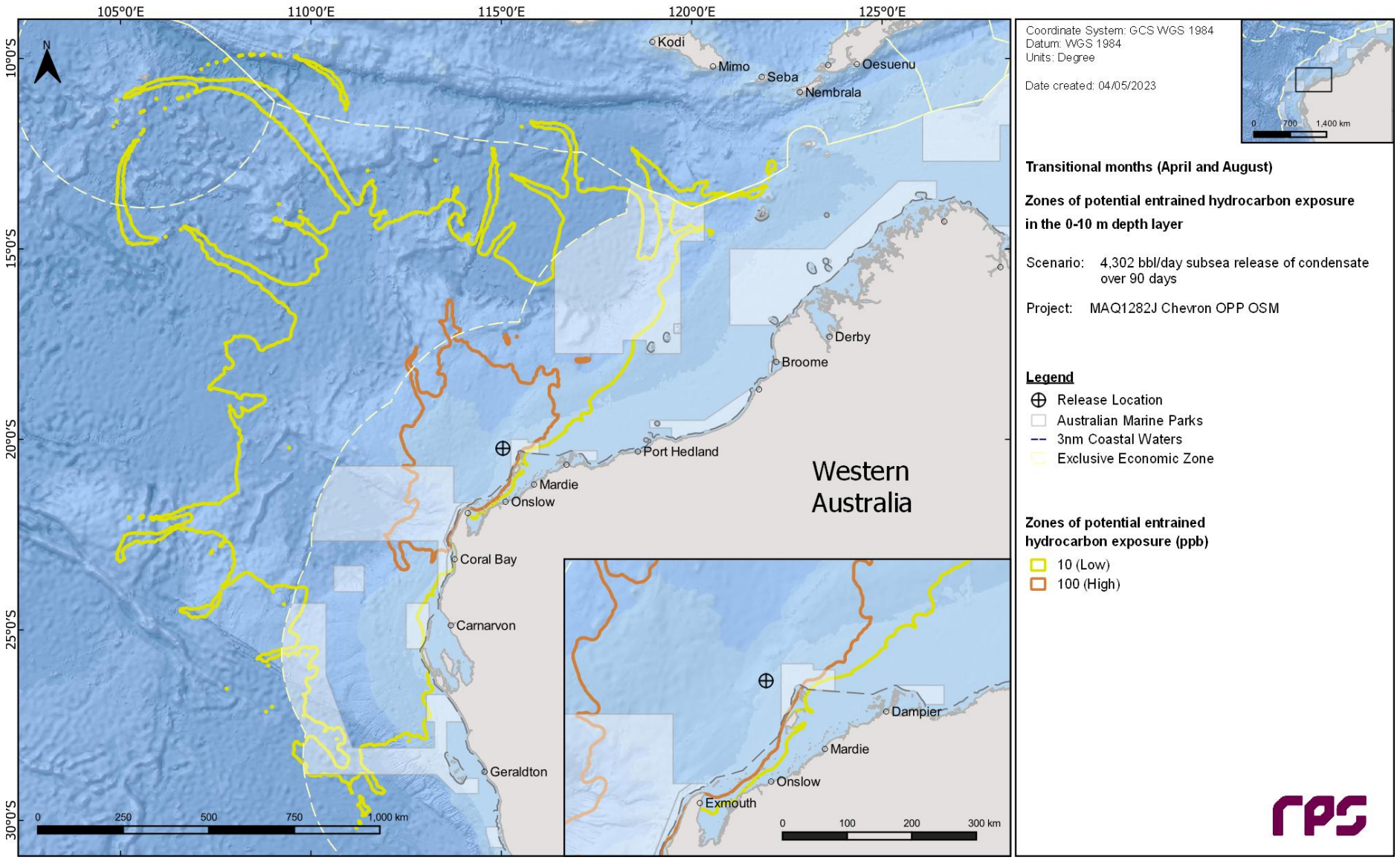


Figure 11.14 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

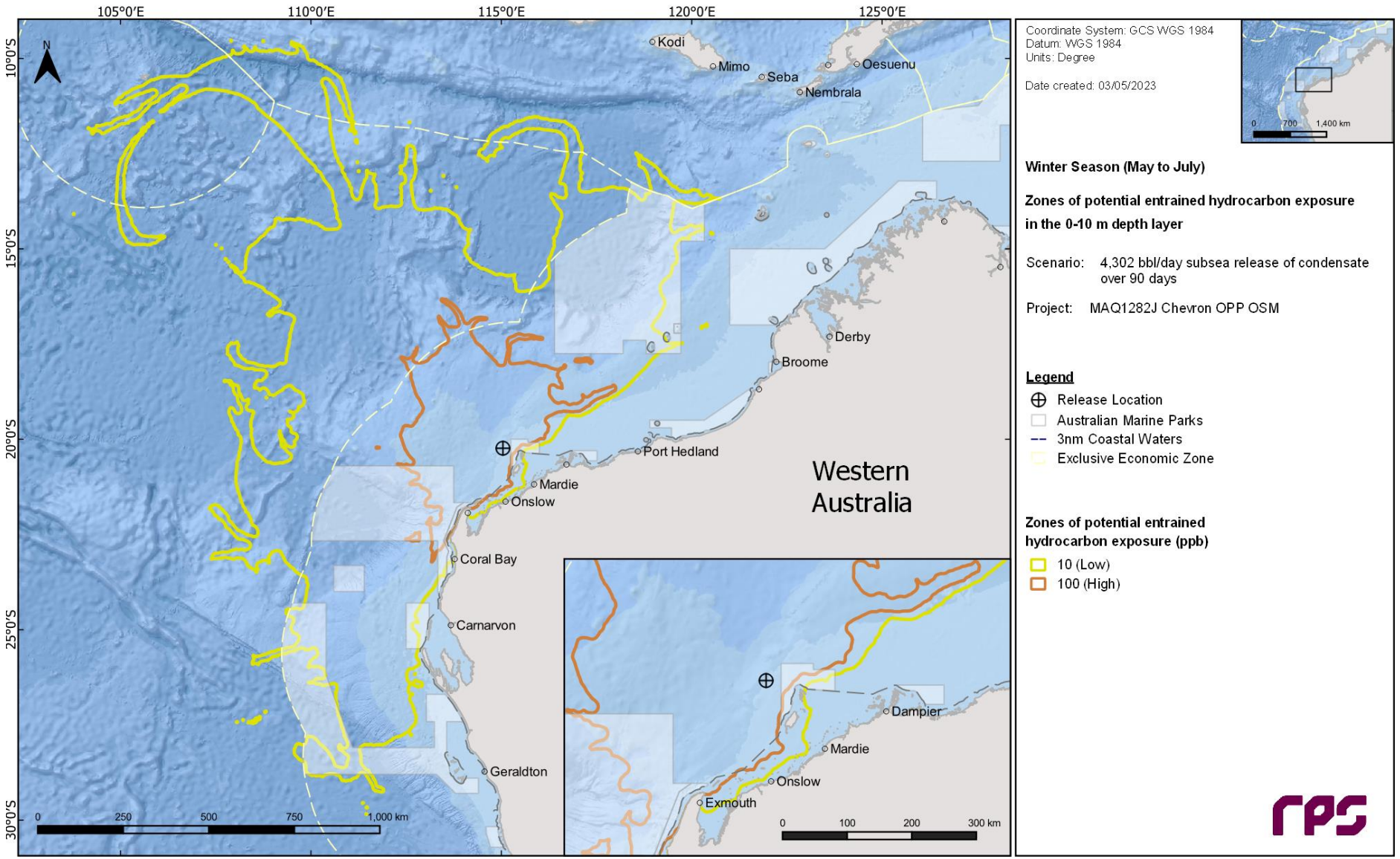


Figure 11.15 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

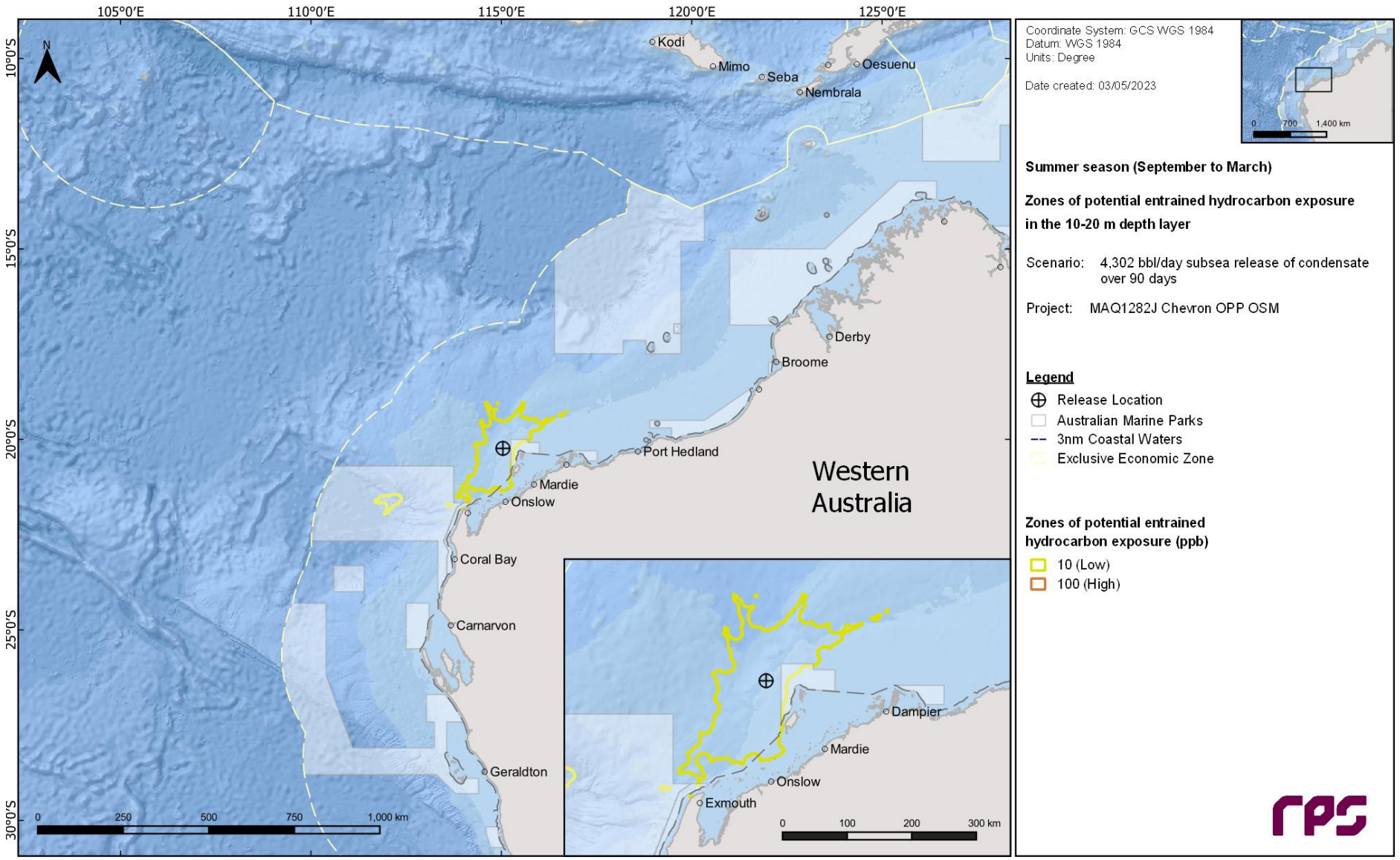


Figure 11.16 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

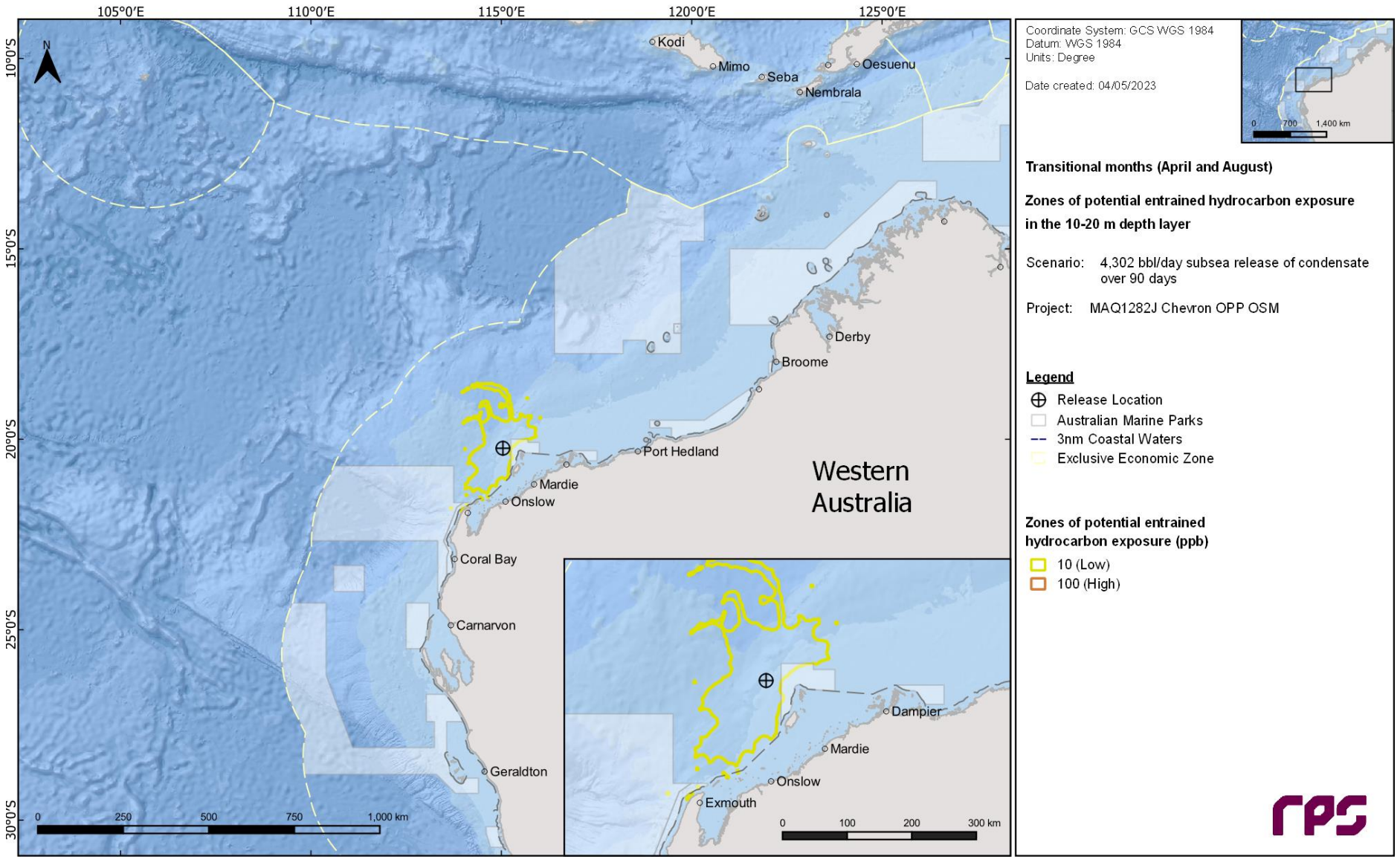


Figure 11.17 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

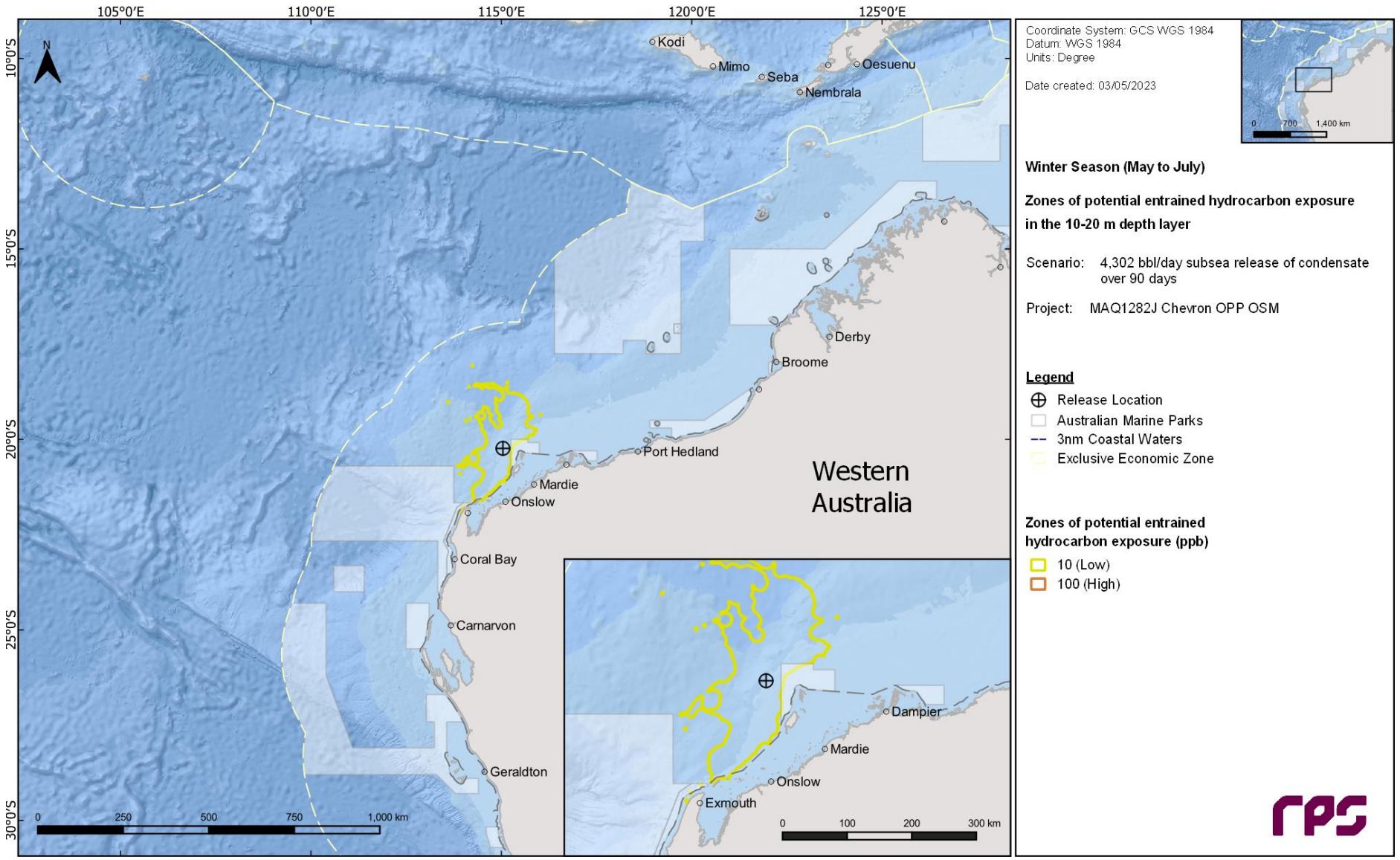


Figure 11.18 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), the largest swept area of floating condensate above 50 g/m^2 (see Section 11.2.2), largest volume of oil ashore (see Section 11.2.3), longest length of shoreline accumulation above 100 g/m^2 (see Section 11.2.4), the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.5), and the largest area of dissolved hydrocarbons above 50 ppb (see Section 11.2.6).

Table 11.9 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 3,033 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 220 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.9 Summary of the deterministic analysis following a subsea LOWC at WTR Well 5.

Variable	Threshold	Deterministic Analysis Criteria					
		Largest swept area of floating condensate above 10 g/m^2	Largest swept area of floating condensate above 50 g/m^2	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb	Largest area of dissolved hydrocarbons above 50 ppb
Season		Summer	Summer	Summer	Summer	Summer	Summer
Run Number		38	31	4	70	60	82
Floating Oil (km^2)	1 g/m^2	3,033	3,481	2,760	3,129	2,356	1,046
	10 g/m^2	**485**	469	330	358	231	111
	50 g/m^2	4	**14**	3	5	1	2
Shoreline Length (km)	10 g/m^2	112	-	145	146	21	-
	100 g/m^2	9	-	35	**38**	1	-
	1,000 g/m^2	-	-	-	-	-	-
Minimum Time (days)		7.04	-	65.91	35.41	41.04	-
Maximum Volume (m^3)		26.1	-	**128**	75.1	5.1	-
Entrained Area (km^2)	10 ppb	230,518	199,868	183,515	204,955	281,749	222,881
	100 ppb	38,746	27,375	29,171	37,256	**45,223**	23,545
Dissolved Area (km^2)	10 ppb	156	136	156	189	176	176
	50 ppb	-	-	-	-	-	**1**
	400 ppb	-	-	-	-	-	-
Start Date		9 January 2012	28 January 2014	7 November 2011	8 December 2011	31 January 2015	14 September 2019

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 was identified as run number 38 during the summer period.

Figure 11.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.20 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.21 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,165	9	1
Entrained (m^3)	9,458	90	6,965
Dissolved (m^3)	3	84	0
Evaporation (m^3)	40,477	101	40,477
Decay (m^3)	14,039	104	14,039
Ashore (m^3)	62	30	30

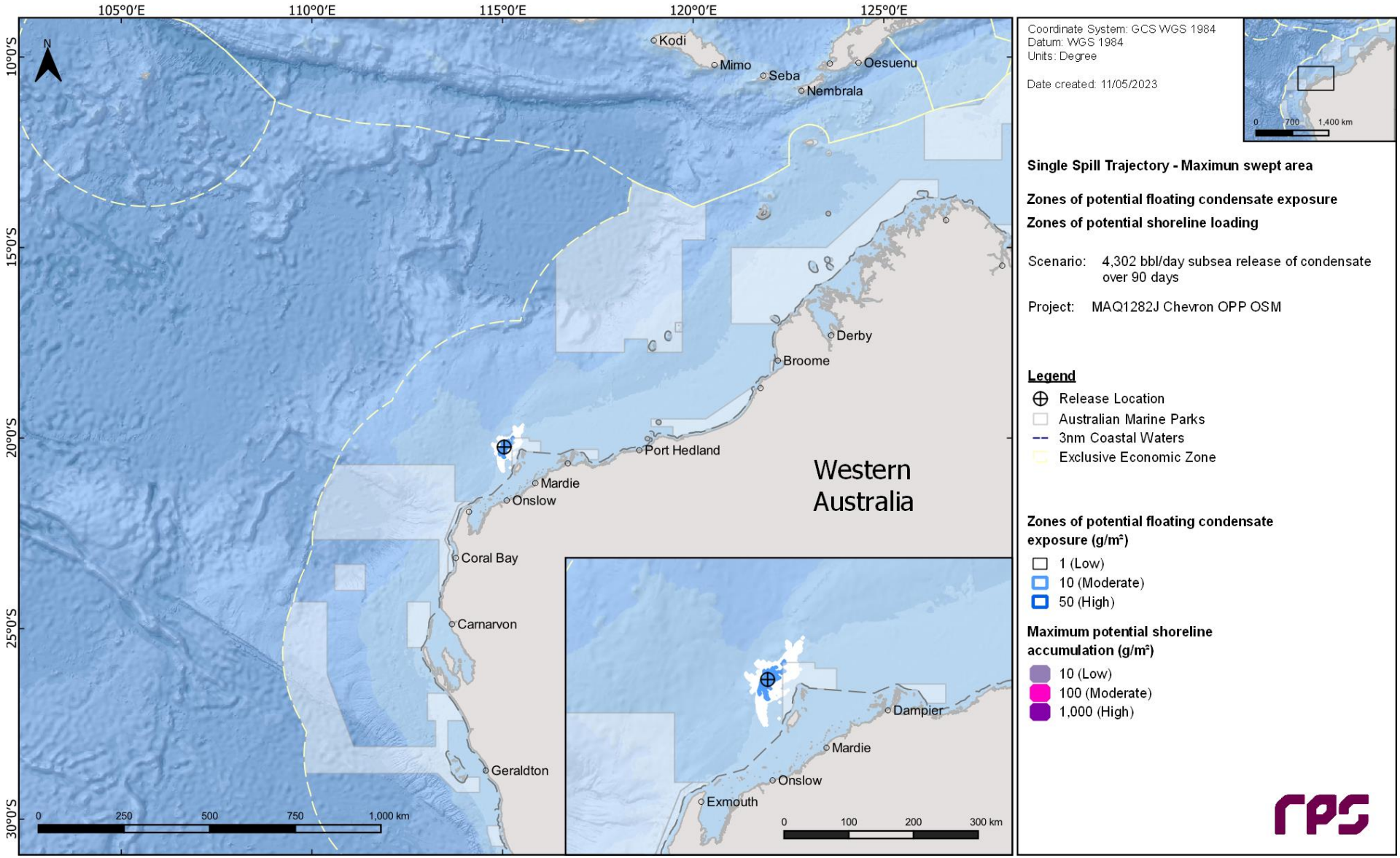


Figure 11.19 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m² following a subsea LOWC at WTR Well 5.

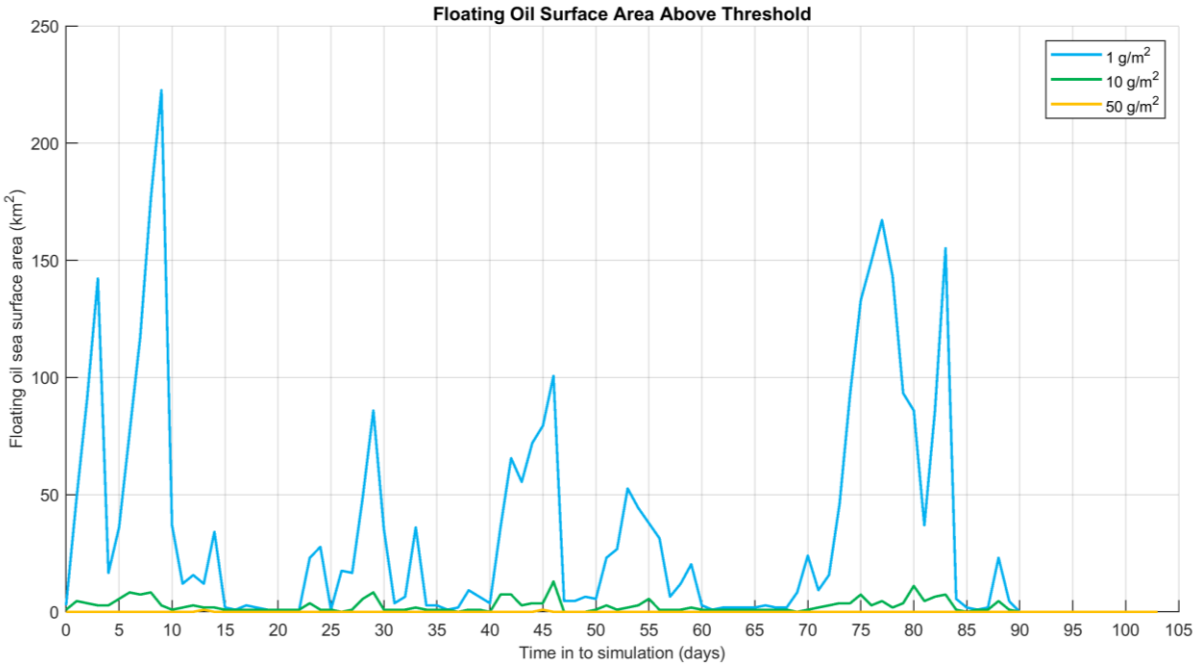


Figure 11.20 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m² following a subsea LOWC at WTR Well 5.

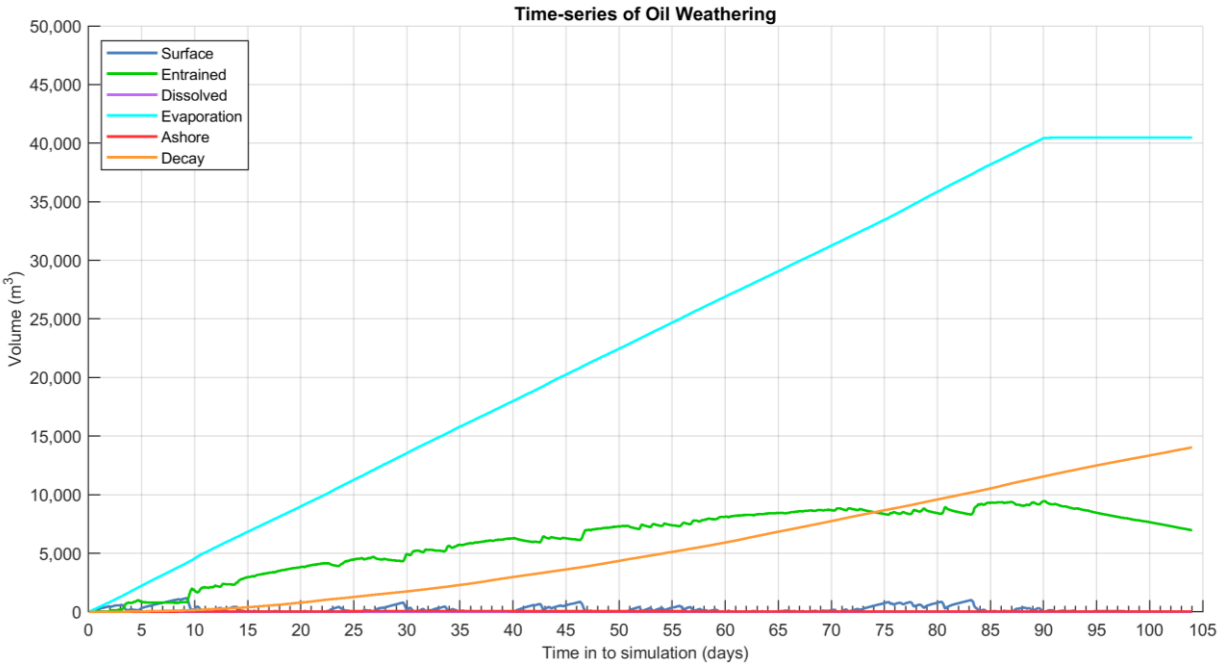


Figure 11.21 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m² following a subsea LOWC at WTR Well 5.

11.2.2 Deterministic Case: Largest swept area of floating condensate above 50 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 50 g/m^2 was identified as run number 31 during the summer period.

Figure 11.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.20 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.21 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	889	60	4
Entrained (m^3)	9,630	90	7,103
Dissolved (m^3)	3	53	0
Evaporation (m^3)	40,650	103	40,650
Decay (m^3)	13,751	104	13,751
Ashore (m^3)	4	101	4

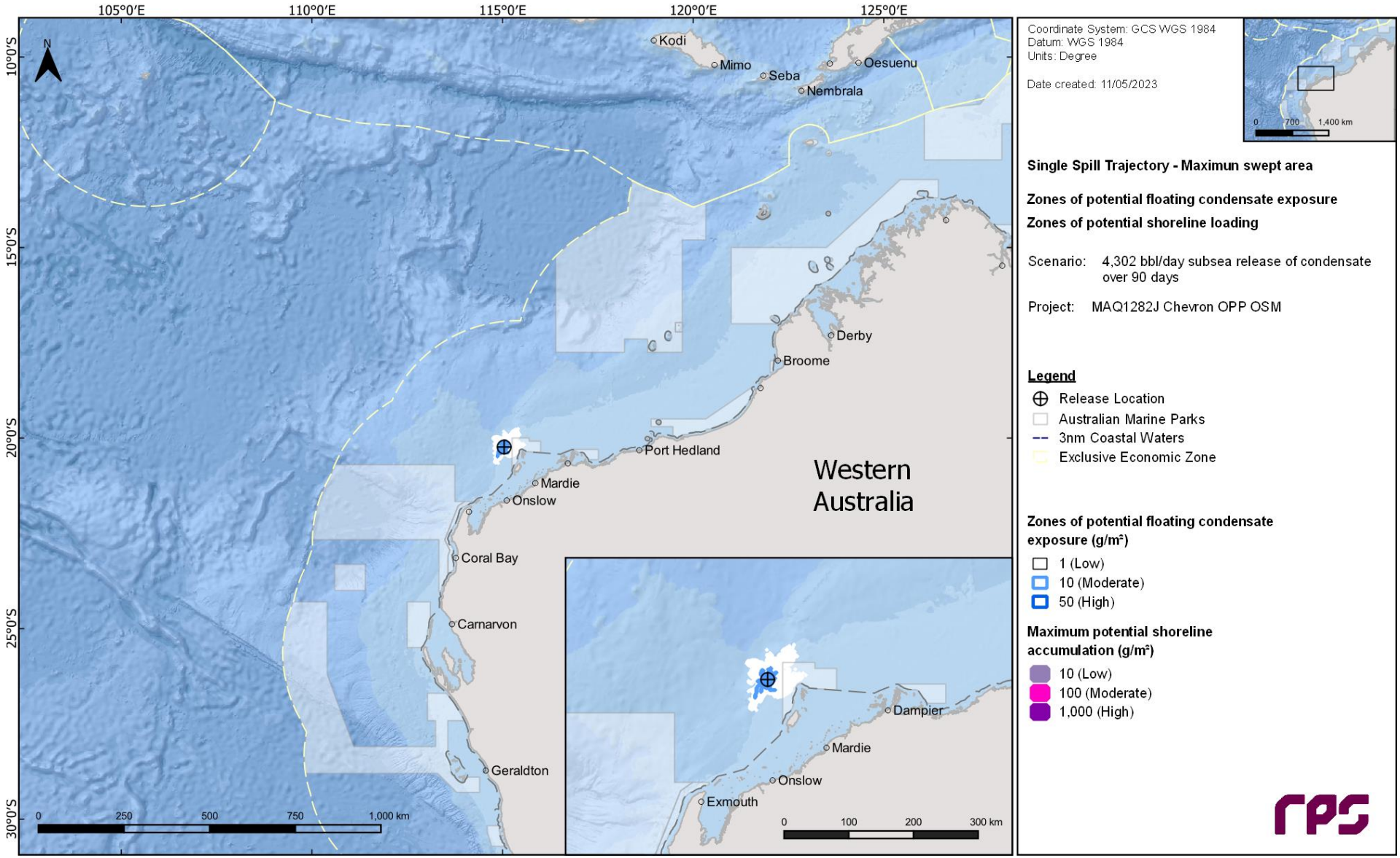


Figure 11.22 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

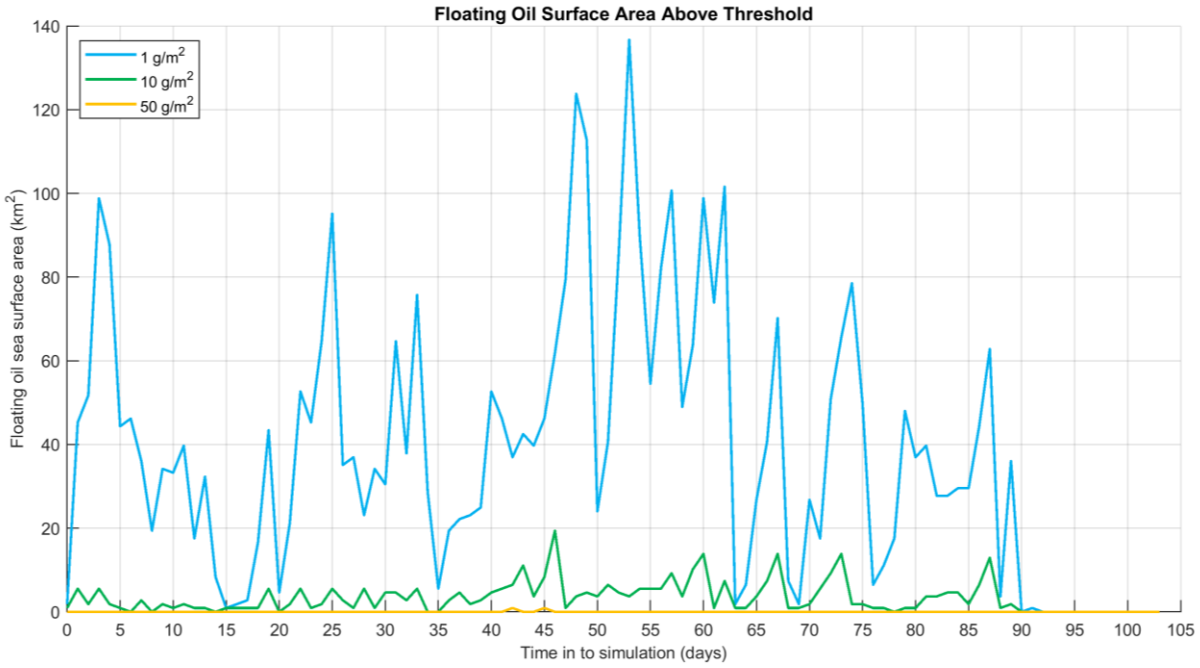


Figure 11.23 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

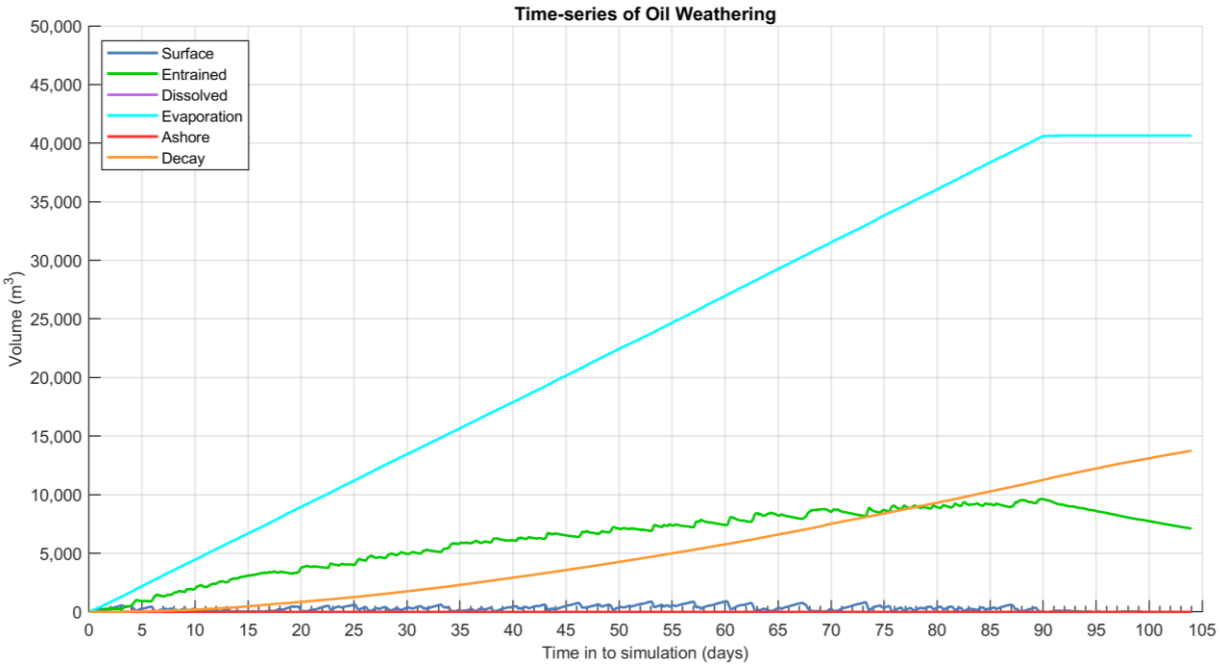


Figure 11.24 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

11.2.3 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 4 during the summer period.

Figure 11.25 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.26 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.27 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.12 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,211	72	20
Entrained (m^3)	8,831	88	6,539
Dissolved (m^3)	3	73	0
Evaporation (m^3)	40,583	104	40,583
Decay (m^3)	14,257	104	14,257
Ashore (m^3)	128	91	113

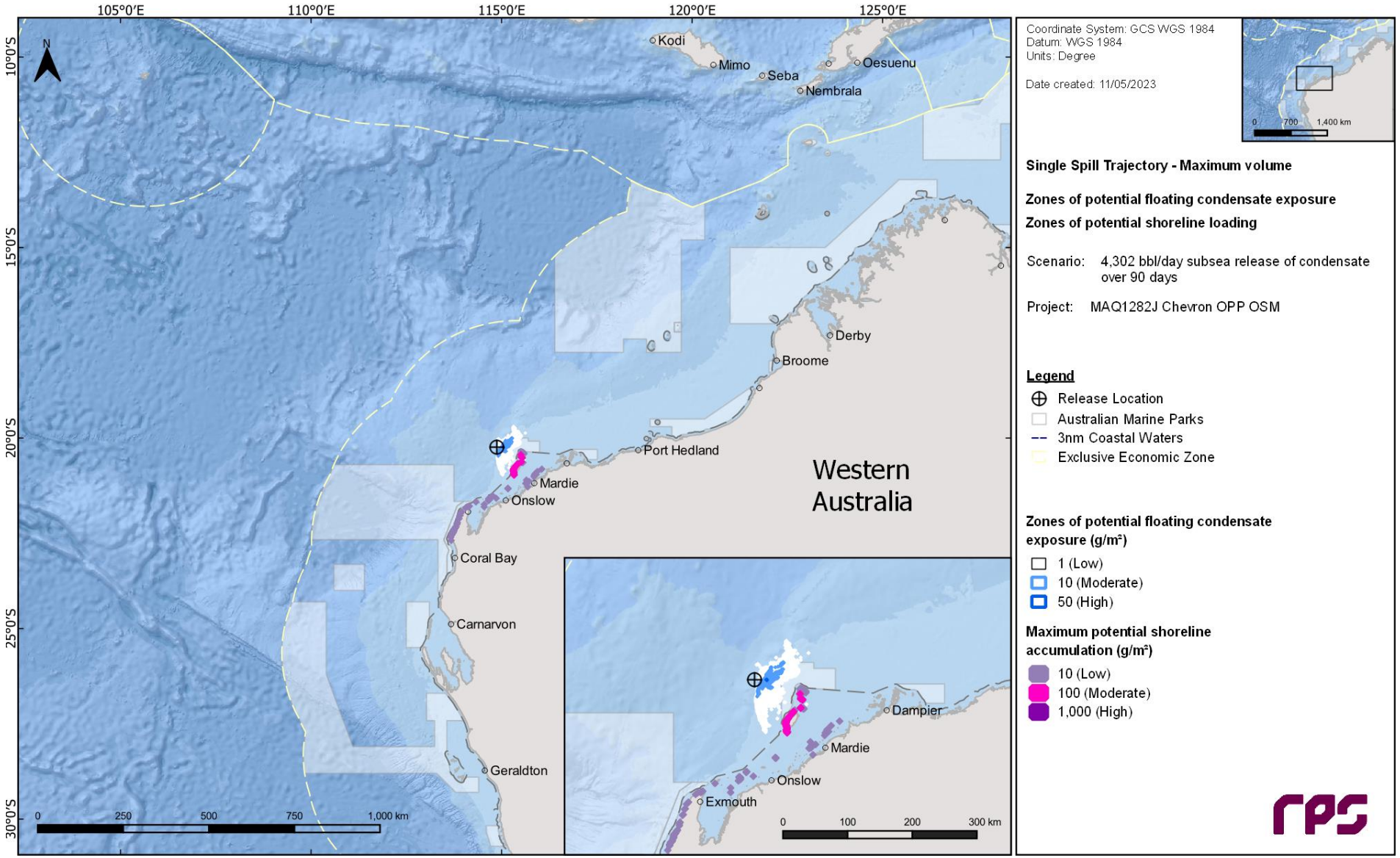


Figure 11.25 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

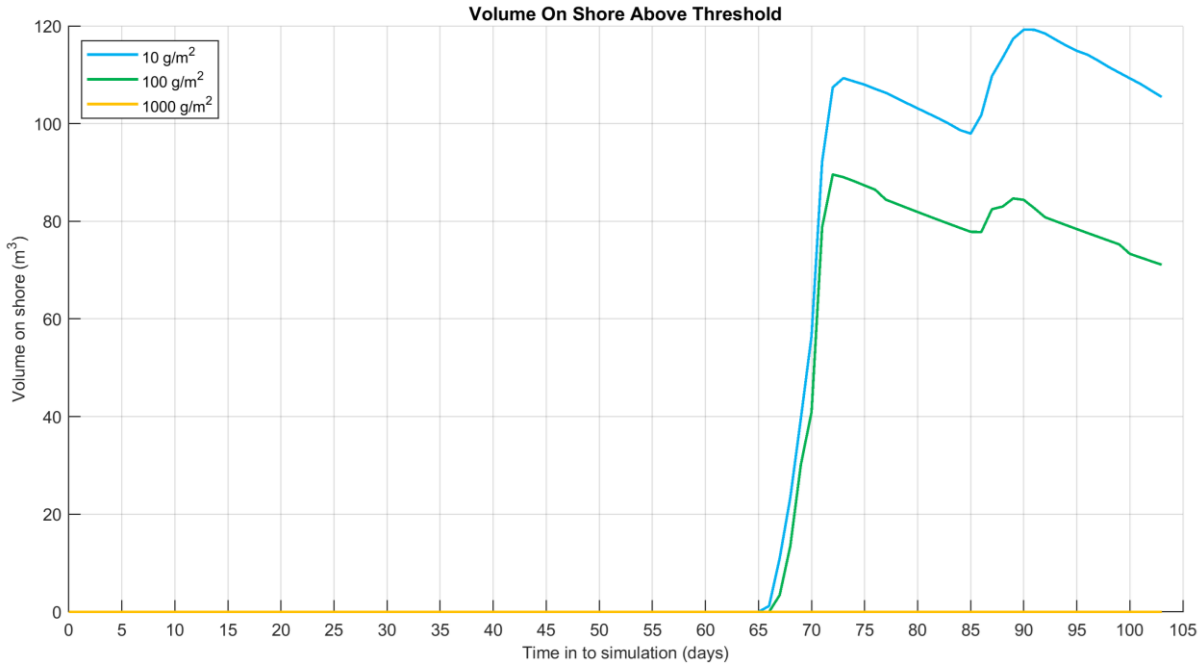


Figure 11.26 Time series of the volume of oil ashore at each threshold for the simulations with the largest volume ashore following a subsea LOWC at WTR Well 5.

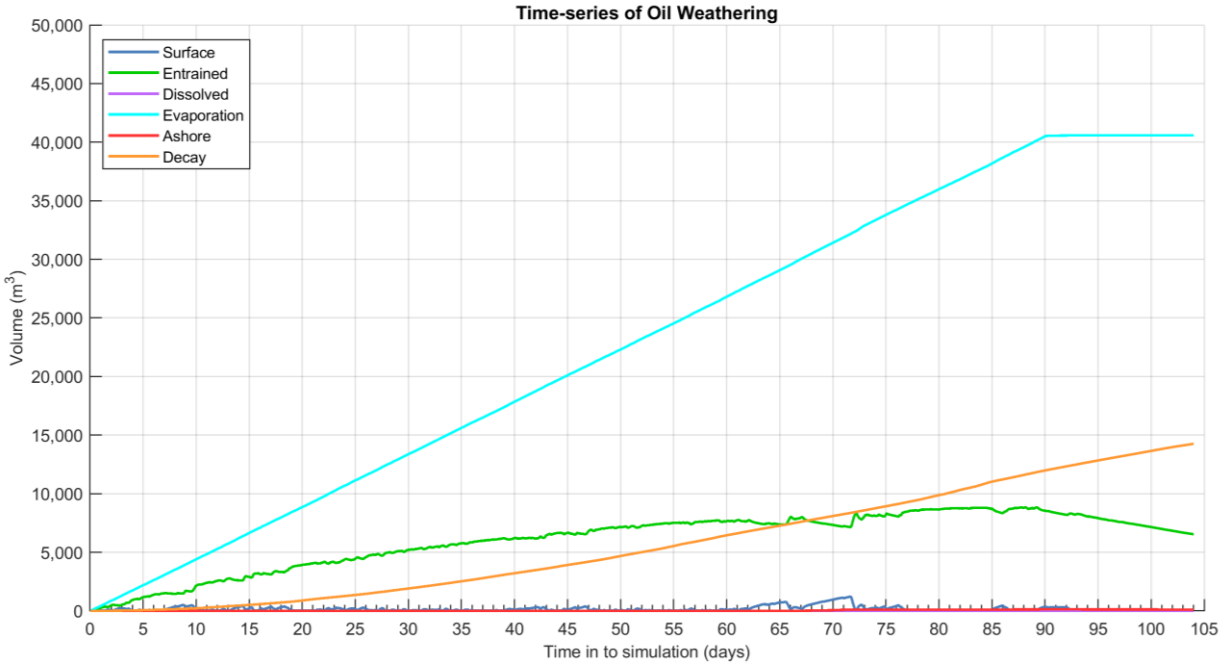


Figure 11.27 Predicted weathering and fates for the simulation with largest volume of oil ashore following a subsea LOWC at WTR Well 5.

11.2.4 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 70 during the summer period.

Figure 11.28 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.29 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.30 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,212	41	1
Entrained (m^3)	9,282	90	6,916
Dissolved (m^3)	3	38	0
Evaporation (m^3)	40,452	104	40,452
Decay (m^3)	14,065	104	14,065
Ashore (m^3)	121	60	80

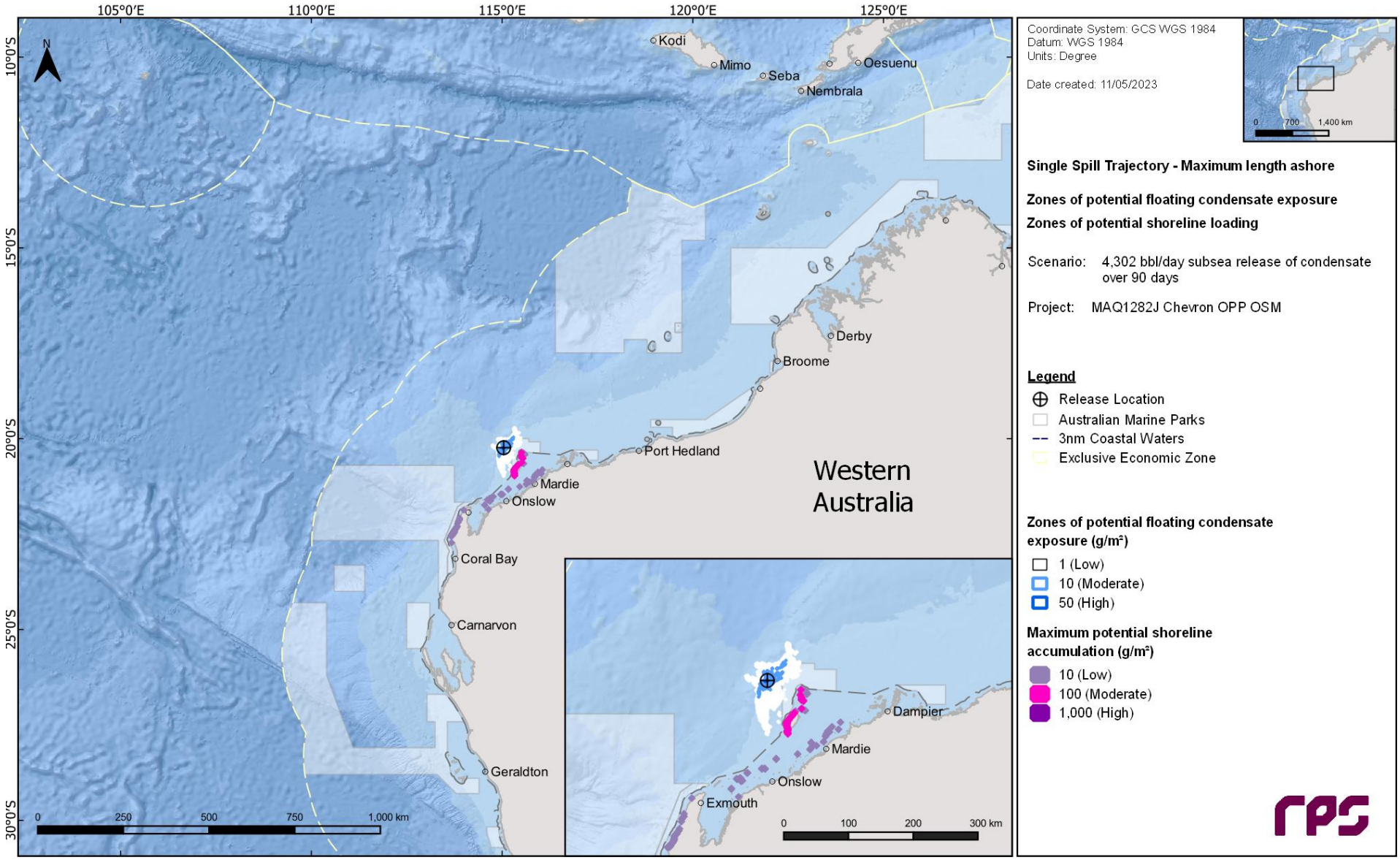


Figure 11.28 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the longest length of shoreline accumulation above 100 g/m² following a subsea LOWC at WTR Well 5.

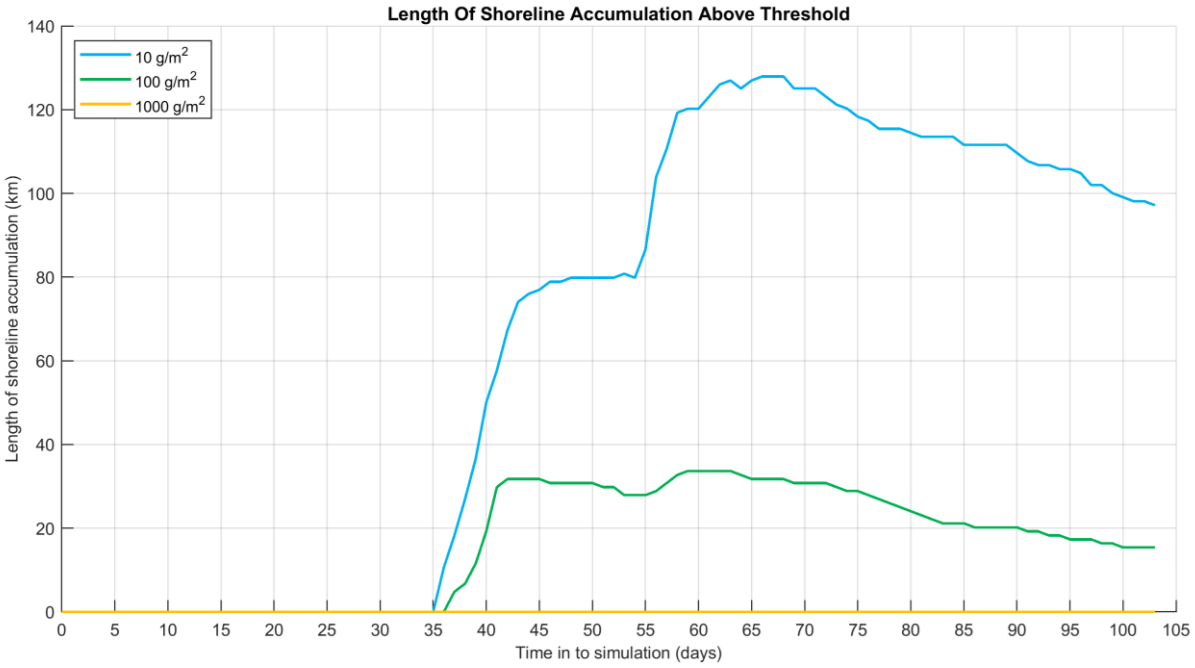


Figure 11.29 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

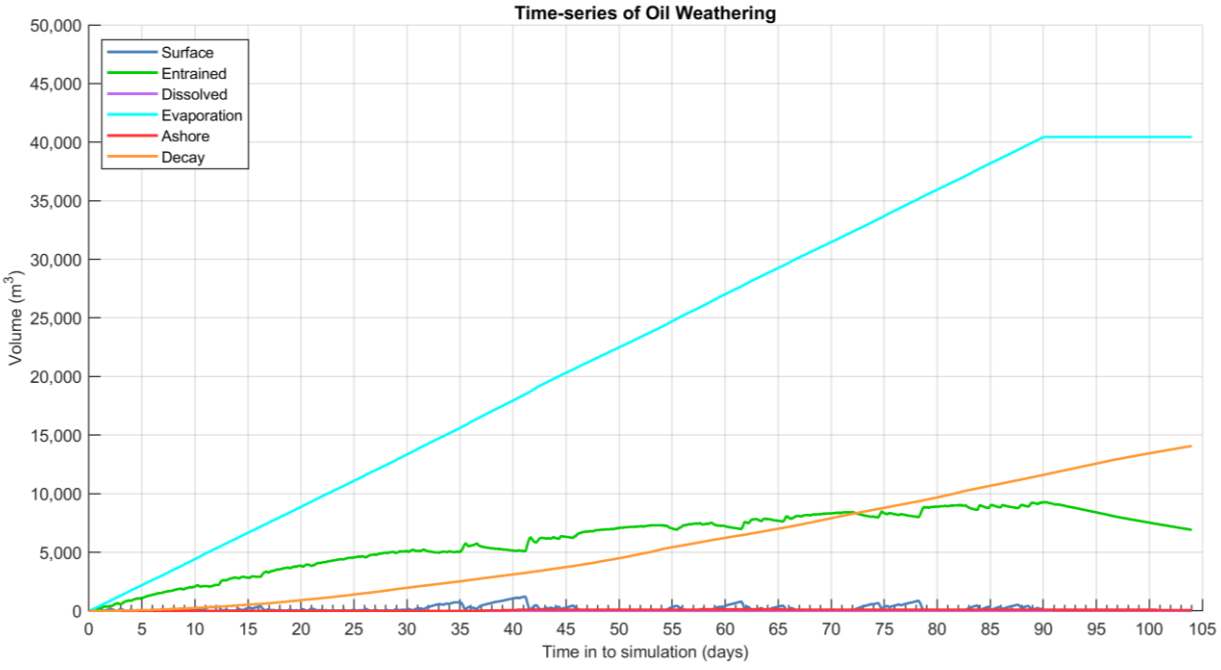


Figure 11.30 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

11.2.5 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 60 during the summer period.

Figure 11.31 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.32 displays the time series of the area of entrained hydrocarbons at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds over the 104-day simulation.

Figure 11.33 presents the fates and weathering for the corresponding single spill trajectory and Table 11.14 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.14 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	780	69	0
Entrained (m^3)	9,262	89	6,603
Dissolved (m^3)	3	76	0
Evaporation (m^3)	40,243	104	40,243
Decay (m^3)	14,659	104	14,659
Ashore (m^3)	10	45	6

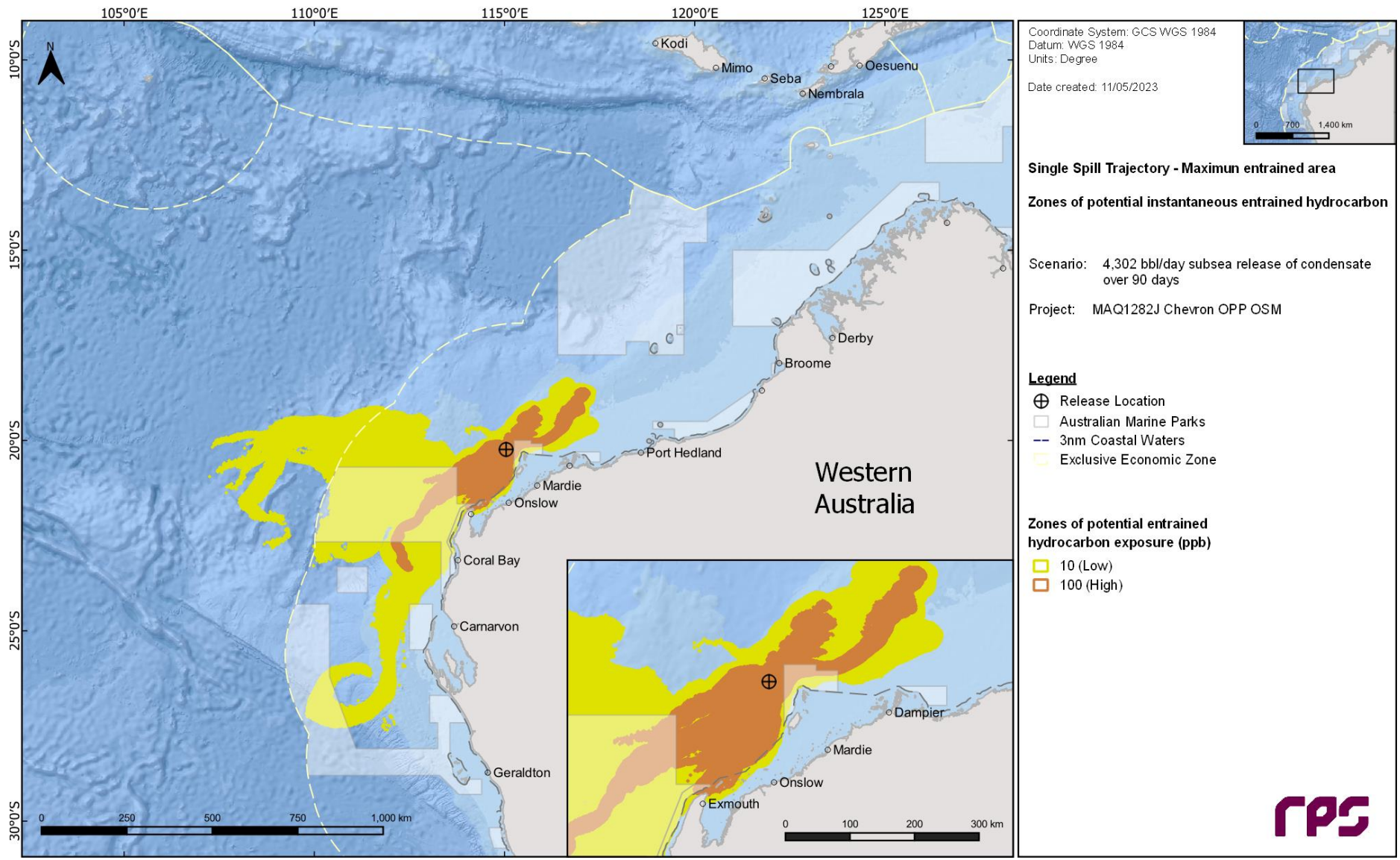


Figure 11.31 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

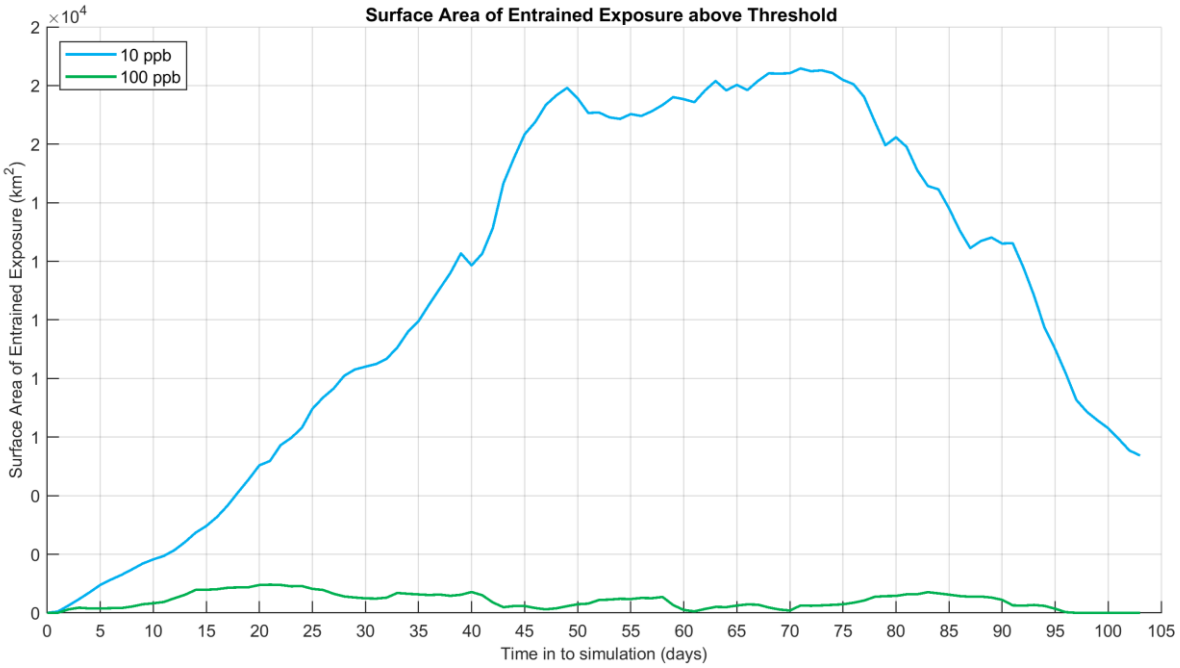


Figure 11.32 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

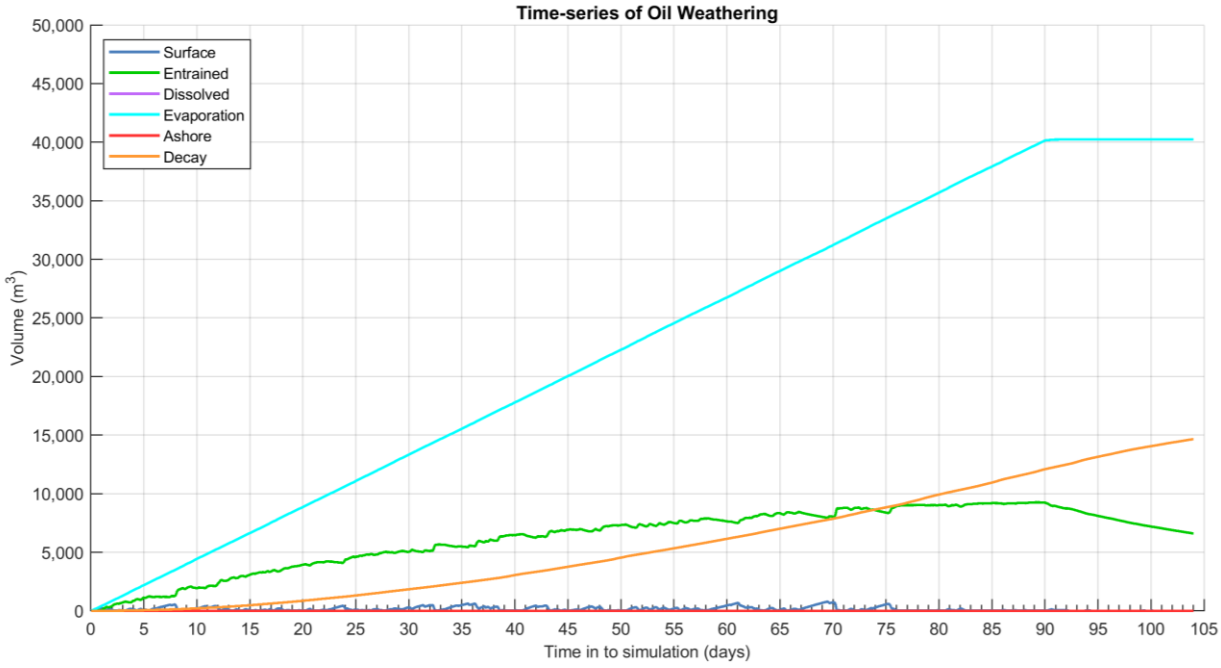


Figure 11.33 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

11.2.6 Deterministic Case: Largest area of dissolved hydrocarbons above 50 ppb

The deterministic simulation that resulted in the largest area of dissolved hydrocarbons above 50 ppb (moderate threshold) was identified as run number 82 during the summer period.

Figure 11.34 presents the extent of the predicted dissolved hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.35 displays the time series of the area of dissolved hydrocarbons at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥400 ppb) thresholds over the 104-day simulation.

Figure 11.36 presents the fates and weathering for the corresponding single spill trajectory and Table 11.15 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.15 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	475	2	7
Entrained (m^3)	9,207	90	6,714
Dissolved (m^3)	3	33	0
Evaporation (m^3)	40,117	104	40,117
Decay (m^3)	14,685	104	14,685
Ashore (m^3)	0	46	0

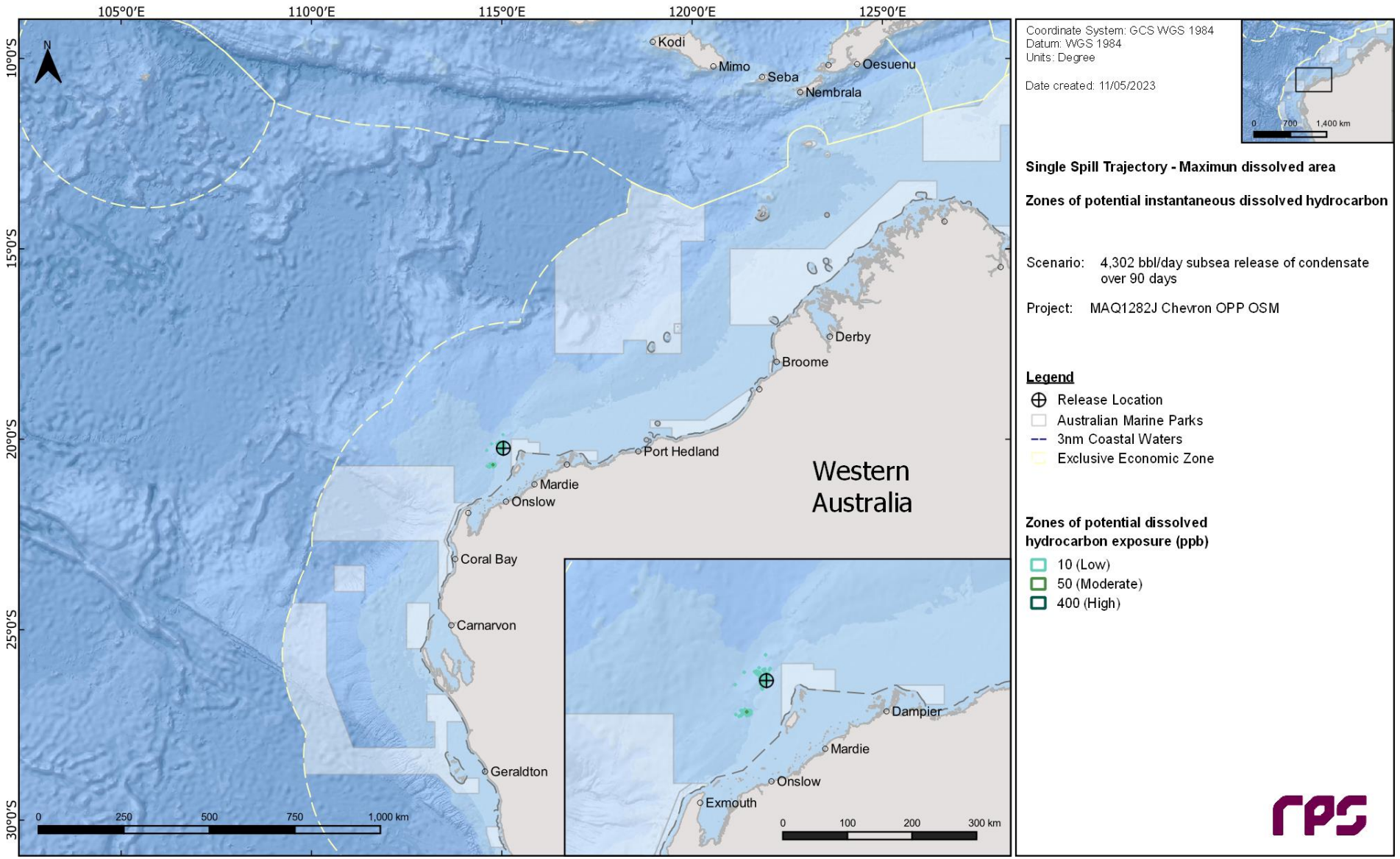


Figure 11.34 Zones of potential dissolved hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

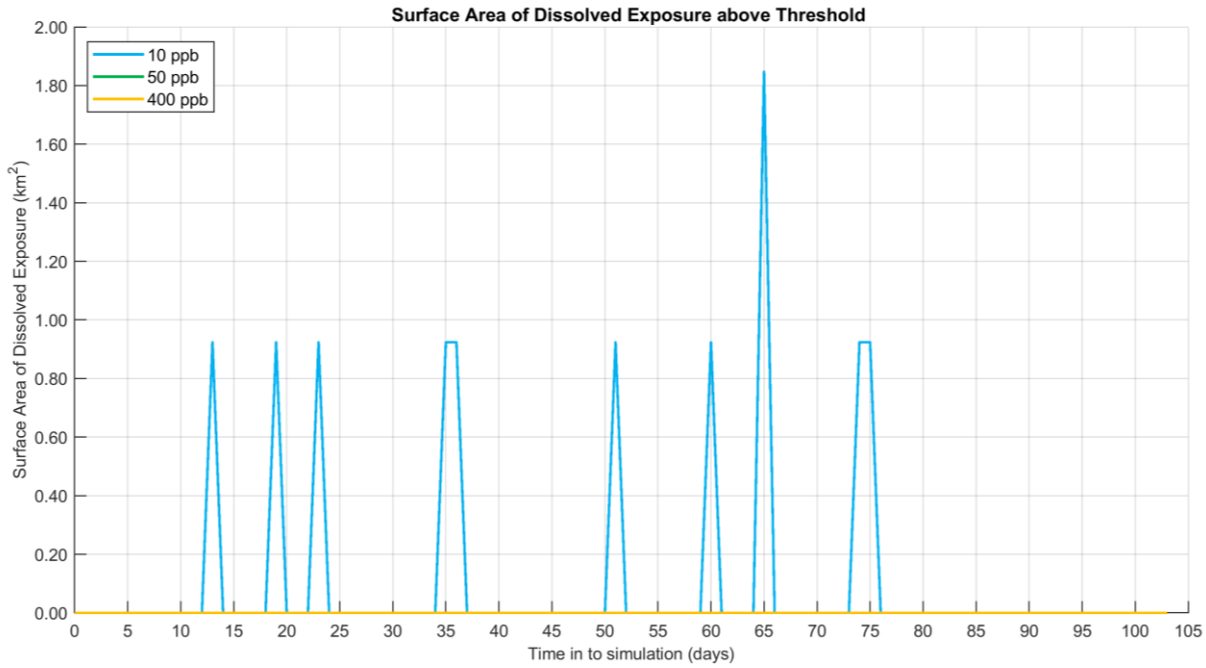


Figure 11.35 Time series of the area of dissolved hydrocarbons for each threshold, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

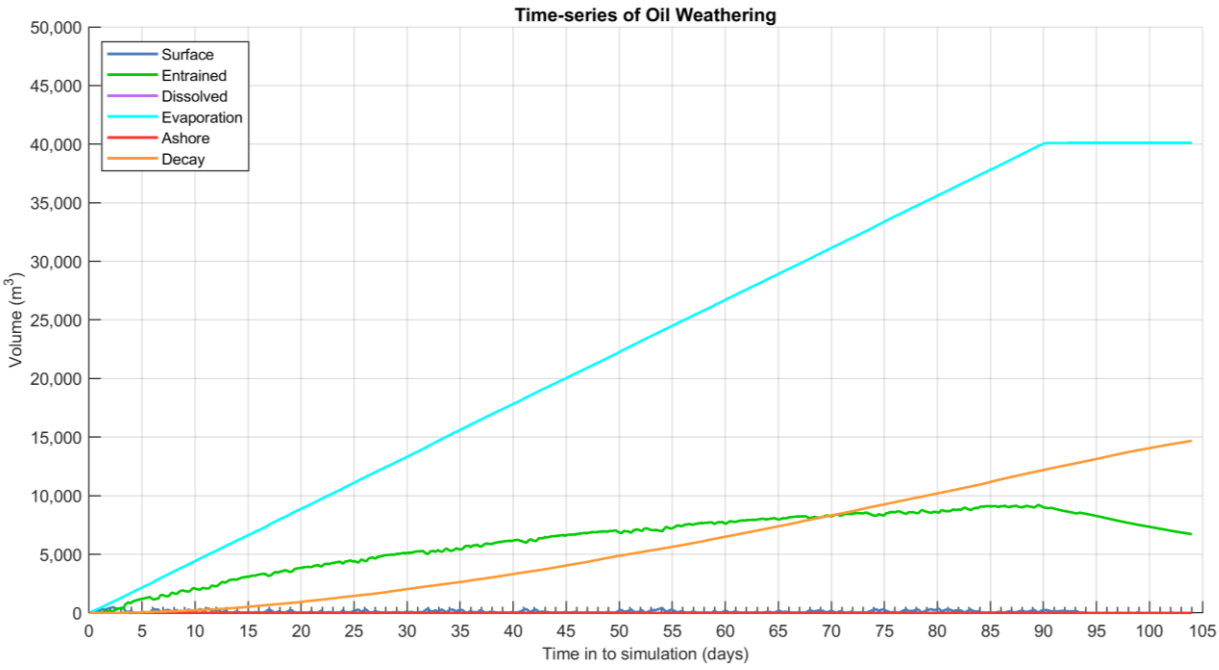


Figure 11.36 Predicted weathering and fates graph for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

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appendix c.3—G&E LOWC (condensate)

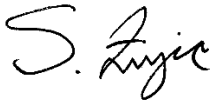
GREATER GORGON – GERYON–EURYTION

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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
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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m^3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating oil 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
g/m^2	Grams per square meter (unit of surface area density)
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.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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

SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Geryon and Eurytion (G&E) fields situated within the Northern Carnarvon Basin in Permit area WA-22-R and WA-39-L, respectively, northwest of Barrow Island off the north-west coast of Western Australia. Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 3,506 stb/day (557.47 m^3/day) subsea release of condensate over 90 days (totalling 315,540 stb or 50,165 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a 10-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Geryon condensate has an API of 42.67, a density of 810 kg/m^3 (at 15ºC) and a low viscosity value of 5.2 cP. When exposed to the atmosphere at local temperatures, about 31.5% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 27.1% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~31.7%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 9.7% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), indicating a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle. The soluble aromatic hydrocarbons contribute approximately 2.9% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 132.6 km south (summer) and 60.4 km southeast (winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these rectors ranged between 51% (all receptors; summer) and 82% (Pygmy Blue Whale - Distribution (BIA) and Offshore Area IAA); winter). Additionally, the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs were also predicted to be exposed at the low threshold during summer (7% and 1%), transitional (13% and 6%) and winter (15% and 13%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs was 5.79 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Continental Slope Demersal Fish Communities (KEF) was 96%, 80% and 84% during summer, transitional and winter, respectively. The corresponding minimum time before low exposure at the Continental Slope Demersal Fish Communities (KEF) was 1.88 days (summer).

- The probability of shoreline accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 23%, while the minimum time before shoreline accumulation was 7.46 days and the maximum volume of oil ashore 23.2 m^3. Additionally, no shoreline accumulation was predicted during transitional conditions, nor was there any high (≥ 1,000 g/m^2) shoreline threshold accumulation predicted during any seasonal conditions modelled.

- During summer conditions, condensate had accumulated on 38 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA and Barrow Island Group (15%). In comparison, during winter conditions, condensate was predicted to accumulate on 4 shoreline receptors and each with an 8% probability.

- No dissolved hydrocarbon exposure was predicted for this scenario at, or above, the low reporting threshold (≥10 ppb) during any of the seasons modelled.

- In the 0-10 m depth layer, a total of 40, 22 and 22 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter conditions respectively. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for Humpback Whale - Migration BIA (95% summer, 91% transitional and 87% winter). Additionally, within the same depth layer, during summer, transitional and winter conditions, 8, 7 and 7 KEFs were predicted to be exposed at the low threshold, respectively. Probabilities ranged between 2–100%, 2–100% and 3–100% for summer, transitional and winter, respectively.

- In the 0-10 m depth layer, a total of 50, 17 and 15 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold during summer, transitional and winter conditions, respectively. Excluding the Offshore IAA, the probabilities for each season ranged between 1–92%, 1–97% and 1–86% under summer, transitional and winter conditions, respectively with the maximum probabilities occurring at the Gascoyne IAA during all seasons. Furthermore, 59, 5 and 4 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter conditions, respectively. Maximum summer, transitional and winter probabilities of 23% for Rankin Bank, 6% for Rankin Bank and Outtrim Patches and 14% for Outtrim Patches, respectively, were predicted.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Geryon and Eurytion (G&E) fields situated within the Northern Carnarvon Basin in Permit area WA-22-R and WA-39-L, respectively, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the G&E fields, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 3,506 stb/day (557.47 m^3/day) subsea release of condensate over 90 days (totalling 315,540 stb or 50,165 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 Geryon–Eurytion release location.

Location	Latitude	Longitude	Depth (mLAT)
GER FL 2	19.56º S	114.53º E	1,100

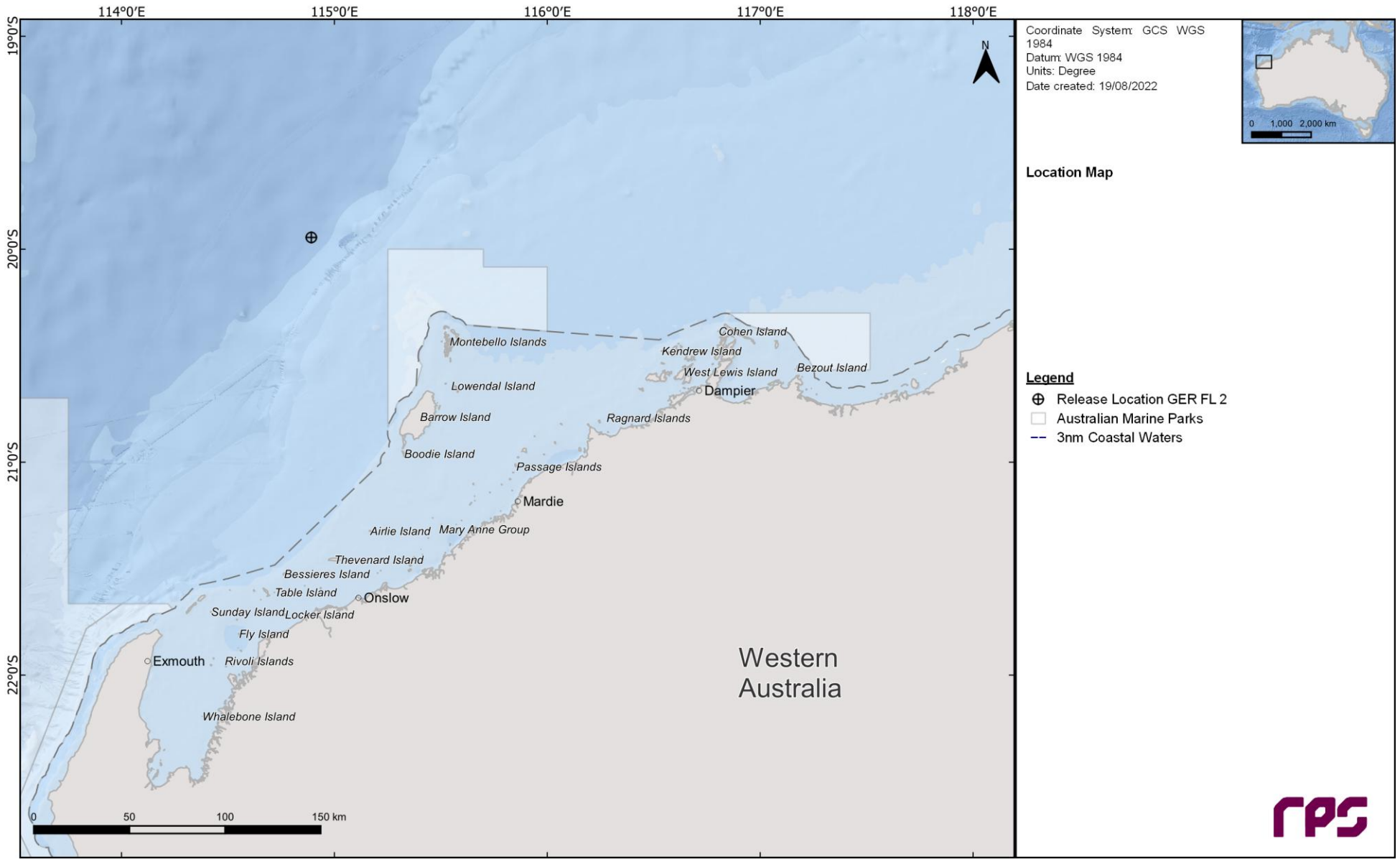


Figure 1.1 Geryon and Eurytion hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate 10-years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
    a. Largest swept area of floating hydrocarbon above 10 g/m^2
    b. Largest swept area of floating hydrocarbon above 50 g/m^2
    c. Largest volume of oil ashore
    d. Longest length of shoreline accumulation above 100 g/m^2
    e. Largest area of entrained hydrocarbons above 100 ppb
    f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

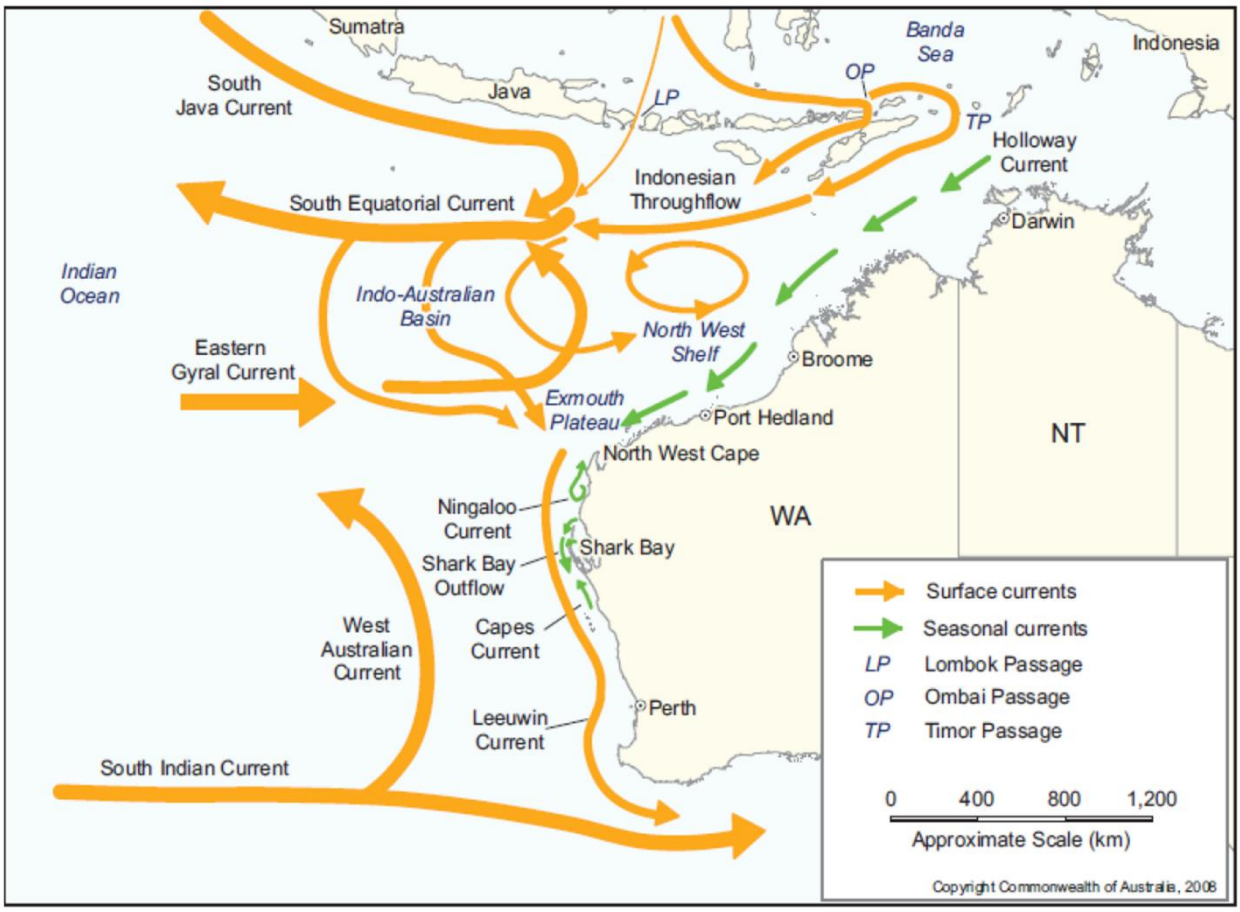


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

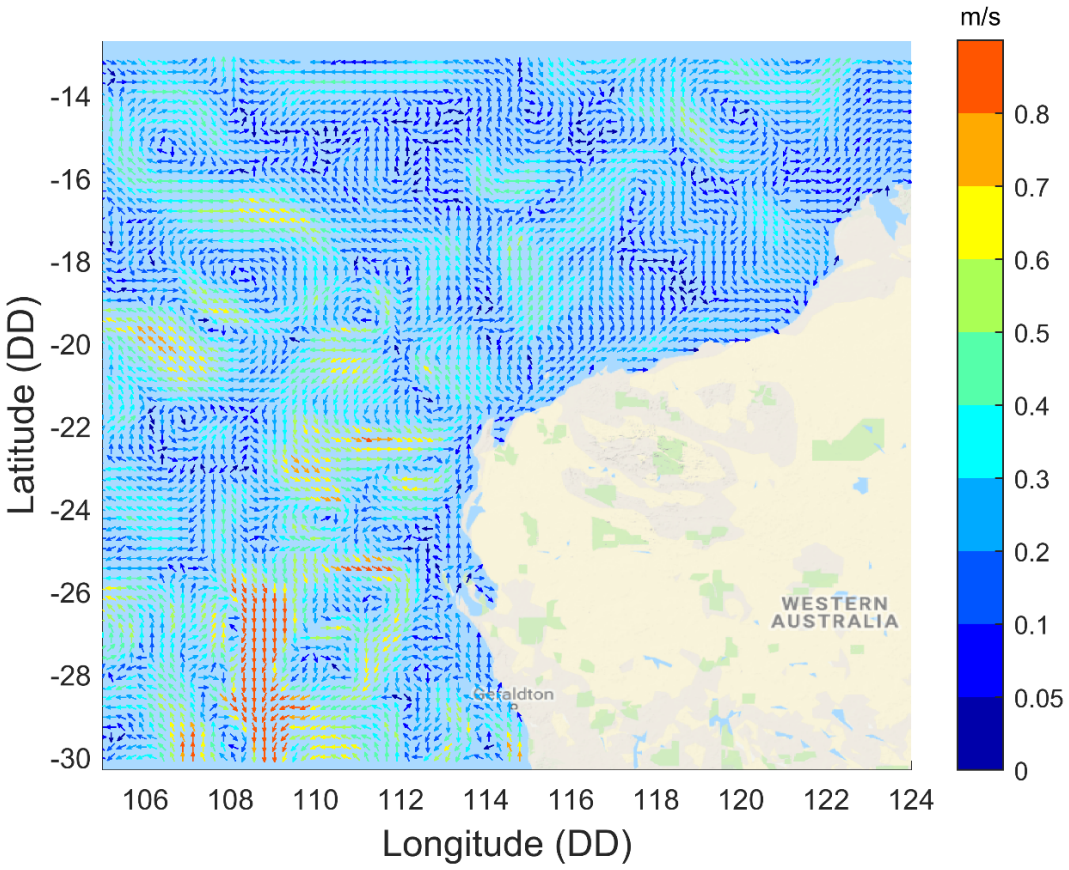


Figure 3.2 Typical ocean current circulation pattern during the summer months.

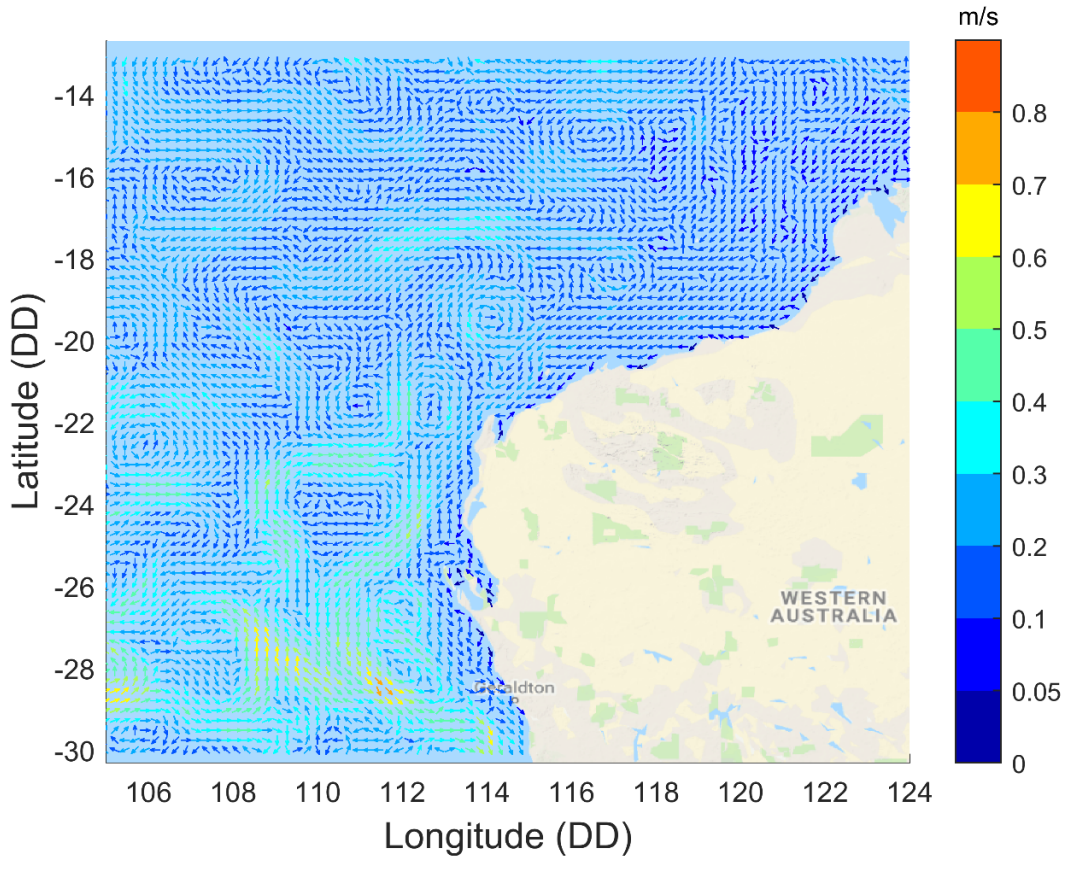


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

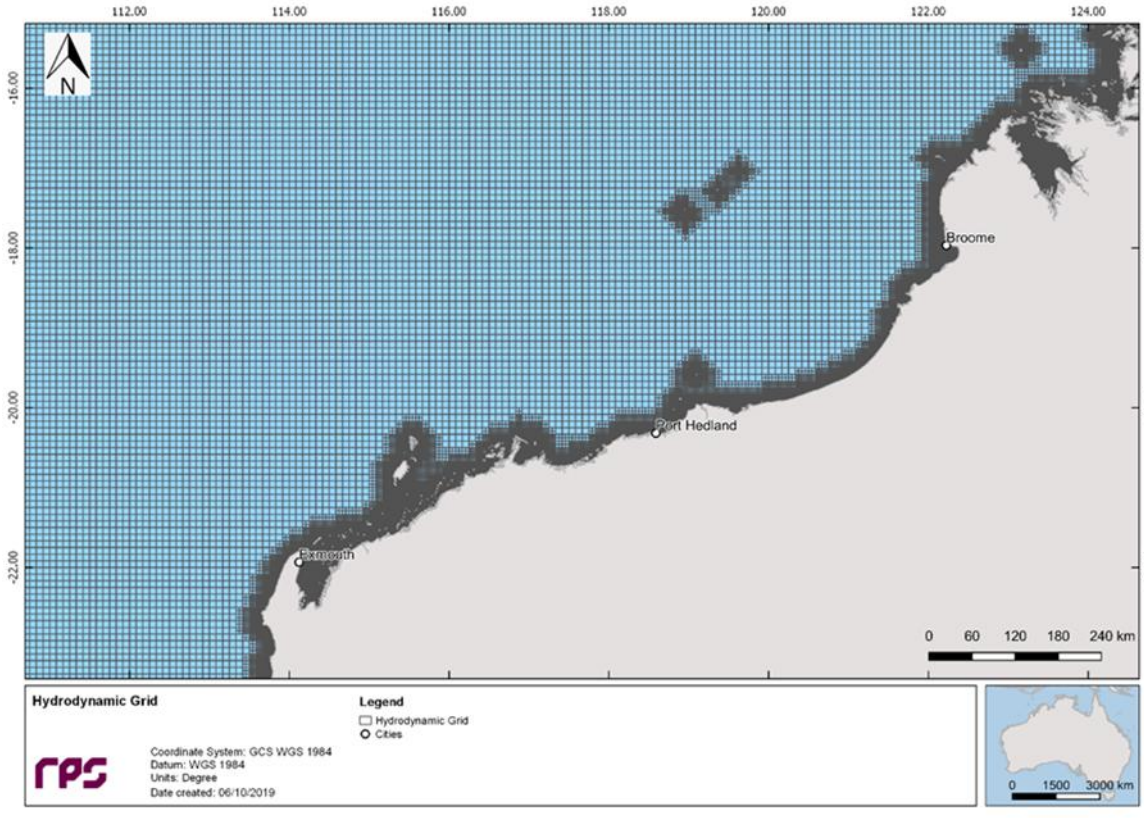


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

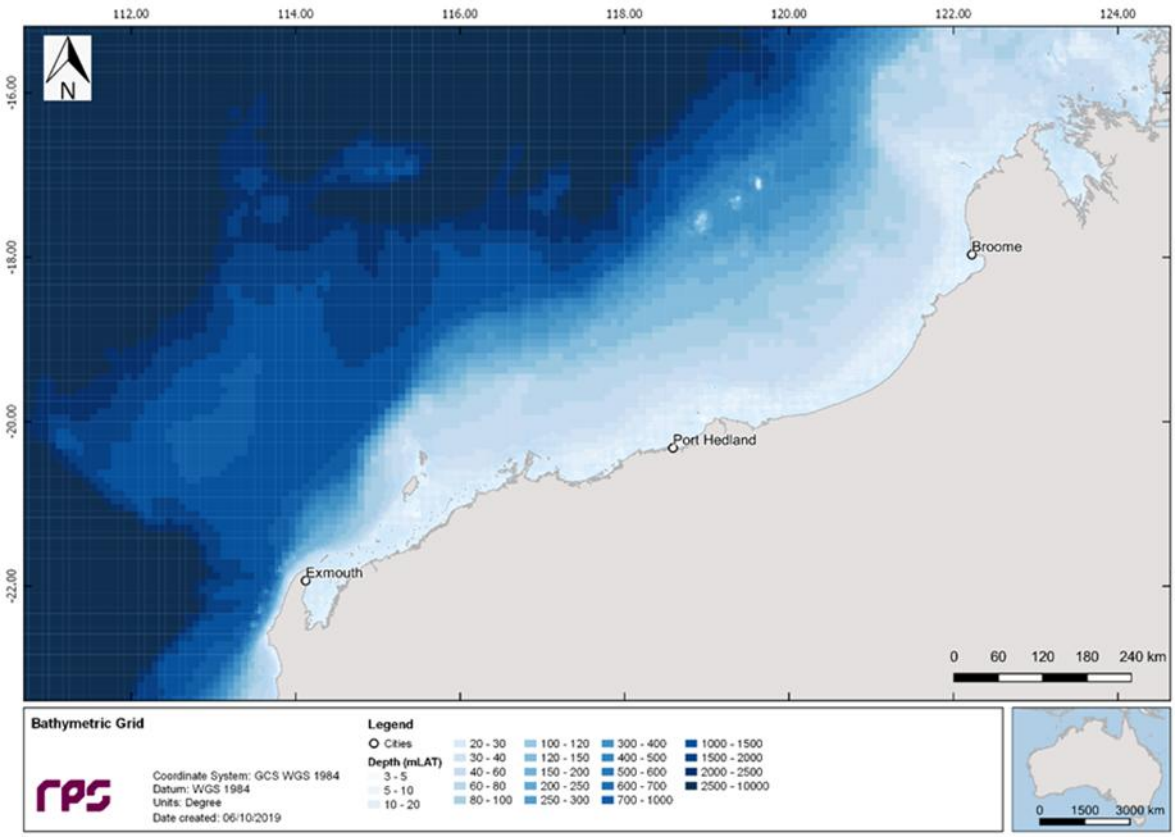


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.19 m/s (February, November and December) and 0.25 m/s (June). Additionally, the monthly maximums ranged between 0.62 m/s (November) and 1.53 m/s (January). The general surface current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total surface current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.20	1.53	Variable
	February	0.19	1.11	Variable
	March	0.21	1.35	Southwest
Transitional	April	0.23	1.02	Southwest
Winter	May	0.23	0.78	Southwest
	June	0.25	0.84	Southwest
	July	0.23	0.90	Southwest
Transitional	August	0.21	0.79	Variable
Summer	September	0.22	0.83	Northeast and Southwest
	October	0.19	0.63	Northeast and Southwest
	November	0.19	0.62	Southwest
	December	0.19	0.71	Southwest
Minimum		**0.19**	**0.62**	
Maximum		**0.25**	**1.53**	

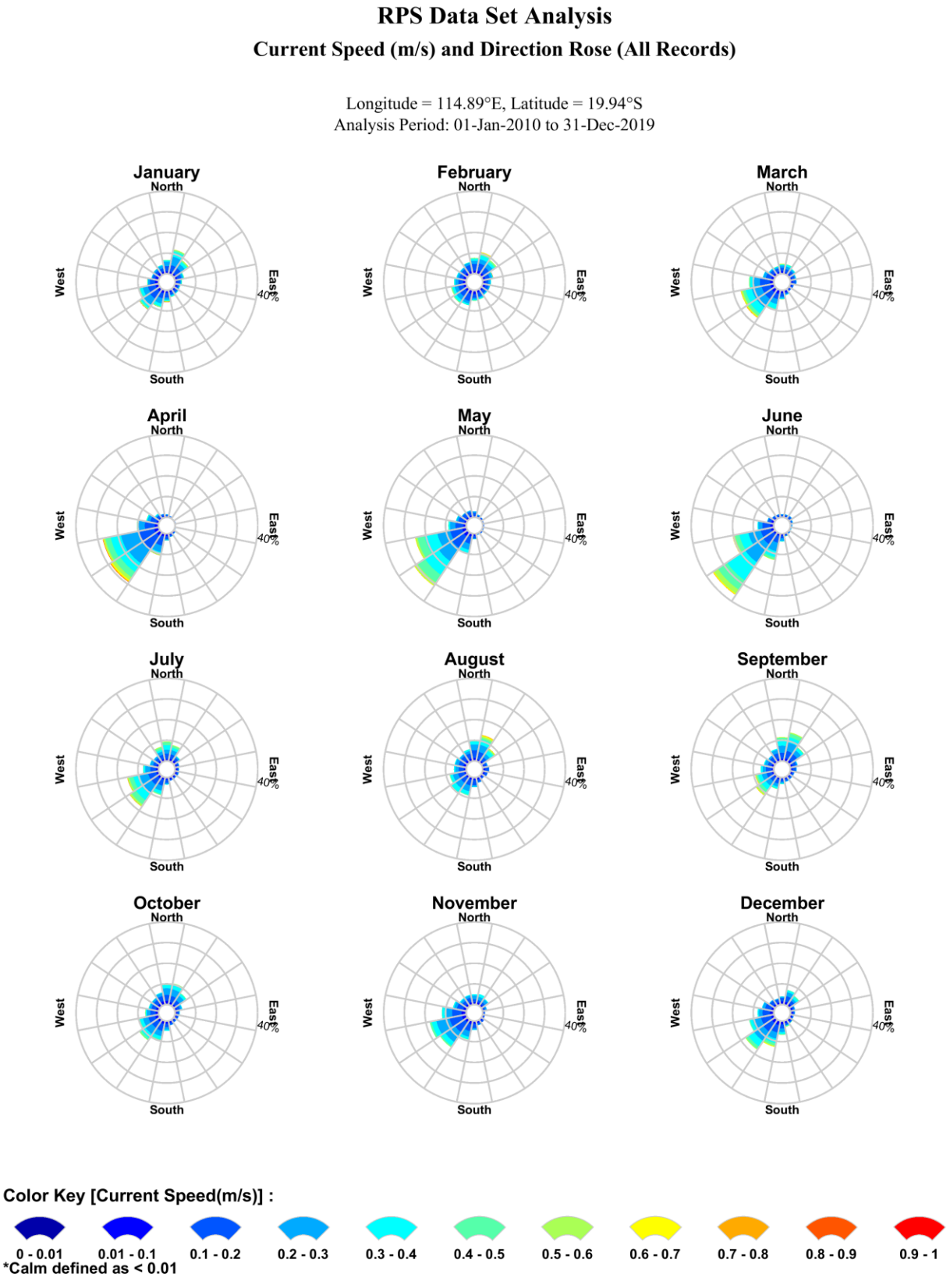


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

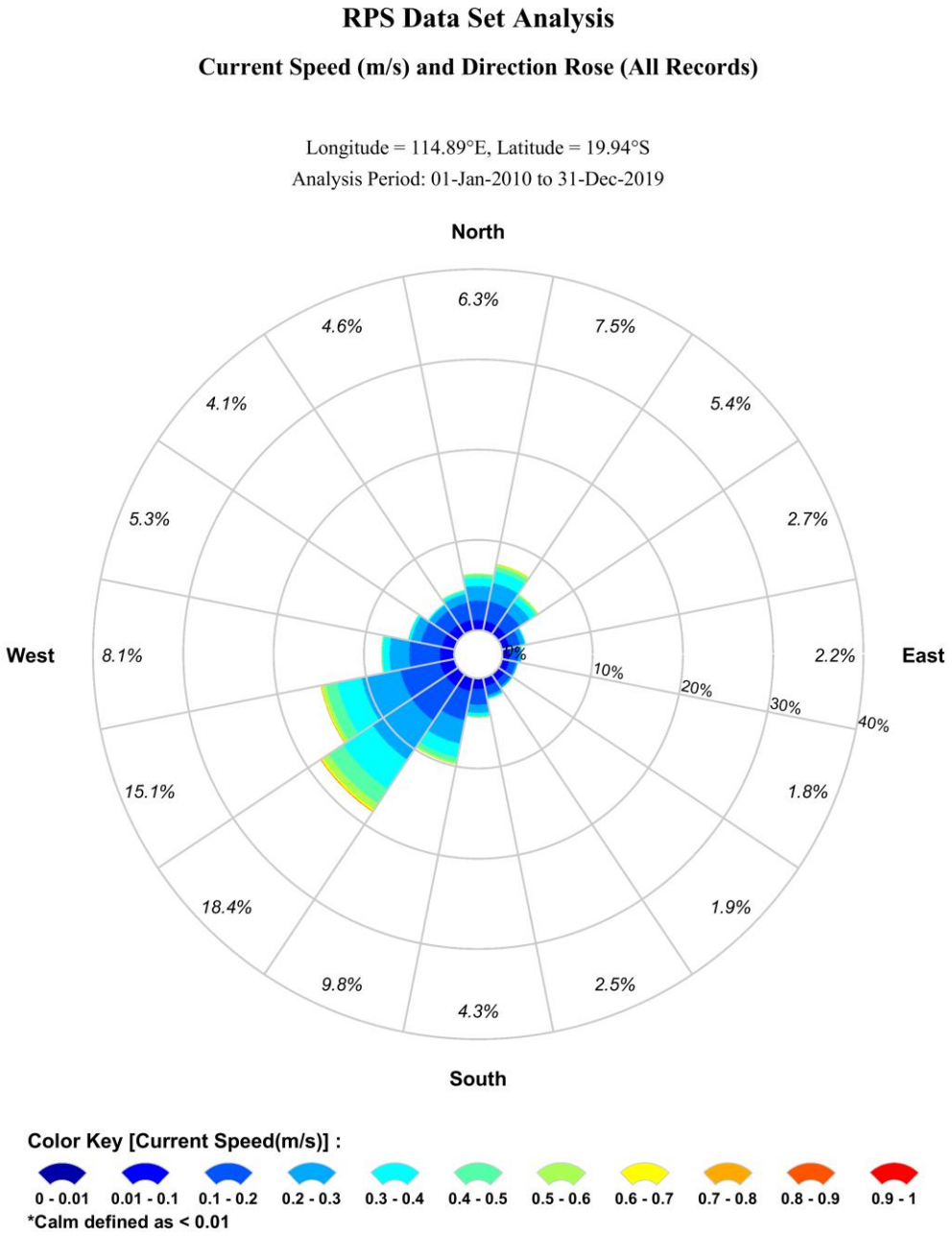


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 45 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

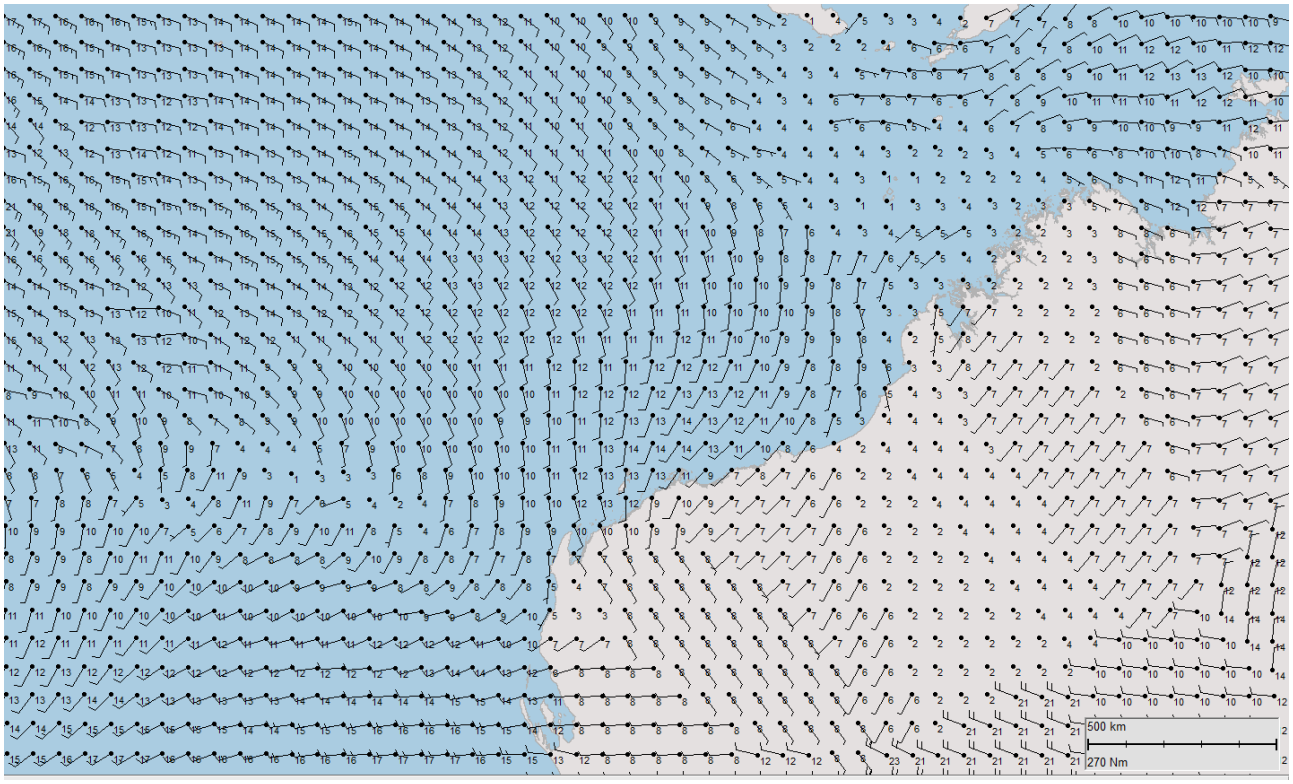


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	42	Southwest
	February	11	43	Southwest
	March	10	35	Southwest
Transitional	April	10	37	Variable
Winter	May	12	39	East
	June	14	30	East
	July	13	45	East to South
Transitional	August	11	30	Variable
Summer	September	12	27	South-Southwest
	October	13	26	South-Southwest
	November	13	25	South-Southwest
	December	12	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**45**	

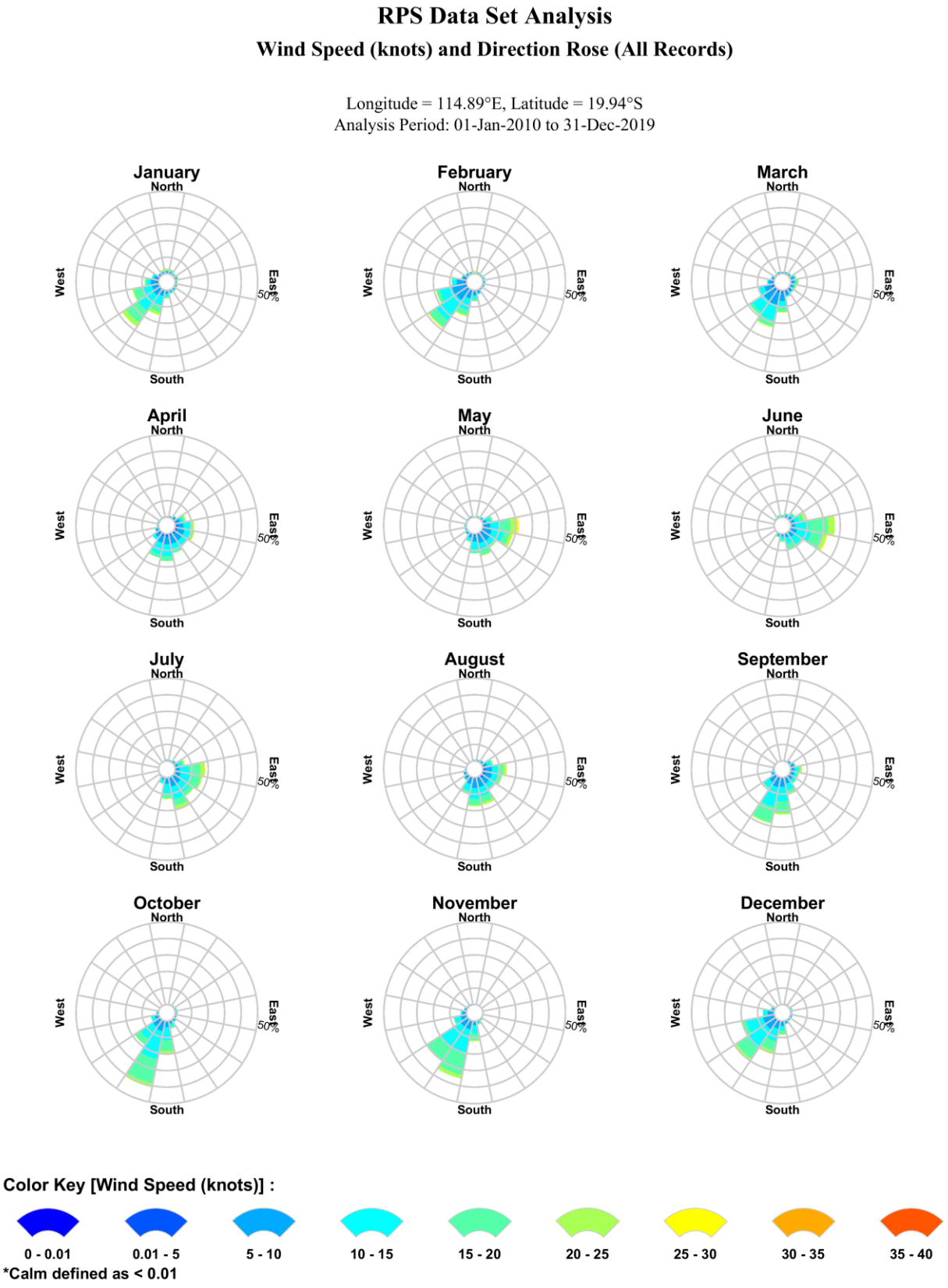


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

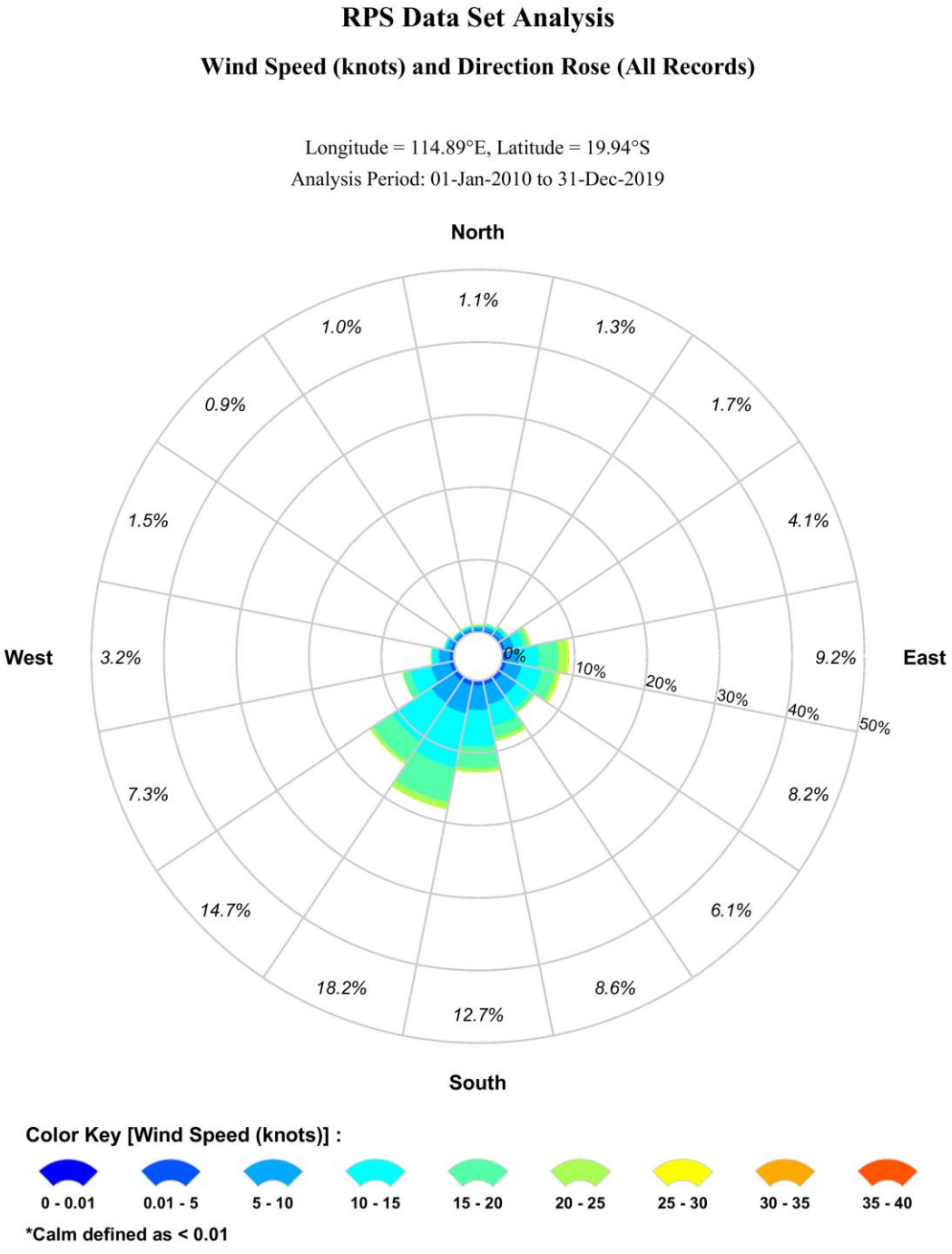


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from HYCOM (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.1°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.9	27.8	26.9	25.4	24.4	24.1	24.9	27.2	27.0
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

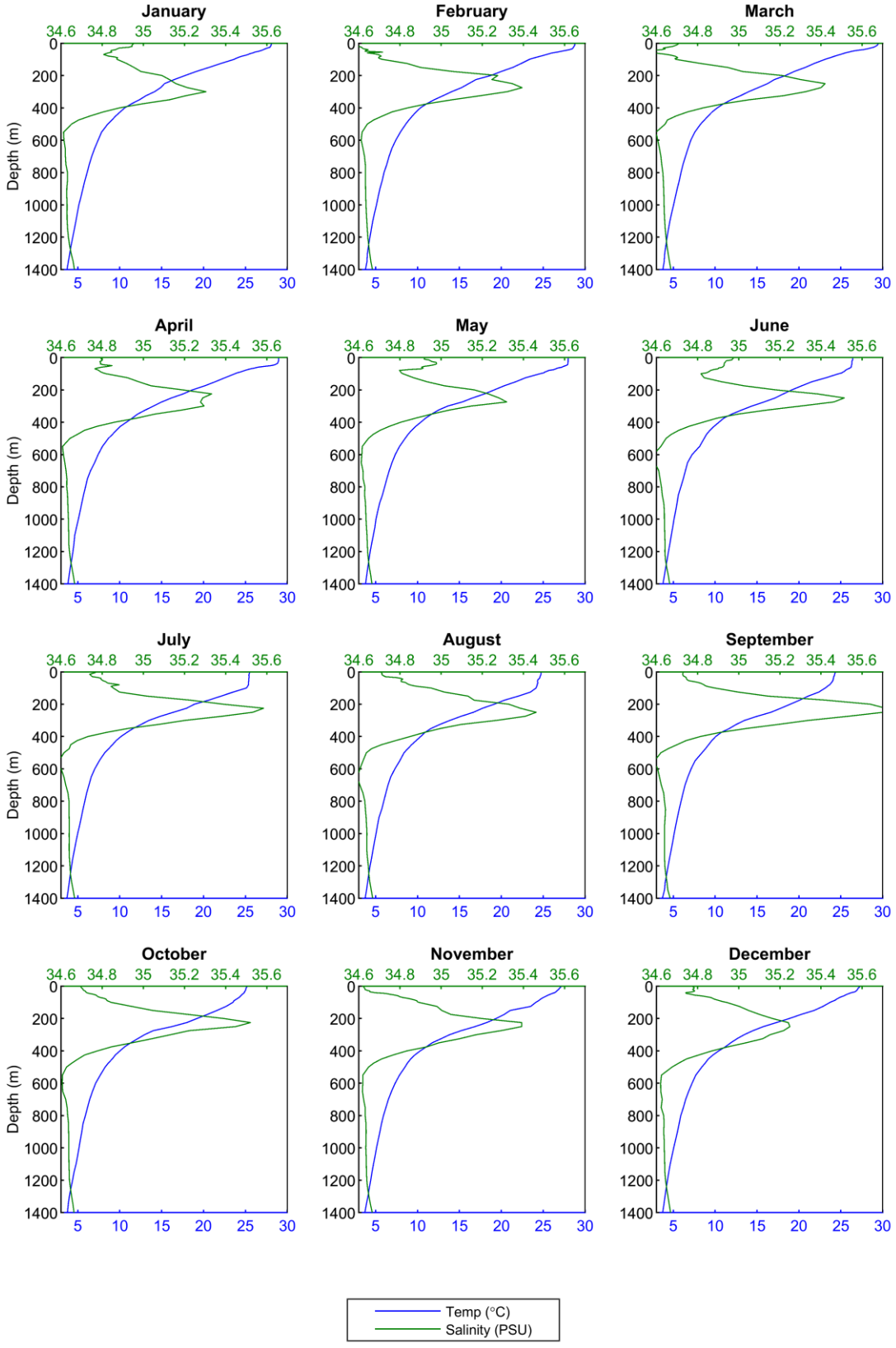


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

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).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 688 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy. The modelling predicted droplets ranging in size from 151 to 654 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	GER FL2
Water depth (m)	1,100
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	3,506
Gas rate (MMscf/day)	551
Gas to condensate ratio (scf/bbl)	157,159
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,670
Key results	
Plume execution depth (m BMSL)	688
Droplet sizes (µm)	151 to 654

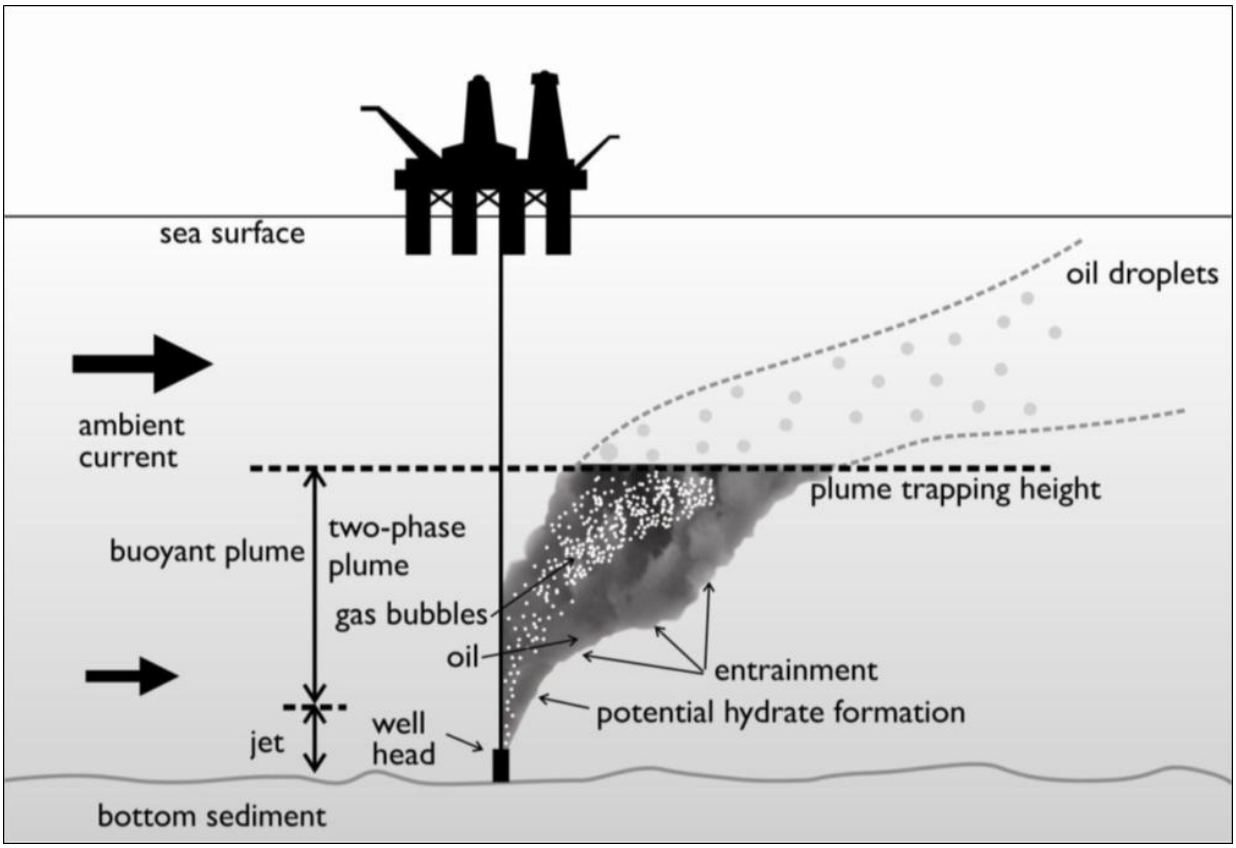


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application. The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

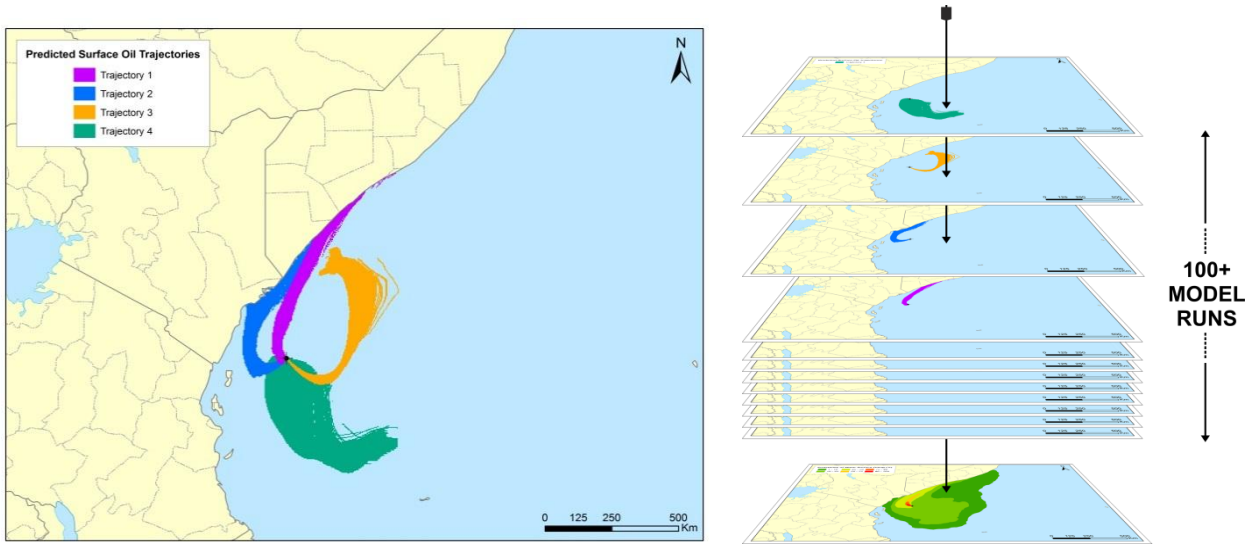


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 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

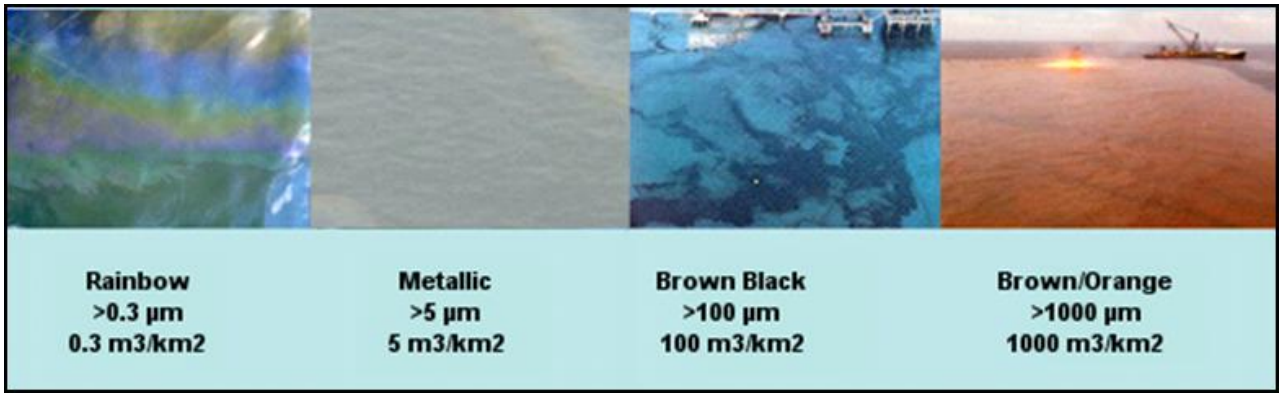


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various

wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential "low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential "moderate shoreline accumulation".

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential "high shoreline accumulation". It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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 In-water Exposure 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; 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 & Di Toro, 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 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on 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 & ARMCANZ (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.

This exposure zone 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 7.4), 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 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

As a conservative approach, Chevron had chosen Geryon condensate for the purposes of the modelling and hence provided physical properties and boiling point distributions, which are presented in Table 8.1 and Table 8.2, respectively.

Geryon condensate has an API of 42.67, a density of 810 kg/m^3 (at 15ºC) and a low viscosity value of 5.2 cP. When exposed to the atmosphere at local temperatures, about 31.5% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 27.1% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~31.7%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 9.7% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), indicating a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle.

Soluble, aromatic hydrocarbons contribute approximately 2.9% by mass of the whole oil. For this condensate they are all contained in the volatile fractions, which are highly soluble. Discharges onto the water surface will favour the process of evaporation over dissolution under calm sea conditions, but increased entrainment of oil and dissolution of soluble compounds can be expected under stronger wind periods with the presence of small breaking waves (whitecaps).

Table 8.1 Physical properties of Geryon condensate.

Characteristic	Geryon Condensate
Density (kg/m^3)	810.0 (at 15°C)
API	42.67
Dynamic viscosity (cP)	5.2 (at 15°C)
Pour point (°C)	-20
Surface tension (dyne/cm)	19
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of Geryon condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Geryon Condensate	% of total	31.5	27.1	31.7	9.7
	% of aromatics	2.9	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 58.8% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Geryon condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 20.9% of the condensate mass is forecast to have entrained and a further 18.3% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (<0.3%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~0.64% per day with an accumulated total of ~4.5% after 7 days, in comparison to a rate of <0.15% per day and an accumulated total of 1.04% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

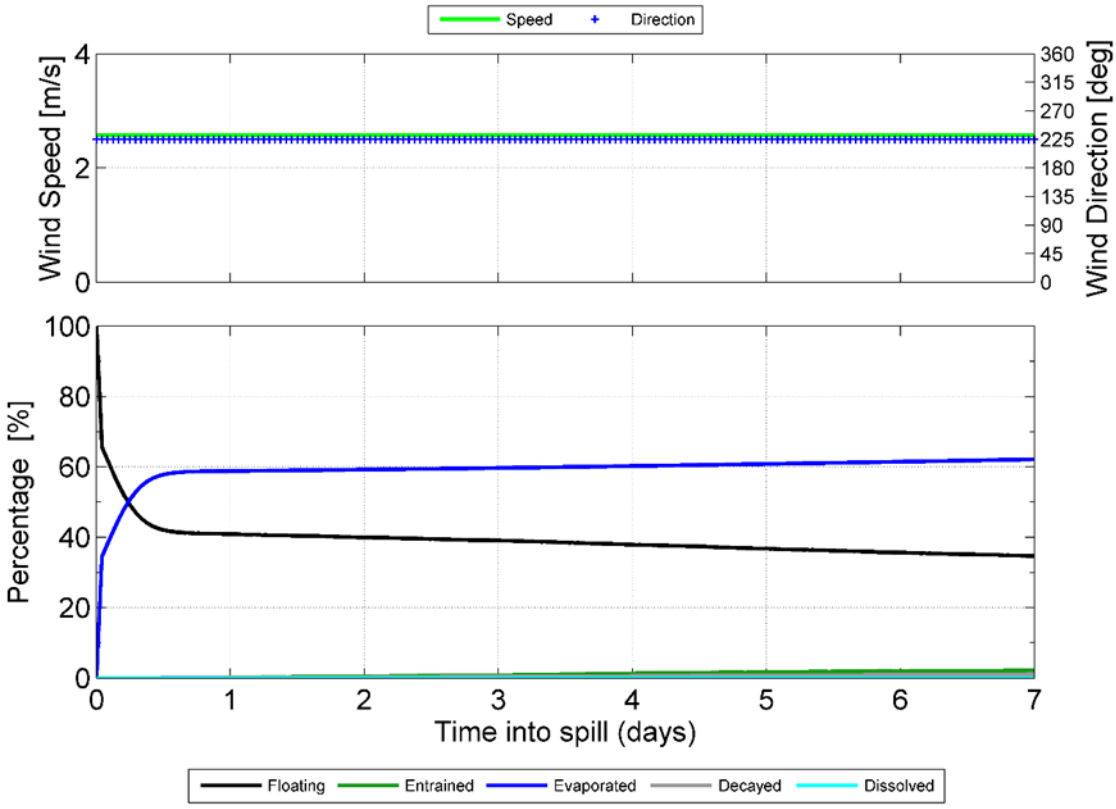


Figure 8.1 Proportional mass balance plot representing the weathering of Geryon condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

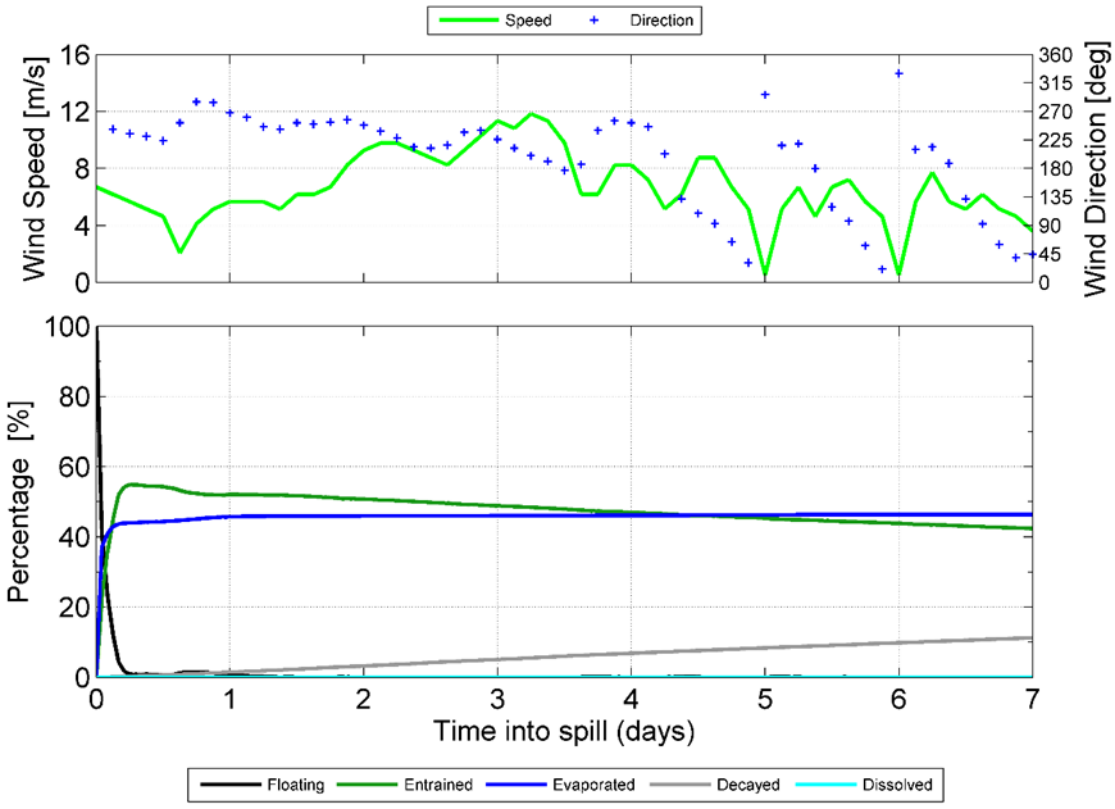


Figure 8.2 Proportional mass balance plot representing the weathering of Geryon condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	GER FL 2
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	50,165 [315,540]
Condensate type	Geryon condensate
Release type (depth)	Subsea (1,100 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, there is no deterministic results presented.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
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 Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓

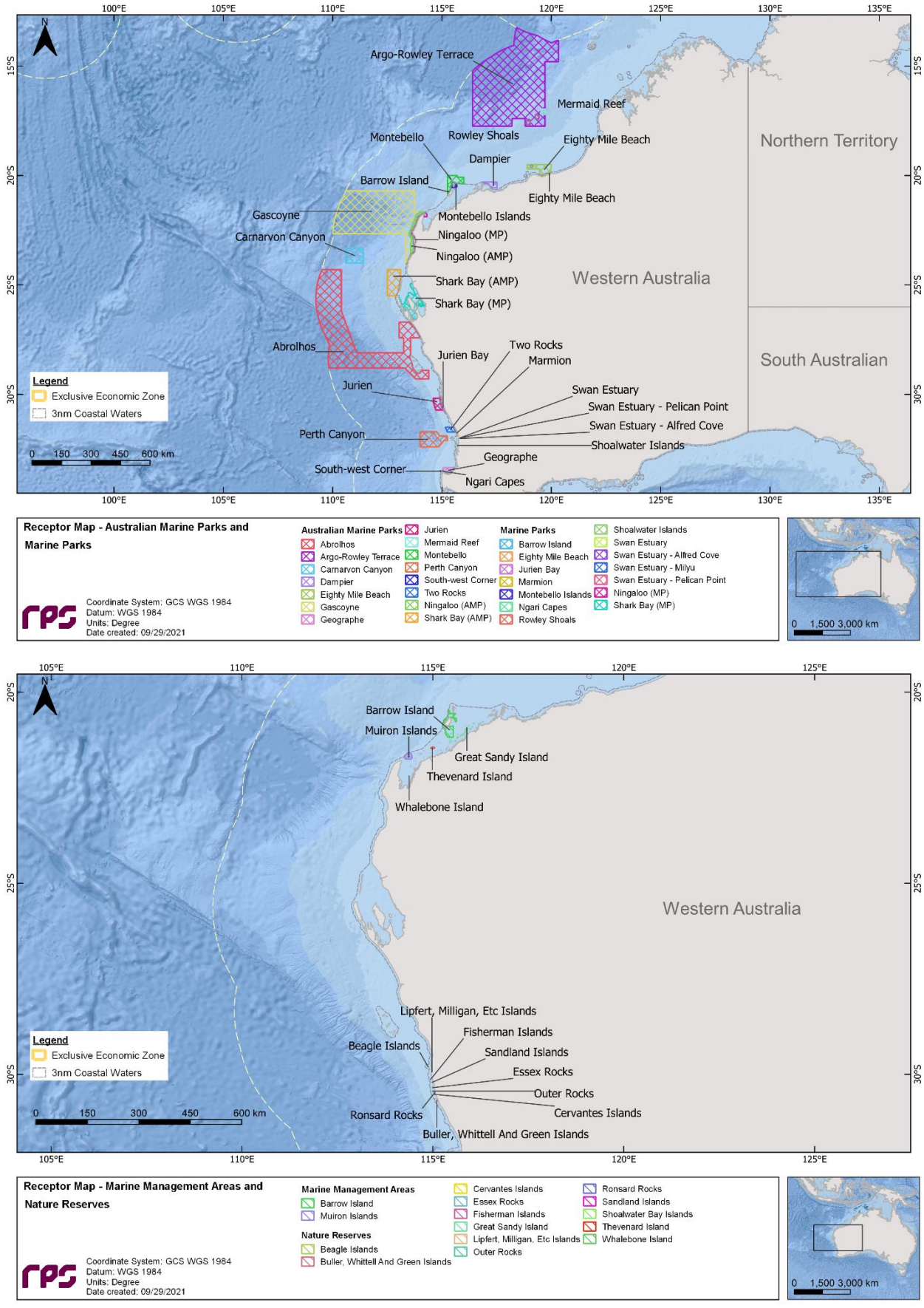


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

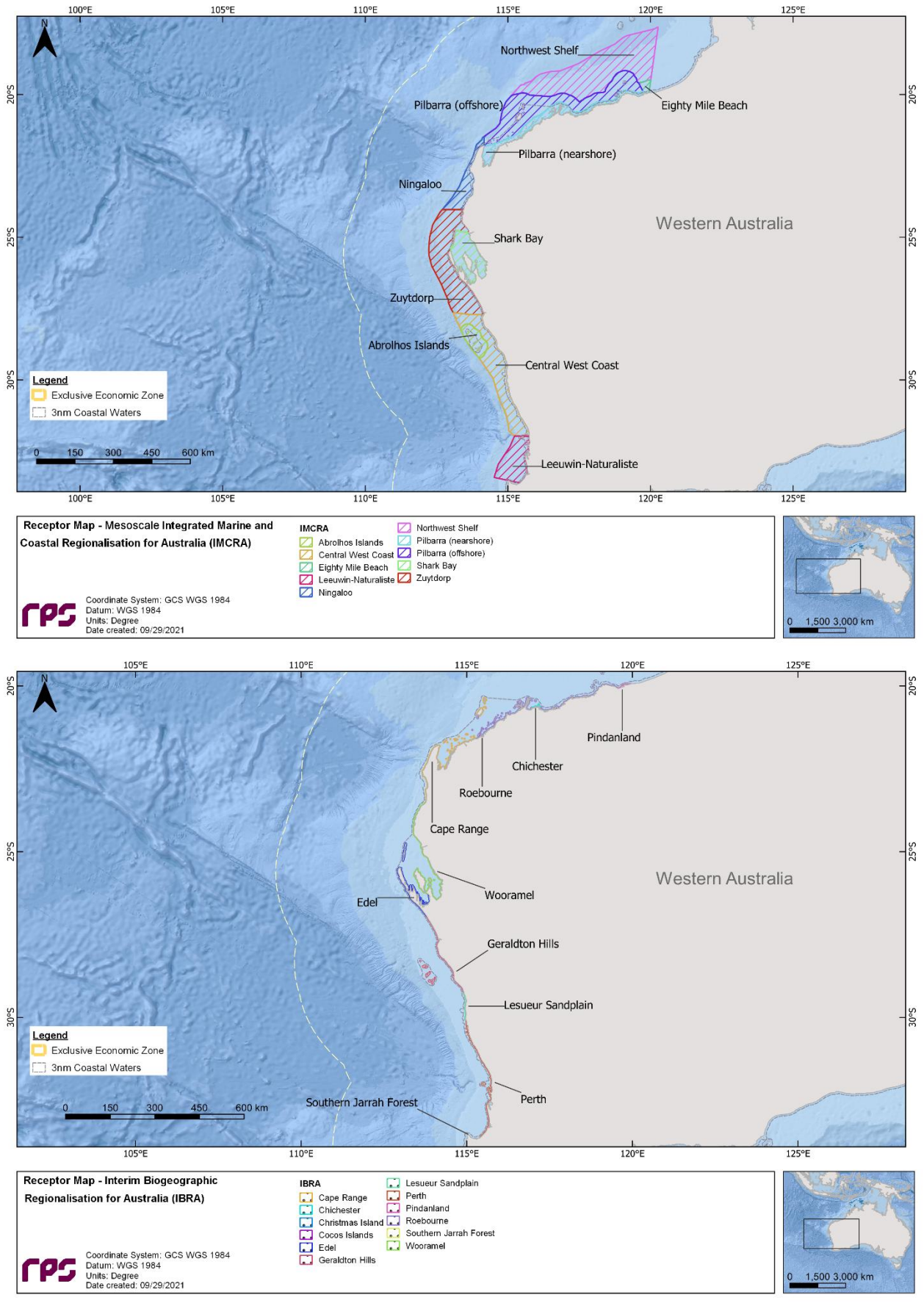


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

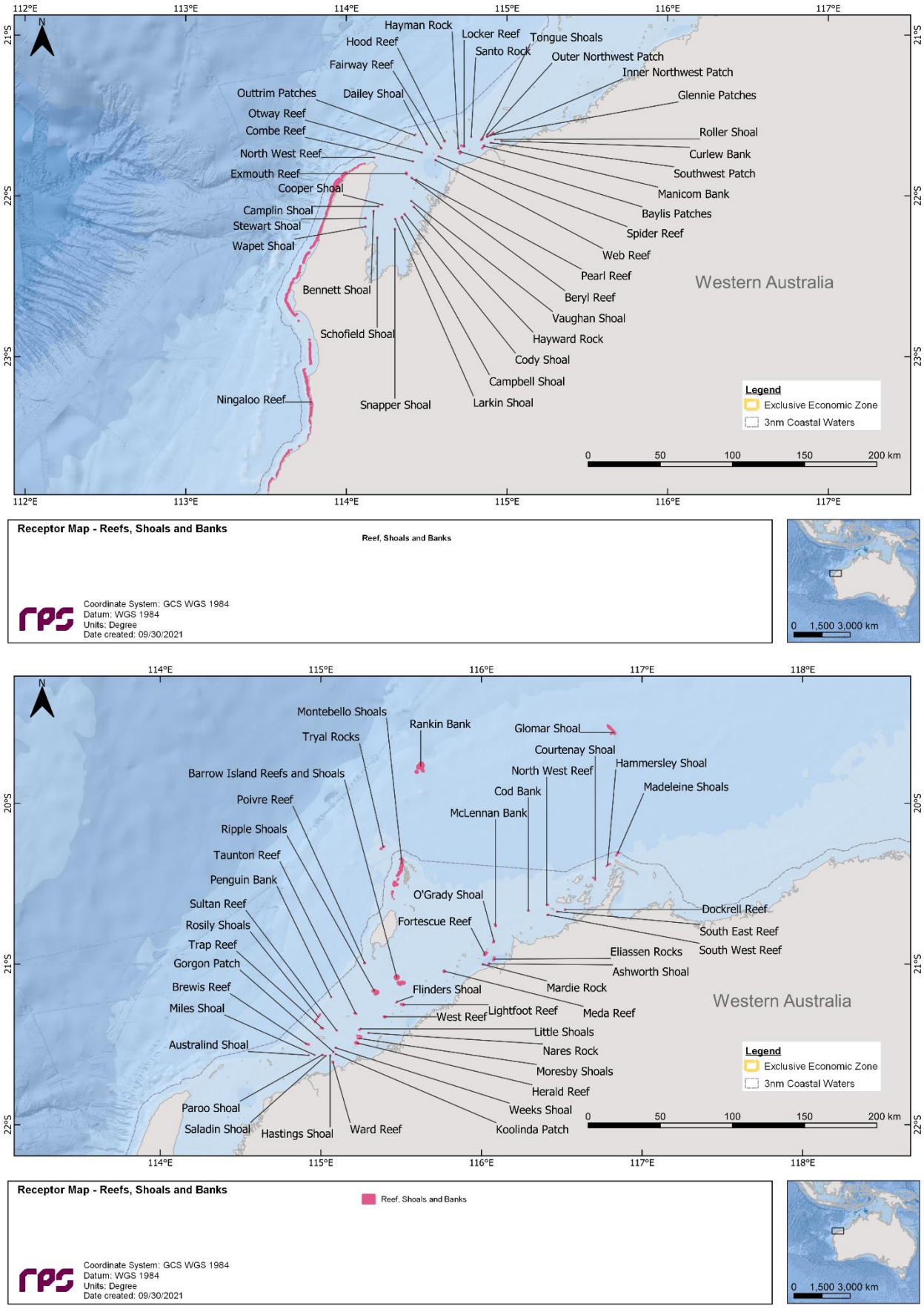


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

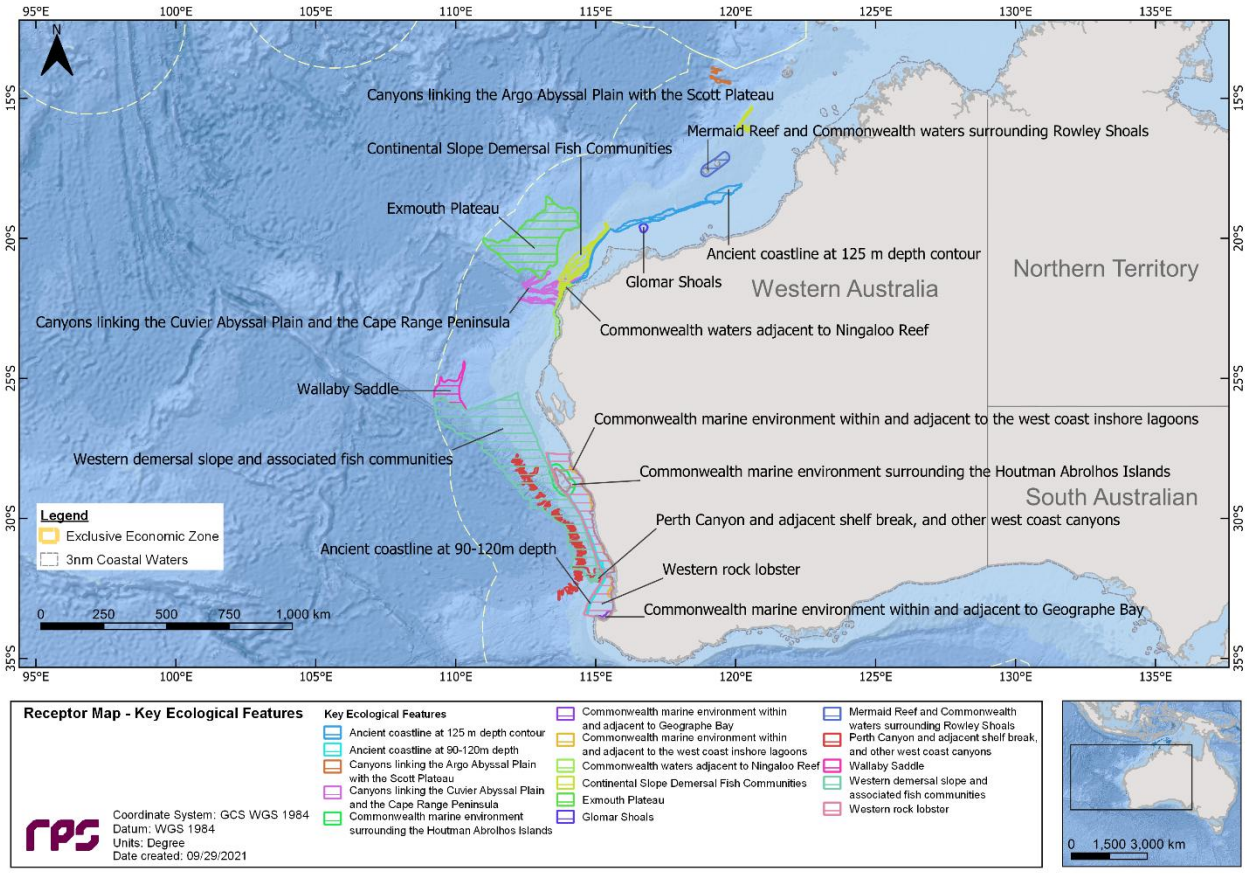


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

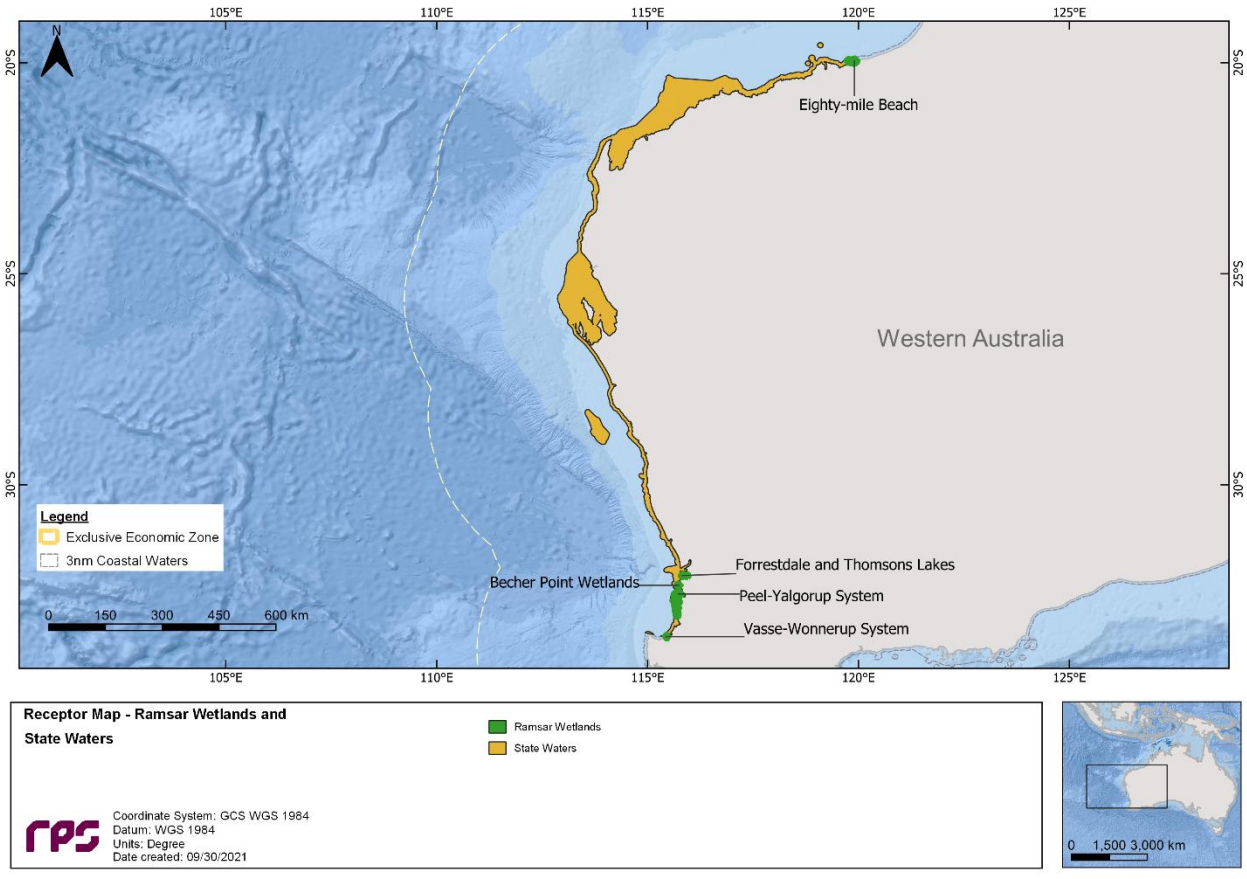


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

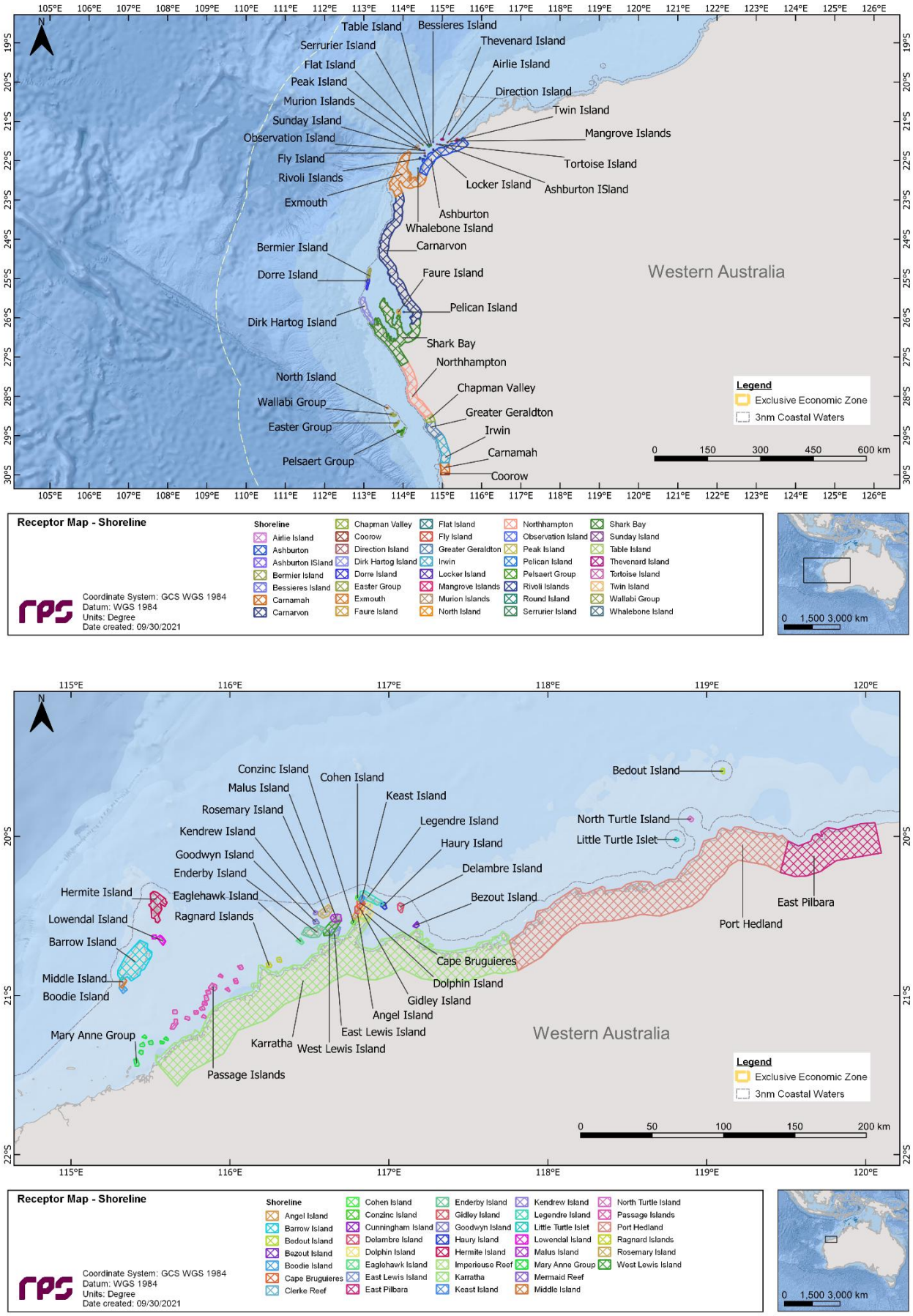


Figure 10.6 Receptor maps for Shorelines (1 of 2).

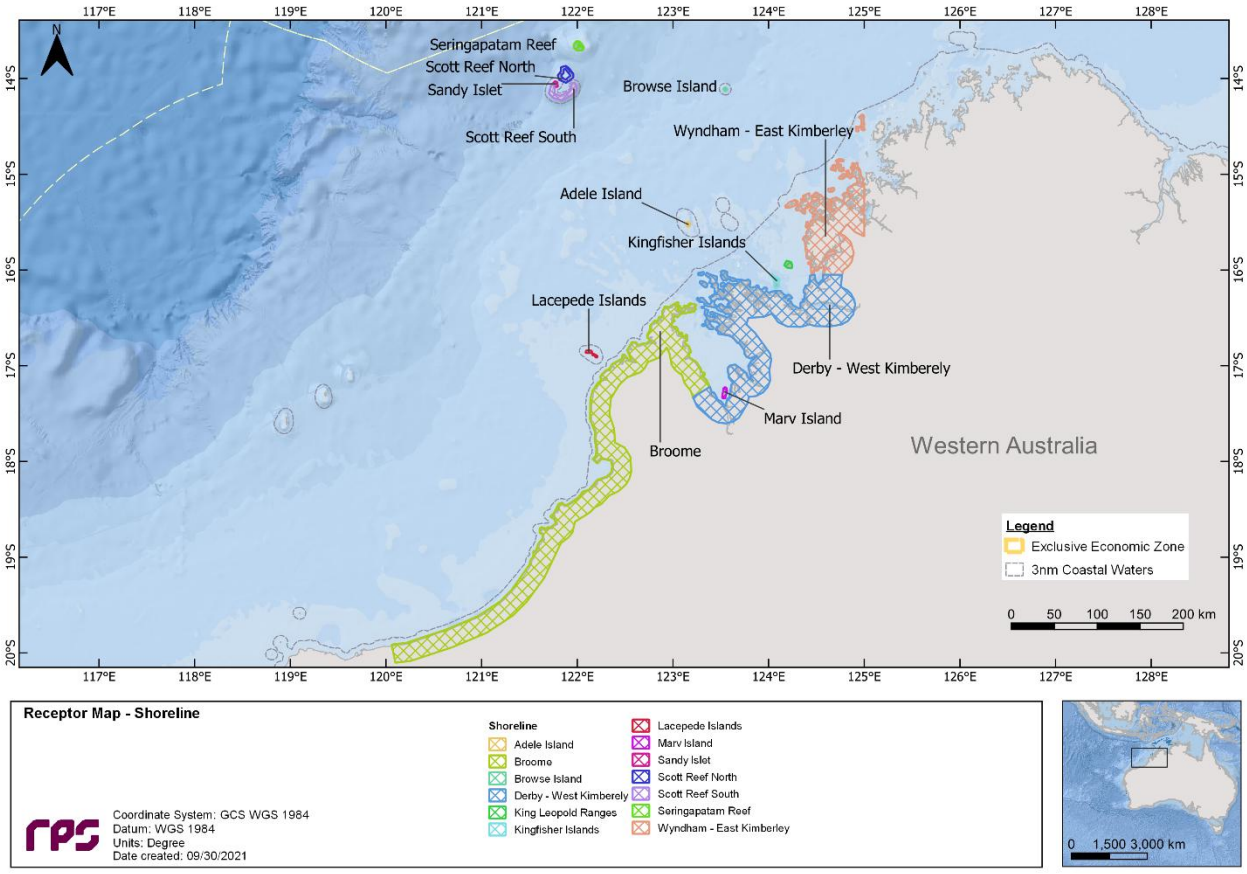


Figure 10.7 Receptor maps for Shorelines (2 of 2).

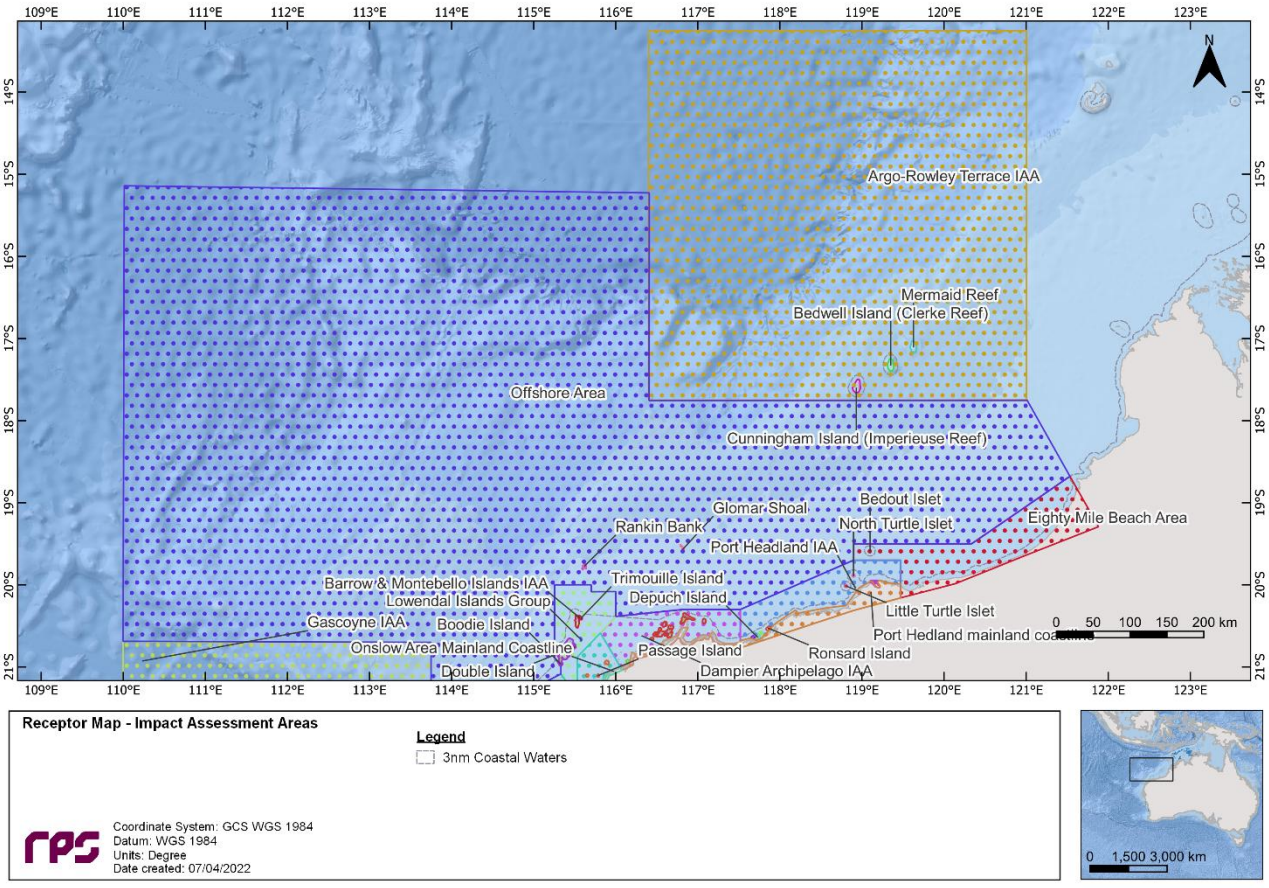


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

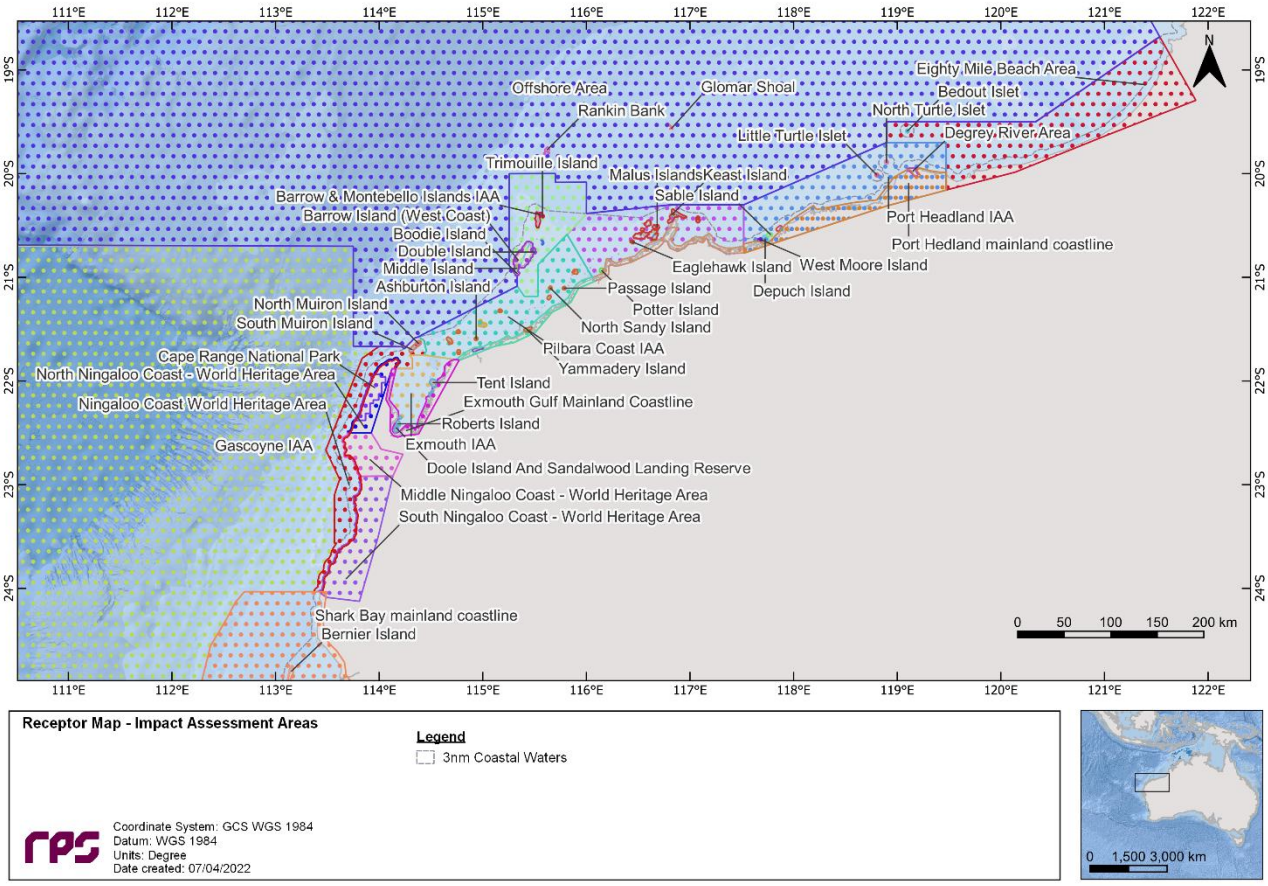


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

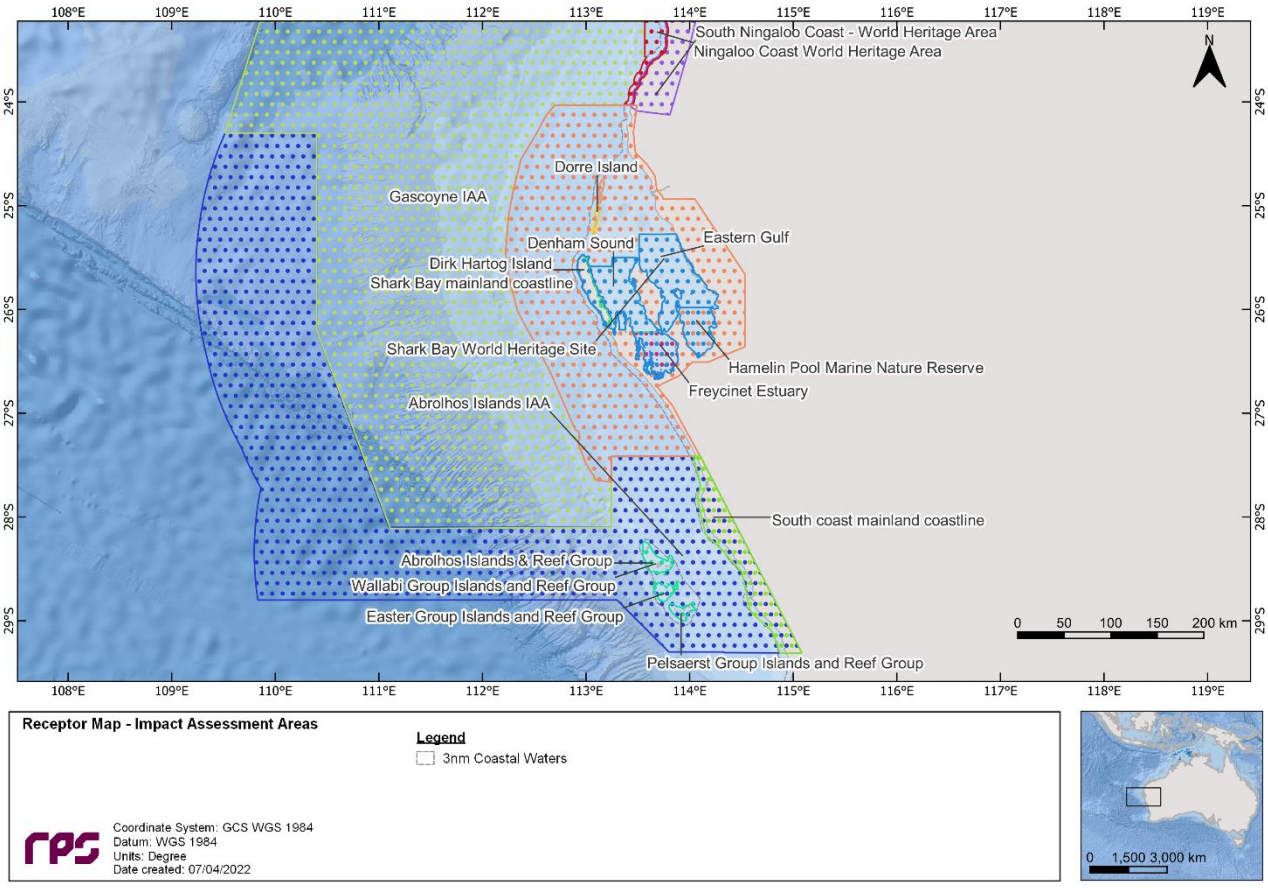


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: GERYON-EURYTION LOSS OF WELL CONTROL

This scenario examined a 315,540 stb (or 50,165 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 132.6 km south (summer) and 60.4 km southeast (winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, which the release location resides within (see Section 10.3), were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these rectors ranged between 51% (all receptors; summer) and 82% (Pygmy Blue Whale - Distribution (BIA) and Offshore Area IAA); winter). Additionally, the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs were also predicted to be exposed at the low threshold during summer (7% and 1%), transitional (13% and 6%) and winter (15% and 13%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs was 5.79 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Continental Slope Demersal Fish Communities (KEF) was 96%, 80% and 84% during summer, transitional and winter, respectively. The corresponding minimum time before low exposure at the Continental Slope Demersal Fish Communities (KEF) was 1.88 days (summer).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	132.6	59.1	-
	Max. distance from release site (km) (99th percentile)	114.1	59.1	-
	Direction	South	Southeast	-
Transitional	Max. distance from release site (km)	129.2	59.9	-
	Max. distance from release site (km) (99th percentile)	105.5	59.9	-
	Direction	South	Southeast	-
Winter	Max. distance from release site (km)	123	60.4	-
	Max. distance from release site (km) (99th percentile)	96	60.3	-
	Direction	South	Southeast	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Flatback Turtle - Internesting Buffer	7	-	-	5.79	-	-	13	-	-	11.04	-	-	15	-	-	22.75	-	-
	Pygmy Blue Whale - Distribution *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
	Wedge-tailed Shearwater - Breeding *	100	51	-	0.46	1.46	-	100	76	-	0.46	1.25	-	100	79	-	0.46	1.17	-
	Whale Shark - Foraging	1	-	-	5.79	-	-	6	-	-	11.04	-	-	13	-	-	22.92	-	-
EEZ	Australian Exclusive Economic Zone *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
IAA	Offshore Area *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
IMCRA	Northwest Shelf	1	-	-	5.79	-	-	5	-	-	11.17	-	-	5	-	-	42.88	-	-
	Pilbara (offshore)	1	-	-	11.71	-	-	2	-	-	11.04	-	-	8	-	-	22.92	-	-
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	58.63	-	-
	Continental Slope Demersal Fish Communities	96	-	-	1.88	-	-	80	-	-	2.29	-	-	84	-	-	2.08	-	-

*The release location resides within the receptor boundaries.

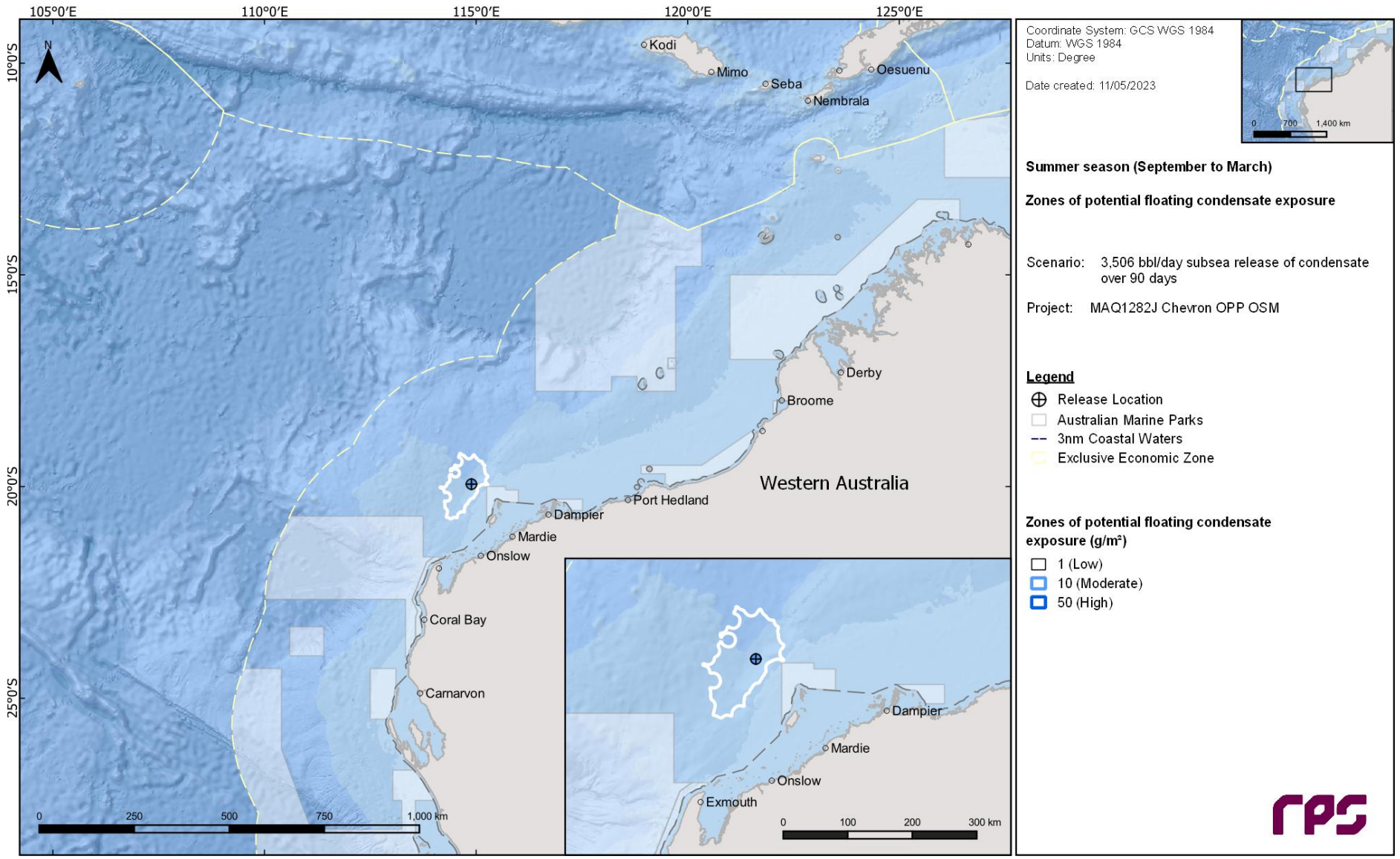


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

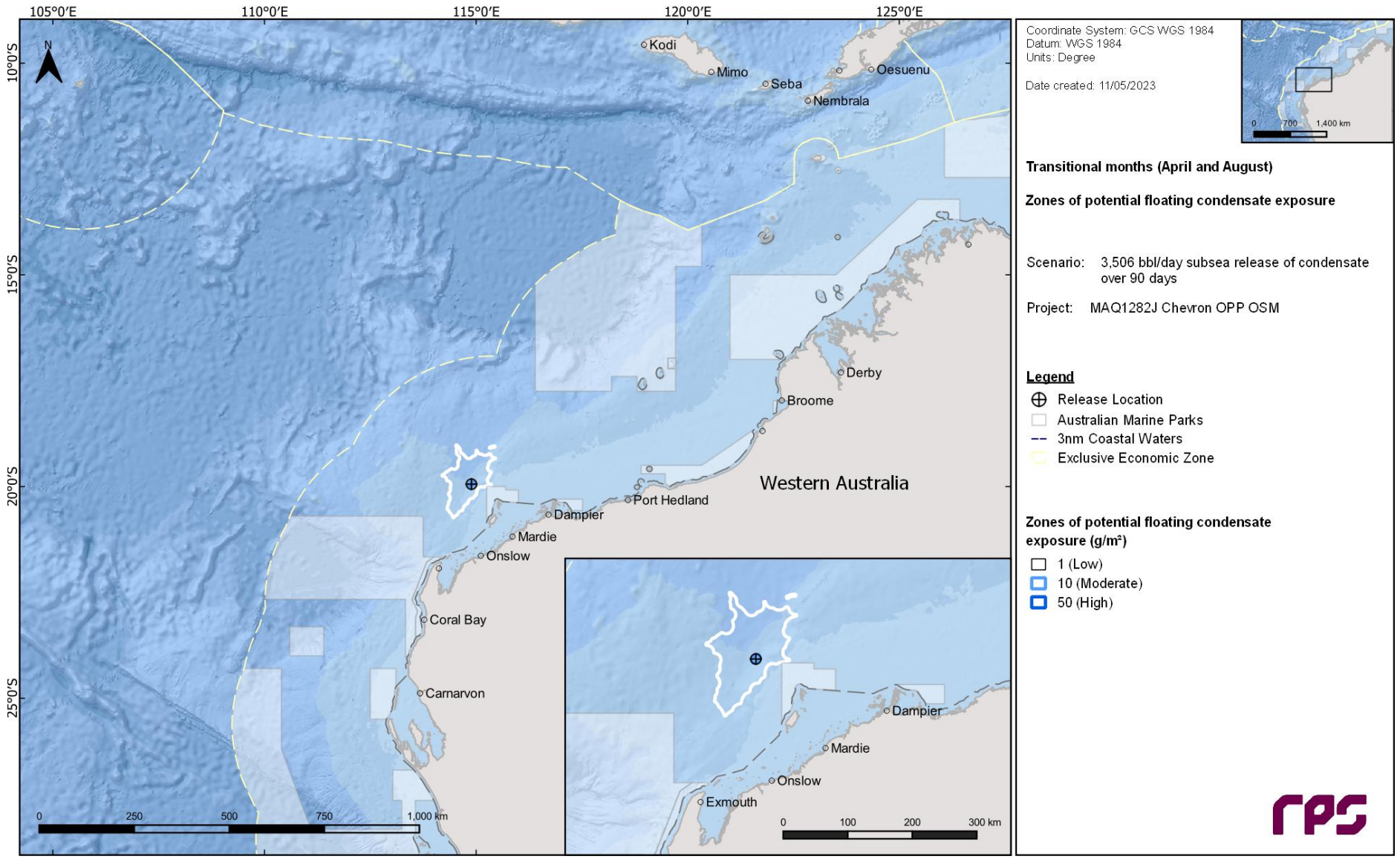


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

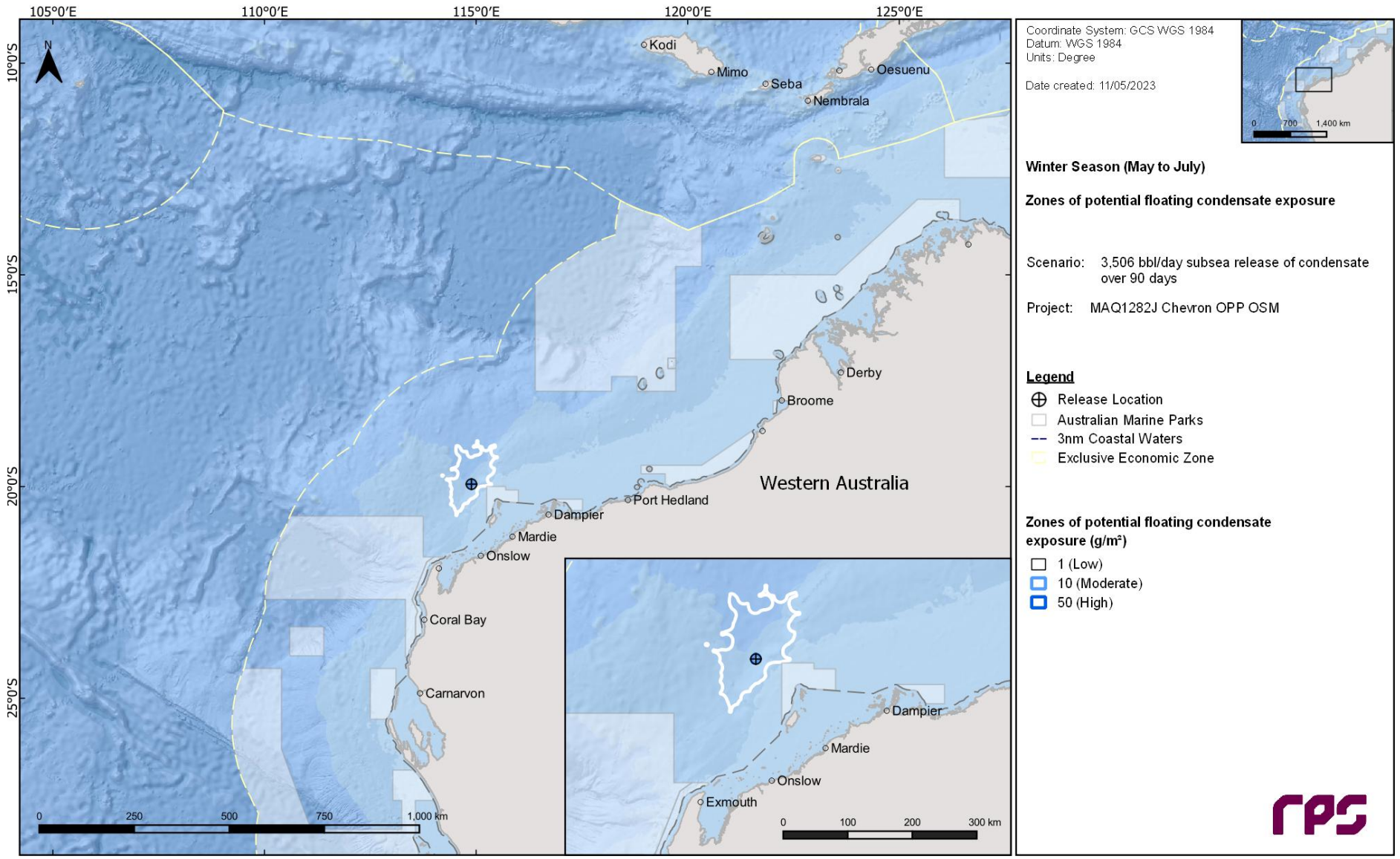


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of shoreline accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 23%, while the minimum time before shoreline accumulation was 7.46 days and the maximum volume of oil ashore was 23.2 m^3. No shoreline accumulation was predicted during transitional conditions.

Additionally, no high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 and Table 11.5 summarises the shoreline accumulation on individual receptors for the summer and winter season.

During summer conditions, condensate had accumulated on 38 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA and Barrow Island Group (15%). In comparison, during winter conditions, condensate was predicted to accumulate on 4 shoreline receptors and each with an 8% probability.

The maximum potential shoreline accumulation is presented for the summer and winter season in Figure 11.4 and Figure 11.5.

Table 11.3 Summary of condensate accumulation across all shorelines for each season and threshold, following a subsea LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	23	-	8
Absolute minimum time for visible oil to shore (days)	7.46	-	43.75
Maximum volume of hydrocarbons ashore (m^3)	23.2	-	1.9
Average volume of hydrocarbons ashore (m^3)	9.4	-	0.8
Maximum length of the shoreline at **10 g/m^2** (km)	79	-	7
Average shoreline length (km) at **10 g/m^2** (km)	31.4	-	4.9
Maximum length of the shoreline at **100 g/m^2** (km)	2	-	-
Average shoreline length (km) at **100 g/m^2** (km)	1.1	-	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	3	-	-	14.38	-	-	6	17	0.2	0.3	1.3	-	-	1.9	-	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	15	7	-	12.5	30.92	-	12	155	10	23.2	31.7	1	-	55.8	1	-
	Barrow Island (West Coast)	14	-	-	12.88	-	-	15	98	5	8.6	16.3	-	-	22.1	-	-
	Barrow Island Group	15	7	-	12.5	30.92	-	18	155	9.2	16.5	23.2	1	-	33.7	1	-
	Bessieres Island	3	-	-	27.83	-	-	7	20	0.2	0.5	1.3	-	-	1.9	-	-
	Boodie Island	14	7	-	12.5	30.92	-	45	155	2.5	4.1	3.4	1	-	3.8	1	-
	Cape Range National Park	11	-	-	7.5	-	-	5	34	2.1	4.7	6.9	-	-	13.5	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	1	-	-	81.75	-	-	4	15	1.5	2.1	2.9	-	-	2.9	-	-
	Dampier Archipelago Island Group	1	-	-	84.38	-	-	4	14	0.7	1.3	1.9	-	-	1.9	-	-
	Enderby Island	1	-	-	88.5	-	-	4	14	0.2	0.5	1	-	-	1	-	-
	Hermite Island	12	-	-	12.92	-	-	8	54	1.3	3.7	6.7	-	-	14.4	-	-
	Middle Island	13	-	-	12.67	-	-	28	90	2.7	4.5	5.5	-	-	7.7	-	-
	Middle Ningaloo Coast - World Heritage Area	8	-	-	8.21	-	-	4	23	0.6	1.2	1.6	-	-	2.9	-	-
	Montebello Islands Group	12	-	-	12.92	-	-	7	54	1.4	4	6.7	-	-	14.4	-	-
	Muiron Islands	11	2	-	7.46	37	-	9	129	1.7	7.6	7	1	-	15.4	1	-
	Ningaloo Coast World Heritage Area	11	2	-	7.46	37	-	6	129	3.3	10.3	16.6	1	-	21.2	1	-
	North Muiron Island	11	2	-	8	37	-	13	129	1	4.3	3.3	1	-	6.7	1	-
	North Ningaloo Coast - World Heritage Area	10	-	-	7.54	-	-	5	26	1.1	2.2	3.6	-	-	5.8	-	-
	Pilbara Coast IAA	5	-	-	14.38	-	-	4	49	0.5	2.9	2.3	-	-	3.8	-	-
	Pilbara Coast Islands Group	5	-	-	14.38	-	-	4	20	0.3	1.1	1.5	-	-	1.9	-	-
	Rosemary Island	1	-	-	84.38	-	-	4	10	0.2	0.4	1	-	-	1	-	-
	South Muiron Island	11	-	-	7.46	-	-	10	66	1.1	3.6	3.7	-	-	8.7	-	-
	Thevenard Island	1	-	-	81.67	-	-	4	12	0.2	0.6	1	-	-	1	-	-
Shoreline	Airlie Island	3	-	-	14.38	-	-	6	17	0.2	0.3	1.3	-	-	1.9	-	-
	Barrow Island	15	-	-	12.88	-	-	15	98	5.7	9.8	16.3	-	-	24	-	-
	Bessieres Island	3	-	-	27.83	-	-	7	20	0.2	0.5	1.3	-	-	1.9	-	-
	Boodie Island	14	7	-	12.5	30.92	-	45	155	3	4.8	4.3	1	-	4.8	1	-
	Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	1	-	-	88.5	-	-	4	14	0.2	0.5	1	-	-	1	-	-
	Exmouth	11	-	-	7.5	-	-	5	34	3.3	8	11.3	-	-	20.2	-	-
	Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Island	9	-	-	13.83	-	-	7	36	0.4	1.3	1.9	-	-	4.8	-	-
	Middle Island	13	-	-	12.5	-	-	29	90	3.6	5.3	7.3	-	-	9.6	-	-
	Montebello Islands	12	-	-	12.83	-	-	7	54	2	5.5	9.3	-	-	20.2	-	-
	Murion Islands	11	2	-	7.46	37	-	9	129	1.7	7.6	7	1	-	15.4	1	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Passage Islands	1	-	-	81.75	-	-	4	15	0.4	0.6	1	-	-	1	-	-
	Peak Island	3	-	-	27.58	-	-	10	49	0.1	0.6	1	-	-	1	-	-
	Rosemary Island	1	-	-	84.38	-	-	4	10	0.2	0.4	1	-	-	1	-	-
	Sunday Island	3	-	-	27.38	-	-	6	13	0.1	0.2	1	-	-	1	-	-
	Thevenard Island	1	-	-	81.67	-	-	4	12	0.2	0.6	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	8	-	-	43.75	-	-	7	29	1.3	1.9	4.7	-	-	6.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	8	-	-	43.75	-	-	7	29	1.2	1.8	4.7	-	-	6.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island	8	-	-	48.75	-	-	6	19	0.5	0.8	1.8	-	-	2.9	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	8	-	-	43.75	-	-	8	29	1.1	1.4	3.8	-	-	4.8	-	-
	Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

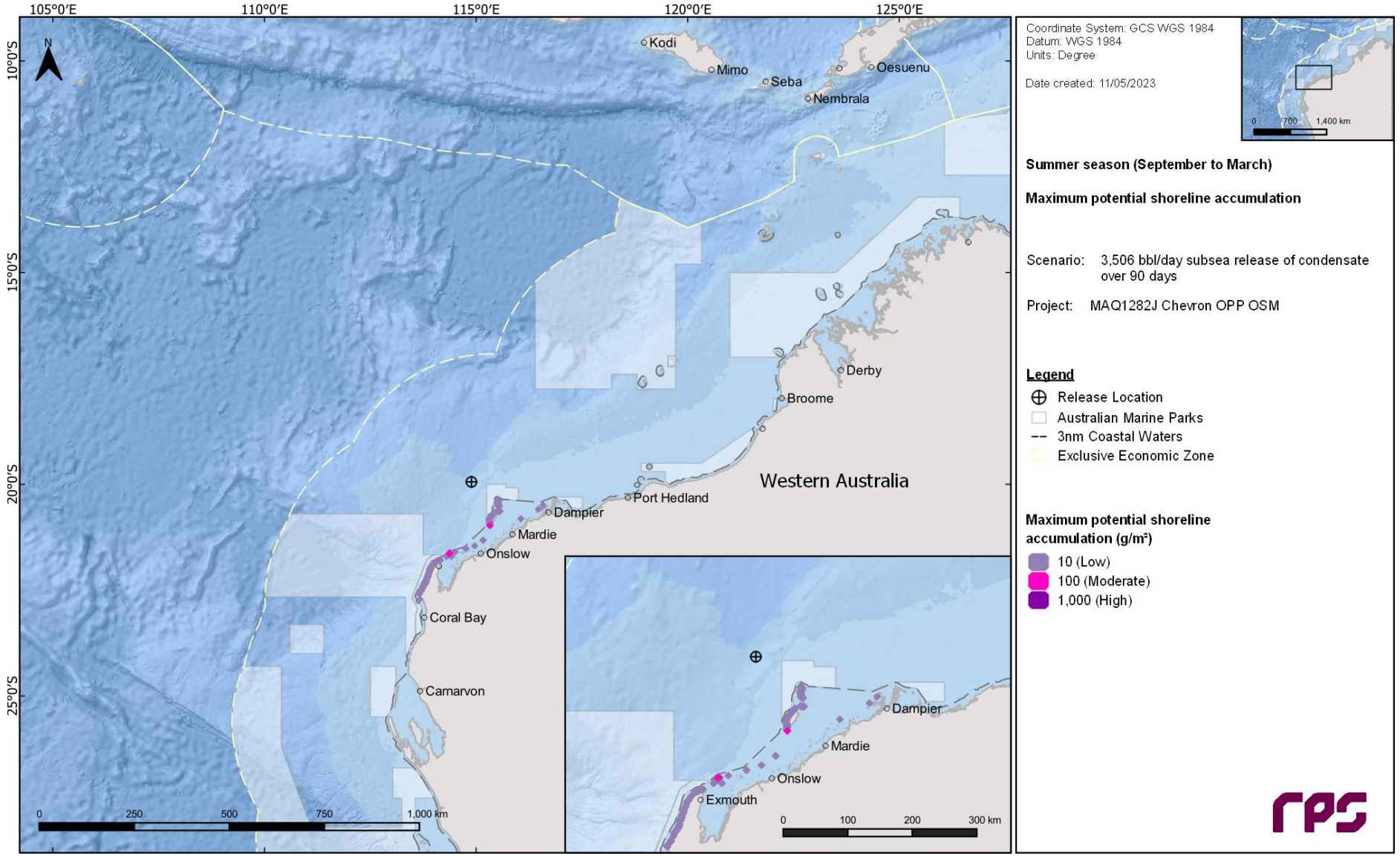


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

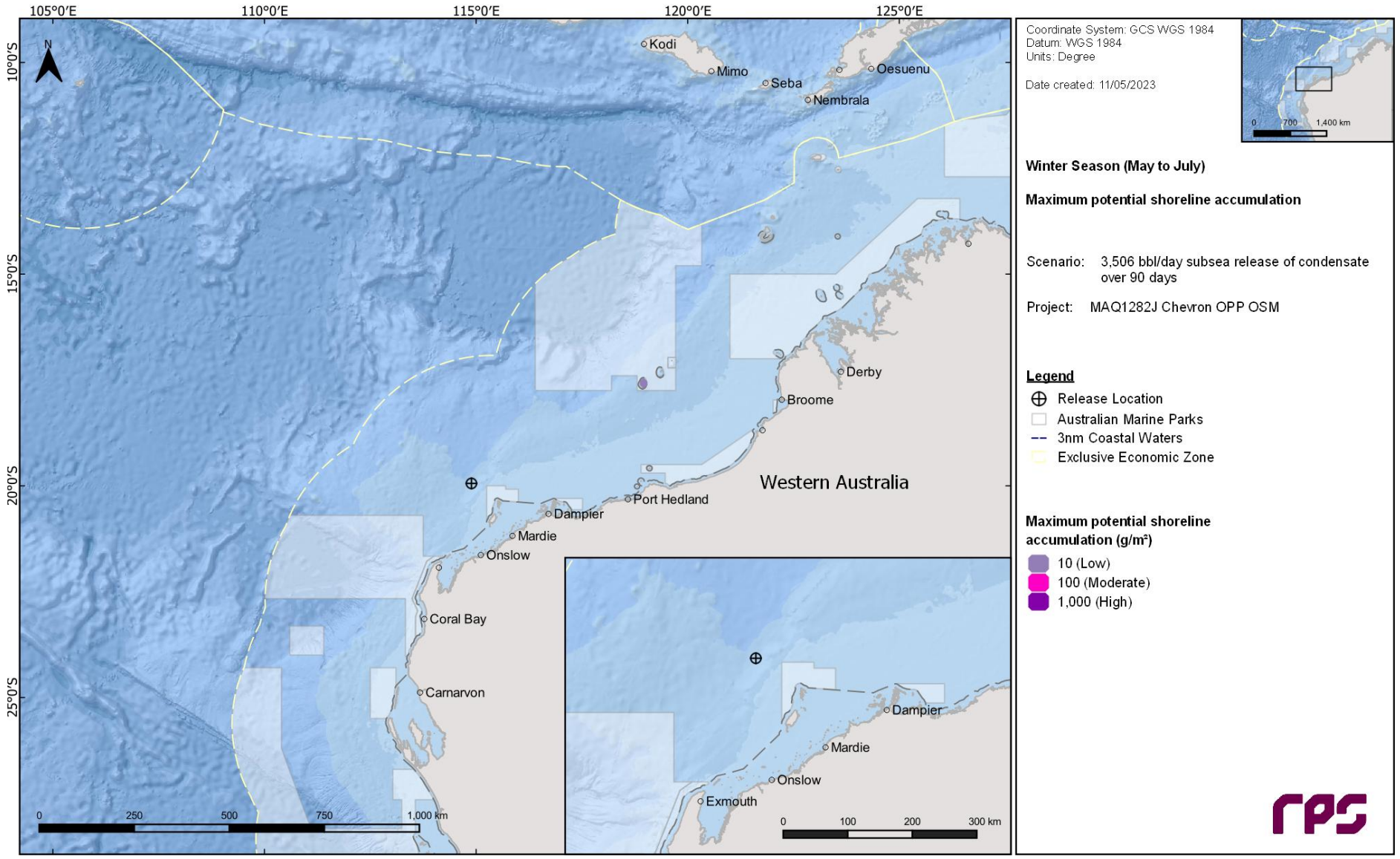


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

No dissolved hydrocarbon exposure was predicted for this scenario above the low reporting threshold (≥10 ppb) during any of the seasons modelled. Consequently, no results are reported.

11.1.3.2 Entrained Hydrocarbons

Table 11.6 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 40, 22 and 22 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter conditions respectively. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for Humpback Whale - Migration BIA (95% summer, 91% transitional and 87% winter).

During summer and transitional conditions, 7 AMPs were predicted to be exposed at, or above the low threshold, and 6 AMPs under winter conditions. The highest probabilities predicted were at the Gascoyne AMP (92% summer, 97% transitional and 86% winter). Furthermore, the Gascoyne AMP during all seasons (3% summer, 6% transitional and 5% winter) and the Montebello AMP during summer (4%) were predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 8, 7 and 7 KEFs were predicted to be exposed at the low threshold, respectively. Probabilities ranged between 2–100%, 2–100% and 3–100% for summer, transitional and winter, respectively.

Additionally, 50, 17 and 15 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold during summer, transitional and winter conditions, respectively. Excluding the Offshore IAA, the probabilities for each season ranged between 1–92%, 1–97% and 1–86% under summer, transitional and winter conditions, respectively with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, 59, 5 and 4 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter conditions, respectively. Maximum summer, transitional and winter probabilities of 23% for Rankin Bank, 6% for Rankin Bank and Outtrim Patches and 14% for Outtrim Patches, respectively, were predicted.

Figure 11.6 to Figure 11.8 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.9 to Figure 11.11.

Table 11.6 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at GER FL2. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	15.6	2	-	37.13	-	14	3	-	37.13	-	13.7	3	-	46.71	-
	Argo-Rowley Terrace	46.3	17	-	19.83	-	50.6	17	-	16.67	-	90.9	25	-	28.21	-
	Carnarvon Canyon	19.2	7	-	35.96	-	23.3	16	-	27.58	-	21.6	17	-	26.92	-
	Gascoyne	118.9	92	3	5.08	16.42	133.4	97	6	5.5	10.54	130.8	86	5	8.04	13.5
	Montebello	130.1	26	4	3.96	27.33	43.4	21	-	7.75	-	43.2	30	-	4.83	-
	Ningaloo	50.6	26	-	5.96	-	18.6	6	-	16.96	-	22.2	12	-	17.08	-
	Shark Bay	12.1	1	-	79.54	-	9.3	-	-	-	-	7	-	-	-	-
BIA	Bridled Tern - Foraging	14.1	7	-	34.92	-	9.2	-	-	-	-	4.4	-	-	-	-
	Dugong - Breeding	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Calving	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Foraging	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Nursing	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Fairy Tern - Breeding	142.6	21	4	6.13	15.21	26.6	2	-	17.25	-	13	6	-	27.38	-
	Flatback Turtle - Aggregation	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Flatback Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Flatback Turtle - Internesting	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Flatback Turtle - Internesting Buffer	235.5	85	24	2.42	7	222.9	85	14	2.21	7.38	397	73	15	3	5.96
	Flatback Turtle - Mating	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Flatback Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Flatback Turtle - Nesting	180	69	5	4.63	10.17	79.5	50	-	3.96	-	73.3	45	-	6.38	-
	Green Turtle - Aggregation	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Green Turtle - Basking	142.6	7	3	11.71	61.38	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Internesting	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Internesting Buffer	142.6	27	4	5.88	13.54	21.6	8	-	9.42	-	38.2	23	-	12.25	-
	Green Turtle - Mating	142.6	7	3	11.71	61.38	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Green Turtle - Nesting	158.1	27	4	5.96	10.83	32.9	8	-	16.25	-	30.4	24	-	12.33	-
	Hawksbill Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Hawksbill Turtle - Internesting	45.9	6	-	12.67	-	1.1	-	-	-	-	2.5	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	142.6	30	4	5.88	12.17	26.6	8	-	9.83	-	38.2	18	-	12.42	-
	Hawksbill Turtle - Mating	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Hawksbill Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Hawksbill Turtle - Nesting	158.1	27	4	6.04	10.83	32.9	7	-	16.25	-	28.8	24	-	12.33	-
	Humpback Whale - Migration	235.5	95	18	3.63	8.46	192.2	91	16	2.21	13.71	195.8	87	14	4.04	10.67
	Humpback Whale - Resting	28.3	3	-	27.33	-	8.8	-	-	-	-	9.2	-	-	-	-
	Lesser Crested Tern - Breeding	148.5	23	4	7.5	11.33	27.8	7	-	16.25	-	17.5	16	-	12.42	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Little Tern - Resting	5.3	-	-	-	-	5.2	-	-	-	-	22.8	8	-	45.46	-
	Loggerhead Turtle - Internesting Buffer	95.6	30	-	5.88	-	21.6	8	-	14.83	-	32.4	20	-	12.42	-
	Loggerhead Turtle - Nesting	72.7	26	-	5.96	-	18.6	8	-	16.54	-	30.4	16	-	14.38	-
	Pygmy Blue Whale - Distribution	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Pygmy Blue Whale - Foraging	76.8	62	-	5.25	-	49.4	40	-	12.04	-	60.2	29	-	12.33	-
	Roseate Tern - Breeding	158.1	38	4	5.79	10.79	20.4	18	-	18.38	-	60.2	17	-	15.71	-
	Sooty Tern - Foraging	13.9	7	-	35.79	-	11.9	2	-	38.71	-	7.8	-	-	-	-
	Wedge-tailed Shearwater - Breeding	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Wedge-tailed Shearwater - Foraging	14.5	7	-	34.92	-	9.2	-	-	-	-	4.9	-	-	-	-
	Whale Shark - Foraging	235.5	83	18	2.46	7.13	201.4	82	9	2.25	7.46	350.6	61	12	3.04	5.96
	White-tailed Tropicbird - Breeding	25.5	9	-	34	-	15.2	4	-	28.29	-	28.6	10	-	40.96	-
CP	Montebello Islands	32.1	4	-	12.83	-	0.9	-	-	-	-	2.4	-	-	-	-
EEZ	Australian Exclusive Economic Zone	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Indonesian Exclusive Economic Zone	8.8	-	-	-	-	11.5	1	-	60	-	12.2	3	-	64.33	-
IAA	Abrolhos Islands IAA	15.6	2	-	37.13	-	14	3	-	37.13	-	13.7	3	-	46.71	-
	Abutilon Island	18	3	-	64.71	-	0.6	-	-	-	-	1.8	-	-	-	-
	Airlie Island	50.9	7	-	13.83	-	2.4	-	-	-	-	2.7	-	-	-	-
	Argo-Rowley Terrace IAA	46.3	17	-	19.83	-	50.6	17	-	16.67	-	90.9	25	-	28.21	-
	Ashburton Island	17.7	3	-	76.88	-	0.5	-	-	-	-	1	-	-	-	-
	Barrow & Montebello Islands IAA	142.6	26	4	3.96	27.33	43.4	21	-	7.75	-	43.2	30	-	4.83	-
	Barrow Island (East Coast)	79.3	7	-	13	-	1.3	-	-	-	-	3.4	-	-	-	-
	Barrow Island (West Coast)	133	7	3	11.83	61.92	1.7	-	-	-	-	4.9	-	-	-	-
	Barrow Island Group	133	7	3	11.83	61.58	1.7	-	-	-	-	4.9	-	-	-	-
	Bessieres Island	48.5	12	-	27.33	-	10.8	1	-	19.13	-	9.5	-	-	-	-
	Boodie Island	126.3	7	3	11.83	61.58	1.3	-	-	-	-	4.2	-	-	-	-
	Cape Range National Park	40.4	11	-	7.58	-	7	-	-	-	-	6.4	-	-	-	-
	Cunningham Island (Imperieuse Reef)	3.5	-	-	-	-	4	-	-	-	-	17.9	8	-	49.88	-
	Dampier Archipelago IAA	38.1	4	-	17.92	-	0.9	-	-	-	-	1.8	-	-	-	-
	Dampier Archipelago Island Group	17.4	4	-	32.67	-	0.1	-	-	-	-	0.3	-	-	-	-
	Dampier mainland coastline	18.3	4	-	30.58	-	0	-	-	-	-	0.2	-	-	-	-
	Double Island	12.4	3	-	65.92	-	0.5	-	-	-	-	2	-	-	-	-
	Eaglehawk Island	15	4	-	32.67	-	0	-	-	-	-	0.1	-	-	-	-
	Enderby Island	15.8	4	-	36.67	-	0	-	-	-	-	0.1	-	-	-	-
	Exmouth IAA	24.9	4	-	26.92	-	9.8	-	-	-	-	13.3	4	-	30.5	-
	Gascoyne IAA	118.9	92	3	5.08	16.42	133.4	97	6	5.5	10.54	130.8	86	5	8.04	13.5
	Glomar Shoal	23.5	3	-	49.29	-	0.4	-	-	-	-	1.2	-	-	-	-
	Goodwyn Island	16.3	4	-	37.21	-	0.1	-	-	-	-	0.1	-	-	-	-
	Great Sandy Island	11	1	-	69	-	0.2	-	-	-	-	0.5	-	-	-	-
	Hermite Island	33	5	-	12.83	-	1.4	-	-	-	-	2.5	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Locker Island	17.8	3	-	75.88	-	1.3	-	-	-	-	1	-	-	-	-
	Lowendal Islands Group	18	3	-	64.71	-	0.6	-	-	-	-	1.8	-	-	-	-
	Malus Islands	11.8	3	-	84.63	-	0	-	-	-	-	0.1	-	-	-	-
	Middle Island	127.6	7	3	11.92	61.67	1.7	-	-	-	-	4.2	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	27.4	17	-	7.96	-	4.3	-	-	-	-	4.2	-	-	-	-
	Montebello Islands Group	33	5	-	12.83	-	1.4	-	-	-	-	2.5	-	-	-	-
	Muiron Islands	72.7	17	-	8	-	15.2	7	-	29.54	-	18.3	15	-	14.46	-
	Ningaloo Coast World Heritage Area	72.7	26	-	5.96	-	18.6	7	-	16.96	-	22.2	16	-	14.13	-
	North Muiron Island	72.7	17	-	8.08	-	14.7	7	-	29.54	-	18.3	15	-	14.46	-
	North Ningaloo Coast - World Heritage Area	40.2	11	-	7.83	-	8	-	-	-	-	7.1	-	-	-	-
	North Sandy Island	12.1	2	-	66.04	-	0.2	-	-	-	-	0.4	-	-	-	-
	Offshore Area	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Onslow Area Mainland Coastline	17.5	3	-	74.29	-	0.8	-	-	-	-	0.4	-	-	-	-
	Pilbara Coast IAA	136.5	19	3	6.54	58	27.9	7	-	16.46	-	19	17	-	13.04	-
	Pilbara Coast Islands Group	50.9	12	-	13.83	-	12	2	-	19.13	-	10.1	1	-	78.71	-
	Pilbara Mainland Coast	17.5	3	-	74.29	-	0.8	-	-	-	-	0.4	-	-	-	-
	Potter Island	14.7	4	-	30.08	-	0	-	-	-	-	0.2	-	-	-	-
	Rankin Bank	133.2	20	4	8.75	26.04	29	4	-	35.17	-	28.8	6	-	77.83	-
	Rosemary Island	17.4	4	-	36.67	-	0.1	-	-	-	-	0.2	-	-	-	-
	Serrurier Island	41.7	11	-	26.96	-	12	2	-	27.54	-	10.1	1	-	78.71	-
	Shark Bay mainland coastline	16.3	7	-	27.17	-	13.2	1	-	33.5	-	8.9	-	-	-	-
	Sholl Island	25.8	4	-	27.04	-	0	-	-	-	-	0.5	-	-	-	-
	South Muiron Island	71.5	16	-	8	-	15.2	7	-	30.13	-	15.5	14	-	14.63	-
	South Ningaloo Coast - World Heritage Area	11.2	2	-	33.13	-	1.7	-	-	-	-	1.6	-	-	-	-
	Thevenard Island	56	7	-	12.42	-	10.2	1	-	19.29	-	4.1	-	-	-	-
	Trimouille Island	23.4	4	-	32.04	-	0.7	-	-	-	-	1.9	-	-	-	-
IBRA	Cape Range	133	17	3	7.58	61.92	15.7	7	-	19.13	-	17.9	15	-	14	-
	Roebourne	127.6	7	3	11.88	61.67	1.9	-	-	-	-	4.2	-	-	-	-
IMCRA	Ningaloo	57.4	29	-	5.79	-	23.1	10	-	13.92	-	23	26	-	12.46	-
	Northwest Shelf	210.1	44	7	2.42	6.71	210.5	44	14	6.38	23.71	206.2	61	13	3.83	10
	Pilbara (nearshore)	34.7	6	-	19.63	-	9.5	-	-	-	-	10.9	1	-	78.83	-
	Pilbara (offshore)	235.5	83	19	3.13	9.29	179.3	83	8	2.25	7.42	378.8	68	12	3.04	5.96
	Zuytdorp	16.3	7	-	27.17	-	13.2	1	-	33.5	-	8.9	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	220.2	67	13	2.92	7.79	153.4	76	6	2.42	24	153.4	58	10	3.42	15.5
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	98.7	76	-	4.96	-	135.8	58	4	10.46	51.5	144.2	63	3	8.58	18.96
	Commonwealth waters adjacent to Ningaloo Reef	50.6	26	-	5.96	-	18.6	6	-	16.96	-	22.2	12	-	17.08	-
	Continental Slope Demersal Fish Communities	336.6	100	57	1.46	3.25	352.3	100	60	1.29	2.04	500.1	100	63	1.58	4.04
	Exmouth Plateau	149.6	96	5	3.88	16.96	166.6	100	13	3.04	10.46	224.3	96	17	2.42	8.04

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Glomar Shoals	27	4	-	24.54	-	0.8	-	-	-	-	2	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	4.6	-	-	-	-	4.9	-	-	-	-	22.8	8	-	45.46	-
	Wallaby Saddle	15.6	2	-	37.92	-	13.3	3	-	79.08	-	13	3	-	46.71	-
	Western demersal slope and associated fish communities	14.5	7	-	34.92	-	11.9	2	-	38.71	-	8.8	-	-	-	-
MMA	Barrow Island	142.6	7	3	11.42	61.29	2.1	-	-	-	-	4.9	-	-	-	-
	Muiron Islands	72.7	17	-	6.88	-	16.7	7	-	29	-	18.3	16	-	14.13	-
MP	Barrow Island	60	7	-	11.63	-	1.5	-	-	-	-	4.6	-	-	-	-
	Montebello Islands	48.3	7	-	12.29	-	1.6	-	-	-	-	3.6	-	-	-	-
	Ningaloo	43.3	17	-	7	-	13.1	2	-	31.21	-	14.2	10	-	29.63	-
	Rowley Shoals	4.1	-	-	-	-	4.8	-	-	-	-	22.8	8	-	45.46	-
NR	Great Sandy Island	35.6	5	-	14.54	-	0.3	-	-	-	-	1.3	-	-	-	-
	Thevenard Island	31.2	6	-	31.08	-	4.5	-	-	-	-	2.6	-	-	-	-
RSB	Ashworth Shoal	14.7	3	-	76.25	-	0	-	-	-	-	0.1	-	-	-	-
	Australind Shoal	18	3	-	76.29	-	0.6	-	-	-	-	1.4	-	-	-	-
	Barrow Island Reefs and Shoals	37.7	5	-	13.79	-	0.7	-	-	-	-	1.7	-	-	-	-
	Baylis Patches	17.2	3	-	75.25	-	2.2	-	-	-	-	2.4	-	-	-	-
	Brewis Reef	25.7	5	-	30.67	-	6.1	-	-	-	-	3.1	-	-	-	-
	Cod Bank	22.7	4	-	23.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Combe Reef	11.5	2	-	41.29	-	7.7	-	-	-	-	5.7	-	-	-	-
	Dailey Shoal	30.8	7	-	26.92	-	11.8	2	-	29.21	-	10.1	1	-	76.63	-
	Eliassen Rocks	14.1	3	-	76.21	-	0	-	-	-	-	0.2	-	-	-	-
	Fairway Reef	16.8	5	-	42.04	-	8.1	-	-	-	-	6	-	-	-	-
	Flinders Shoal	14.7	3	-	63.29	-	0.4	-	-	-	-	0.8	-	-	-	-
	Fortescue Reef	24.7	4	-	27.5	-	0	-	-	-	-	0.3	-	-	-	-
	Glennie Patches	17.7	3	-	77.25	-	0.6	-	-	-	-	0.7	-	-	-	-
	Glomar Shoal	23.5	3	-	49.25	-	0.4	-	-	-	-	1.6	-	-	-	-
	Gorgon Patch	15.4	3	-	79.38	-	0.2	-	-	-	-	0.4	-	-	-	-
	Hastings Shoal	11.2	3	-	80.46	-	0.1	-	-	-	-	0.3	-	-	-	-
	Hayman Rock	19.6	4	-	30.5	-	2.6	-	-	-	-	2.7	-	-	-	-
	Herald Reef	17.6	3	-	82.38	-	0.1	-	-	-	-	0.4	-	-	-	-
	Hood Reef	26.5	8	-	28.63	-	10.8	1	-	45.92	-	6.7	-	-	-	-
	Imperieuse Reef	3.5	-	-	-	-	4	-	-	-	-	17.9	8	-	49.88	-
	Inner Northwest Patch	19.1	4	-	31.58	-	0.6	-	-	-	-	0.8	-	-	-	-
	Koolinda Patch	13.3	3	-	88.17	-	0.2	-	-	-	-	0.3	-	-	-	-
	Lightfoot Reef	11.2	3	-	65.33	-	0.2	-	-	-	-	0.7	-	-	-	-
	Little Shoals	17.8	4	-	36.83	-	0.2	-	-	-	-	0.7	-	-	-	-
	Locker Reef	25.5	4	-	28.96	-	3	-	-	-	-	2.5	-	-	-	-
	Manicom Bank	13.4	3	-	77.29	-	0.4	-	-	-	-	0.4	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Mardie Rock	17.2	3	-	75.17	-	0	-	-	-	-	0.1	-	-	-	-
	McLennan Bank	30.1	4	-	21.71	-	0.1	-	-	-	-	0.4	-	-	-	-
	Meda Reef	12.7	3	-	67.54	-	0.1	-	-	-	-	0.2	-	-	-	-
	Miles Shoal	18.1	3	-	77.25	-	0.4	-	-	-	-	0.6	-	-	-	-
	Montebello Shoals	48.2	7	-	12.25	-	1.3	-	-	-	-	3.4	-	-	-	-
	Moresby Shoals	19.6	4	-	37.25	-	0.2	-	-	-	-	0.5	-	-	-	-
	Nares Rock	18.7	4	-	37.92	-	0.1	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	40.4	17	-	7.38	-	9.6	-	-	-	-	6.4	-	-	-	-
	North West Reef	17.1	4	-	24.79	-	0	-	-	-	-	0.1	-	-	-	-
	North West Reef	29.8	8	-	26.42	-	7.3	-	-	-	-	8.8	-	-	-	-
	O'Grady Shoal	24.5	4	-	26	-	0	-	-	-	-	0.5	-	-	-	-
	Otway Reef	16.2	3	-	27.42	-	7.9	-	-	-	-	5.6	-	-	-	-
	Outtrim Patches	55.3	8	-	25.92	-	14.4	6	-	29.46	-	15.7	14	-	14.58	-
	Paroo Shoal	16	3	-	77.33	-	0.4	-	-	-	-	0.6	-	-	-	-
	Penguin Bank	122.1	10	4	11.5	12.29	3.6	-	-	-	-	9.7	-	-	-	-
	Poivre Reef	125.5	7	3	11.71	60.96	1.1	-	-	-	-	3.5	-	-	-	-
	Rankin Bank	134.5	23	4	8.75	23.83	29	6	-	35.13	-	28.8	8	-	58.5	-
	Ripple Shoals	46.8	6	-	12.88	-	0.7	-	-	-	-	2.4	-	-	-	-
	Roller Shoal	10.7	1	-	93.38	-	0.2	-	-	-	-	0.2	-	-	-	-
	Rosily Shoals	81.5	11	-	11.71	-	14.5	2	-	19.25	-	8.7	-	-	-	-
	Saladin Shoal	14.5	3	-	78.25	-	0.2	-	-	-	-	0.5	-	-	-	-
	Santo Rock	26.5	4	-	28.88	-	3.6	-	-	-	-	2.2	-	-	-	-
	South East Reef	12.6	3	-	43.08	-	0	-	-	-	-	0.1	-	-	-	-
	South West Reef	18.2	4	-	32.63	-	0	-	-	-	-	0.1	-	-	-	-
	Southwest Patch	11.1	2	-	78.33	-	0.2	-	-	-	-	0.4	-	-	-	-
	Sultan Reef	23.3	6	-	32.13	-	1.3	-	-	-	-	1.9	-	-	-	-
	Taunton Reef	36.9	6	-	13.96	-	0.8	-	-	-	-	1.9	-	-	-	-
	Tongue Shoals	20.1	4	-	31.04	-	1.3	-	-	-	-	0.9	-	-	-	-
	Trap Reef	56.1	7	-	12.71	-	5.5	-	-	-	-	4.6	-	-	-	-
	Tryal Rocks	46.1	10	-	12.38	-	3.7	-	-	-	-	4	-	-	-	-
	Ward Reef	10	1	-	103.79	-	0.1	-	-	-	-	0.2	-	-	-	-
	Web Reef	11.6	1	-	82.33	-	5.7	-	-	-	-	3.1	-	-	-	-
	Weeks Shoal	15.2	3	-	78.83	-	0.2	-	-	-	-	0.4	-	-	-	-
	West Reef	11.1	2	-	84.21	-	0.2	-	-	-	-	0.9	-	-	-	-
Nearshore Waters	Airlie Island	50.9	7	-	13.83	-	2.4	-	-	-	-	2.7	-	-	-	-
	Ashburton	11.5	3	-	89.25	-	1.2	-	-	-	-	0.6	-	-	-	-
	Ashburton Island	17.7	3	-	77.25	-	0.5	-	-	-	-	1	-	-	-	-
	Barrow Island	133	7	3	11.92	61.92	1.7	-	-	-	-	4.9	-	-	-	-
	Bessieres Island	48.5	12	-	27.33	-	10.8	1	-	19.13	-	9.5	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Boodie Island	122.6	7	3	11.88	61.67	1.1	-	-	-	-	4.2	-	-	-	-
	Carnarvon	12.3	2	-	32.54	-	1.7	-	-	-	-	1.7	-	-	-	-
	Cunningham Island	2.9	-	-	-	-	3.4	-	-	-	-	12.6	8	-	50.58	-
	Direction Island	17	3	-	80.42	-	0.1	-	-	-	-	0.4	-	-	-	-
	Eaglehawk Island	17.8	4	-	32.46	-	0	-	-	-	-	0.1	-	-	-	-
	Enderby Island	15.8	4	-	36.17	-	0	-	-	-	-	0.2	-	-	-	-
	Exmouth	40.4	17	-	7.58	-	8	-	-	-	-	7.1	-	-	-	-
	Flat Island	35.6	11	-	26.92	-	13.5	2	-	27.63	-	11.5	1	-	28.96	-
	Fly Island	11.5	1	-	79.67	-	4.5	-	-	-	-	2.8	-	-	-	-
	Goodwyn Island	16.3	4	-	37	-	0.1	-	-	-	-	0.1	-	-	-	-
	Imperieuse Reef	3.2	-	-	-	-	3.5	-	-	-	-	16.1	8	-	50.17	-
	Karratha	18.9	4	-	29.96	-	0.2	-	-	-	-	0.3	-	-	-	-
	Kendrew Island	17	4	-	25.42	-	0.1	-	-	-	-	0.2	-	-	-	-
	Locker Island	17.8	3	-	75.88	-	1.3	-	-	-	-	1	-	-	-	-
	Lowendal Island	41.2	5	-	12.71	-	1.1	-	-	-	-	2.4	-	-	-	-
	Malus Island	11.8	3	-	84.63	-	0	-	-	-	-	0.1	-	-	-	-
	Mangrove Islands	16.8	3	-	83.46	-	0.1	-	-	-	-	0.2	-	-	-	-
	Mary Anne Group	14.3	3	-	65.29	-	0.3	-	-	-	-	0.9	-	-	-	-
	Middle Island	127.6	7	3	11.92	61.67	1.7	-	-	-	-	4.2	-	-	-	-
	Montebello Islands	39.5	6	-	12.75	-	1.4	-	-	-	-	2.9	-	-	-	-
	Murion Islands	72.7	17	-	8	-	15.2	7	-	29.54	-	17.9	15	-	14.46	-
	Observation Island	15.3	3	-	32.25	-	7.3	-	-	-	-	5.8	-	-	-	-
	Passage Islands	28.2	4	-	22.25	-	0.3	-	-	-	-	0.5	-	-	-	-
	Peak Island	58.8	8	-	25.96	-	15.7	4	-	28.46	-	15	12	-	14	-
	Ragnard Islands	17.6	4	-	30.92	-	0	-	-	-	-	0.2	-	-	-	-
	Rosemary Island	17.4	4	-	36.67	-	0.2	-	-	-	-	0.2	-	-	-	-
	Round Island	36.6	9	-	28.04	-	9.1	-	-	-	-	7.5	-	-	-	-
	Serrurier Island	40.6	11	-	26.96	-	12	2	-	27.54	-	10.1	1	-	78.71	-
	Sunday Island	42.3	7	-	26.33	-	11.5	2	-	30.21	-	12.4	10	-	29.42	-
	Table Island	36.9	7	-	27.75	-	9.5	-	-	-	-	5.6	-	-	-	-
	Thevenard Island	35.8	7	-	31.08	-	4.3	-	-	-	-	2.7	-	-	-	-
	Tortoise Island	23.1	5	-	31.08	-	1.8	-	-	-	-	3.6	-	-	-	-
	Twin Island	15.3	3	-	82.46	-	0.2	-	-	-	-	0.3	-	-	-	-
State Waters	Western Australia State Waters	148.5	19	4	6.88	11.67	26.6	7	-	16.88	-	22.8	17	-	13.21	-

*The release location resides within the receptor boundaries.

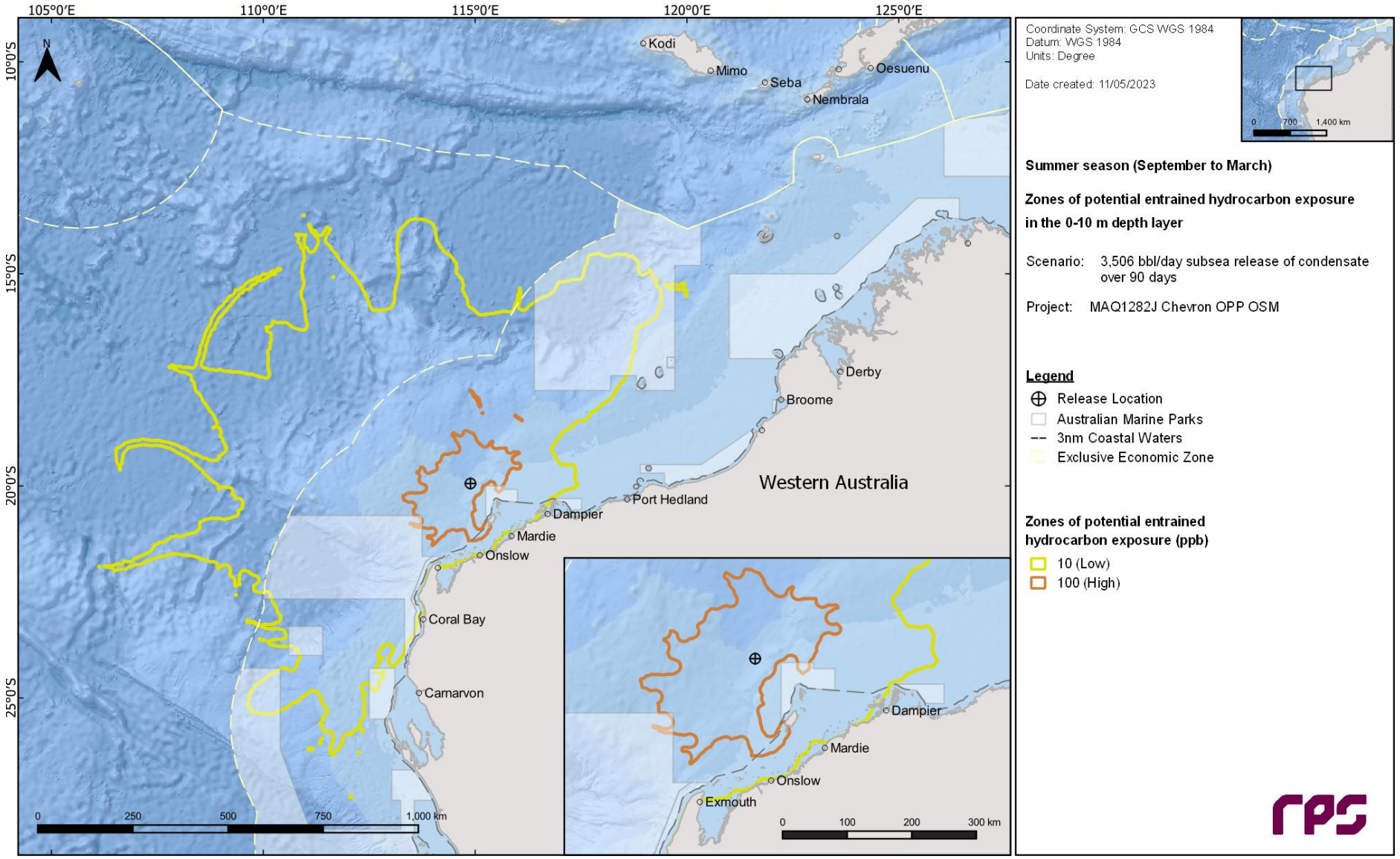


Figure 11.6 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

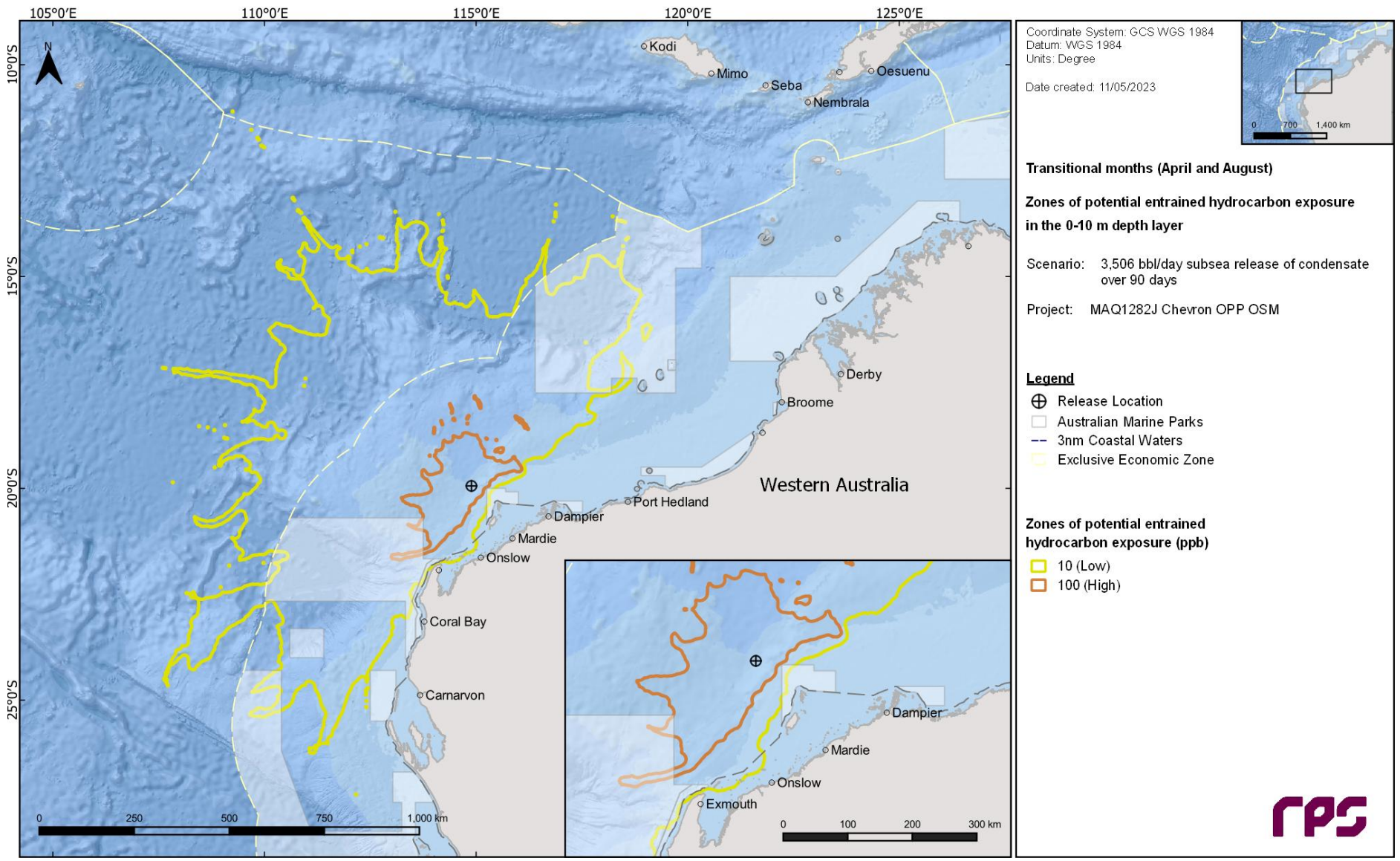


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

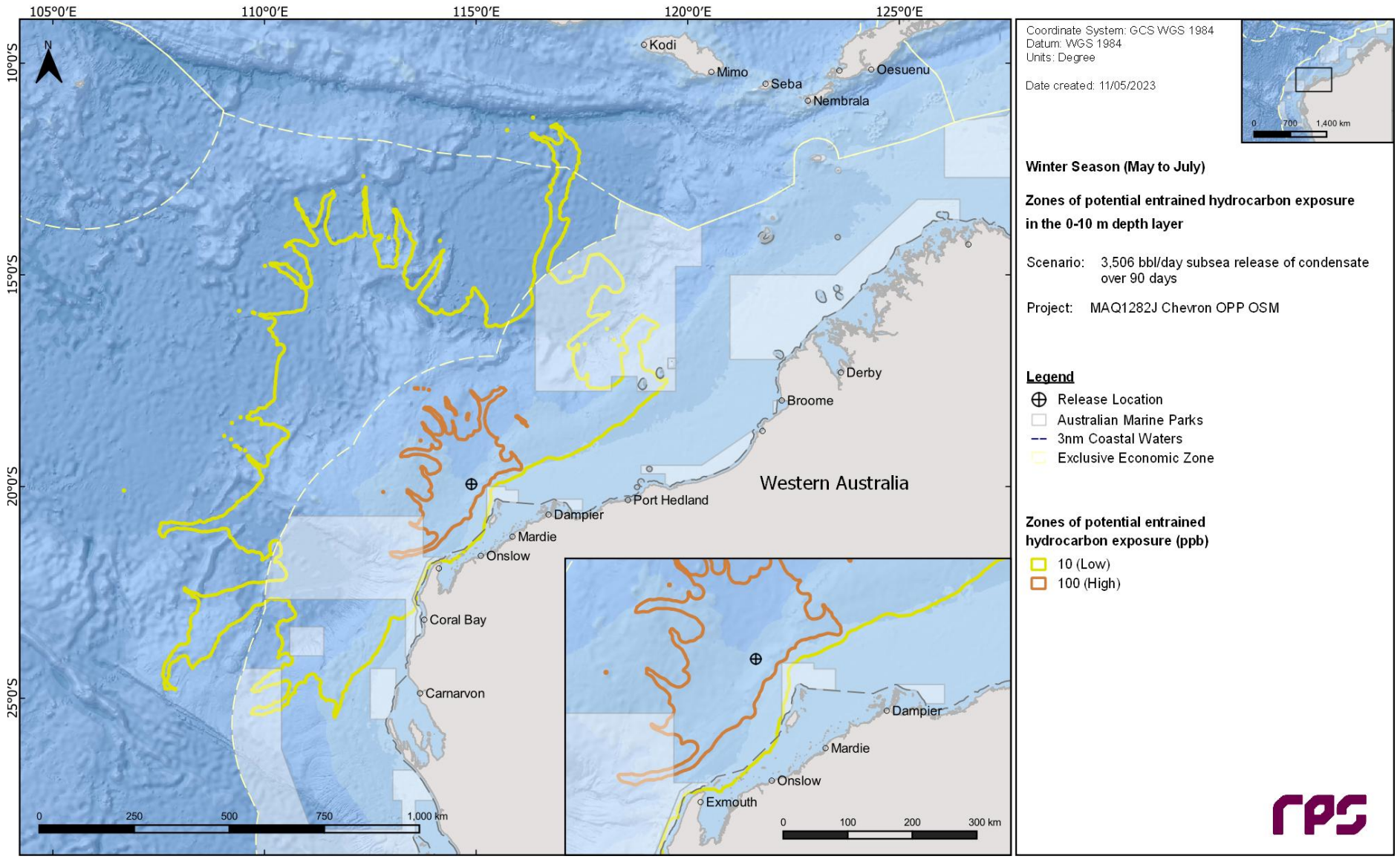


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

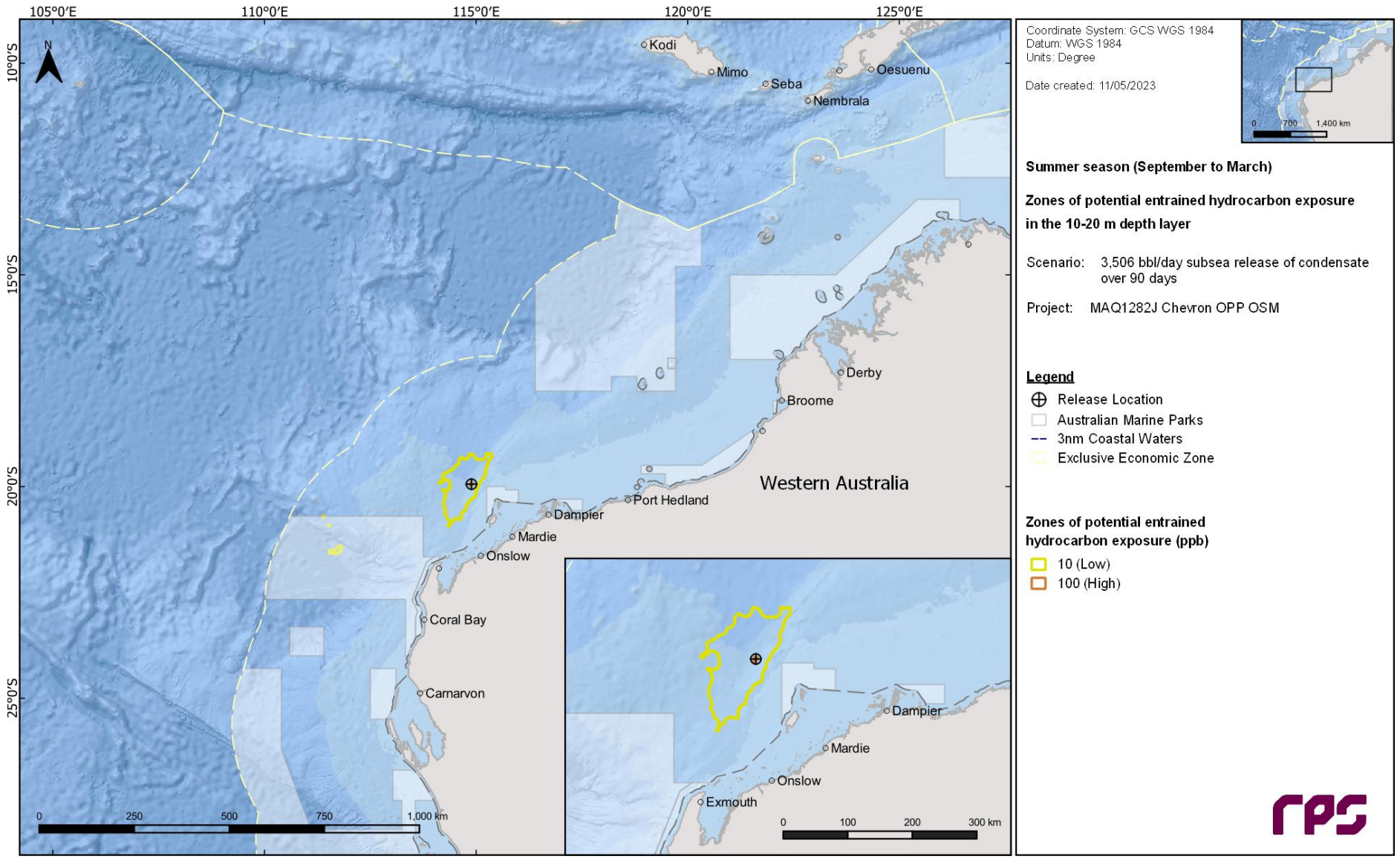


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

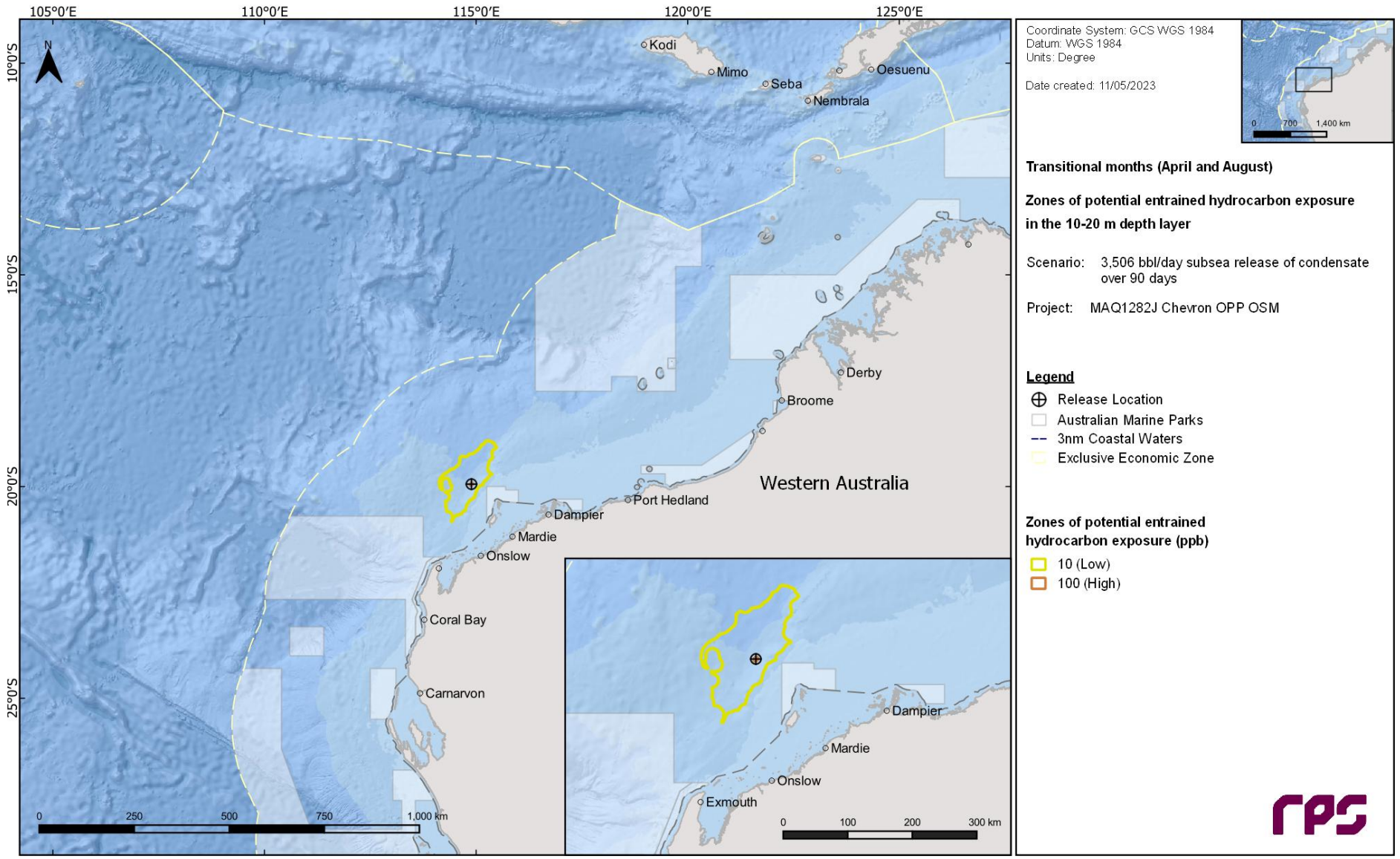


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

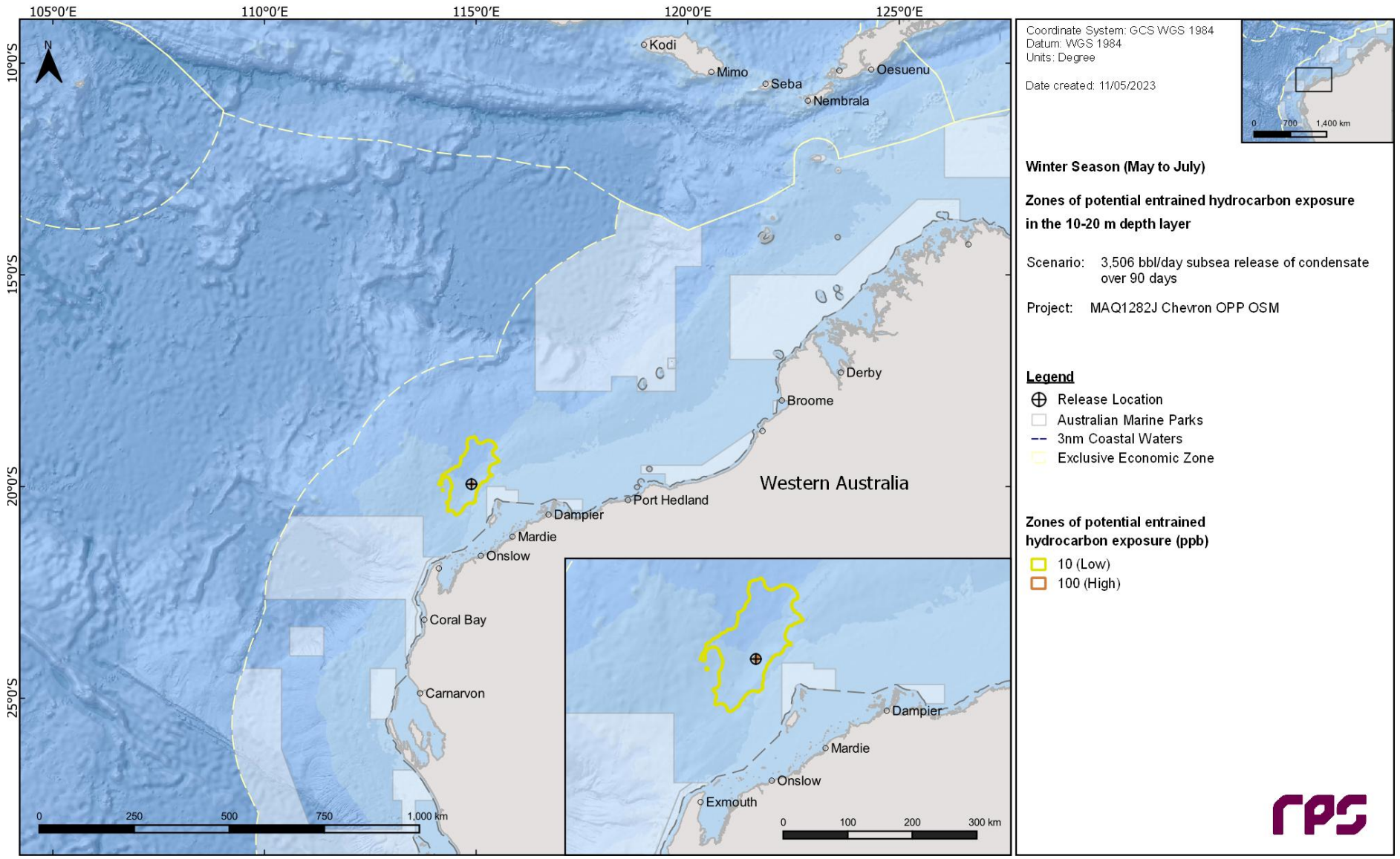


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), largest volume of oil ashore (see Section 11.2.2), longest length of shoreline accumulation above 100 g/m^2 (see Section 11.2.2) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.7 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Note that there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 932 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 68 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.7 Summary of the deterministic analysis following a subsea LOWC at GER FL2.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m^2	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Winter	Summer	Summer	Summer
Run Number		64	40	51	15
Floating Oil (km^2)	**1 g/m^2**	932.0	804.6	856.3	914.5
	10 g/m^2	**22.2**	6.5	4.6	3.7
	50 g/m^2	-	-	-	-
Shoreline Length (km)	**10 g/m^2**	-	50	76	55
	100 g/m^2	-	1	**2**	-
	1,000 g/m^2	-	-	-	-
Minimum Time (days)		-	73.9	12.5	59.0
Maximum Volume (m^3)		-	**23.2**	22	13
Entrained Area (km^2)	**10 ppb**	140,946	152,629	129,032	144,042
	100 ppb	2,598	8,677	5,635	**8,847**
Dissolved Area (km^2)	**10 ppb**	-	-	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		20 June 2011	6 October 2010	6 December 2010	21 October 2010

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 64 during the winter period.

Figure 11.12 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.13 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.14 presents the fates and weathering for the corresponding simulation and Table 11.8 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.8 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	442	52.42	1
Entrained (m^3)	4,828	90.00	2,999
Dissolved (m^3)	7	81.46	0
Evaporation (m^3)	33,388	103.54	33,388
Decay (m^3)	14,140	104.00	14,140
Ashore (m^3)	0	0.04	0

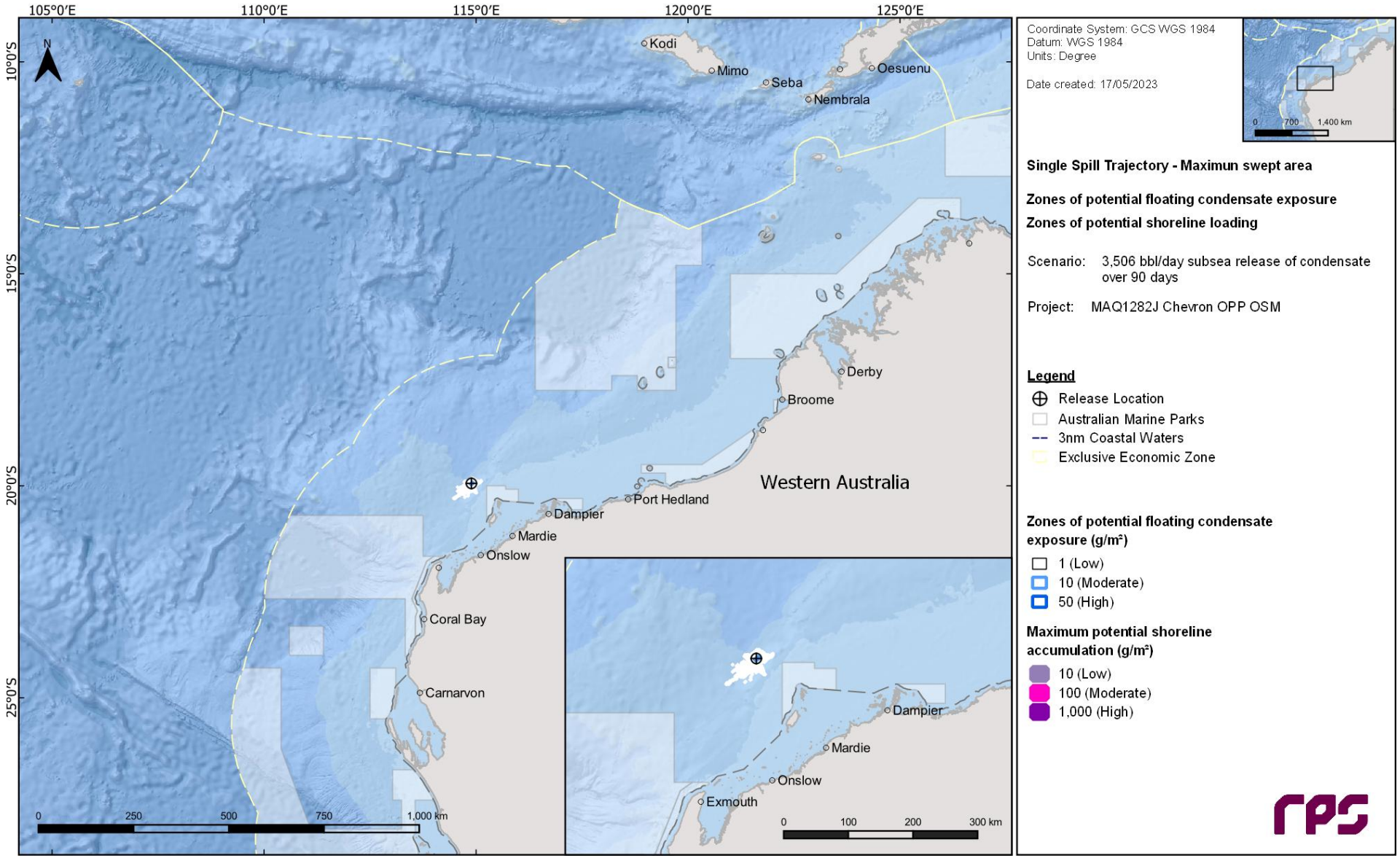


Figure 11.12 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at GER FL2.

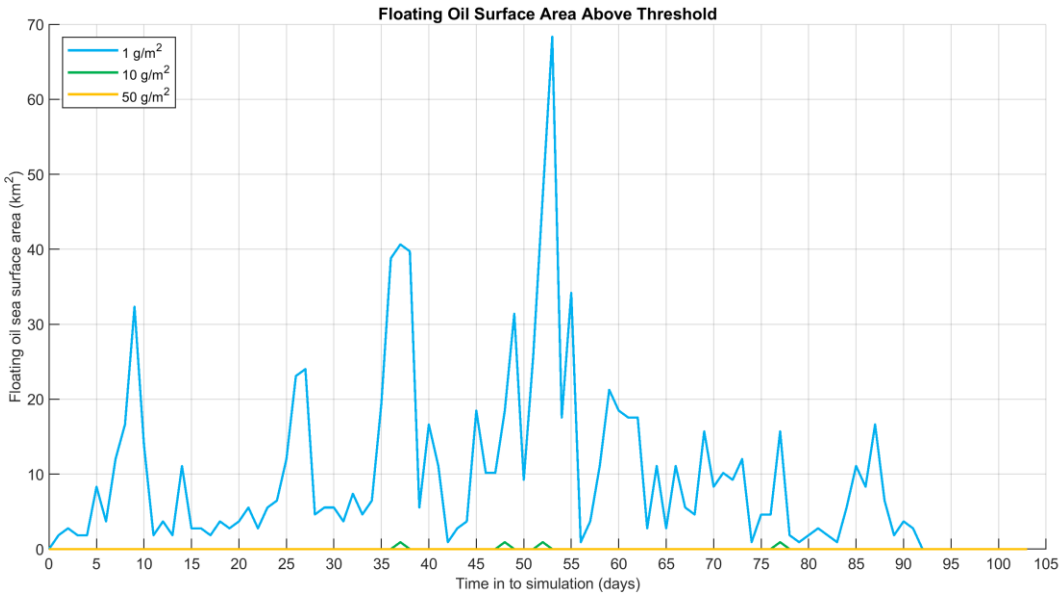


Figure 11.13 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at GER FL2.

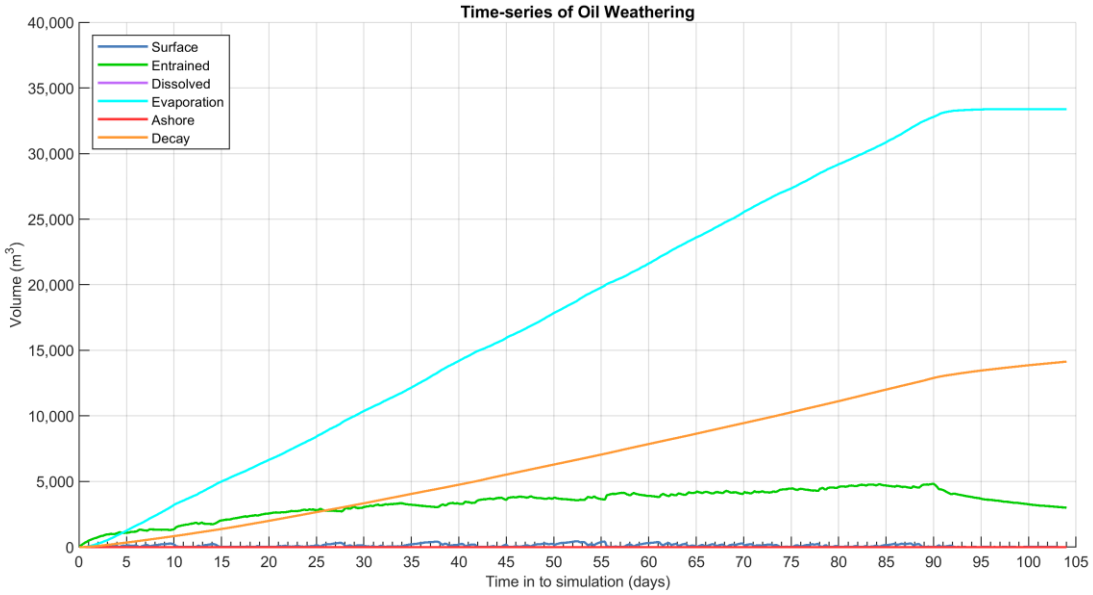


Figure 11.14 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at GER FL2.

11.2.2 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 40, during the summer season.

Figure 11.15 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.16 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.9 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	277	14	3
Entrained (m^3)	4,975	89	3,112
Dissolved (m^3)	7	69	0
Evaporation (m^3)	32,924	104	32,924
Decay (m^3)	14,469	104	14,469
Ashore (m^3)	23.2	94	19

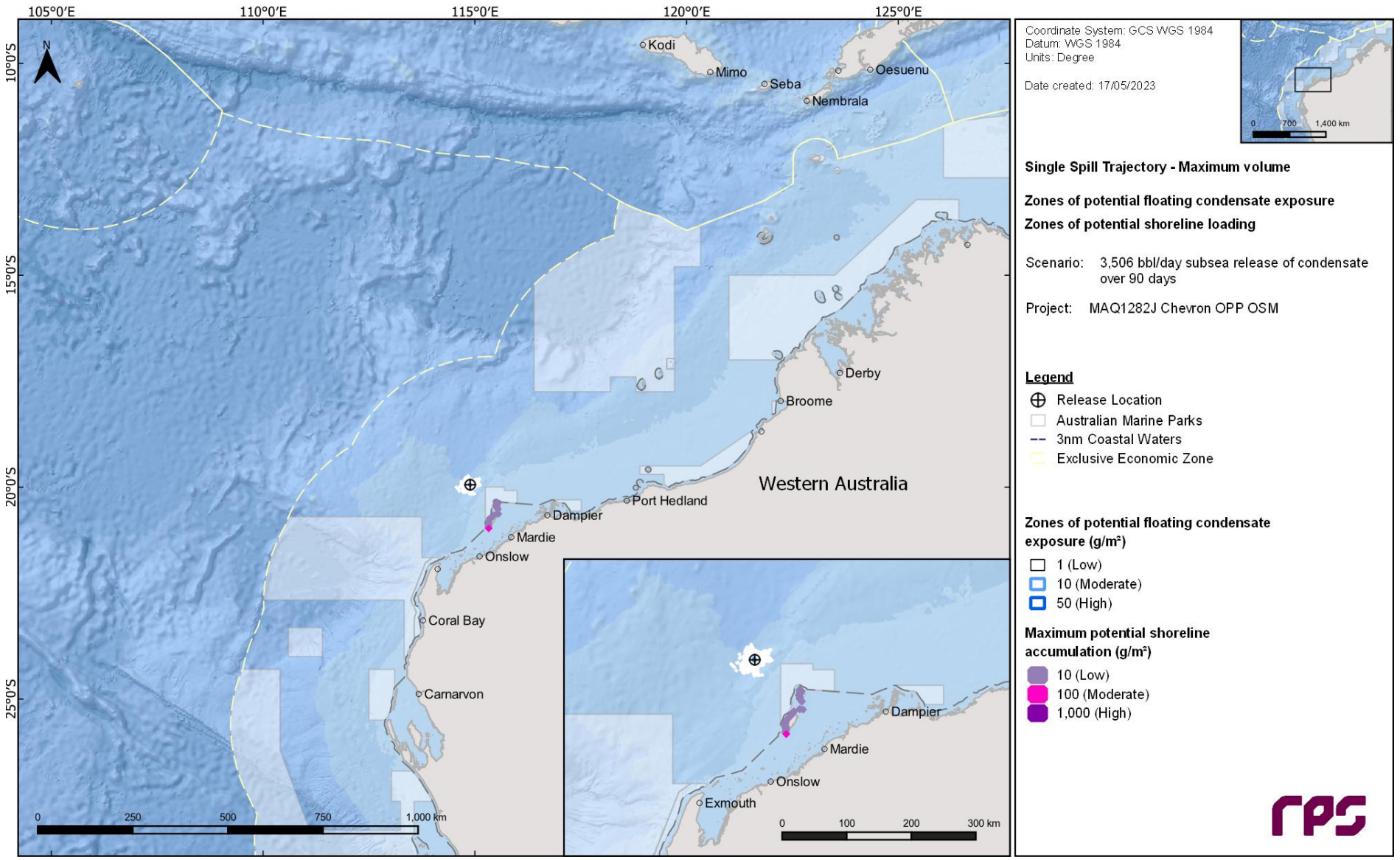


Figure 11.15 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a LOWC at GER FL2.

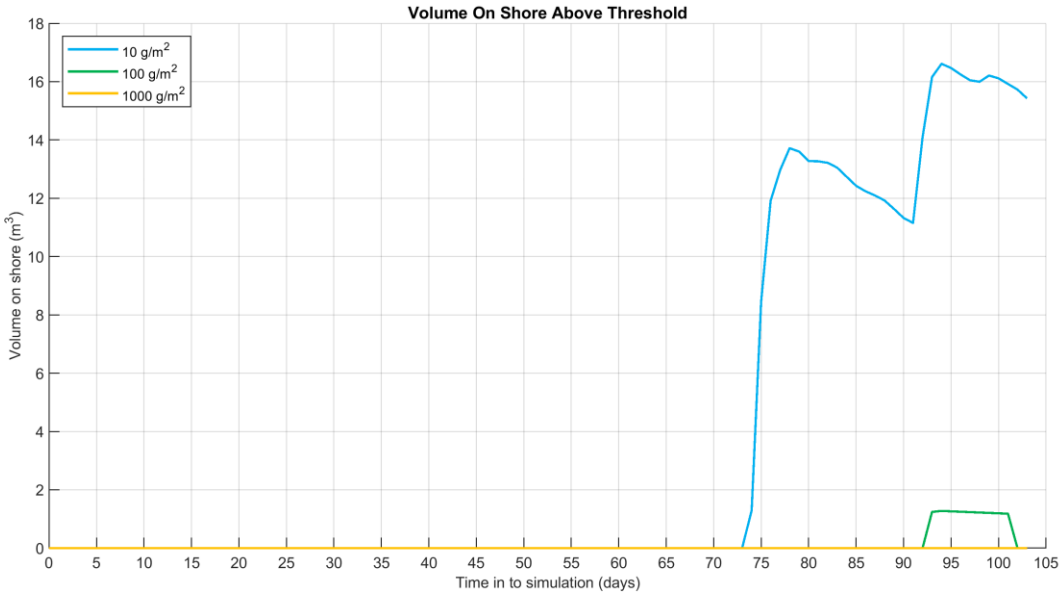


Figure 11.16 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore following a LOWC at GER FL2.

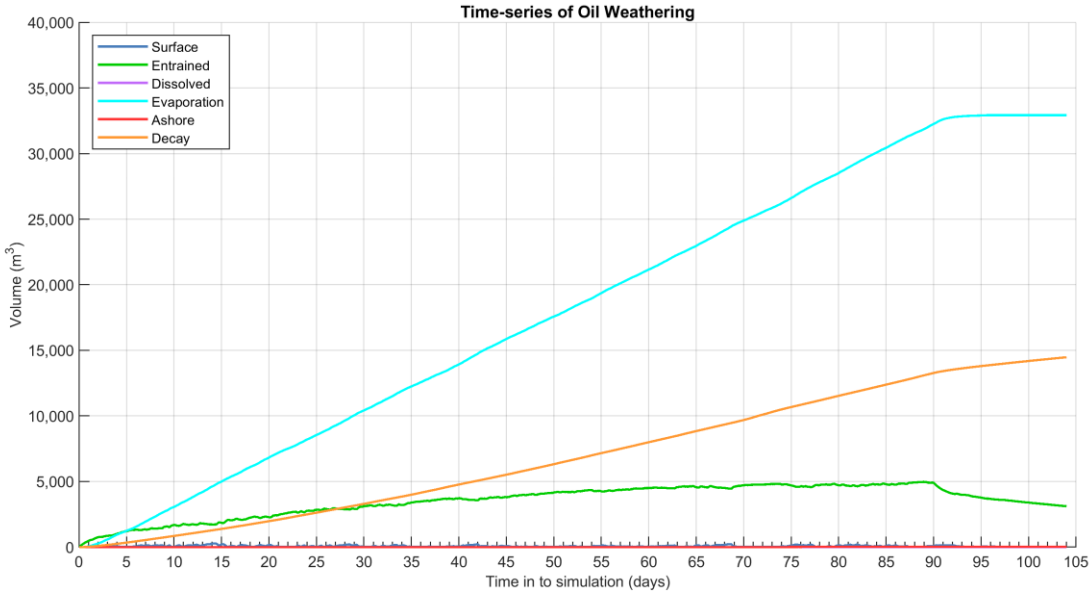


Figure 11.17 Predicted weathering and fates for the simulation with the largest volume of oil ashore following a LOWC at GER FL2.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 51 during the summer period.

Figure 11.15 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.16 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	227	55	1
Entrained (m^3)	4,738	89	3,015
Dissolved (m^3)	7	74	0
Evaporation (m^3)	33,548	104	33,548
Decay (m^3)	13,938	104	13,938
Ashore (m^3)	22	82	21

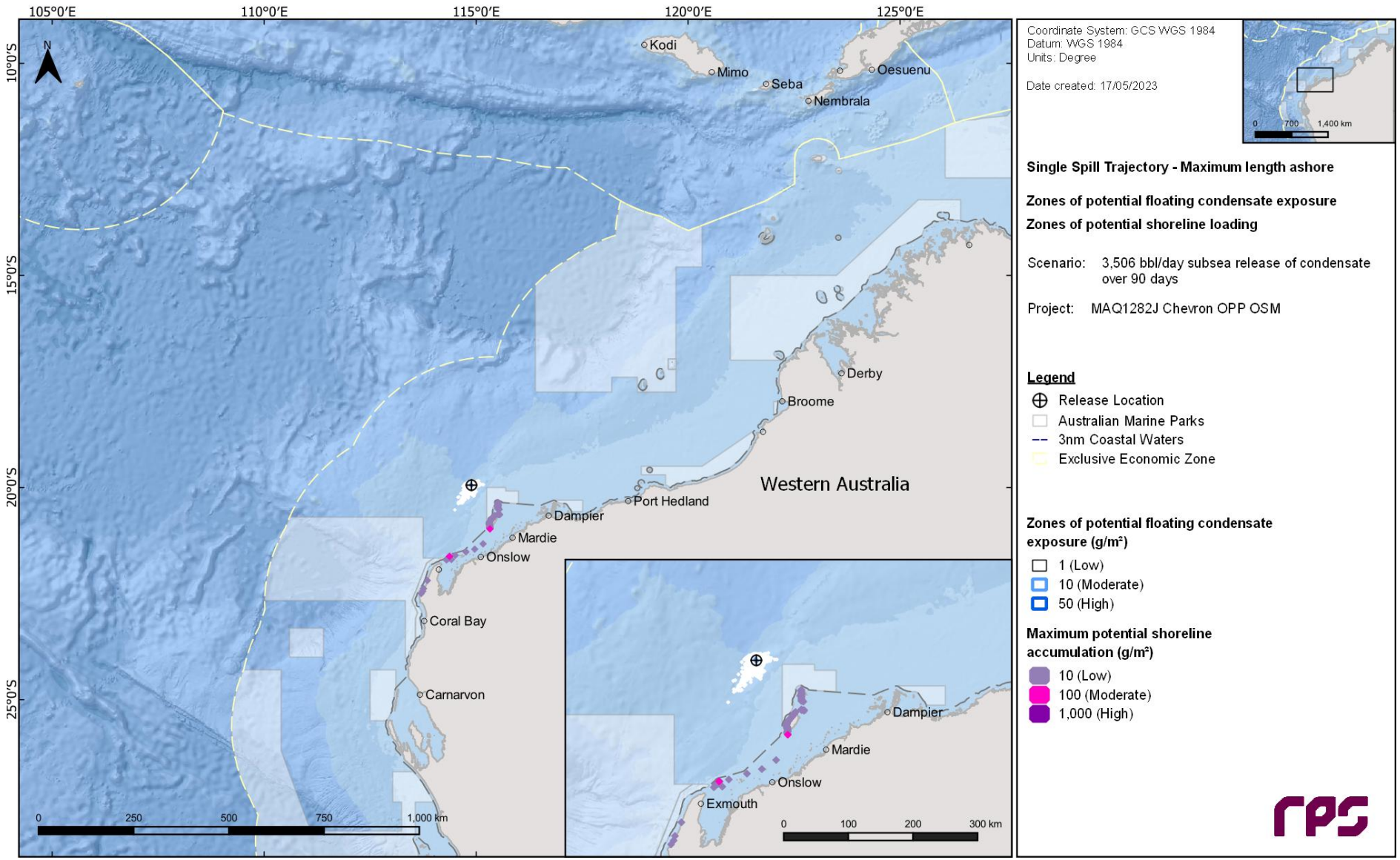


Figure 11.18 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at GER FL2.

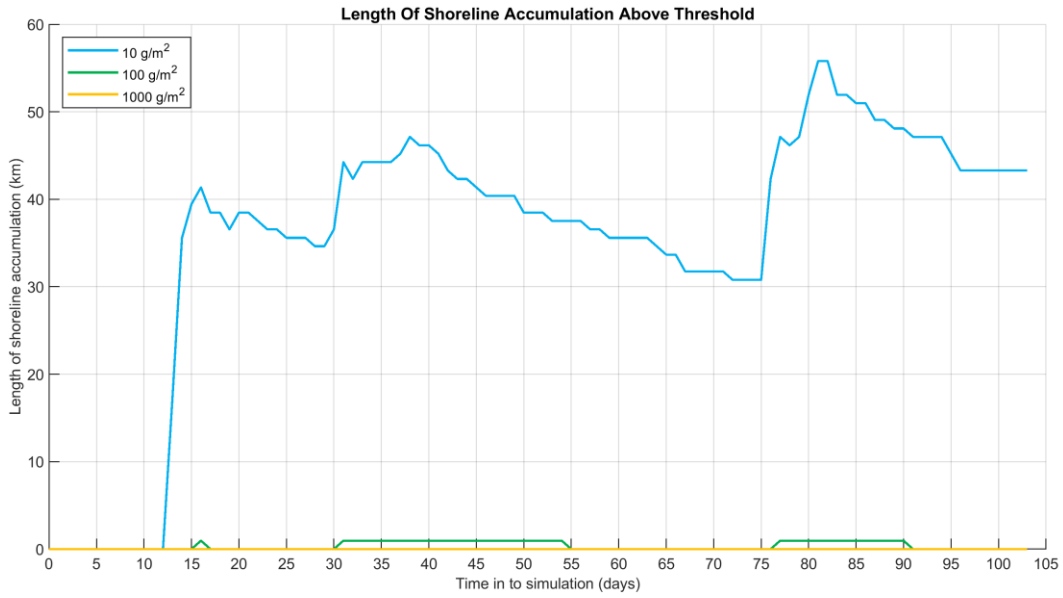


Figure 11.19 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at GER FL2.

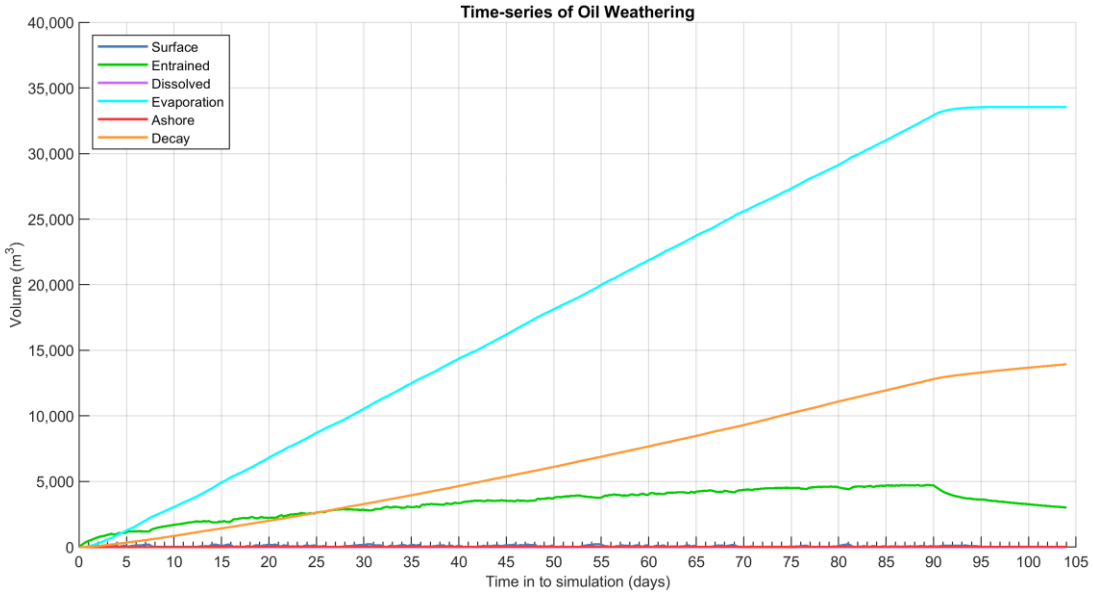


Figure 11.20 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at GER FL2.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (low threshold) was identified as run number 15 during the summer period.

Figure 11.21 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.22 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.23 presents the fates and weathering for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary of the peak volumes and times of occurrence for each oil phase and the volumes at day 104, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	216	54	3
Entrained (m^3)	4,869	89	3,072
Dissolved (m^3)	7	54	0
Evaporation (m^3)	33,018	103	33,018
Decay (m^3)	14,419	104	14,419
Ashore (m^3)	18	80	16

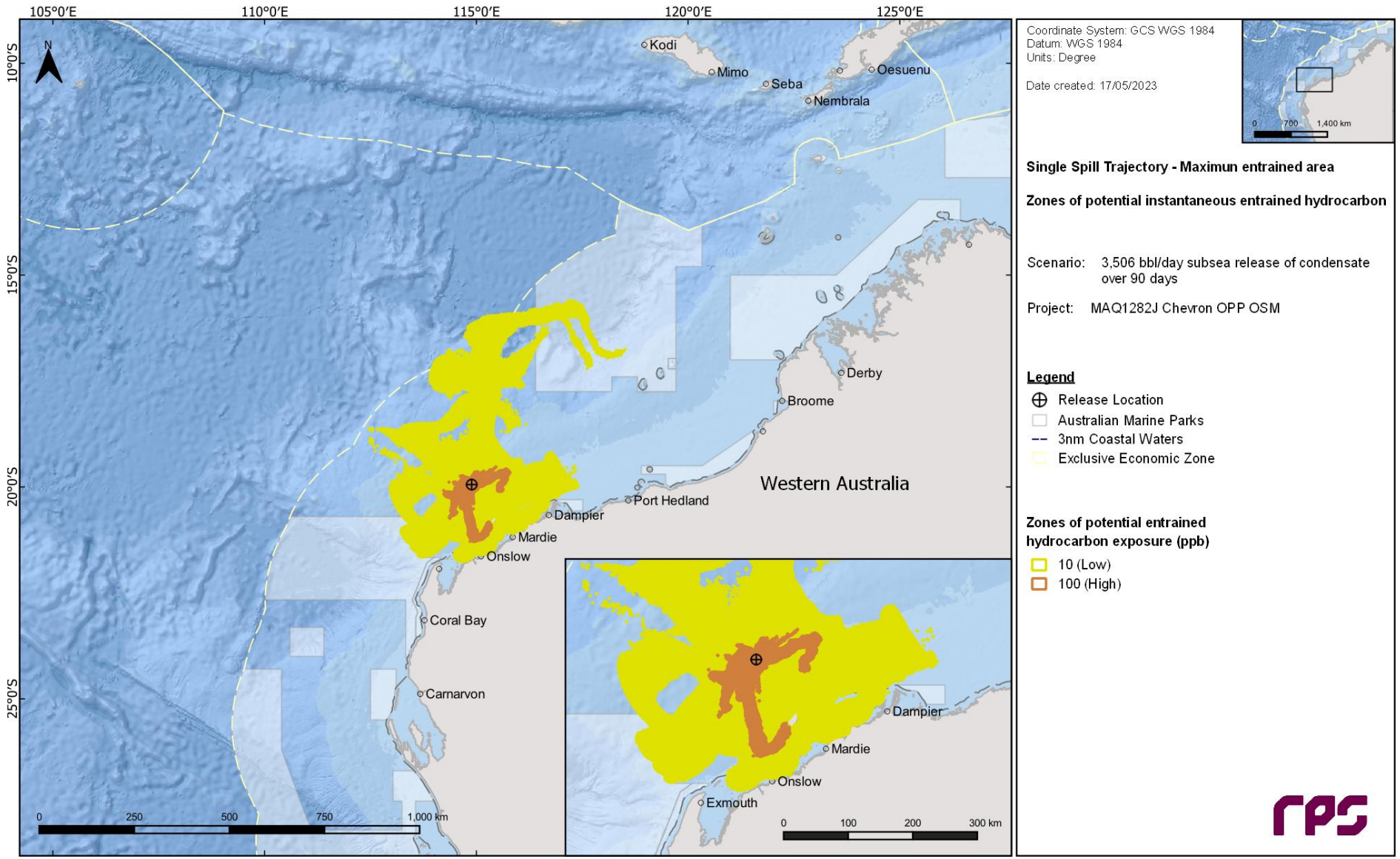


Figure 11.21 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

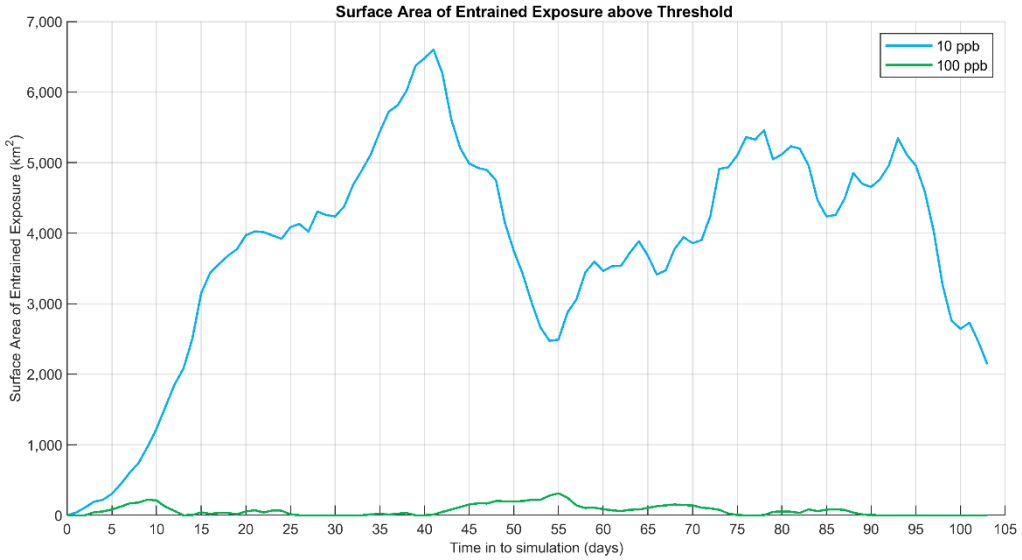


Figure 11.22 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

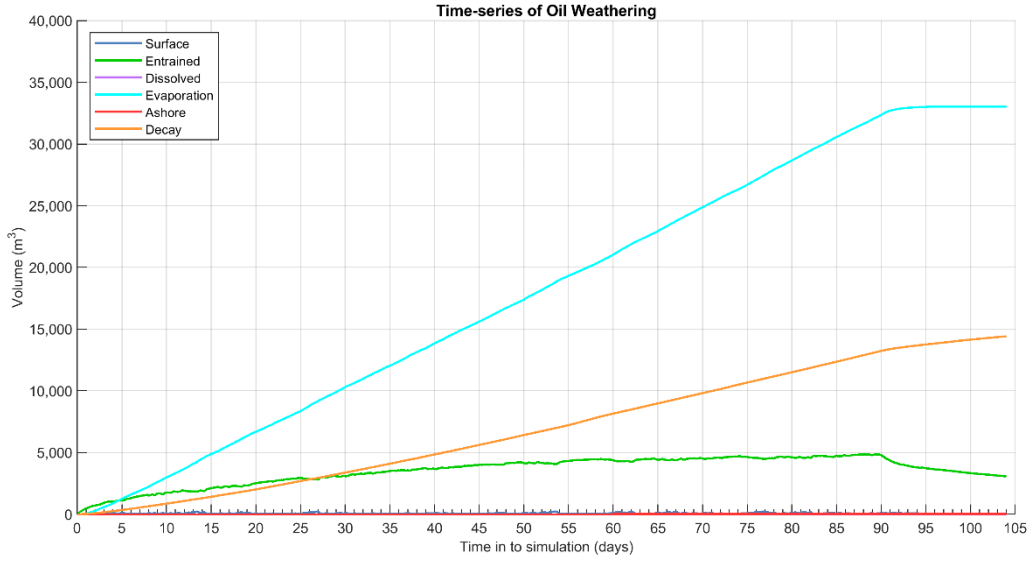


Figure 11.23 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

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appendix c.4—C&D LOWC (condensate)

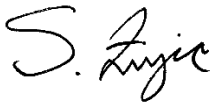
GREATER GORGON – THE CHRYSAOR AND DIONYSUS

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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
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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating oil 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
g/m^2	Grams per square meter (unit of surface area density)
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.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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

SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chrysaor and Dionysus (C&D) fields situated within the Northern Carnarvon Basin in Permit area WA-15-R northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,308 stb/day (207.9 m^3/day) subsea release of condensate over 90 days (totalling 117,720 stb or 18,715 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Chrysaor condensate physical properties and boiling point distributions were provided by Chevron. The condensate has an API of 40.2, a density of 824 kg/m^3 (at 15ºC) and a low viscosity value of 5.6 cP. When exposed to the atmosphere at local temperatures, about 23.8% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 33.0% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~32.9%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 10.3% of the condensate is shown to be persist in the marine environment for longer period and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. Soluble aromatic hydrocarbons contribute approximately 3.0% by mass of the whole oil (contained in the volatile fraction).

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 82.0 km west (summer) and 4.3 km northeast (transitional and winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, and the Continental Slope Demersal Fish Communities KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold were 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 89% (all receptors; summer) and 99% (all receptors; winter). Additionally, the Flatback Turtle - Internesting Buffer BIA was also predicted to be exposed at the low threshold during summer (95%), transitional (100%) and winter (97%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer BIA was 0.67 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour (KEF) was 88%, 84% and 89% during summer, transitional and winter conditions and 31%, 27% and 41% summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure at the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour FEF was 0.88 days (summer) and 2.21 days (winter).

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 32%, while the minimum time before shoreline accumulation was 4.29 days and the maximum volume of oil ashore was 32.0 m^3.

- During summer conditions, condensate had accumulated on 56 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands and Ningaloo Coast World Heritage Area IAAs (22%). In comparison, during transitional and winter conditions, condensate had accumulated on 6 and 4 shoreline receptors, respectively. The greatest probabilities of shoreline accumulation occurred at Muiron Islands, Ningaloo Coast World Heritage Area and North Muiron Island, all 3% probability during transitional season and at Muiron Islands, Ningaloo Coast World Heritage Area and South Muiron Island, all 1% probability during winter.

- No dissolved hydrocarbon exposure was predicted for this scenario at or above the low reporting threshold (≥10 ppb) during any of the seasons modelled.

- In the 0-10 m depth layer, a total of 38, 12 and 11 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore, the probabilities for each season ranged between 1–80%, 1–82% and 1–87% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons. Furthermore, 46, 5 and 2 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold with maximum seasonal probabilities of 36%, 18% and 26% for Rankin Bank, during summer, transitional and winter, respectively.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chrysaor and Dionysus (C&D) fields situated within the Northern Carnarvon Basin in Permit area WA-15-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the C&D fields, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,308 stb/day (207.9 m^3/day) subsea release of condensate over 90 days (totalling 117,720 stb or 18,715 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 Chrysaor–Dionysus release location.

Location	Latitude	Longitude	Depth (mLAT)
Chrysaor Well 5	20.23988º S	114.87716º E	800

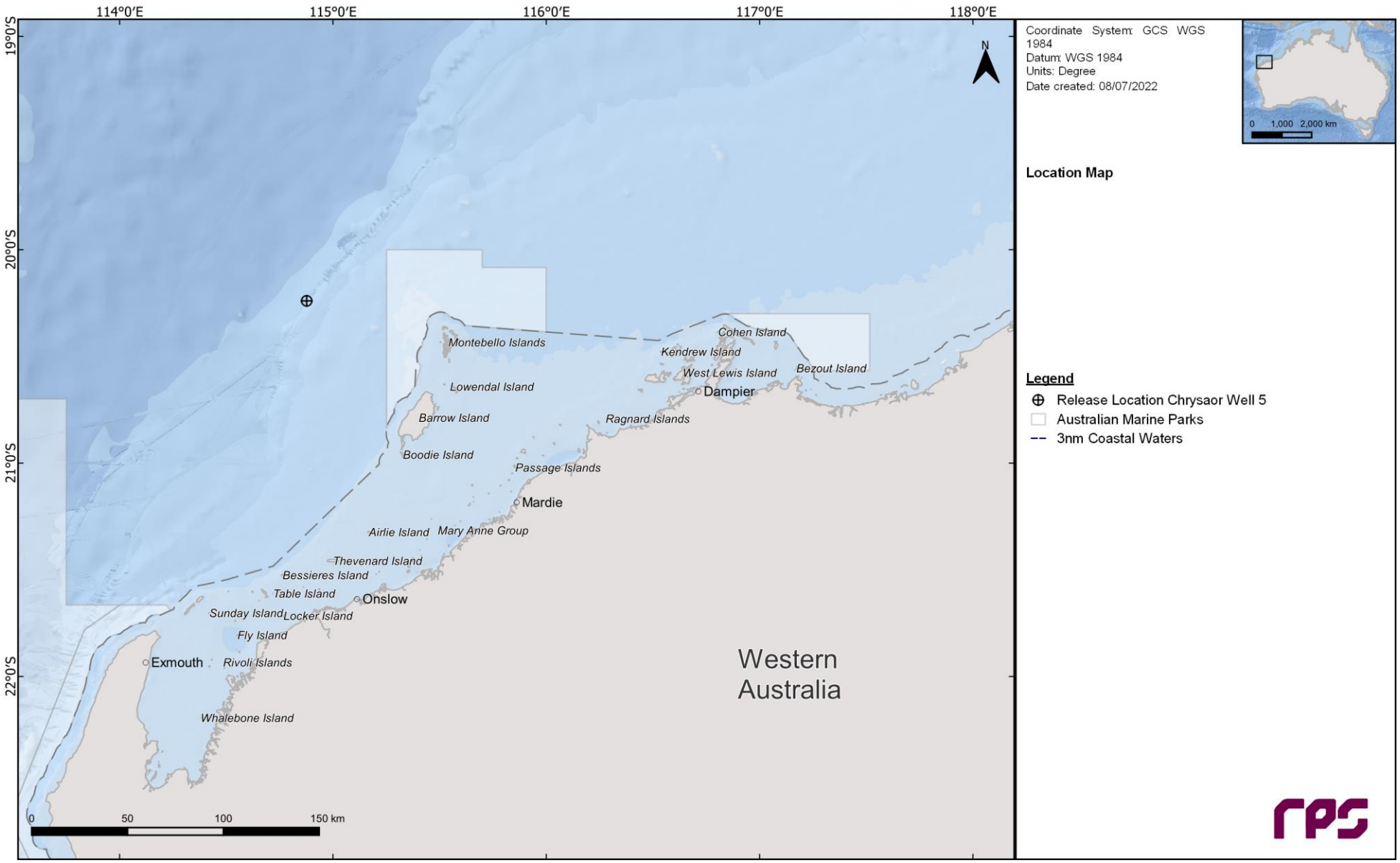


Figure 1.1 Chrysaor and Dionysus hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
    a. Largest swept area of floating hydrocarbon above 10 g/m^2
    b. Largest swept area of floating hydrocarbon above 50 g/m^2
    c. Largest volume of oil ashore
    d. Longest length of shoreline accumulation above 100 g/m^2
    e. Largest area of entrained hydrocarbons above 100 ppb
    f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

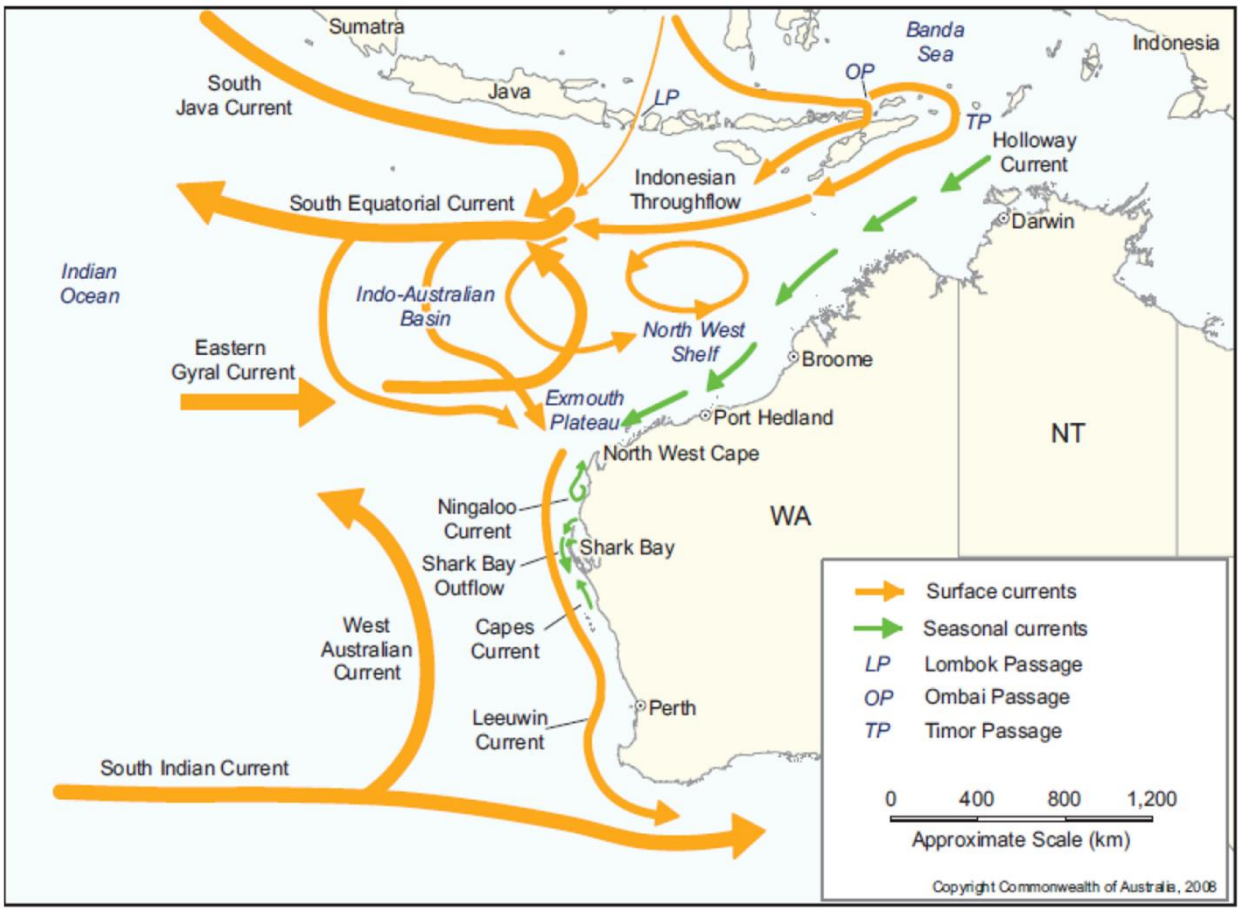


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

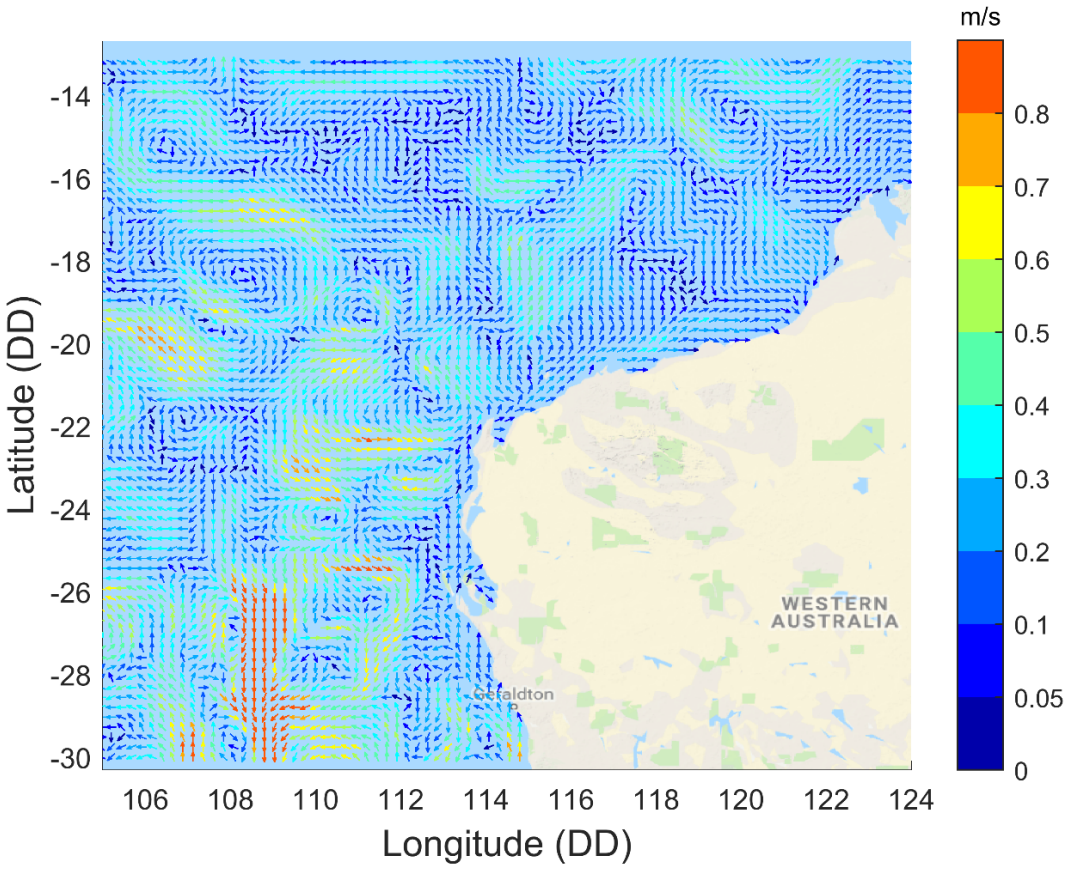


Figure 3.2 Typical ocean current circulation pattern during the summer months.

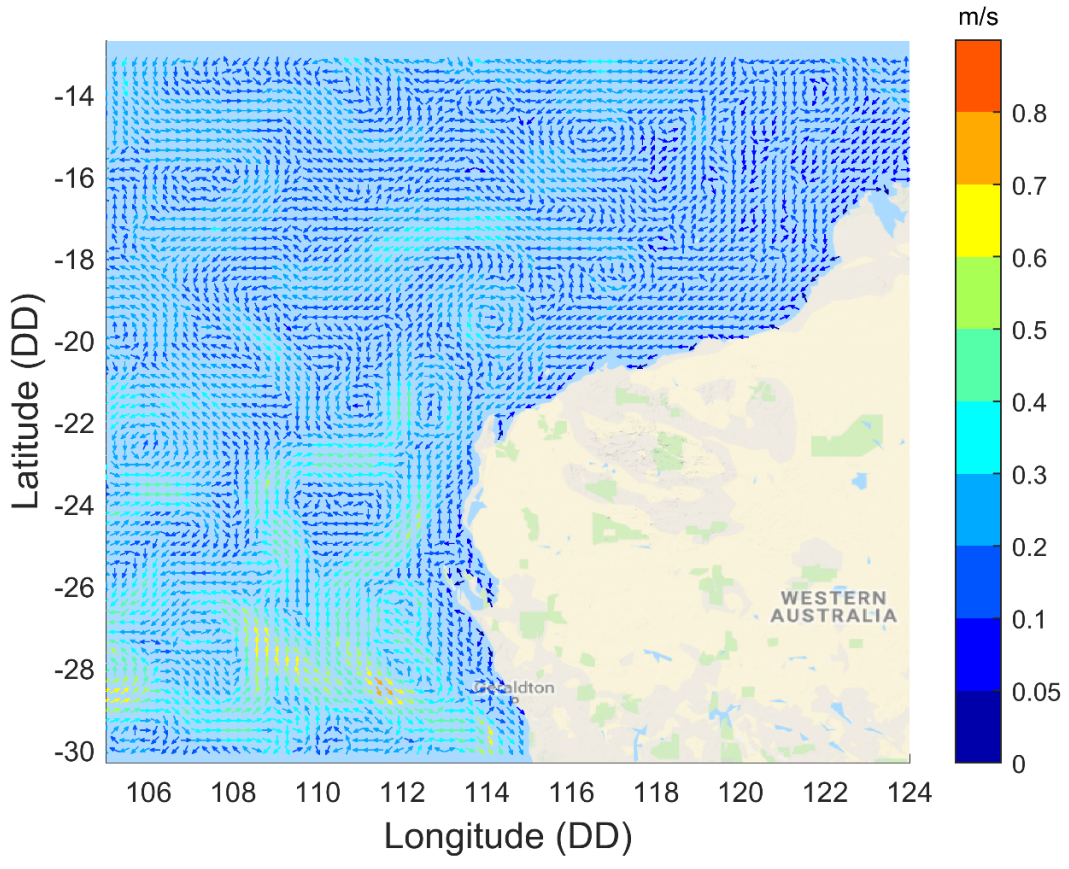


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

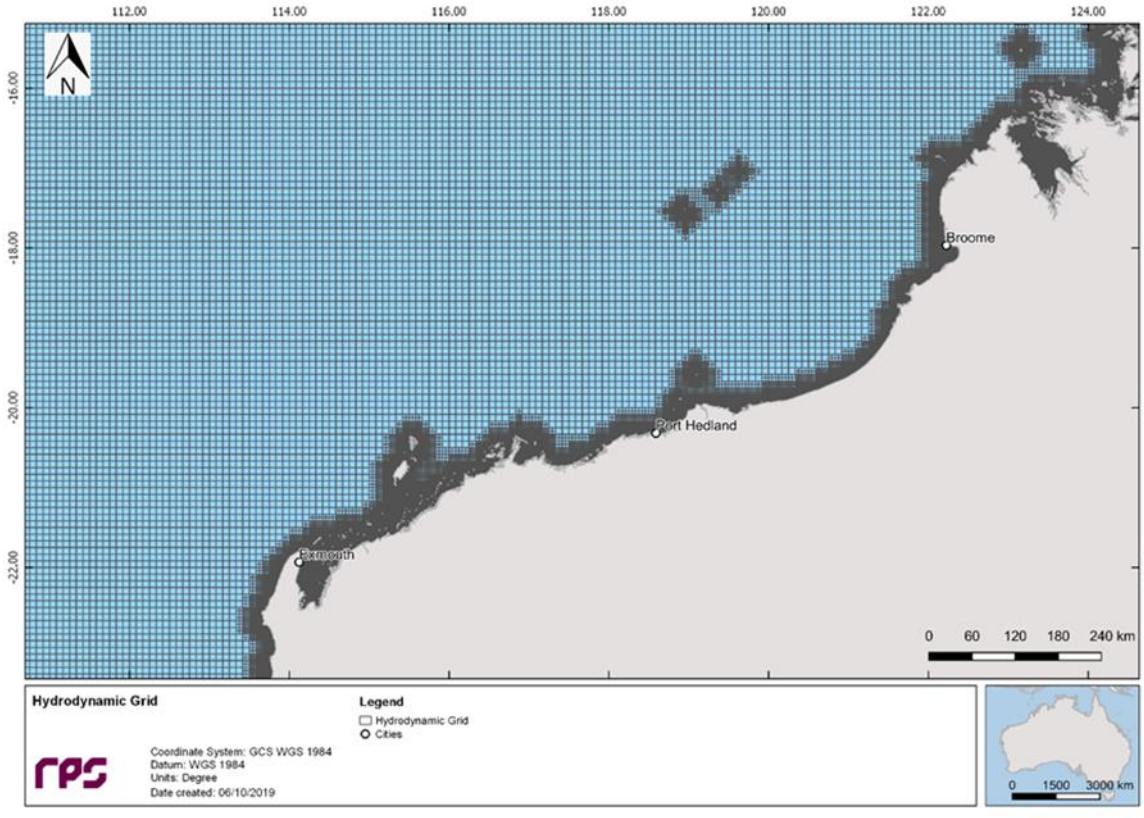


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

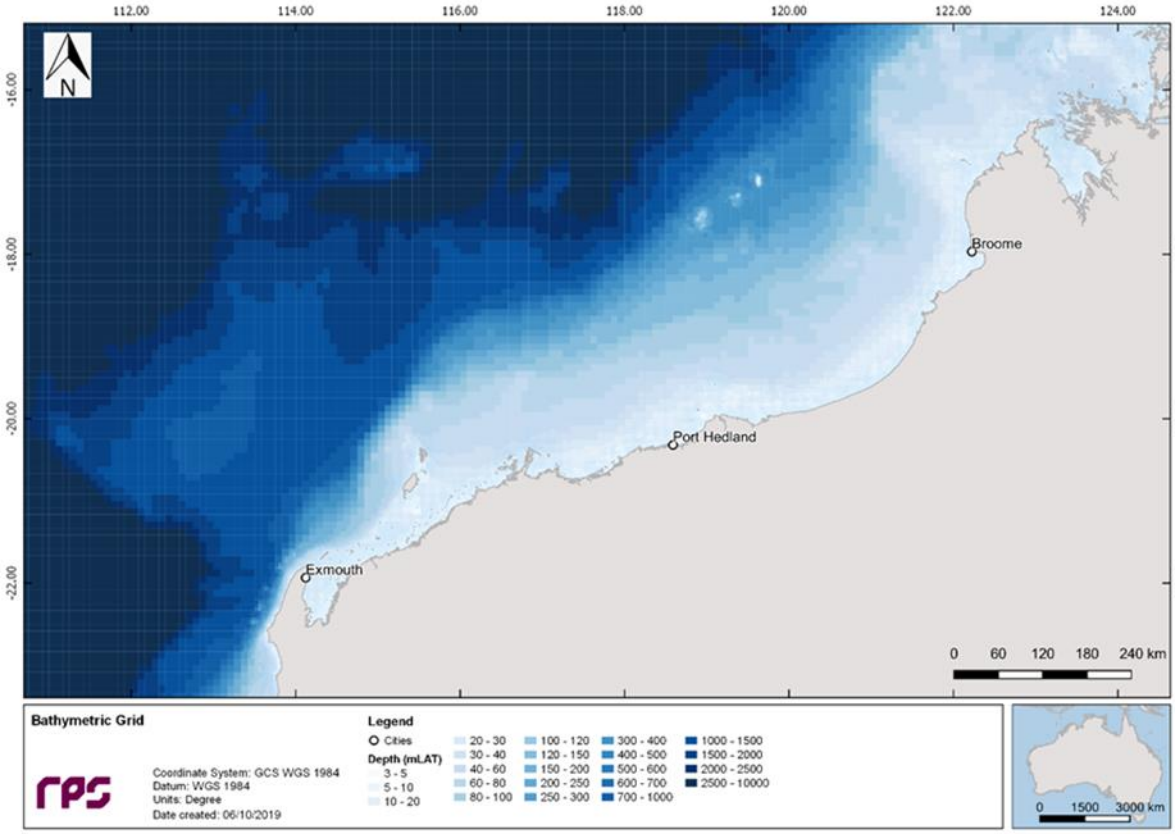


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.27 m/s (June). Additionally, the maximums ranged between 0.55 m/s (November) and 1.76 m/s (January). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.21	1.76	North and Southwest
	February	0.19	1.08	Variable
	March	0.21	1.73	Southwest
Transitional	April	0.22	1.02	Southwest
Winter	May	0.24	0.78	Southwest
	June	0.27	0.81	Southwest
	July	0.20	0.90	Southwest
Transitional	August	0.18	0.60	Southwest
Summer	September	0.19	0.93	Northeast and Southwest
	October	0.20	0.75	Northeast and Southwest
	November	0.16	0.55	Southwest
	December	0.21	0.74	Southwest
Minimum		**0.16**	**0.55**	
Maximum		**0.27**	**1.76**	

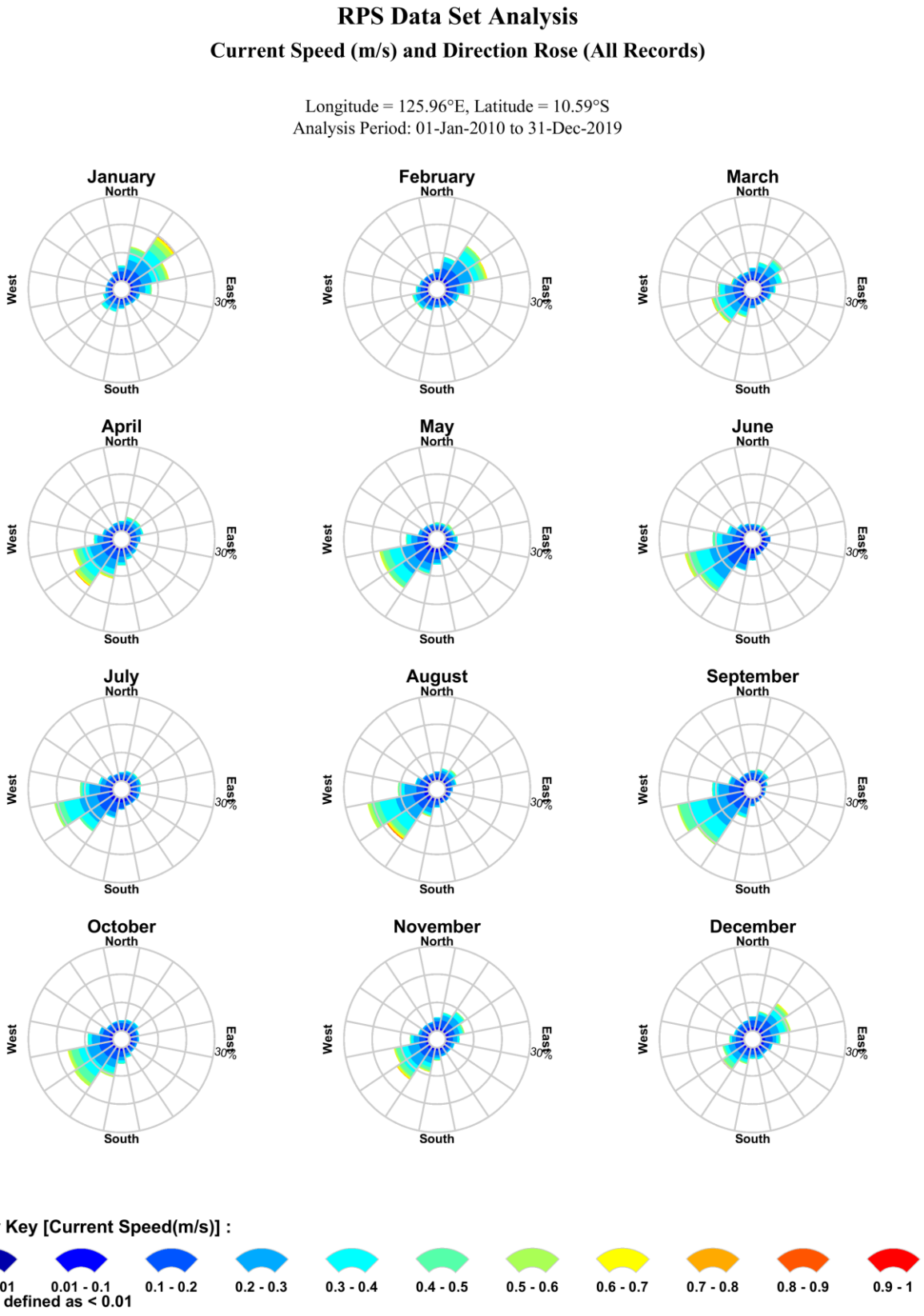


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

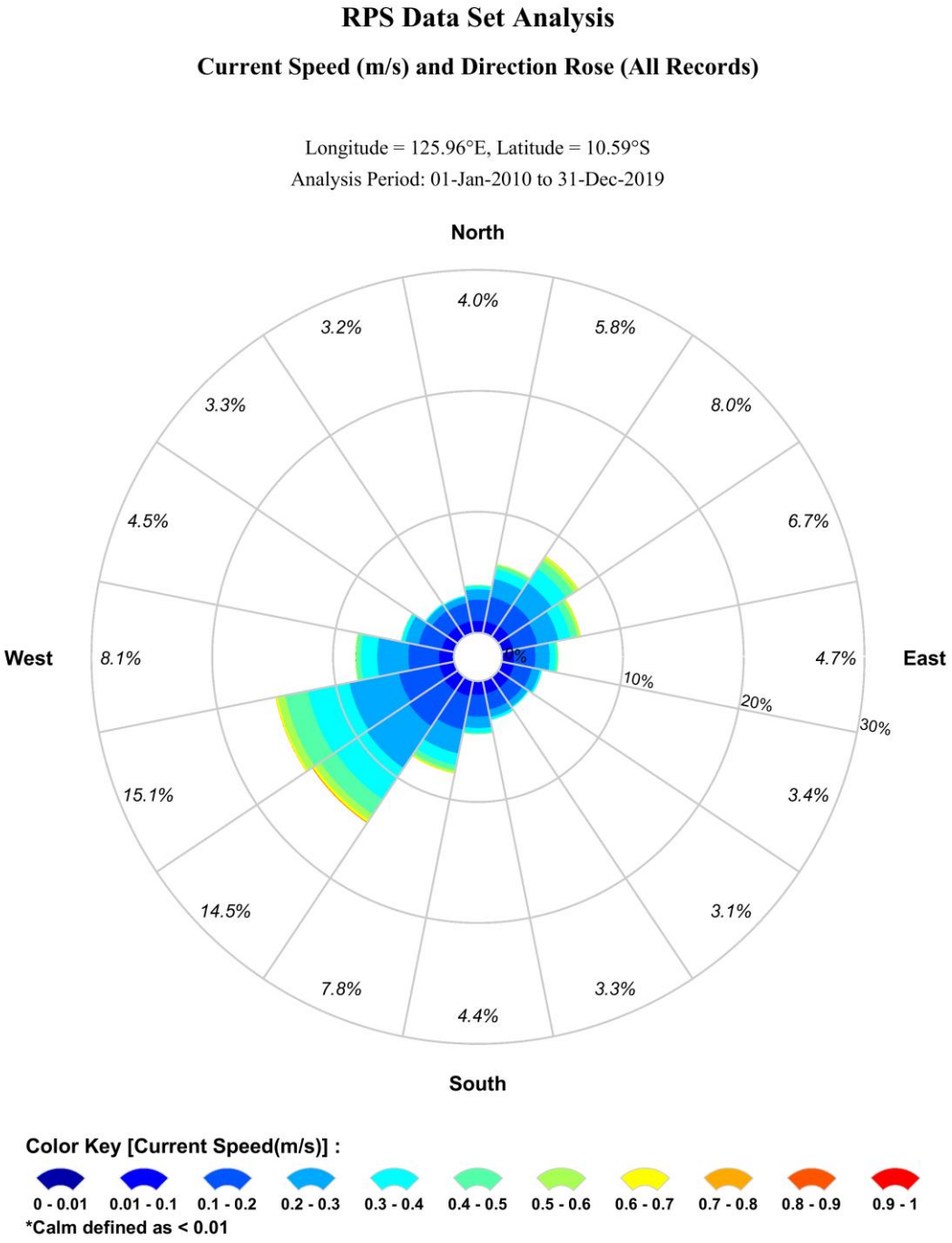


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 48 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

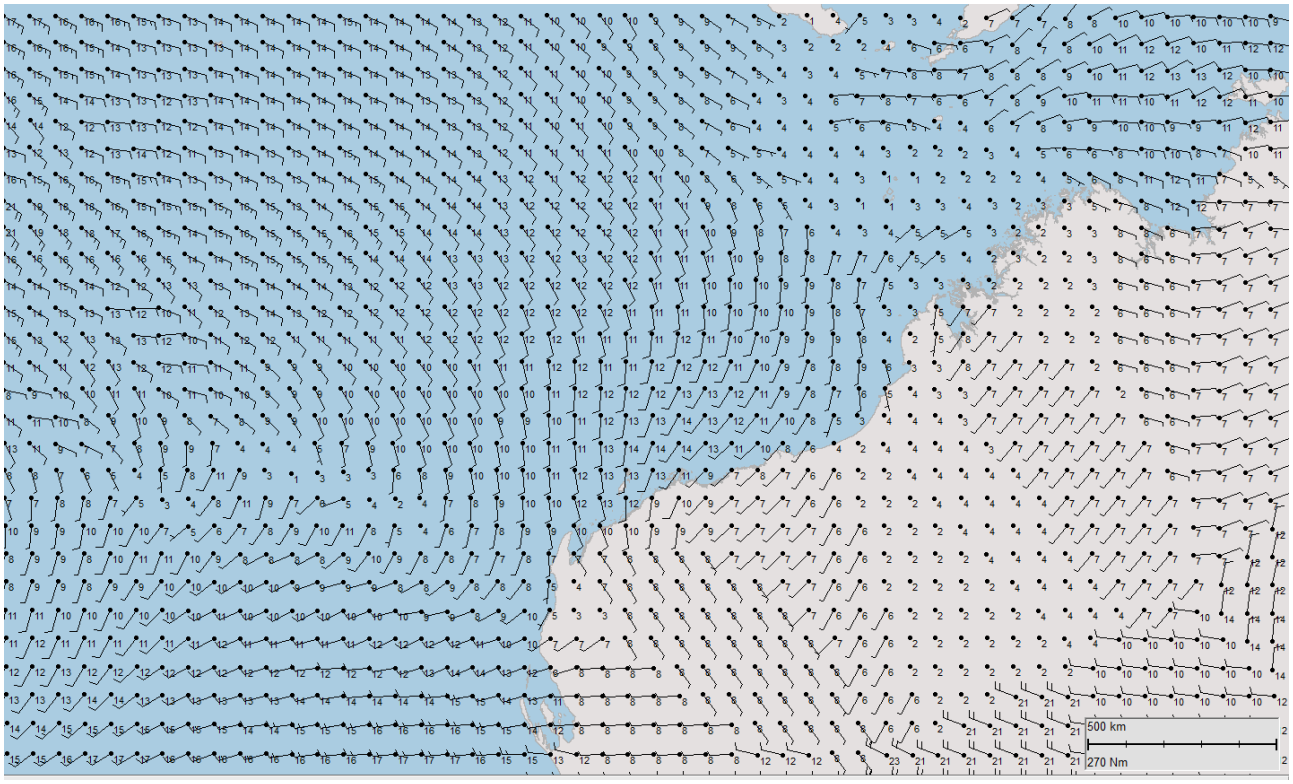


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	45	Southwest
	February	11	46	Southwest
	March	10	34	Southwest
Transitional	April	10	39	Variable
Winter	May	12	43	East
	June	14	29	East
	July	13	48	East to South
Transitional	August	11	30	Variable
Summer	September	12	27	South-Southwest
	October	13	27	South-Southwest
	November	13	25	South-Southwest
	December	13	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**48**	

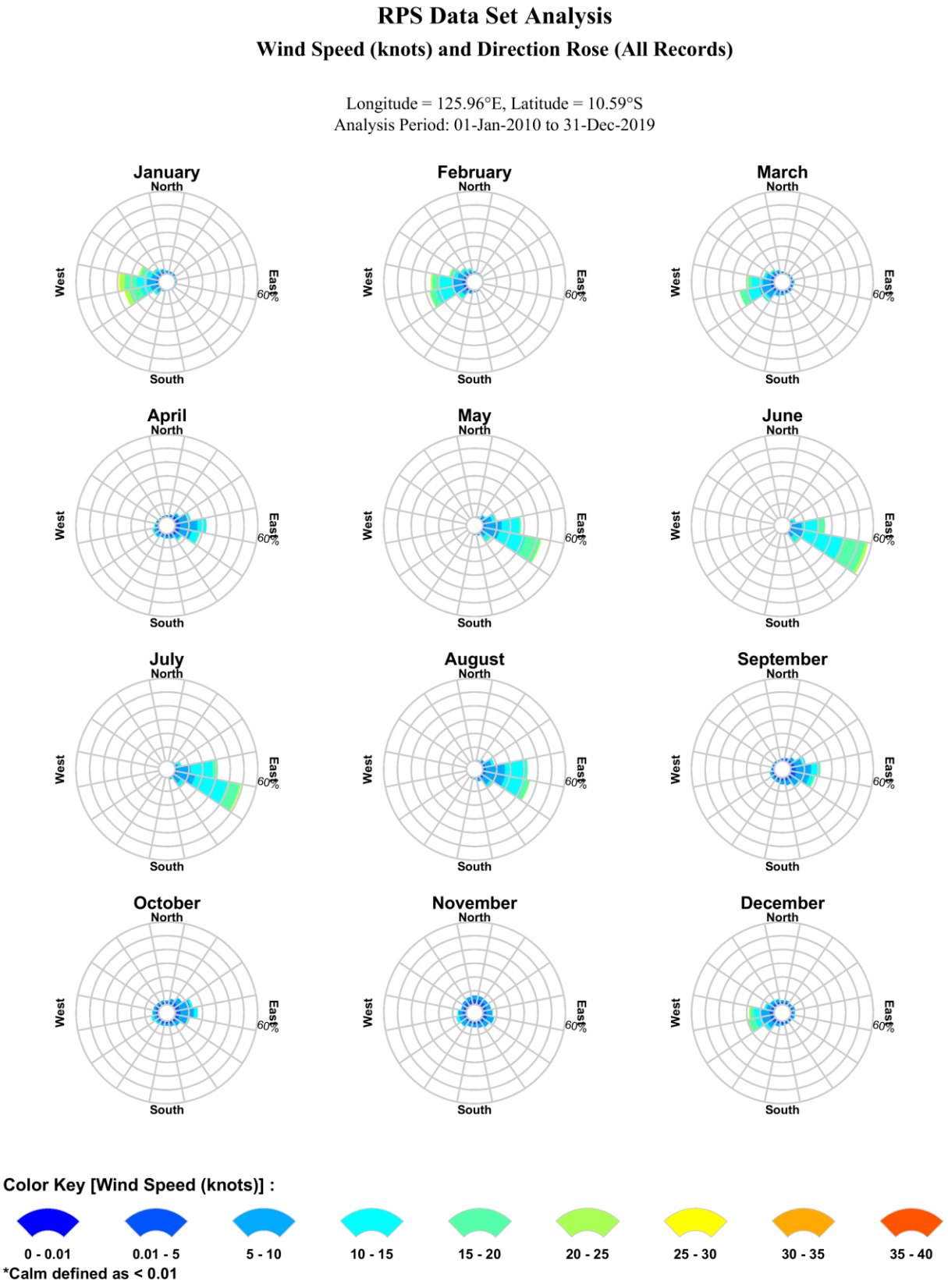


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

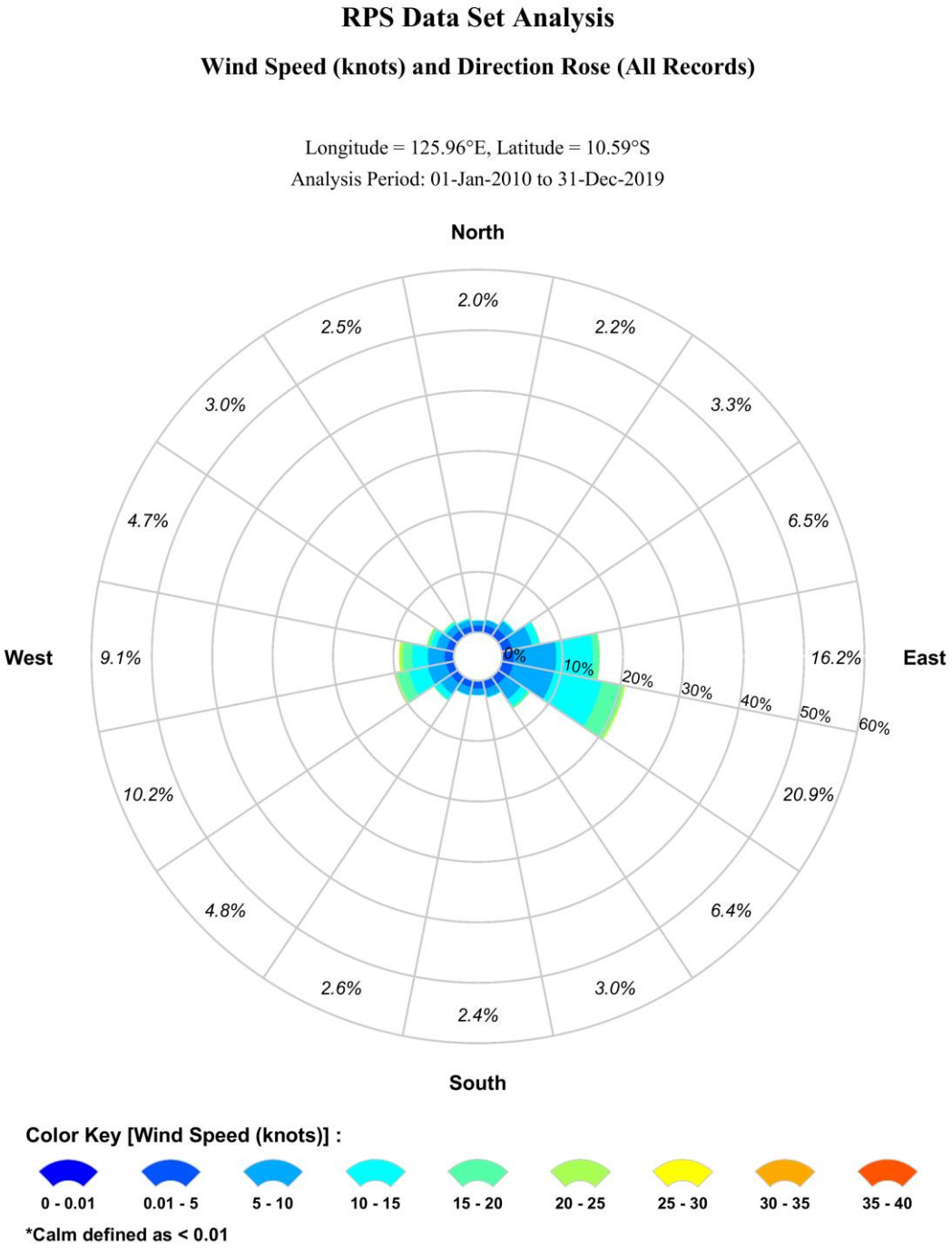


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.1°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.9	27.8	26.9	25.4	24.4	24.1	24.9	27.2	27.0
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

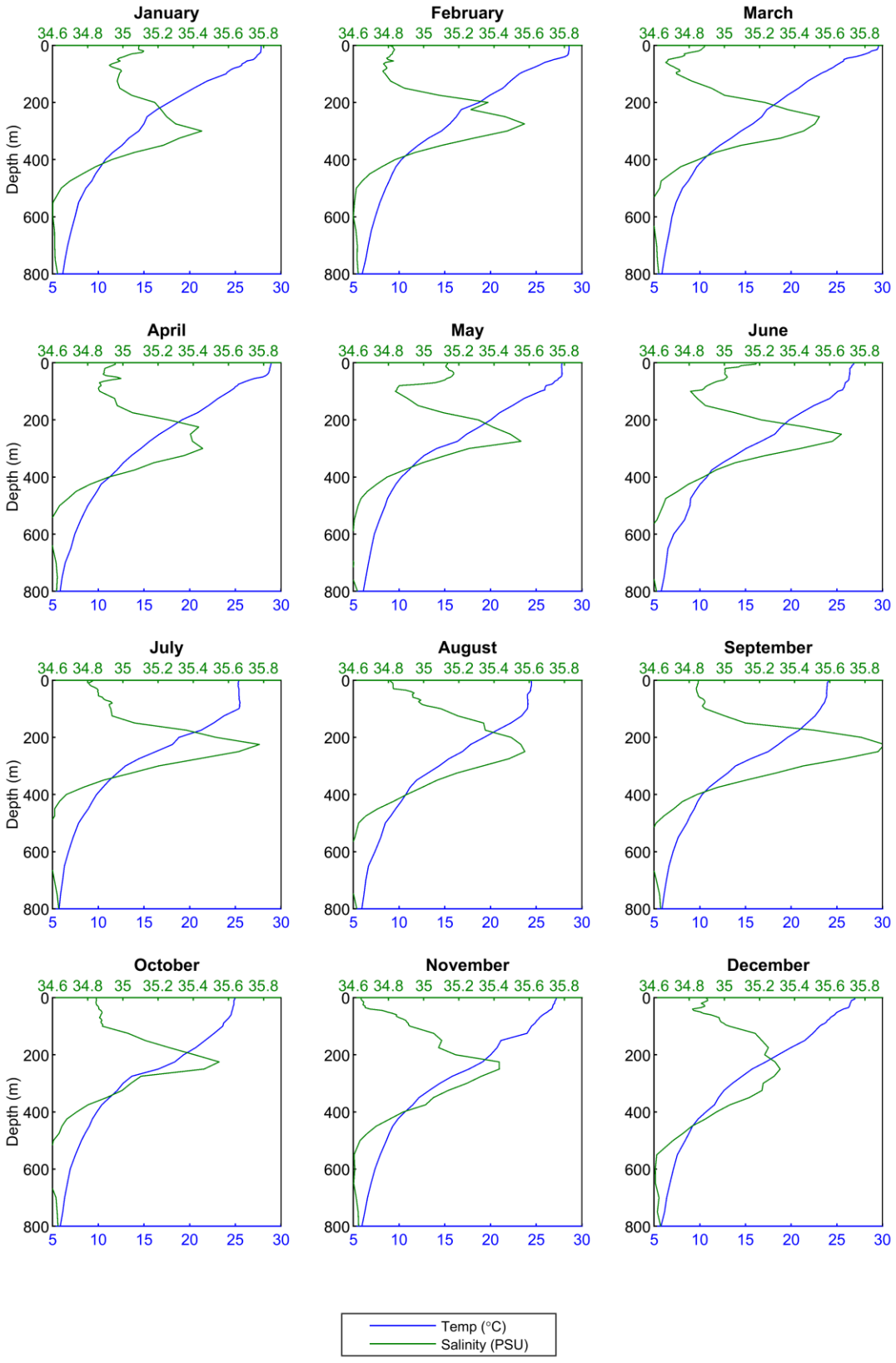


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

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).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 492 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which range in size from 366 to 1,583 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Chrysaor Well 5
Water depth (m)	800
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	1,308
Gas rate (MMscf/day)	239
Gas to condensate ratio (scf/bbl)	182,722
Formation water flow rate (stb/day)	0
Operating pressure (psia)	5,097
Key results	
Plume execution depth (m BMSL)	492
Droplet sizes (µm)	366 to 1,583

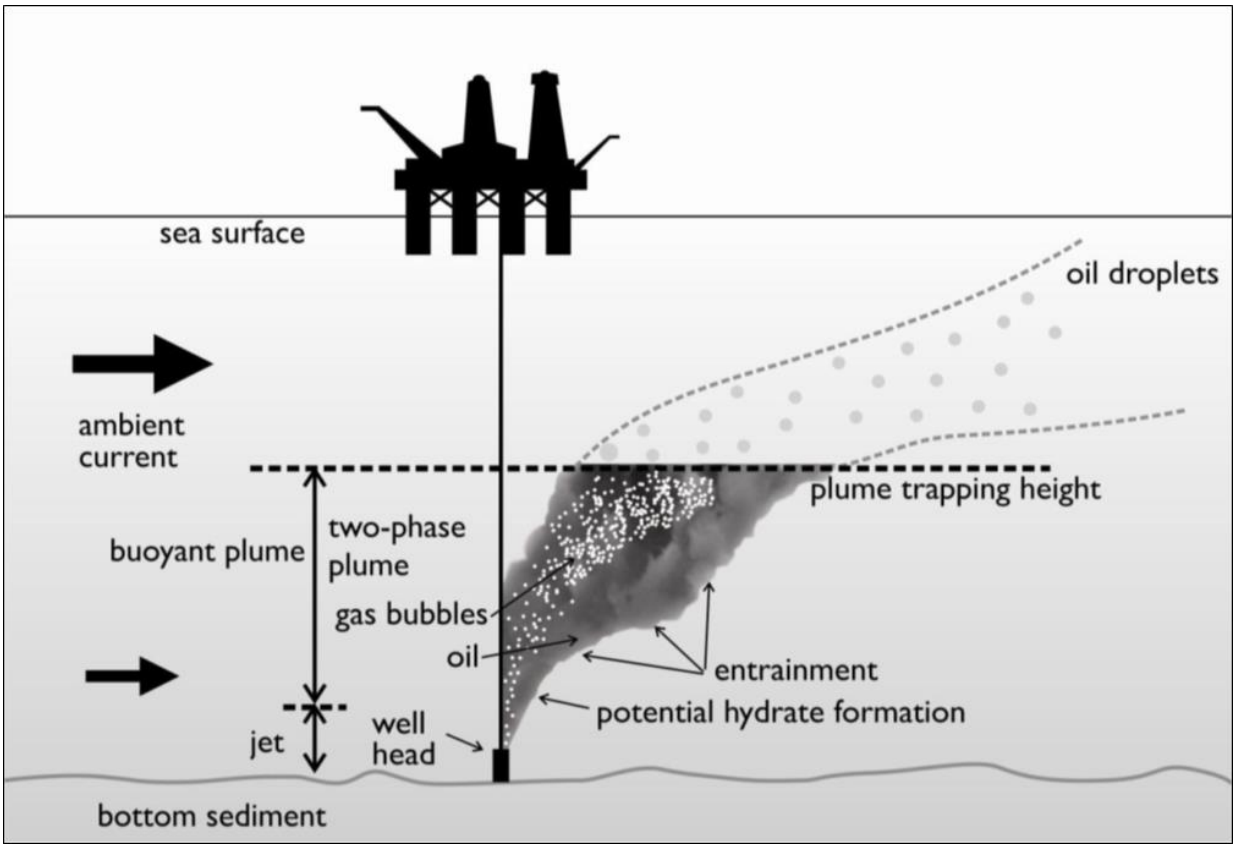


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

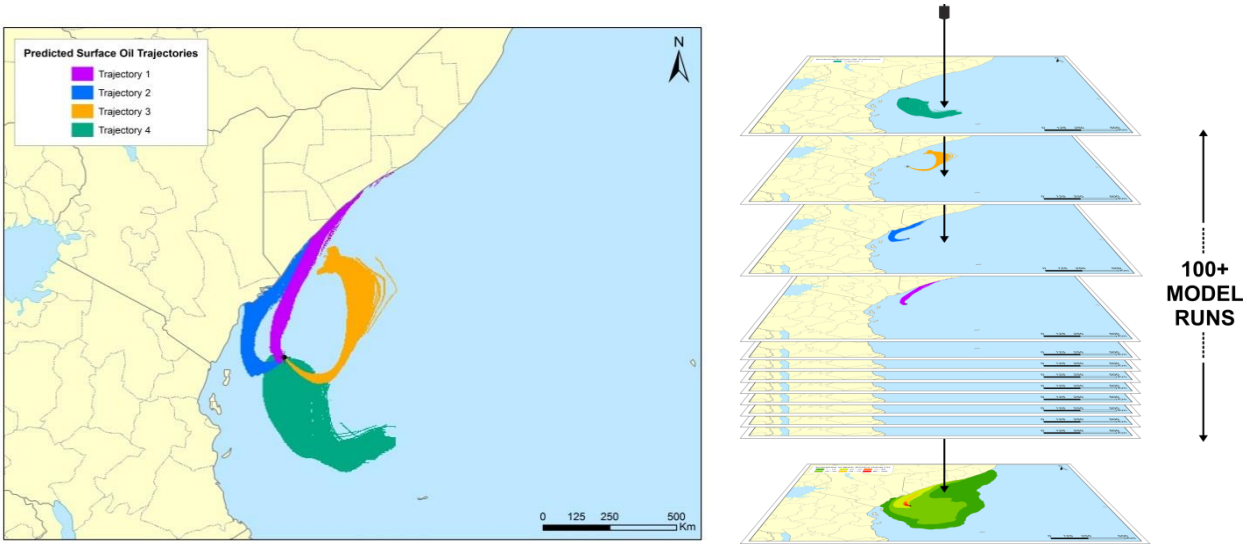


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 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

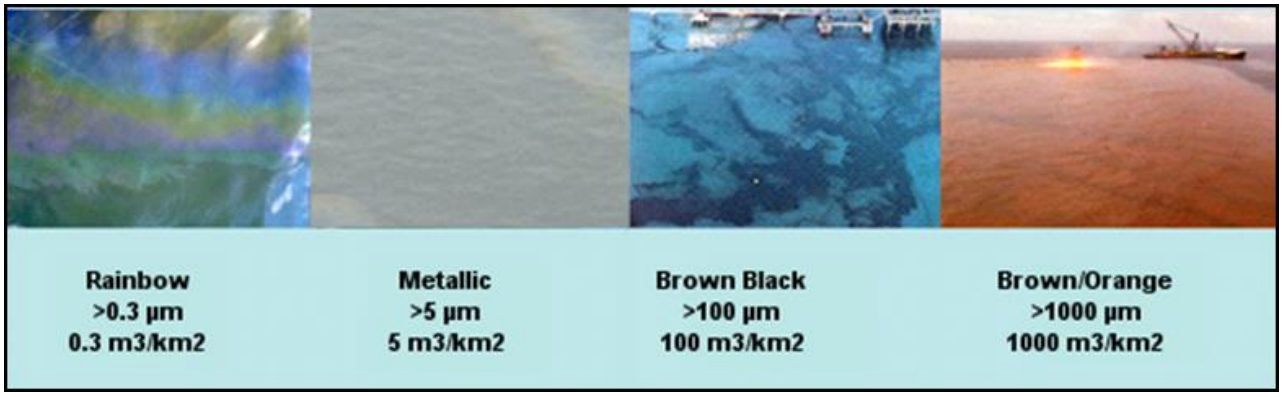


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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 In-water Exposure 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 & Di Toro, 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 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on 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 & ARMCANZ (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.

This exposure zone 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 7.4), 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 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

As a conservative approach, Chevron had chosen Chrysaor condensate for the purposes of the modelling and hence provided physical properties and boiling point distributions, which are presented in Table 8.1 and Table 8.2, respectively.

Chrysaor condensate has an API of 40.20, a density of 824 kg/m^3 (at 15ºC) and a low viscosity value of 5.6 cP. When exposed to the atmosphere at local temperatures, about 23.8% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 33.0% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~32.9%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 10.3% of the condensate is shown to be persist in the marine environment for longer period and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion.

Soluble, aromatic hydrocarbons contribute approximately 3.0% by mass of the whole oil. For this condensate they are all contained in the volatile fractions, which are highly soluble. Discharges onto the water surface will favour the process of evaporation over dissolution under calm sea conditions, but increased entrainment of oil and dissolution of soluble compounds can be expected under stronger wind periods with the presence of small breaking waves (whitecaps).

The actual fate of released oil in the marine environment will depend greatly on the amount of oil that reaches the surface, either through the initial release or by rising after discharge in the water column.

Table 8.1 Physical properties of Chrysaor condensate.

Characteristic	Chrysaor Condensate
Density (kg/m^3)	824 (at 15°C)
API	40.20
Dynamic viscosity (cP)	5.6 (at 15°C)
Pour point (°C)	-9
Surface tension (dyne/cm)	19
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of Chrysaor condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Chrysaor Condensate	% of total	23.8	33.0	32.9	10.3
	% of aromatics	3.0	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 57.0% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Chrysaor condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 58.7% of the condensate mass is forecast to have entrained and a further 39.1% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (0.5%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.9% per day with an accumulated total of ~13% after 7 days, in comparison to a rate of 0.16% per day and an accumulated total of 1.09% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

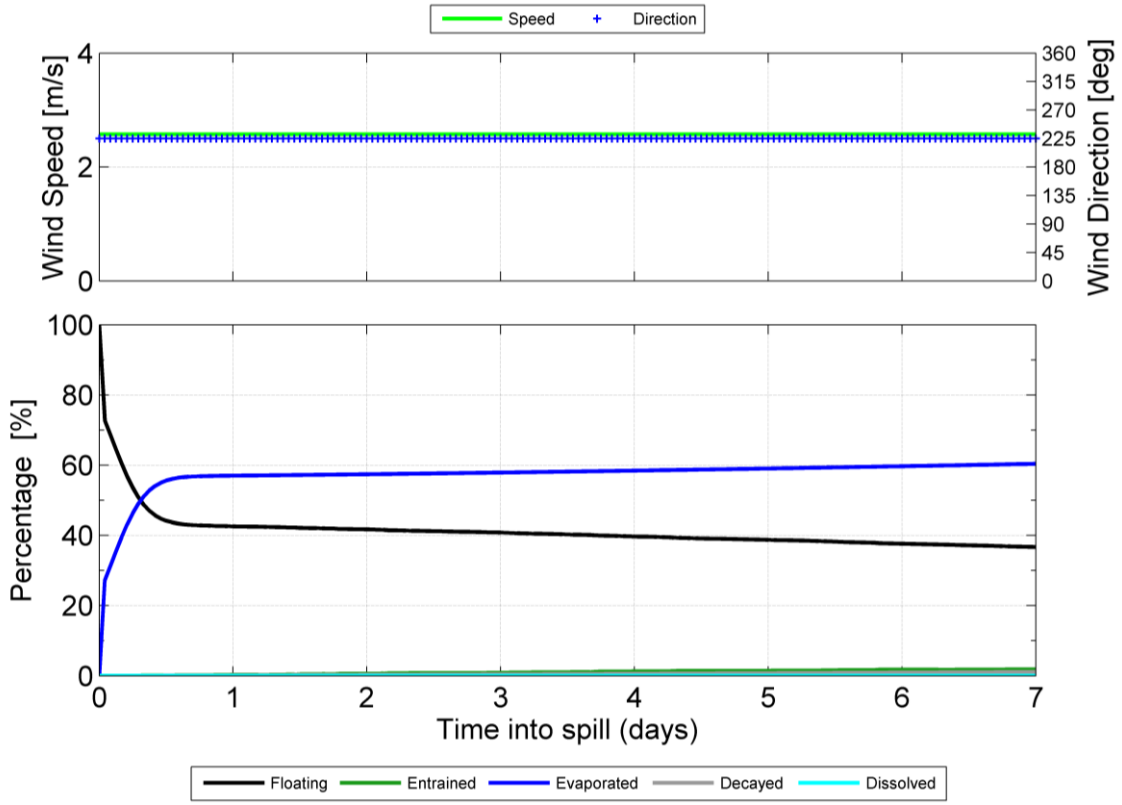


Figure 8.1 Proportional mass balance plot representing the weathering of Chrysaor condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature and 25°C air temperature.

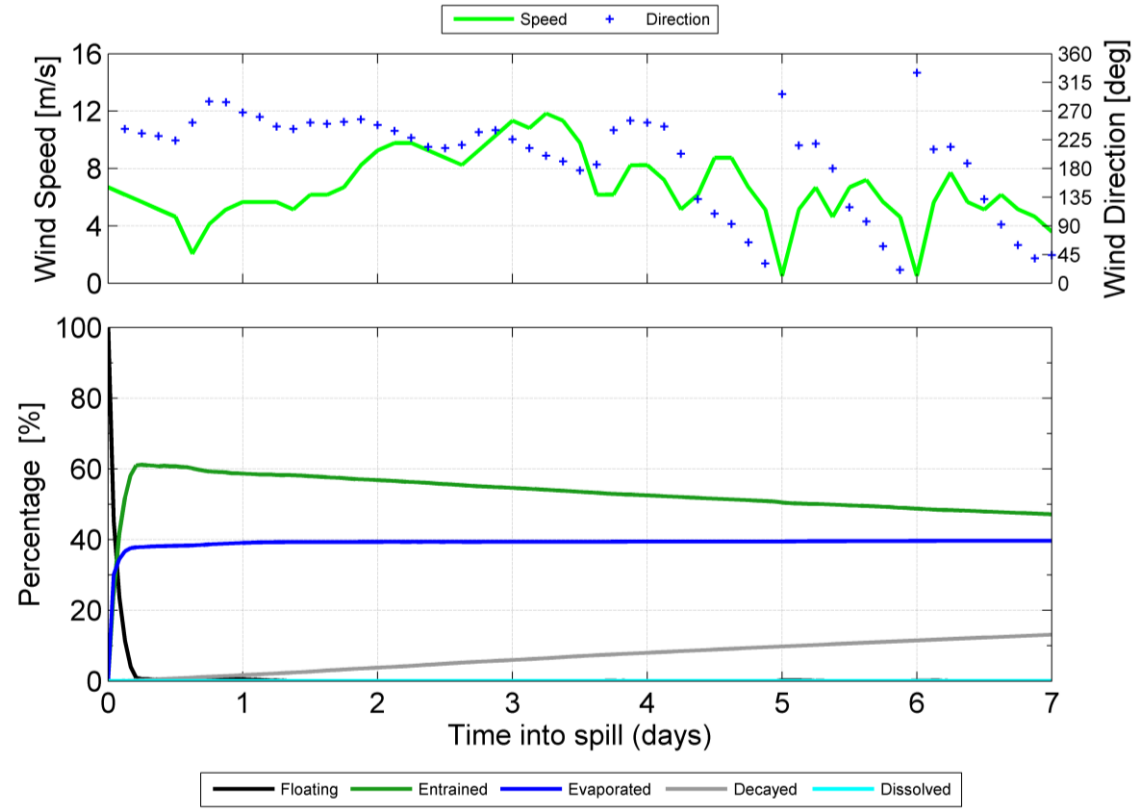


Figure 8.2 Proportional mass balance plot representing the weathering of Chrysaor condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature and 25°C air temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Chrysaor Well 5
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	18,715 [117,720]
Condensate type	Chrysaor condensate
Release type (depth)	Subsea (800 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria's a - e.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
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 Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓
Continental Slope Demersal Fish Communities	KEF	✓

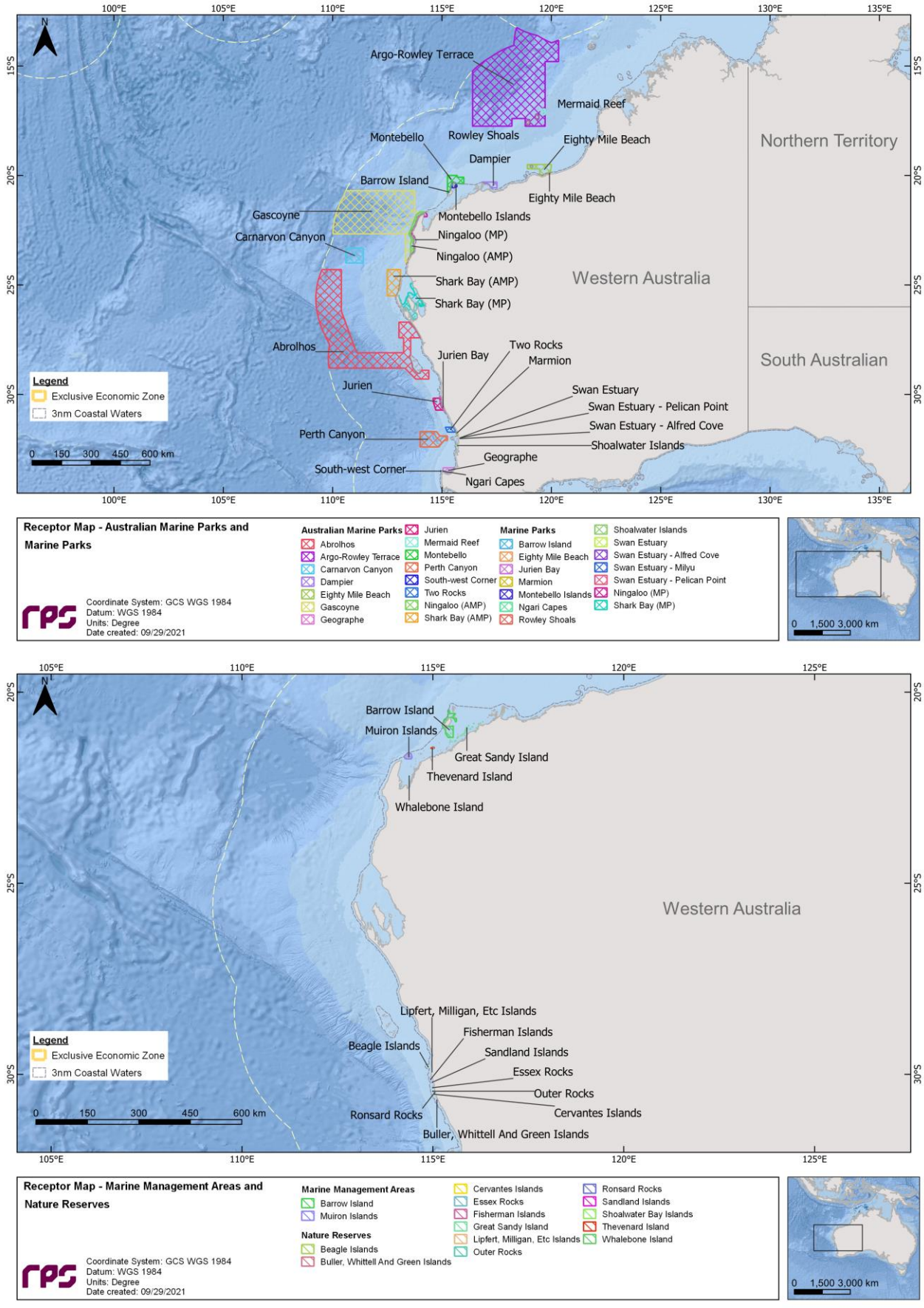


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

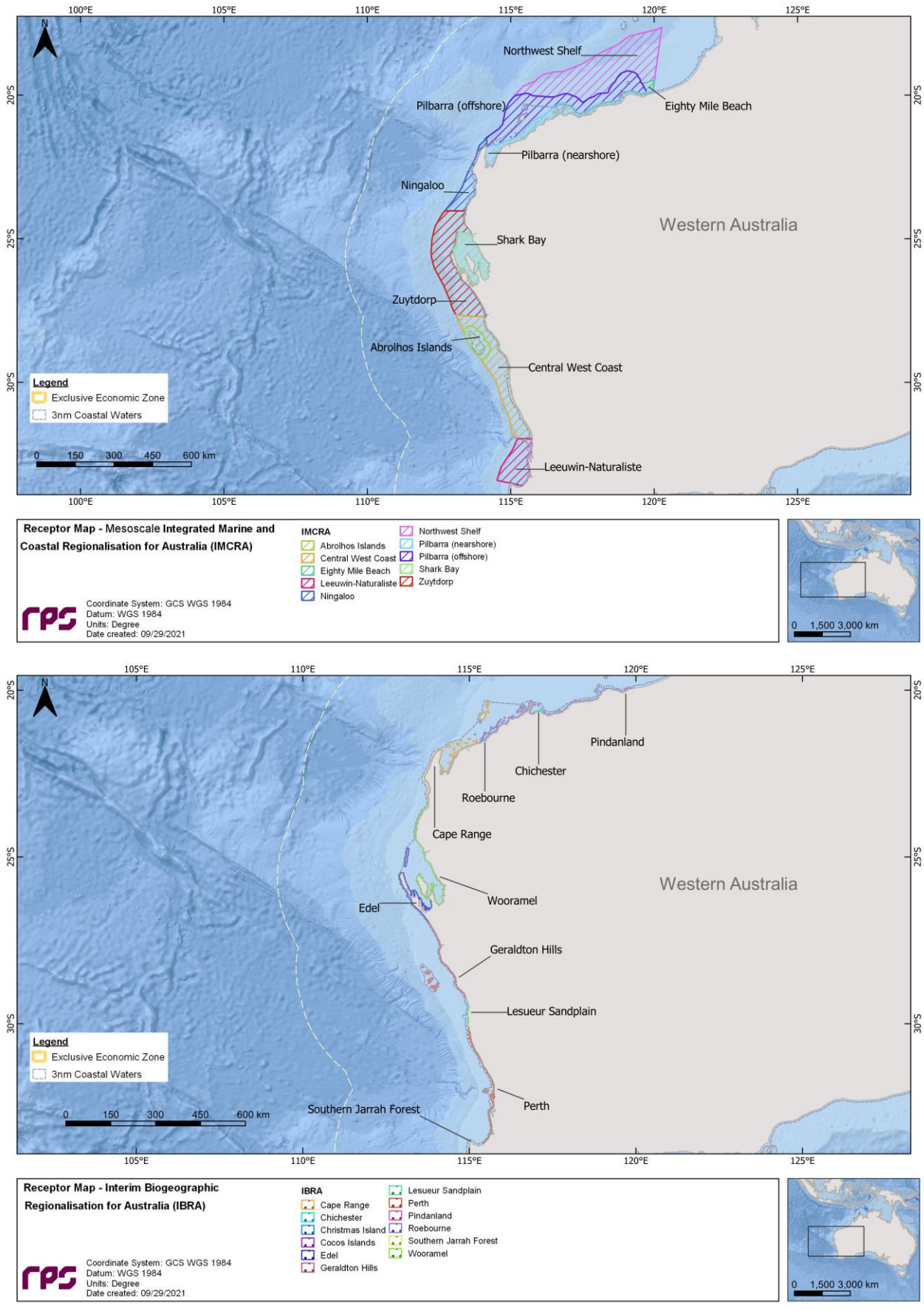


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

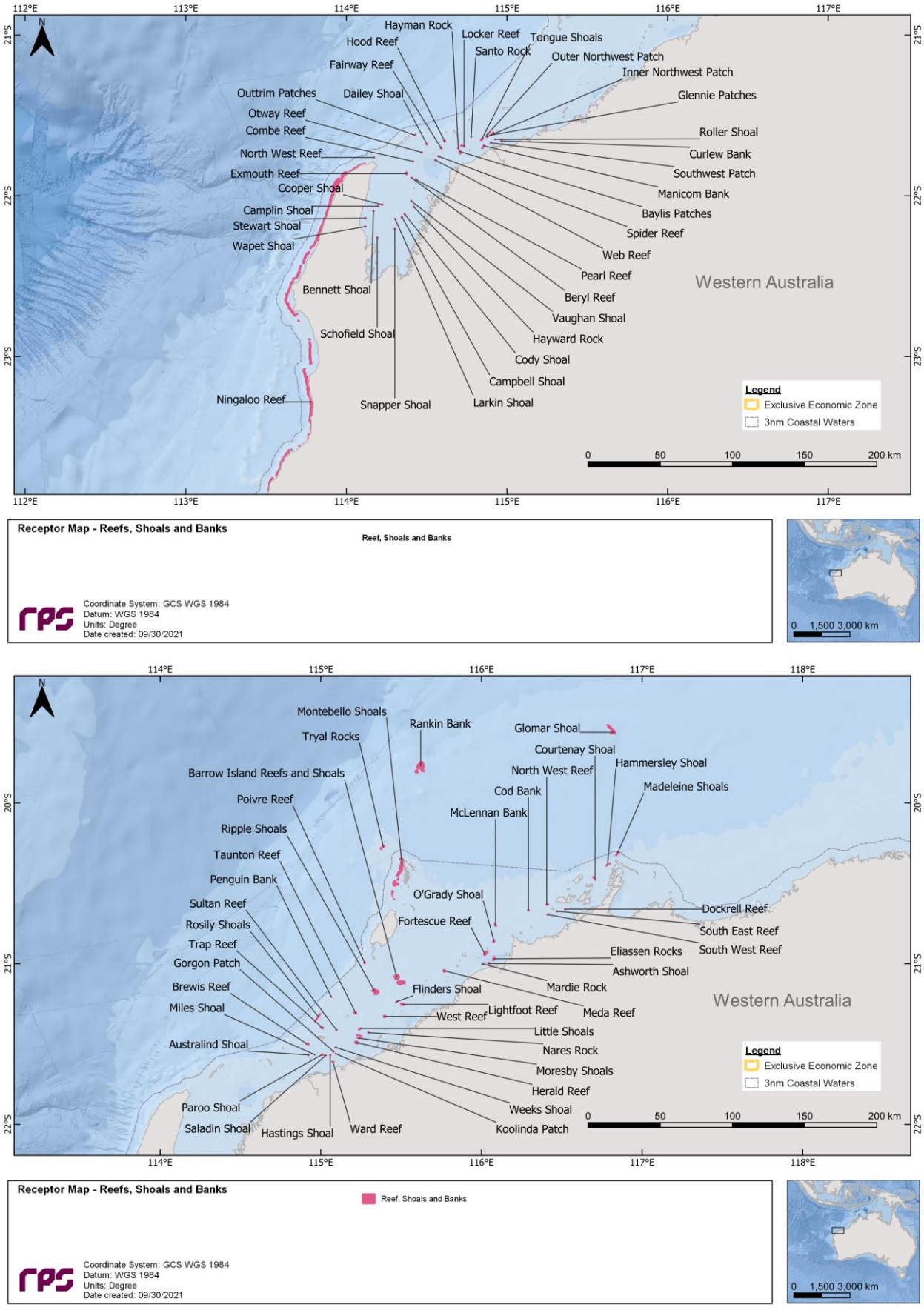


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

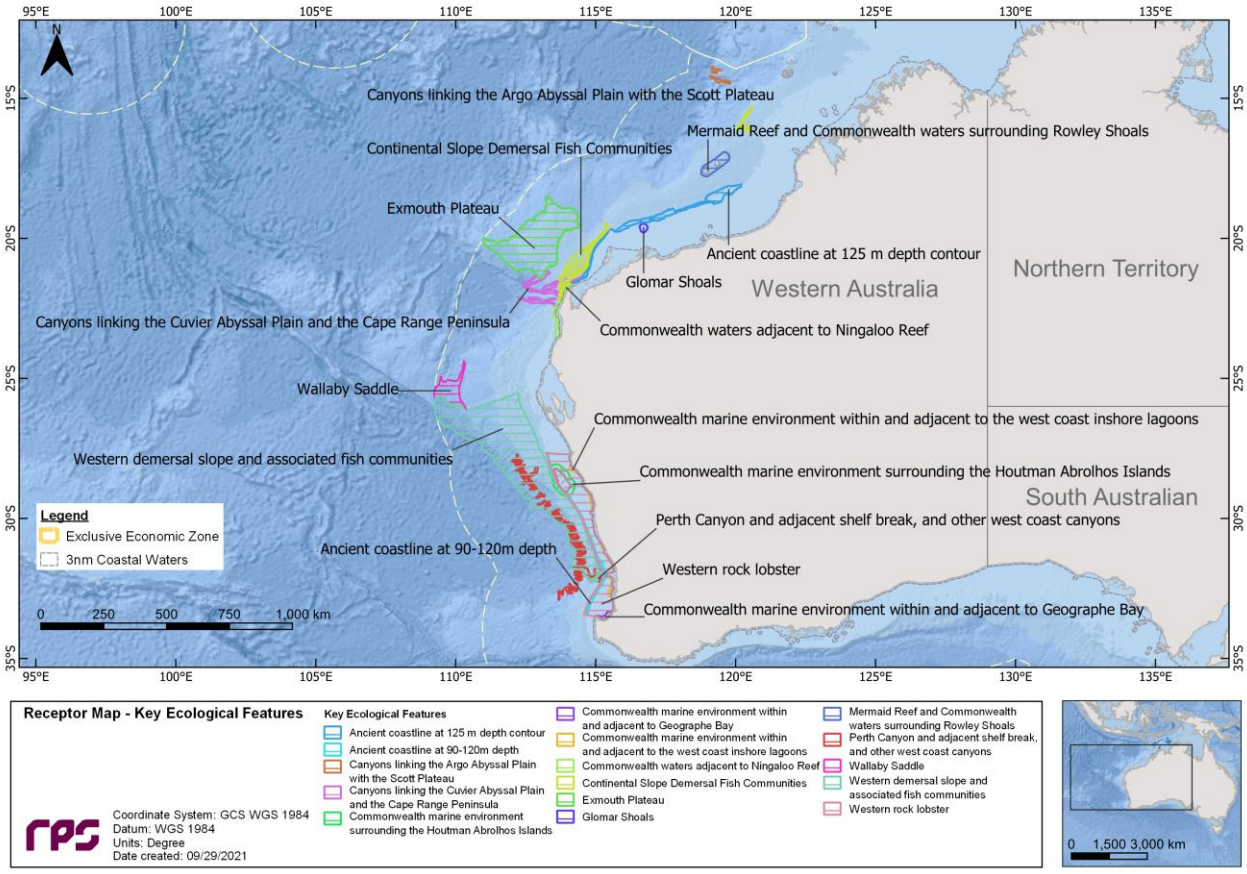


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

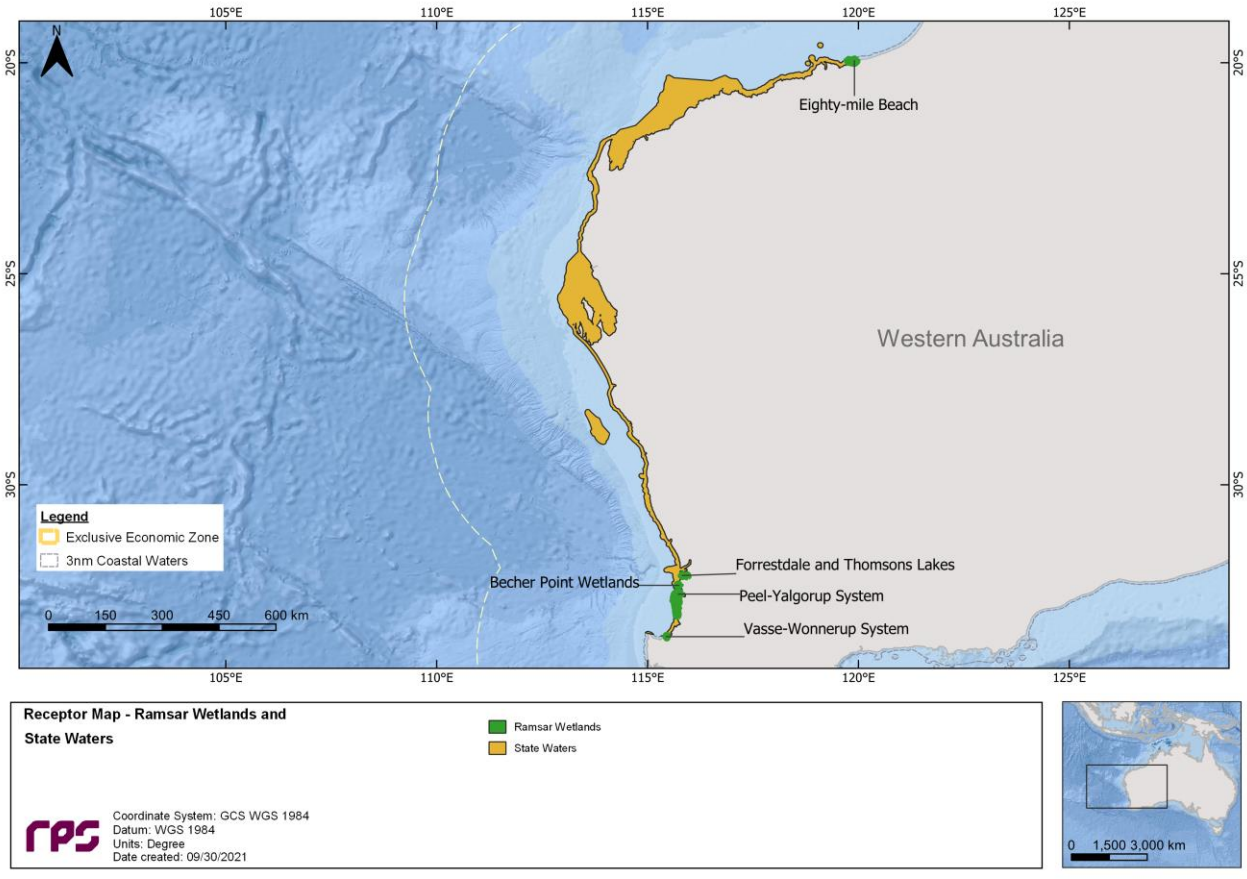


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

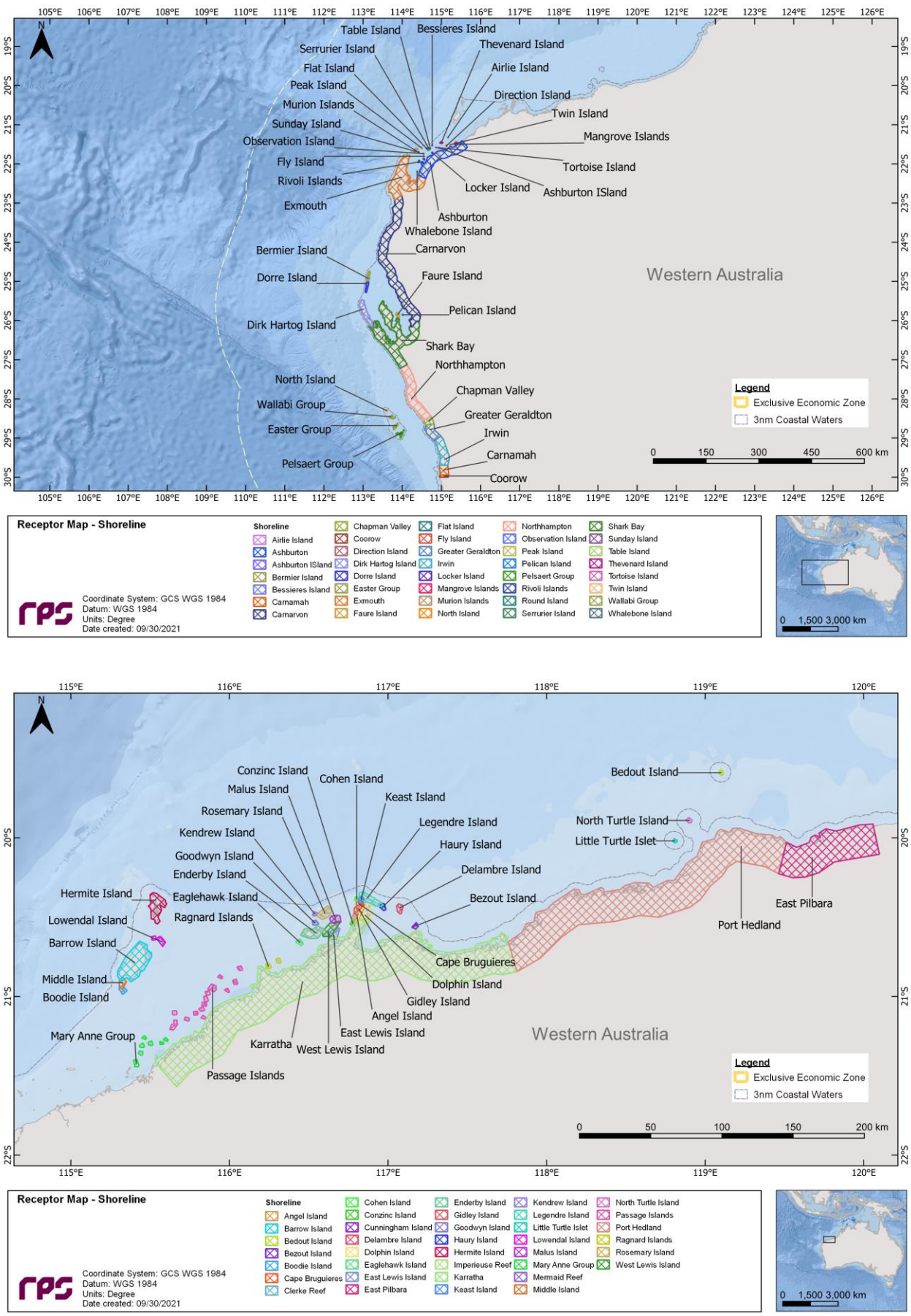


Figure 10.6 Receptor maps for Shorelines (1 of 2).

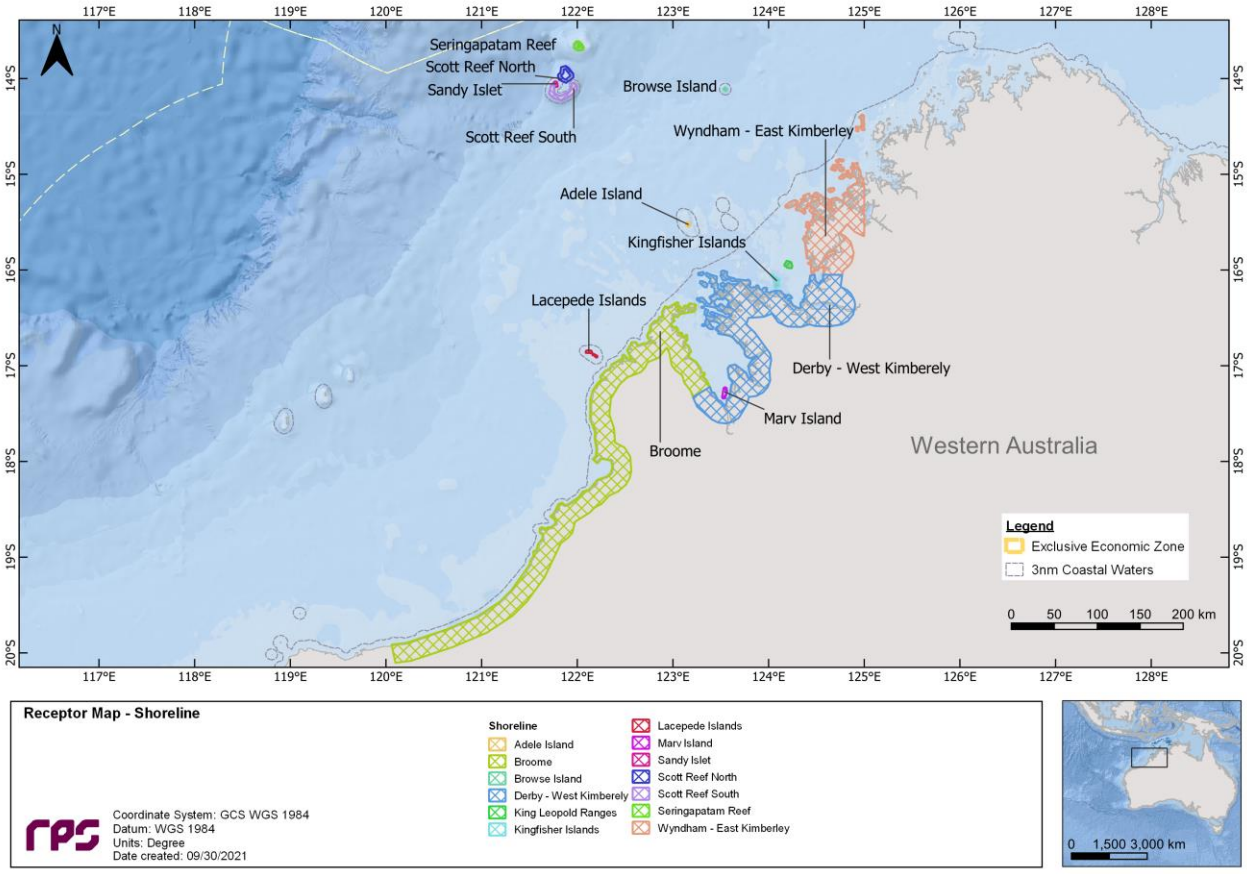


Figure 10.7 Receptor maps for Shorelines (2 of 2).

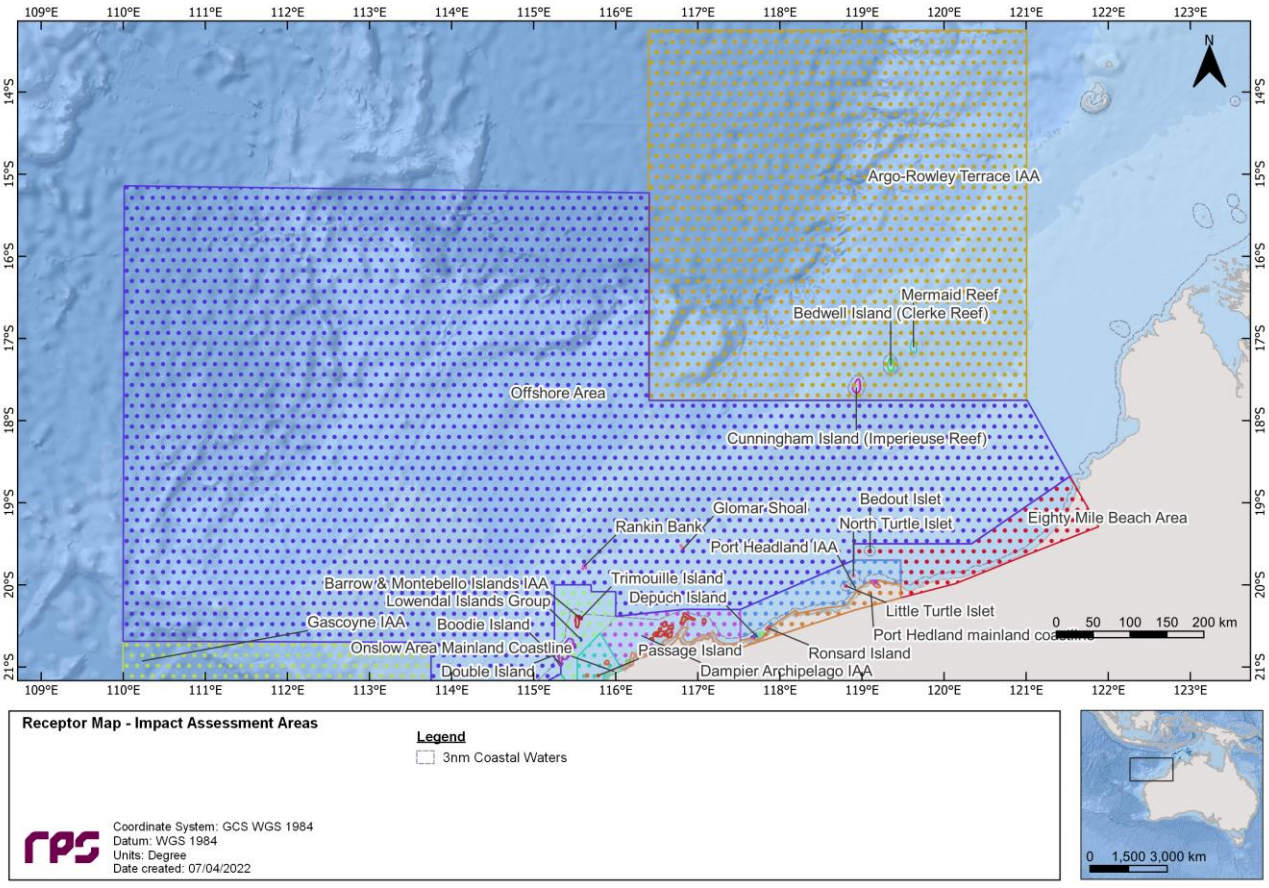


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

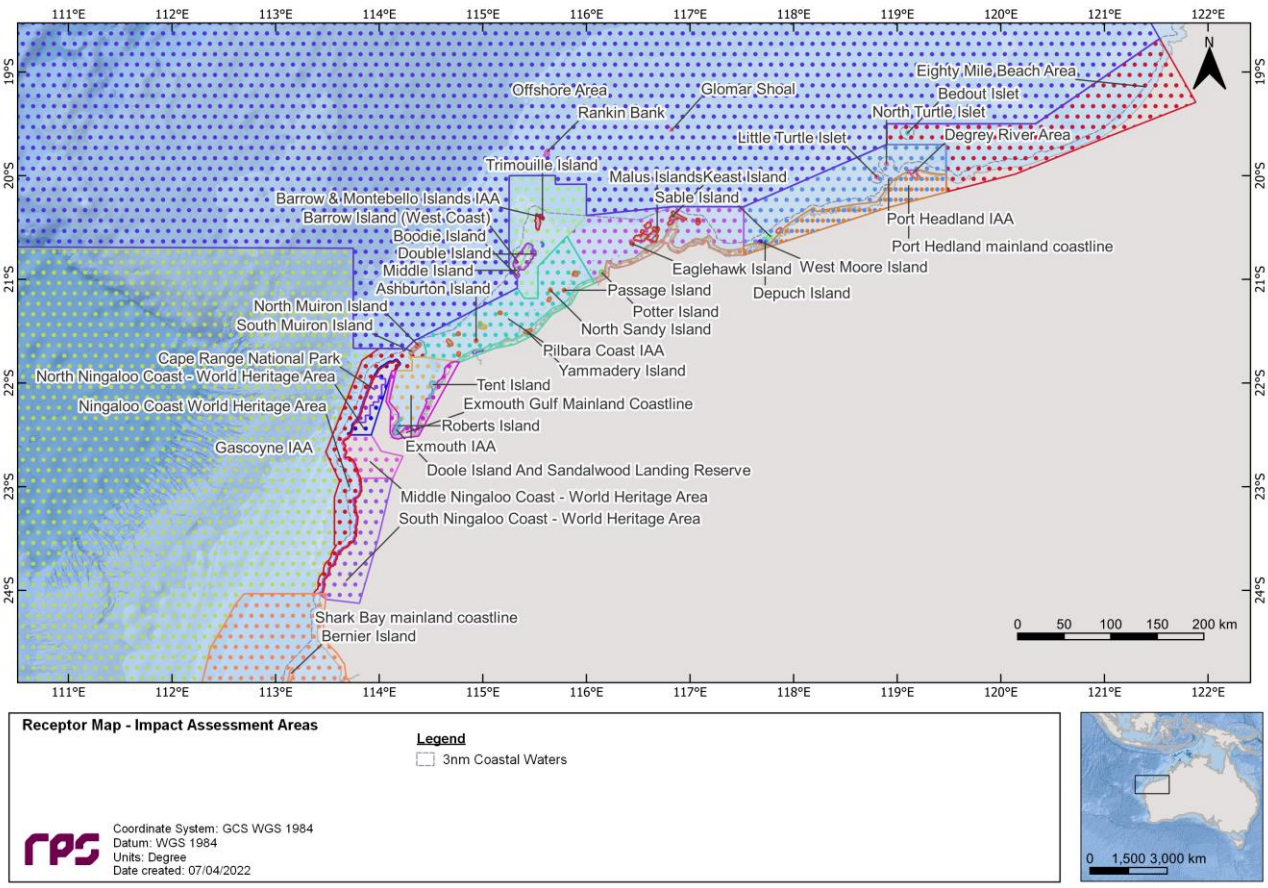


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

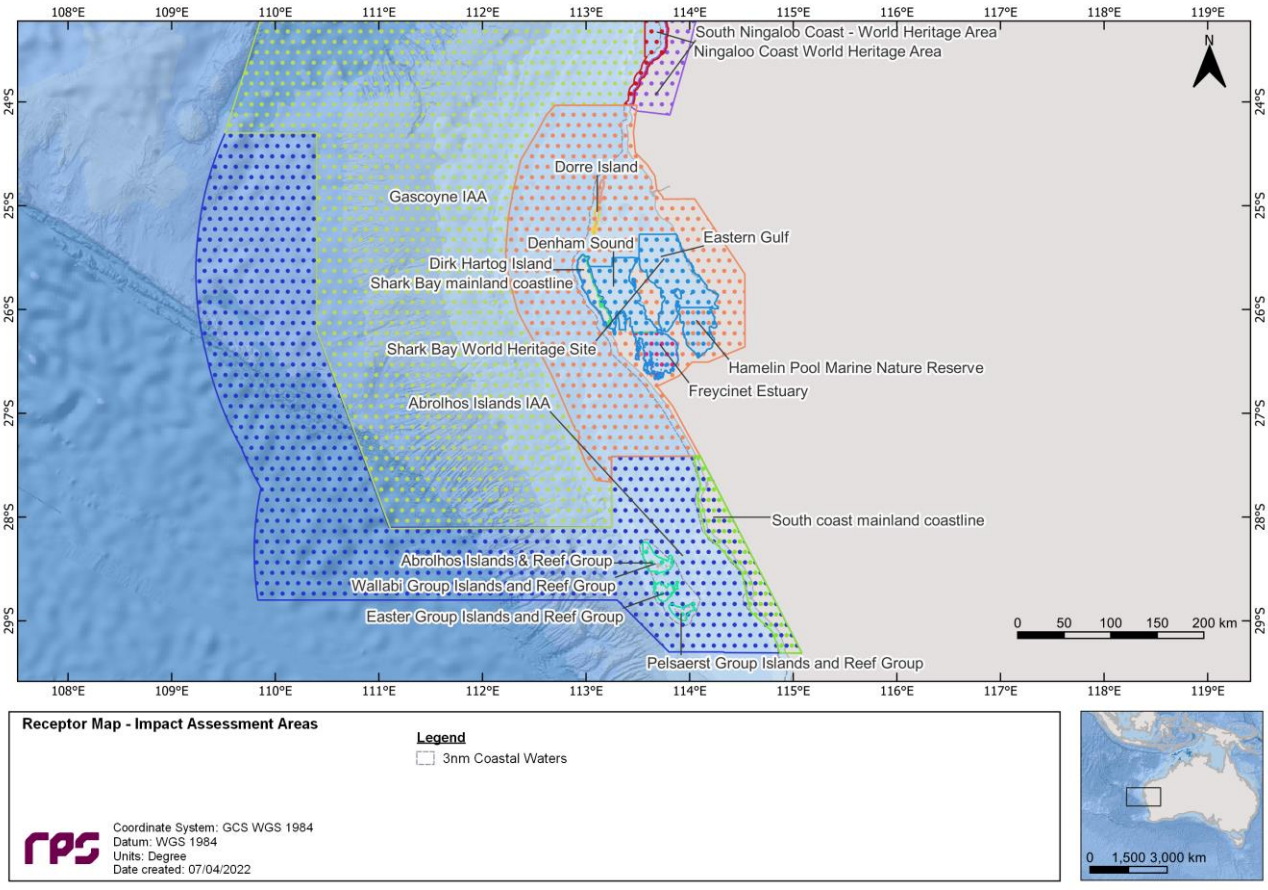


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: CHRYSAOR–DIONYSUS LOSS OF WELL CONTROL

This scenario examined a 117,720 stb (or 18,715 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 82.0 km west (summer) and 4.3 km northeast (transitional and winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, and the Continental Slope Demersal Fish Communities KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold were 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 89% (all receptors; summer) and 99% (all receptors; winter). Additionally, the Flatback Turtle - Internesting Buffer BIA was also predicted to be exposed at the low threshold during summer (95%), transitional (100%) and winter (97%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer BIA was 0.67 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour (KEF) was 88%, 84% and 89% during summer, transitional and winter conditions and 31%, 27% and 41% summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure at the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour FEF was 0.88 days (summer) and 2.21 days (winter).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	82.0	2.6	-
	Max. distance from release site (km) (99th percentile)	45.4	2.6	-
	Direction	West	Southwest	-
Transitional	Max. distance from release site (km)	73.5	4.3	-
	Max. distance from release site (km) (99th percentile)	60.5	4.3	-
	Direction	North-northeast	Northeast	-
Winter	Max. distance from release site (km)	70.3	4.3	-
	Max. distance from release site (km) (99th percentile)	58.5	4.3	-
	Direction	East-northeast	Northeast	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.79	-	-
BIA	Flatback Turtle - Internesting Buffer	95	-	-	0.67	-	-	100	-	-	0.88	-	-	97	-	-	0.71	-	-
	Flatback Turtle - Nesting	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.67	-	-
	Humpback Whale - Migration	11	-	-	7.75	-	-	15	-	-	3.29	-	-	20	-	-	3.88	-	-
	Pygmy Blue Whale - Distribution*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
	Wedge-tailed Shearwater – Breeding*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
	Whale Shark - Foraging	89	-	-	0.88	-	-	81	-	-	1.08	-	-	87	-	-	1.29	-	-
EEZ	Australian Exclusive Economic Zone*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
IAA	Barrow & Montebello Islands IAA	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.79	-	-
	Offshore Area*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
IMCRA	Northwest Shelf	3	-	-	32.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara (offshore)	88	-	-	0.88	-	-	84	-	-	1.04	-	-	89	-	-	1.29	-	-
KEF	Ancient coastline at 125 m depth contour	31	-	-	5.79	-	-	27	-	-	3.13	-	-	41	-	-	2.21	-	-
	Continental Slope Demersal Fish Communities*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-

*The release location resides within the receptor boundaries.

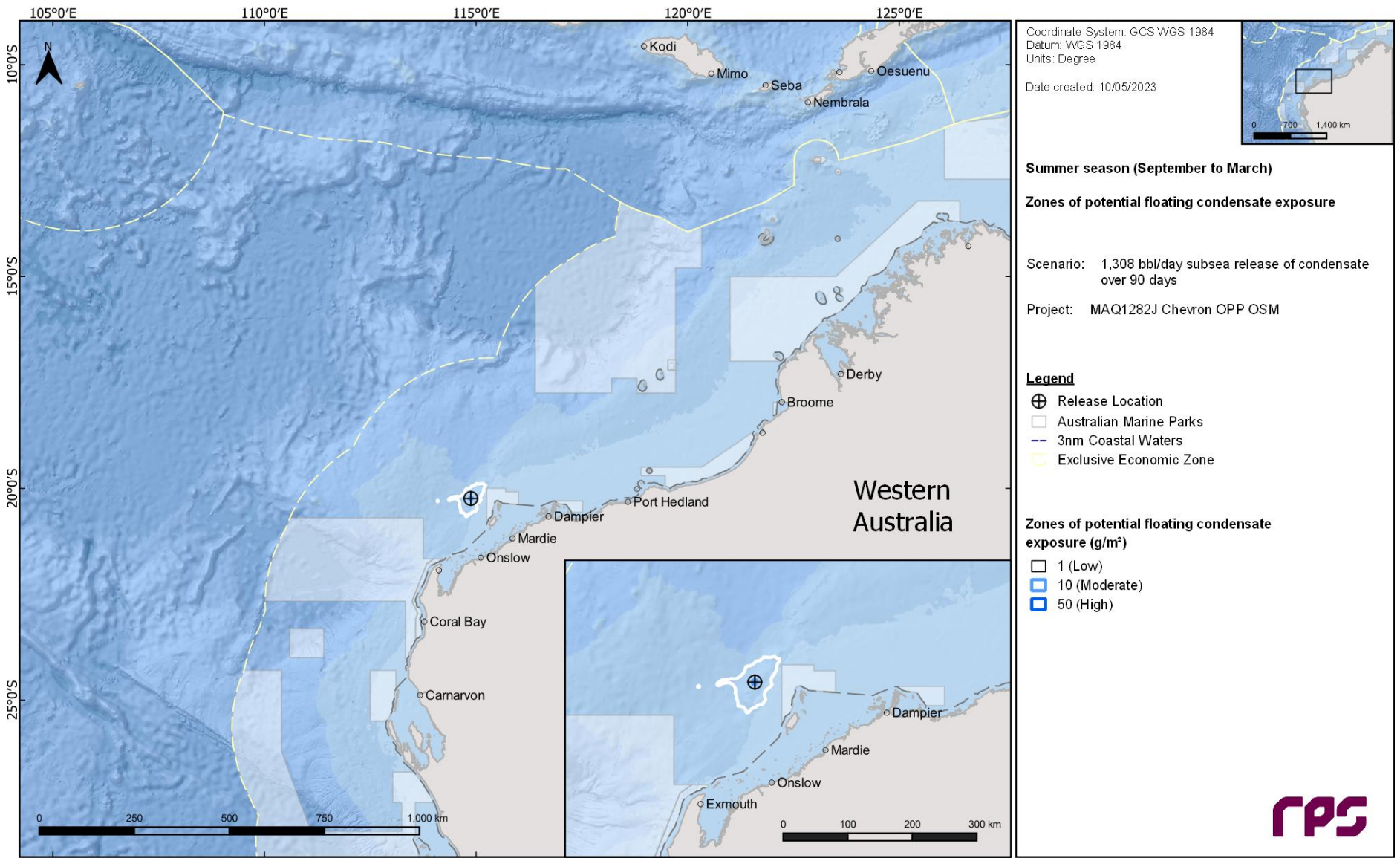


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

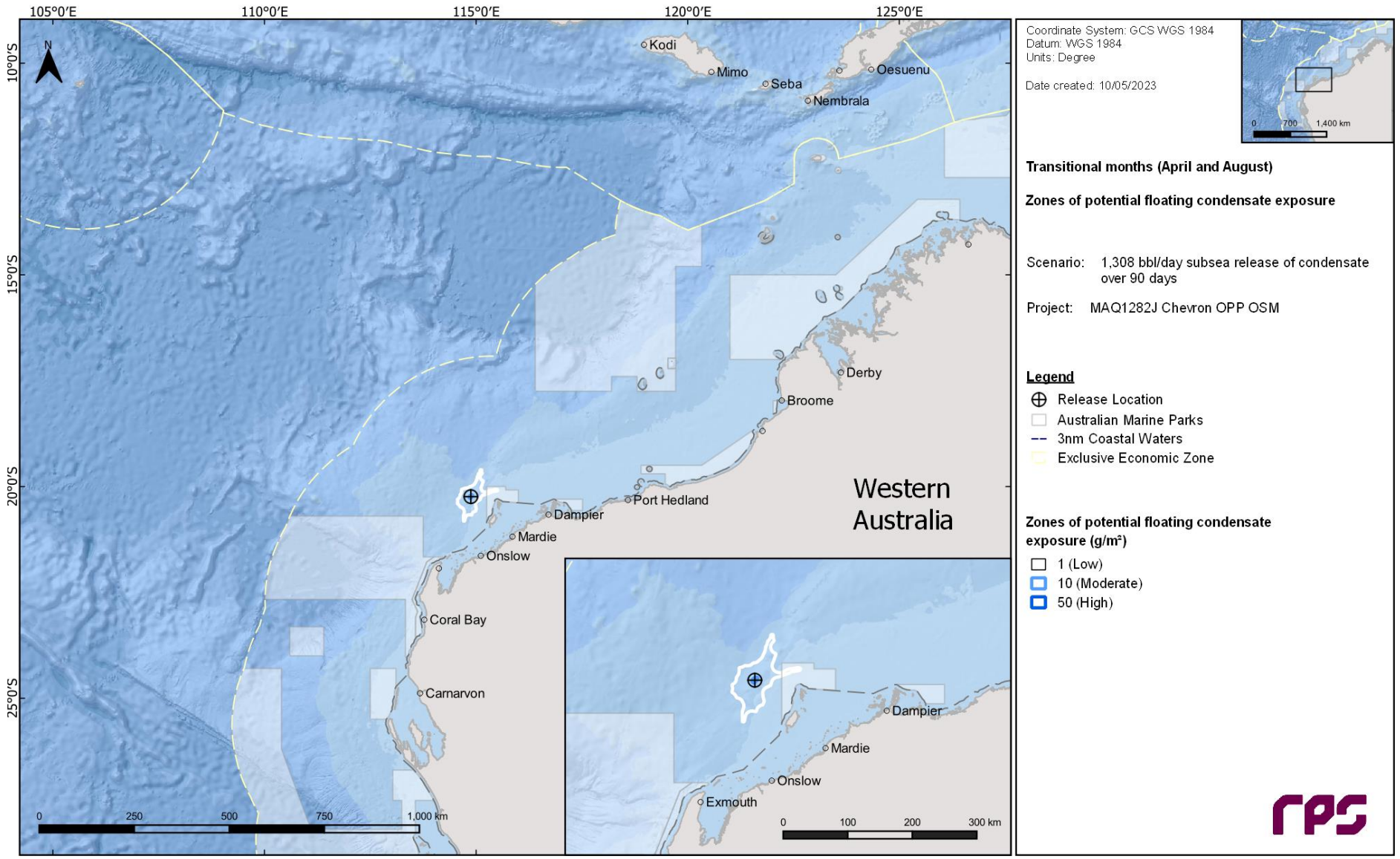


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

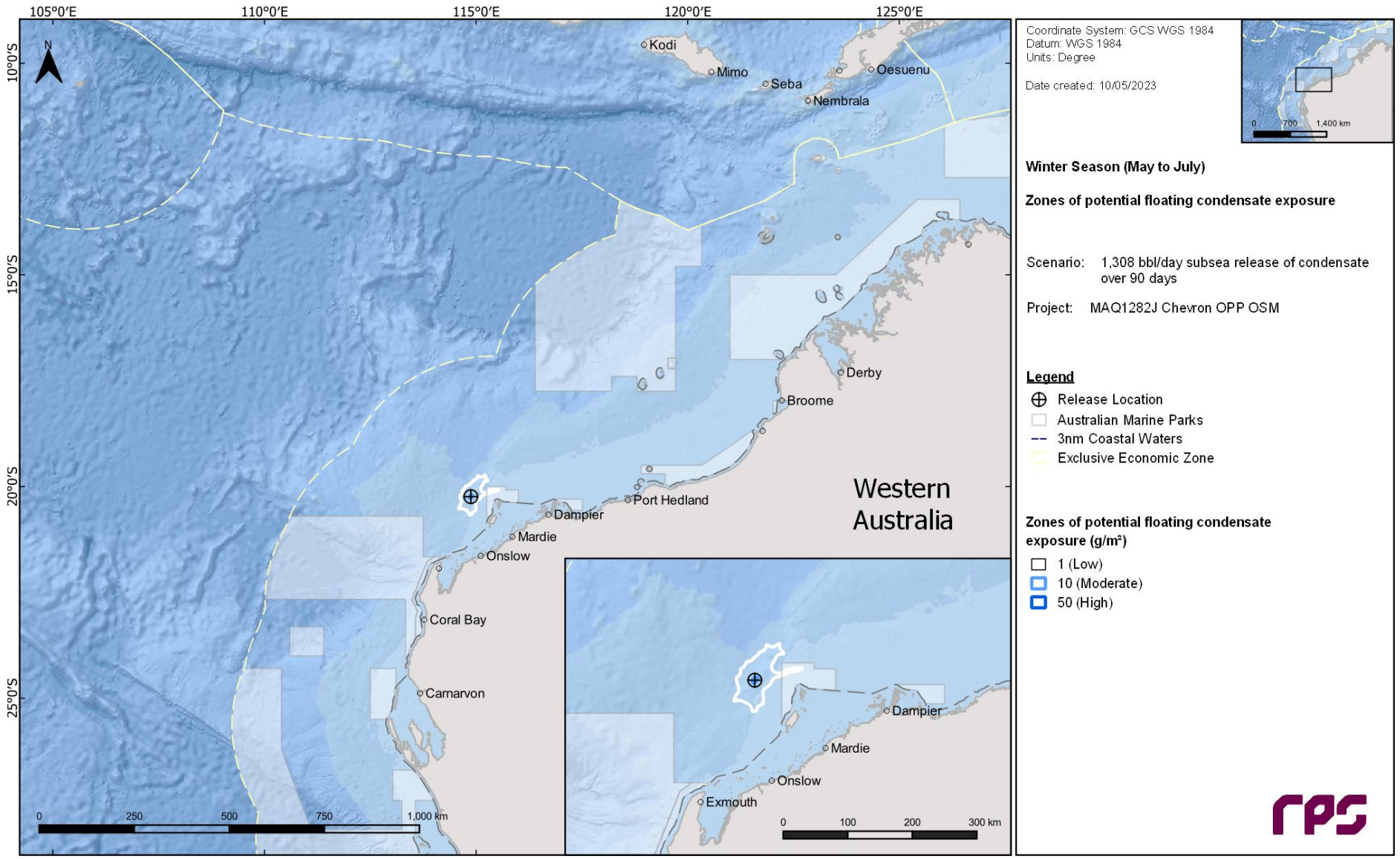


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 32%, while the minimum time before shoreline accumulation was 4.29 days and the maximum volume of oil ashore was 32.0 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, condensate had accumulated on 56 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands and Ningaloo Coast World Heritage Area IAAs (22%). In comparison, during transitional and winter conditions, condensate had accumulated on 6 and 4 shoreline receptors, respectively. The greatest probabilities of shoreline accumulation occurred at Muiron Islands, Ningaloo Coast World Heritage Area and North Muiron Island, all 3% probability during transitional season and at Muiron Islands, Ningaloo Coast World Heritage Area and South Muiron Island, all 1% probability during winter.

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.6.

Table 11.3 Summary of condensate accumulation across all shorelines for each season and threshold, following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	32	3	1
Absolute minimum time for visible oil to shore (days)	4.29	18.83	36.42
Maximum volume of hydrocarbons ashore (m^3)	32.0	1.2	0.8
Average volume of hydrocarbons ashore (m^3)	9.2	0.2	0.2
Maximum length of the shoreline at **10 g/m^2** (km)	131	2	2
Average shoreline length (km) at **10 g/m^2** (km)	38.8	1.7	2
Maximum length of the shoreline at **100 g/m^2** (km)	5	-	-
Average shoreline length (km) at **100 g/m^2** (km)	2.7	-	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	11	-	-	19.04	-	-	44	85	1.6	2.1	2.4	-	-	2.9	-	-
	Ashburton Island	5	-	-	19.5	-	-	7	17	0.2	0.4	1.3	-	-	1.9	-	-
	Barrow & Montebello Islands IAA	22	4	-	8	23.25	-	7	170	4.6	15.7	22.2	1	-	47.1	1	-
	Barrow Island (West Coast)	15	-	-	19.42	-	-	7	48	1.8	4.9	11	-	-	15.4	-	-
	Barrow Island Group	15	4	-	18.29	23.25	-	9	170	3.6	10.7	19.4	1	-	25	1	-
	Bessieres Island	11	-	-	19.21	-	-	16	52	0.7	1.1	2.1	-	-	2.9	-	-
	Boodie Island	14	4	-	18.29	23.25	-	17	170	1.1	3.7	3.5	1	-	3.8	1	-
	Cape Range National Park	13	-	-	4.5	-	-	5	42	1.4	5.4	6.8	-	-	17.3	-	-
	Dampier Archipelago IAA	2	-	-	44.92	-	-	3	19	0.6	2.1	1.9	-	-	2.9	-	-
	Dampier mainland coastline	1	-	-	45.04	-	-	3	19	0.4	0.8	1.9	-	-	1.9	-	-
	Great Sandy Island	11	-	-	25.13	-	-	12	33	0.5	0.9	2.1	-	-	2.9	-	-
	Hermite Island	17	-	-	24.33	-	-	7	48	1	4.3	6.5	-	-	15.4	-	-
	Lowendal Islands Group	1	-	-	73	-	-	4	10	0.1	0.3	1	-	-	1	-	-
	Middle Island	15	-	-	19.29	-	-	14	84	1.1	2.9	5.2	-	-	6.7	-	-
	Middle Ningaloo Coast - World Heritage Area	5	-	-	83.54	-	-	4	13	0.6	1.4	1.2	-	-	1.9	-	-
	Montebello Islands Group	17	-	-	24.33	-	-	6	48	1.1	4.6	6.6	-	-	15.4	-	-
	Muiron Islands	18	-	-	4.54	-	-	6	34	0.8	2.6	3.3	-	-	9.6	-	-
	Ningaloo Coast World Heritage Area	22	-	-	4.29	-	-	6	69	2.6	8.5	9.2	-	-	22.1	-	-
	North Muiron Island	14	-	-	22.58	-	-	6	26	0.3	0.9	1.6	-	-	3.8	-	-
	North Ningaloo Coast - World Heritage Area	17	-	-	4.29	-	-	7	69	1.7	8	6.1	-	-	22.1	-	-
	North Sandy Island	4	-	-	27.71	-	-	6	15	0.1	0.3	1	-	-	1	-	-
	Onslow Area Mainland Coastline	6	-	-	29.29	-	-	4	22	2.2	3.9	4.2	-	-	4.8	-	-
	Pilbara Coast IAA	14	6	-	17.88	18.71	-	9	278	9.4	28.1	31.4	3.7	-	46.2	4.8	-
	Pilbara Coast Islands Group	11	6	-	17.92	18.71	-	19	278	6.9	16.4	15.7	3.7	-	19.2	4.8	-
	Pilbara Mainland Coast	6	-	-	29.29	-	-	4	22	2.2	3.9	4.2	-	-	4.8	-	-
	Serrurier Island	11	6	-	17.92	18.71	-	41	278	5.1	12.8	7.8	3.7	-	9.6	4.8	-
	Sholl Island	3	-	-	44.33	-	-	5	16	0.2	0.5	1.3	-	-	1.9	-	-
	South Muiron Island	13	-	-	4.54	-	-	7	34	0.5	1.6	2.9	-	-	5.8	-	-
	Thevenard Island	11	-	-	19	-	-	23	95	3	4.8	7.2	-	-	9.6	-	-
	Trimouille Island	2	-	-	48.46	-	-	4	14	0.2	0.4	1	-	-	1	-	-
	Varanus Island	1	-	-	73	-	-	4	10	0.1	0.2	1	-	-	1	-	-
Shoreline	Airlie Island	11	-	-	19.04	-	-	44	85	1.6	2.1	2.4	-	-	2.9	-	-
	Ashburton Island	5	-	-	19.5	-	-	7	17	0.2	0.4	1.3	-	-	1.9	-	-
	Barrow Island	15	-	-	19.42	-	-	7	84	2.1	6	12.2	-	-	16.4	-	-
	Bessieres Island	11	-	-	19.21	-	-	16	52	0.7	1.1	2.1	-	-	2.9	-	-
	Boodie Island	15	4	-	18.29	23.25	-	18	170	1.3	4	4.2	1	-	4.8	1	-
	Direction Island	1	-	-	33.96	-	-	7	15	< 0.1	0.2	1	-	-	1	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	18	-	-	4.29	-	-	6	69	2.9	12.1	11	-	-	35.6	-	-
Flat Island	11	-	-	17.88	-	-	19	75	0.8	2	2.5	-	-	3.8	-	-
Karratha	7	-	-	29.29	-	-	4	25	2.1	4.3	4.7	-	-	6.7	-	-
Lowendal Island	11	-	-	36.04	-	-	7	31	0.4	1.1	1.7	-	-	2.9	-	-
Mangrove Islands	1	-	-	43.33	-	-	4	11	0.3	0.4	1	-	-	1	-	-
Mary Anne Group	11	-	-	23.04	-	-	14	50	2	2.8	7.3	-	-	8.7	-	-
Middle Island	15	-	-	19.29	-	-	14	84	1.4	3.9	6.7	-	-	8.7	-	-
Montebello Islands	18	-	-	8	-	-	6	48	1.6	7.1	9.8	-	-	25	-	-
Muiron Islands	18	-	-	4.54	-	-	6	34	0.8	2.6	3.3	-	-	9.6	-	-
Observation Island	2	-	-	68.88	-	-	6	18	0.1	0.3	1	-	-	1	-	-
Passage Islands	11	-	-	25.13	-	-	6	48	1.6	3.5	4.8	-	-	9.6	-	-
Peak Island	4	-	-	32.63	-	-	7	13	< 0.1	0.2	1	-	-	1	-	-
Round Island	8	-	-	21.29	-	-	12	20	0.1	0.2	1	-	-	1	-	-
Serrurier Island	11	6	-	17.92	18.71	-	41	278	5.1	12.8	7.8	3.7	-	9.6	4.8	-
Sunday Island	5	-	-	23.67	-	-	7	19	0.1	0.4	1.3	-	-	1.9	-	-
Table Island	8	-	-	33.13	-	-	11	20	0.1	0.2	1	-	-	1	-	-
Thevenard Island	11	-	-	19	-	-	23	95	3	4.8	7.2	-	-	9.6	-	-
Tortoise Island	2	-	-	18.38	-	-	9	25	0.1	0.3	1	-	-	1	-	-
Twin Island	3	-	-	44.63	-	-	5	12	0.1	0.3	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IAA	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	3	-	-	18.83	-	-	4	30	0.2	0.9	1	-	-	1	-	-
	Ningaloo Coast World Heritage Area	3	-	-	18.83	-	-	4	30	0.2	1	1	-	-	1	-	-
	North Muiron Island	3	-	-	18.83	-	-	5	30	0.1	0.7	1	-	-	1	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	19.67	-	-	6	15	0.1	0.2	1	-	-	1	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	3	-	-	18.83	-	-	4	30	0.2	0.9	1	-	-	1	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	2	-	-	19.67	-	-	10	15	0.1	0.2	1	-	-	1	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tortoise Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Twin Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11.6 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IAA	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	1	-	-	36.42	-	-	4	18	0.2	0.6	1.9	-	-	1.9	-	-
	Ningaloo Coast World Heritage Area	1	-	-	36.42	-	-	4	18	0.1	0.7	1.9	-	-	1.9	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	1	-	-	36.42	-	-	5	18	0.1	0.4	1.9	-	-	1.9	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	1	-	-	36.42	-	-	4	18	0.2	0.6	1.9	-	-	1.9	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tortoise Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Twin Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

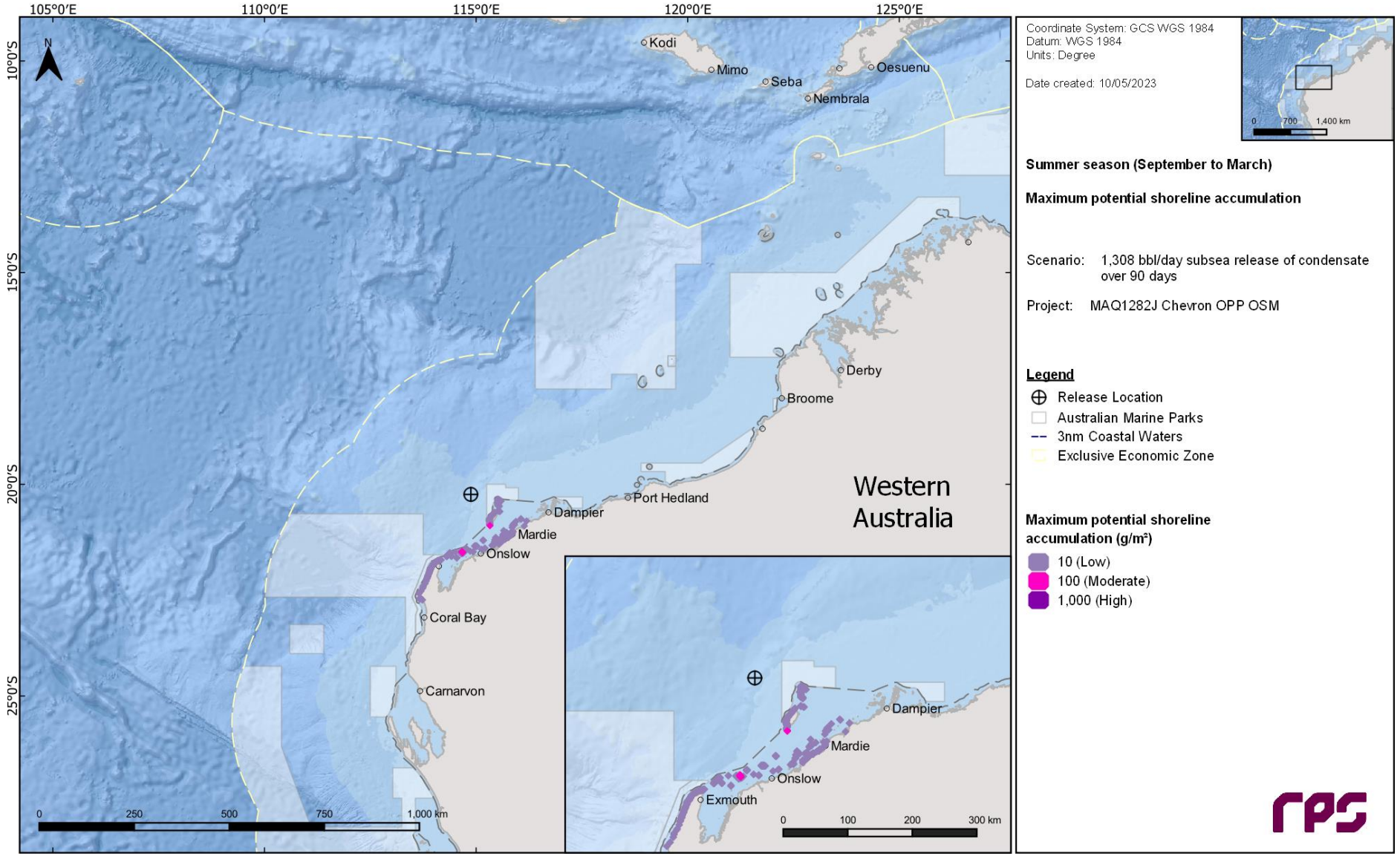


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

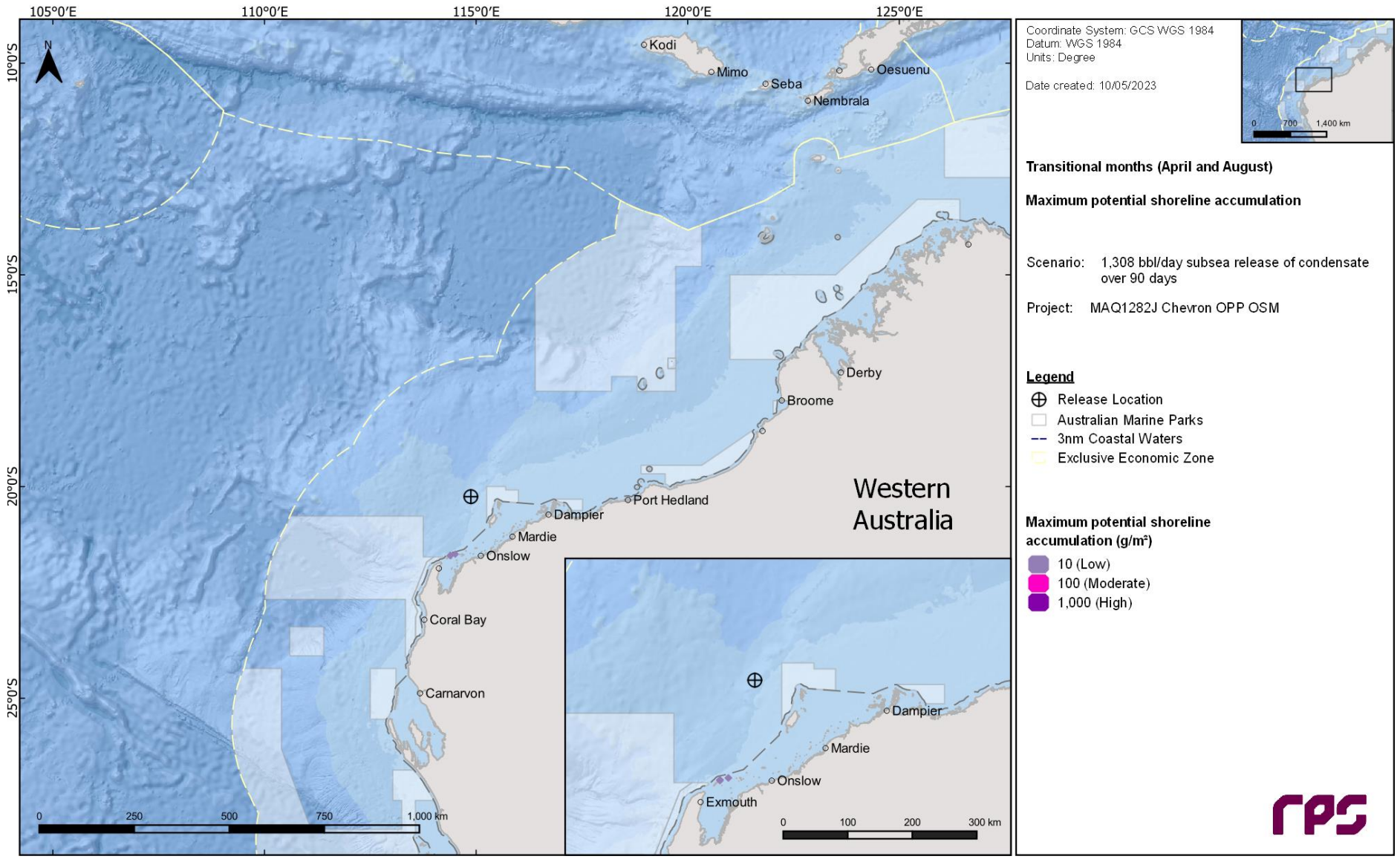


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

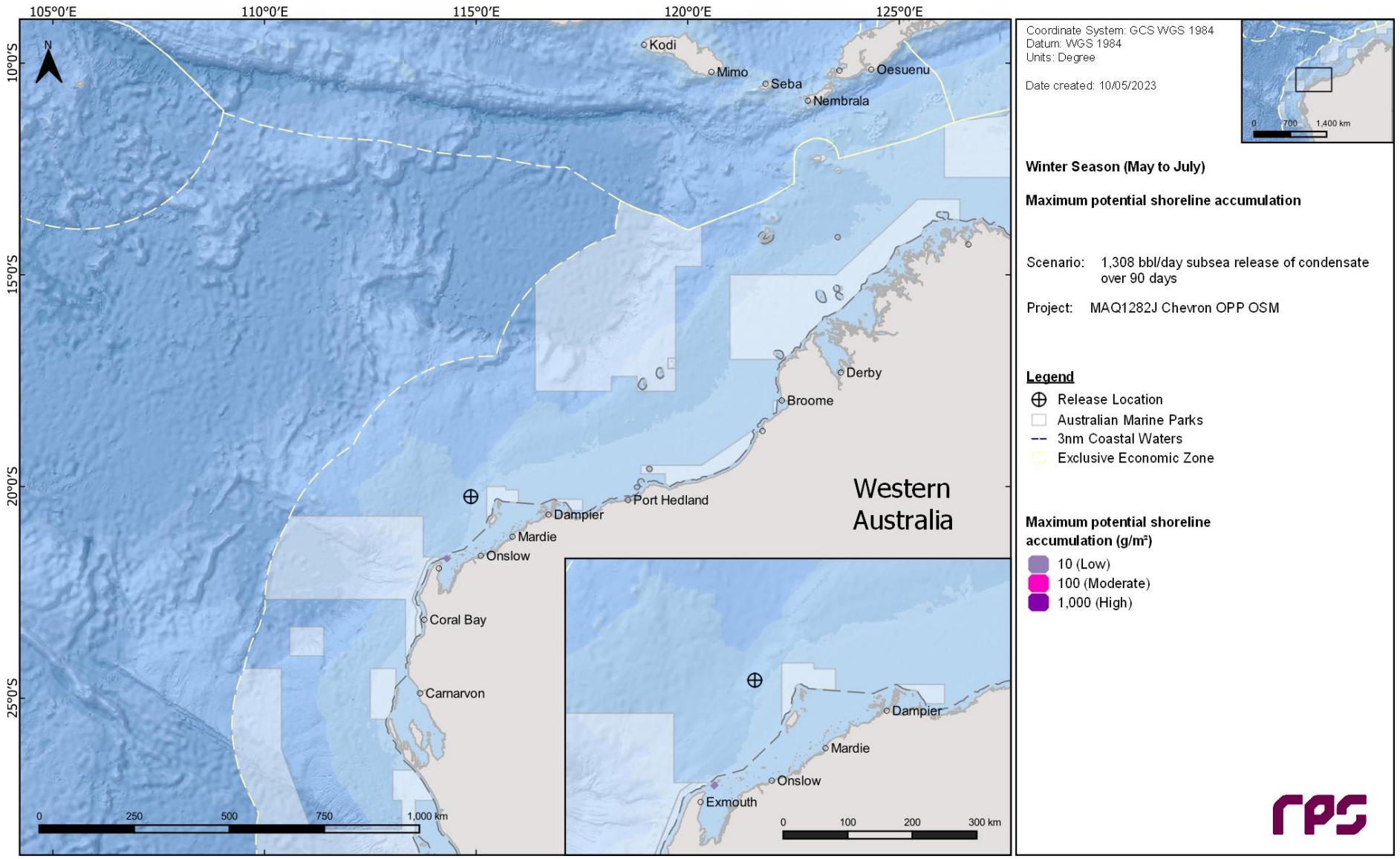


Figure 11.6 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

No dissolved hydrocarbon exposure was predicted for this scenario above the low reporting threshold (≥10 ppb) during any of the seasons modelled. Consequently, no results are reported.

11.1.3.2 Entrained Hydrocarbons

Table 11.7 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 35 BIAs were predicted to be exposed at, or above, the low threshold during summer, compared to 20 during transitional and winter. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for the Flatback Turtle - Internesting Buffer and Humpback Whale - Migration BIAs at 100% during all seasons.

During summer conditions, 6 AMPs were predicted to be exposed at, or above the low threshold, and 5 AMPs under transitional and winter conditions. The highest probabilities predicted were at the Gascoyne AMP (80% summer, 82% transitional and 87% winter). Furthermore, the Montebello AMP was predicted to be exposed to entrained hydrocarbons at the high threshold during summer (3%), transitional (6%) and winter (3%), respectively.

During summer, transitional and winter conditions, 7, 5 and 5 KEFs were predicted to be exposed by at the low threshold, respectively. Probabilities ranged between 5–100%, 16–100% and 18–100%, for each season, respectively. Excluding the KEF that the release location resides within (Continental Slope Demersal Fish Communities), the ancient coastline at 125 m depth contour KEF recorded the highest probability of exposure for all three seasons (98%, 100% and 95% during summer, transitional and winter, respectively).

Additionally, 38, 12 and 11 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore, the probabilities for each season ranged between 1–80%, 1–82% and 1–87% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, a total of 46, 5 and 2 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold with maximum seasonal probabilities of 36%, 18% and 26% for Rankin Bank, during summer, transitional and winter, respectively.

Figure 11.7 to Figure 11.9 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.10 to Figure 11.12.

Table 11.7 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Argo-Rowley Terrace	28.8	11	-	21.17	-	27.9	8	-	22.46	-	31.5	9	-	41.04	-
	Carnarvon Canyon	12.9	2	-	99.5	-	12.4	2	-	42.75	-	15.2	3	-	22.88	-
	Gascoyne	100.6	80	1	2.42	73.13	93.3	82	-	5.67	-	73.8	87	-	4.58	-
	Montebello	117.3	49	3	3.17	7.08	121.6	30	6	6.17	27.42	123.6	41	3	6.63	54.46
	Ningaloo	67.8	25	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.92	-
	Shark Bay	15.8	4	-	82	-	9.3	-	-	-	-	7.9	-	-	-	-
BIA	Dugong - Breeding	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Calving	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Foraging	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Nursing	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Fairy Tern - Breeding	80.8	20	-	3.75	-	25.8	11	-	12.21	-	24.1	15	-	9.33	-
	Flatback Turtle - Aggregation	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Flatback Turtle - Foraging	39.1	11	-	18	-	2.3	-	-	-	-	2.1	-	-	-	-
	Flatback Turtle - Internesting	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Flatback Turtle - Internesting Buffer	362.9	100	80	0.46	0.75	348.9	100	55	0.88	3.21	345.8	100	77	0.38	0.63
	Flatback Turtle - Mating	39.1	11	-	18	-	2.3	-	-	-	-	2.1	-	-	-	-
	Flatback Turtle - Nesting	149.4	75	6	1.63	15.54	86.5	62	-	4.25	-	105.4	75	1	2.75	3.96
	Green Turtle - Aggregation	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Green Turtle - Basking	39.1	11	-	17.92	-	1.7	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Foraging	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Internesting	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Internesting Buffer	123.3	30	6	2.5	16.75	41.8	25	-	8.33	-	43	31	-	4.92	-
	Green Turtle - Mating	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Nesting	123.3	30	6	2.63	16.71	44.7	21	-	8.38	-	43.9	23	-	5.33	-
	Hawksbill Turtle - Foraging	39.1	11	-	18	-	1.7	-	-	-	-	2.1	-	-	-	-
	Hawksbill Turtle - Internesting	17.7	8	-	37.63	-	0.6	-	-	-	-	1.2	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	90.8	33	-	2.67	-	42.9	24	-	8.25	-	43	21	-	4.96	-
	Hawksbill Turtle - Mating	39.1	11	-	18	-	1.7	-	-	-	-	2.1	-	-	-	-
	Hawksbill Turtle - Nesting	123.3	30	6	2.63	16.71	40.9	21	-	8.38	-	43.7	23	-	5.33	-
	Humpback Whale - Migration	188.3	100	12	0.54	4.54	141.5	100	10	1.79	5.42	143	100	14	1.17	3.25
	Humpback Whale - Resting	44.6	15	-	17.67	-	5.6	-	-	-	-	5.5	-	-	-	-
	Lesser Crested Tern - Breeding	92.1	24	-	3.75	-	41.8	12	-	11.13	-	42.8	13	-	6.08	-
	Little Tern - Resting	12.9	1	-	65.58	-	3.6	-	-	-	-	3.8	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	123.3	33	6	2.5	16.75	32.9	24	-	9.83	-	38.7	31	-	6.67	-
	Loggerhead Turtle - Nesting	67.8	29	-	2.83	-	25.8	17	-	11.96	-	25.2	19	-	8.38	-
	Pygmy Blue Whale – Distribution*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Pygmy Blue Whale - Foraging	49.8	57	-	2.46	-	45.4	38	-	6.08	-	35.6	35	-	5.75	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Roseate Tern - Breeding	109.8	25	1	2.92	47.5	42.6	17	-	7.25	-	39.6	28	-	6.54	-
	Wedge-tailed Shearwater – Breeding*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Whale Shark - Foraging	336.2	100	59	0.63	1.21	309	100	42	1.21	3.38	306.5	100	54	0.46	1.58
	White-tailed Tropicbird - Breeding	14.5	2	-	60.54	-	7.1	-	-	-	-	6.7	-	-	-	-
CP	Montebello Islands	22.8	9	-	41.08	-	0.7	-	-	-	-	0.5	-	-	-	-
EEZ	Australian Exclusive Economic Zone *	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Airlie Island	43.6	11	-	18.42	-	2.3	-	-	-	-	2.9	-	-	-	-
	Argo-Rowley Terrace IAA	28.8	11	-	21.17	-	27.9	8	-	22.46	-	31.5	9	-	41.04	-
	Ashburton Island	20	6	-	18.42	-	0.5	-	-	-	-	0.6	-	-	-	-
	Barrow & Montebello Islands IAA	117.3	49	3	3.17	7.08	121.6	30	6	6.17	27.42	123.6	41	3	6.63	54.46
	Barrow Island (East Coast)	19.5	11	-	36.46	-	0.3	-	-	-	-	1.2	-	-	-	-
	Barrow Island (West Coast)	36.8	11	-	18.46	-	1.3	-	-	-	-	1.6	-	-	-	-
	Barrow Island Group	39.1	11	-	18	-	1.3	-	-	-	-	1.7	-	-	-	-
	Bessieres Island	63.5	14	-	16.25	-	15.7	4	-	17.29	-	7.4	-	-	-	-
	Boodie Island	38.6	11	-	18	-	0.5	-	-	-	-	1.5	-	-	-	-
	Cape Range National Park	23.8	9	-	37.42	-	11.7	1	-	17.38	-	8.5	-	-	-	-
	Dampier Archipelago IAA	13	5	-	28.88	-	1.1	-	-	-	-	1.5	-	-	-	-
	Exmouth IAA	31.6	20	-	16.58	-	8.5	-	-	-	-	7.4	-	-	-	-
	Gascoyne IAA	100.6	80	1	2.42	73.13	93.3	82	-	5.67	-	73.8	87	-	4.58	-
	Glomar Shoal	26.4	5	-	30.71	-	0.6	-	-	-	-	0.8	-	-	-	-
	Great Sandy Island	27.4	6	-	23.58	-	0.3	-	-	-	-	0.4	-	-	-	-
	Hermite Island	22.8	10	-	40.29	-	1	-	-	-	-	0.6	-	-	-	-
IAA	Middle Island	39.1	11	-	21.5	-	0.5	-	-	-	-	1.7	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	14.2	8	-	6.46	-	7.5	-	-	-	-	7.5	-	-	-	-
	Montebello Islands Group	22.8	10	-	40.29	-	1	-	-	-	-	0.6	-	-	-	-
	Muiron Islands	45.9	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	Ningaloo Coast World Heritage Area	67.8	29	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.42	-
	North Muiron Island	41.7	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	North Ningaloo Coast - World Heritage Area	53.9	22	-	17.67	-	6.4	-	-	-	-	5	-	-	-	-
	North Sandy Island	18.3	6	-	27.75	-	0.2	-	-	-	-	0.3	-	-	-	-
	Offshore Area*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Onslow Area Mainland Coastline	17.3	6	-	25.63	-	0.3	-	-	-	-	0.7	-	-	-	-
	Passage Island	11.7	4	-	29.13	-	0.1	-	-	-	-	0.3	-	-	-	-
	Pilbara Coast IAA	123.3	29	6	3.42	16.71	21.8	11	-	11.38	-	19	7	-	6.83	-
	Pilbara Coast Islands Group	118.5	14	5	16.17	21.25	15.8	4	-	17.29	-	10.2	1	-	48.17	-
	Pilbara Mainland Coast	17.3	6	-	25.63	-	0.3	-	-	-	-	0.7	-	-	-	-
	Rankin Bank	111.7	36	1	4.83	14.67	108.4	17	3	9.33	29.04	110.8	26	3	6.75	56.08
	Serrurier Island	118.5	14	5	16.17	21.25	15.8	4	-	18.13	-	10.2	1	-	48.17	-
	Shark Bay mainland coastline	19.6	4	-	81.08	-	11.1	1	-	48	-	9.8	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Sholl Island	11.2	1	-	46.04	-	0.1	-	-	-	-	0.3	-	-	-	-
	South Muiron Island	45.9	27	-	13.71	-	7.9	-	-	-	-	7.9	-	-	-	-
	Thevenard Island	51.6	12	-	17.13	-	3.3	-	-	-	-	2.7	-	-	-	-
	Trimouille Island	13.7	4	-	42.21	-	0.4	-	-	-	-	0.5	-	-	-	-
	Yammadery Island	11.6	4	-	37.79	-	0.1	-	-	-	-	0.2	-	-	-	-
IBRA	Cape Range	119.5	29	5	3.54	17.75	16.5	6	-	17.38	-	10.4	1	-	34.33	-
	Roebourne	41.4	11	-	18	-	2.3	-	-	-	-	2.9	-	-	-	-
IMCRA	Ningaloo	67.8	39	-	2.83	-	34.3	27	-	11.08	-	34.6	24	-	8.42	-
	Northwest Shelf	174.7	76	4	1.92	5.54	178.7	71	9	7.08	25.83	184.9	70	5	4.29	30.21
	Pilbara (nearshore)	47.4	22	-	16.58	-	9.9	-	-	-	-	8.7	-	-	-	-
	Pilbara (offshore)	337.1	100	63	0.63	1.21	323	100	47	1.25	3.42	332.3	100	59	0.42	1.54
	Zuytdorp	19.6	4	-	81.04	-	11.1	1	-	48	-	9.8	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	243.4	98	35	0.88	3.75	194.5	100	16	1.92	7.79	179.3	95	17	0.71	2.79
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	66.8	76	-	2.17	-	70.3	60	-	5.46	-	58.4	67	-	5.29	-
	Commonwealth waters adjacent to Ningaloo Reef	67.8	25	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.92	-
	Continental Slope Demersal Fish Communities*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Exmouth Plateau	74.1	78	-	4.46	-	83.9	82	-	4.29	-	90.3	82	-	3.08	-
	Glomar Shoals	29	5	-	16.08	-	1	-	-	-	-	1.1	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	14.5	1	-	65.08	-	3.6	-	-	-	-	5.1	-	-	-	-
MMA	Barrow Island	46.5	12	-	5.04	-	4	-	-	-	-	2.6	-	-	-	-
	Muiron Islands	60	29	-	3.54	-	14.7	4	-	24.25	-	15.7	6	-	8.42	-
MP	Barrow Island	28.5	11	-	18	-	2.7	-	-	-	-	1.9	-	-	-	-
	Montebello Islands	25.4	12	-	5.42	-	4.3	-	-	-	-	1.7	-	-	-	-
	Ningaloo	66.6	25	-	4.13	-	23.9	10	-	13.5	-	23.1	8	-	9.67	-
	Rowley Shoals	11.6	1	-	65.96	-	3.6	-	-	-	-	3.8	-	-	-	-
NR	Great Sandy Island	38.6	11	-	21.46	-	0.2	-	-	-	-	0.5	-	-	-	-
	Thevenard Island	49.3	11	-	17.92	-	1.8	-	-	-	-	1.7	-	-	-	-
RSB	Australind Shoal	26.1	6	-	18.38	-	0.7	-	-	-	-	0.6	-	-	-	-
	Barrow Island Reefs and Shoals	38.6	11	-	21.08	-	0.4	-	-	-	-	0.8	-	-	-	-
	Brewis Reef	49.6	11	-	17.46	-	1.3	-	-	-	-	1.6	-	-	-	-
	Combe Reef	17.6	10	-	32.58	-	6.6	-	-	-	-	4.6	-	-	-	-
	Dailey Shoal	84.2	26	-	14.88	-	11.4	1	-	24.21	-	7.9	-	-	-	-
	Exmouth Reef	10.4	1	-	92.96	-	2.2	-	-	-	-	2.9	-	-	-	-
	Fairway Reef	53.9	14	-	17.04	-	7.4	-	-	-	-	6.9	-	-	-	-
	Flinders Shoal	34.2	6	-	22.08	-	0.3	-	-	-	-	0.4	-	-	-	-
	Glennie Patches	12.4	2	-	22.58	-	0.7	-	-	-	-	0.6	-	-	-	-
	Glomar Shoal	26.4	5	-	30.71	-	0.6	-	-	-	-	1	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Gorgon Patch	16.6	6	-	34.42	-	0.3	-	-	-	-	0.5	-	-	-	-
	Hastings Shoal	12.6	5	-	35.38	-	0.1	-	-	-	-	0.3	-	-	-	-
	Hayman Rock	10.3	2	-	77.83	-	2.1	-	-	-	-	2	-	-	-	-
	Herald Reef	13.7	5	-	33.71	-	0.2	-	-	-	-	0.6	-	-	-	-
	Hood Reef	89	14	-	16.42	-	9.5	-	-	-	-	9.1	-	-	-	-
	Inner Northwest Patch	10.7	1	-	83.88	-	0.3	-	-	-	-	0.8	-	-	-	-
	Koolinda Patch	13	5	-	37.17	-	0.1	-	-	-	-	0.4	-	-	-	-
	Lightfoot Reef	29.5	6	-	22.5	-	0.3	-	-	-	-	0.4	-	-	-	-
	Little Shoals	29.8	6	-	20.46	-	0.3	-	-	-	-	0.5	-	-	-	-
	Locker Reef	16	5	-	18.08	-	2.2	-	-	-	-	2.1	-	-	-	-
	McLennan Bank	11.8	1	-	45.38	-	0.1	-	-	-	-	0.3	-	-	-	-
	Meda Reef	10.8	1	-	94.71	-	0.1	-	-	-	-	0.3	-	-	-	-
	Miles Shoal	18.6	6	-	18.46	-	0.3	-	-	-	-	0.6	-	-	-	-
	Montebello Shoals	23.5	10	-	5.83	-	2.5	-	-	-	-	1.1	-	-	-	-
	Moresby Shoals	17.2	6	-	20.5	-	0.3	-	-	-	-	0.4	-	-	-	-
	Nares Rock	19.6	6	-	21.46	-	0.2	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	50.8	22	-	4.38	-	13.3	4	-	15.83	-	12	3	-	9.96	-
	North West Reef	55.6	21	-	17.13	-	4.9	-	-	-	-	5.2	-	-	-	-
	Otway Reef	30.5	20	-	17.17	-	7.4	-	-	-	-	6.1	-	-	-	-
	Outtrim Patches	40.8	27	-	12.46	-	9	-	-	-	-	7	-	-	-	-
	Paroo Shoal	16.9	6	-	19.42	-	0.4	-	-	-	-	0.7	-	-	-	-
	Penguin Bank	37.8	15	-	16.13	-	17.4	4	-	11.29	-	2.4	-	-	-	-
	Poivre Reef	36.9	11	-	17.54	-	0.8	-	-	-	-	1.7	-	-	-	-
	Rankin Bank	111.7	36	1	4.42	14.67	108.4	18	3	9.13	29.04	110.8	26	3	6.75	56.08
	Ripple Shoals	44.6	11	-	19	-	0.6	-	-	-	-	1.6	-	-	-	-
	Rosily Shoals	54.6	14	-	16.29	-	14.6	4	-	15	-	3.2	-	-	-	-
	Saladin Shoal	13.9	5	-	23.71	-	0.3	-	-	-	-	0.5	-	-	-	-
	Santo Rock	18.4	6	-	17.46	-	1.6	-	-	-	-	1.6	-	-	-	-
	Spider Reef	14.1	8	-	78.38	-	5.3	-	-	-	-	5.5	-	-	-	-
	Sultan Reef	35.4	10	-	18.46	-	1.3	-	-	-	-	1.5	-	-	-	-
	Taunton Reef	33.1	11	-	19.38	-	1.4	-	-	-	-	1.6	-	-	-	-
	Tongue Shoals	11.6	3	-	22.67	-	0.6	-	-	-	-	1.1	-	-	-	-
	Trap Reef	41.8	11	-	17.29	-	2.4	-	-	-	-	2.4	-	-	-	-
	Tryal Rocks	24.2	15	-	5.08	-	6.1	-	-	-	-	1.4	-	-	-	-
	Weeks Shoal	16.2	6	-	20.5	-	0.2	-	-	-	-	0.5	-	-	-	-
	West Reef	26.5	6	-	21.58	-	0.4	-	-	-	-	0.5	-	-	-	-
Nearshore Waters	Airlie Island	43.6	11	-	18.42	-	2.3	-	-	-	-	2.9	-	-	-	-
	Ashburton	17.3	6	-	33.13	-	1	-	-	-	-	1.4	-	-	-	-
	Ashburton Island	17.2	6	-	18.42	-	0.4	-	-	-	-	0.6	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Barrow Island	36.8	11	-	18.46	-	1.1	-	-	-	-	1.6	-	-	-	-
	Bessieres Island	63.5	14	-	16.25	-	15.7	4	-	17.29	-	7.4	-	-	-	-
	Boodie Island	38.6	11	-	18	-	0.5	-	-	-	-	1.5	-	-	-	-
	Direction Island	14.8	6	-	34.42	-	0.3	-	-	-	-	0.4	-	-	-	-
	Exmouth	53.9	22	-	6.46	-	10.7	1	-	17.38	-	8.4	-	-	-	-
	Flat Island	119.5	16	5	16.13	17.75	16.5	6	-	18.13	-	10.4	1	-	48.33	-
	Karratha	16.9	6	-	25.75	-	0.4	-	-	-	-	0.5	-	-	-	-
	Lowendal Island	14.9	5	-	38.13	-	0.4	-	-	-	-	0.7	-	-	-	-
	Mangrove Islands	12.6	6	-	35.5	-	0.2	-	-	-	-	0.3	-	-	-	-
	Mary Anne Group	29	6	-	22.08	-	0.5	-	-	-	-	0.6	-	-	-	-
	Middle Island	39.1	11	-	21.21	-	0.5	-	-	-	-	1.7	-	-	-	-
	Montebello Islands	23.9	10	-	38.54	-	1.5	-	-	-	-	1.1	-	-	-	-
	Muiron Islands	45.9	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	Observation Island	37.2	12	-	17.38	-	7.5	-	-	-	-	7.5	-	-	-	-
	Passage Islands	27.4	6	-	23.58	-	0.3	-	-	-	-	0.5	-	-	-	-
	Peak Island	114.9	26	3	12.54	32.04	11.8	2	-	18.58	-	9.4	-	-	-	-
	Round Island	104.2	14	1	16.38	82.33	10.6	1	-	21.75	-	8	-	-	-	-
	Serrurier Island	118.5	14	5	16.17	21.25	14.1	4	-	18.13	-	10.2	1	-	48.17	-
	Sunday Island	37.9	27	-	13.96	-	9.6	-	-	-	-	7.1	-	-	-	-
	Table Island	77.4	14	-	16.83	-	8.8	-	-	-	-	6.5	-	-	-	-
	Thevenard Island	51.6	11	-	17.92	-	1.8	-	-	-	-	1.9	-	-	-	-
	Tortoise Island	37.7	10	-	17.46	-	1.2	-	-	-	-	1.5	-	-	-	-
	Twin Island	12.1	3	-	35.42	-	0.2	-	-	-	-	0.4	-	-	-	-
State Waters	Western Australia State Waters	123.3	29	6	3.54	16.71	27.2	10	-	10.29	-	23.1	8	-	7.79	-

*The release location resides within the receptor boundaries.

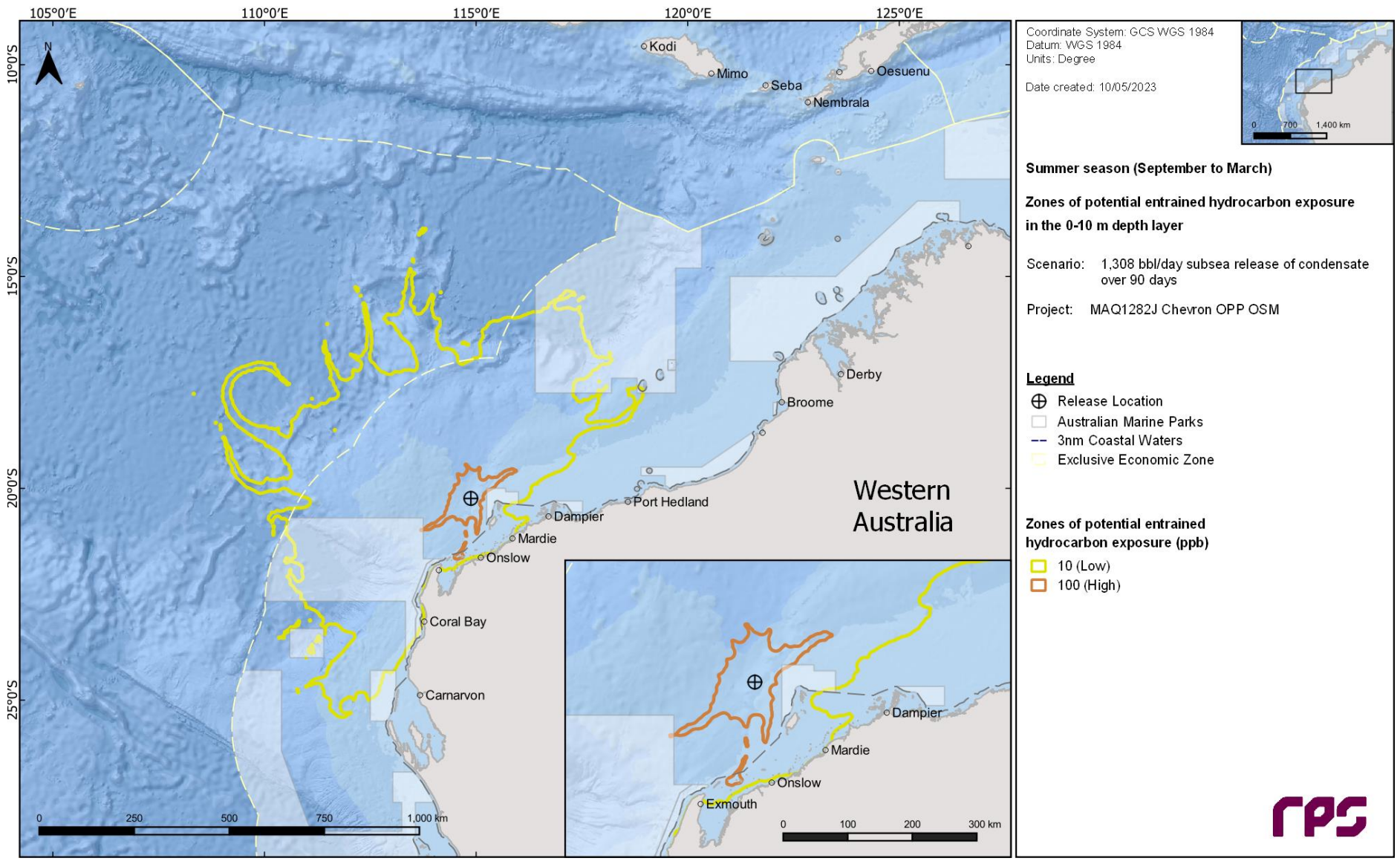


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

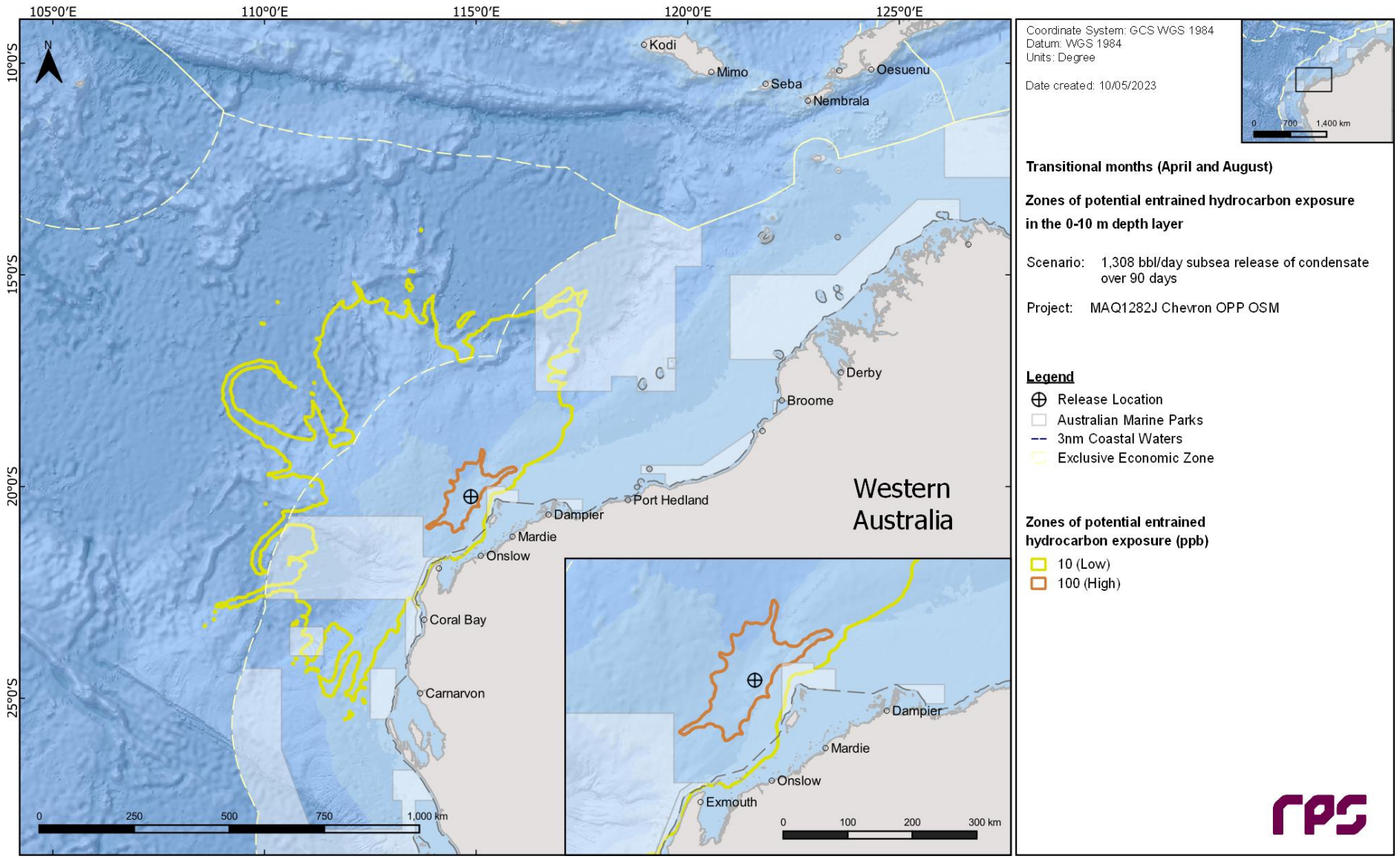


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

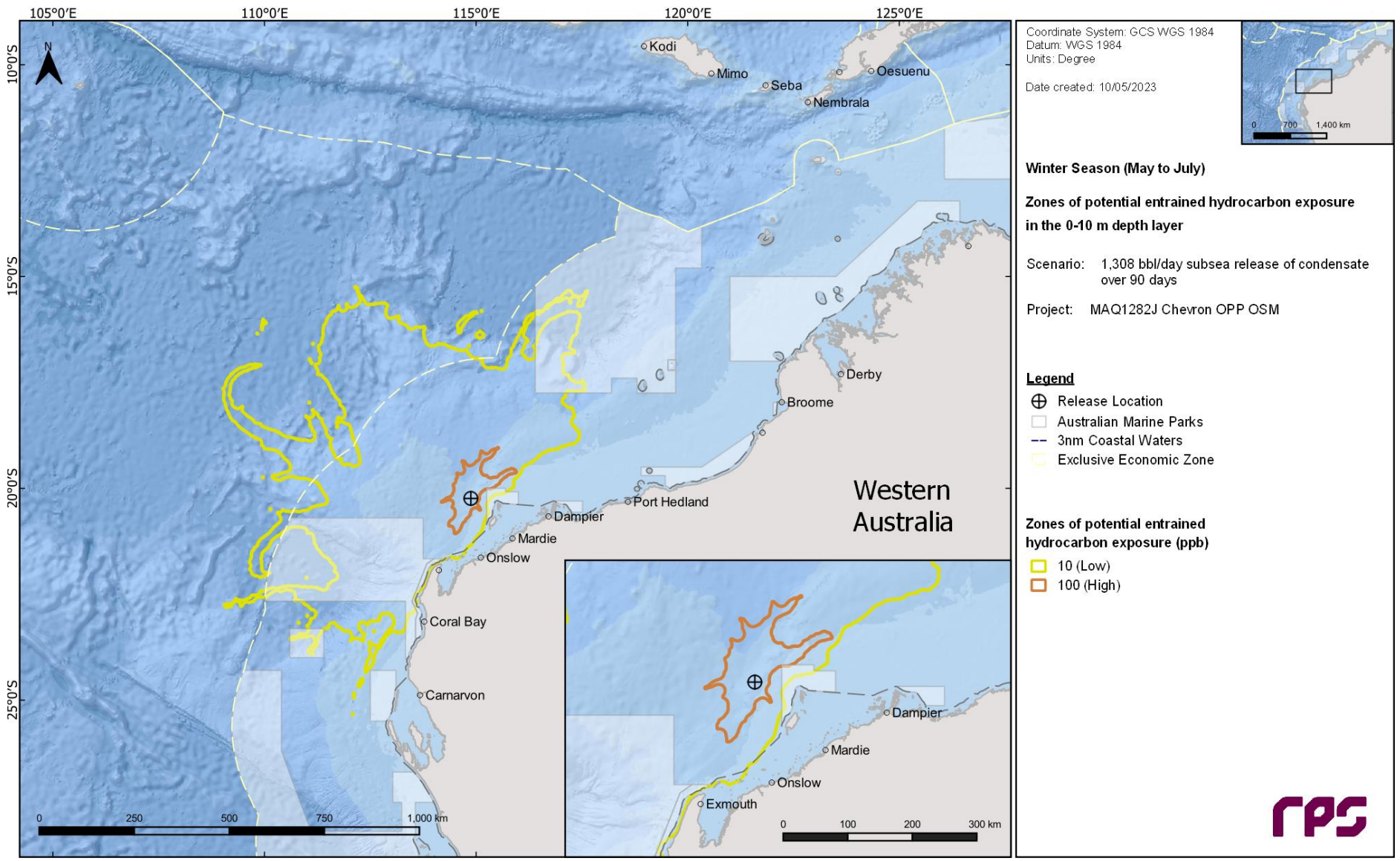


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

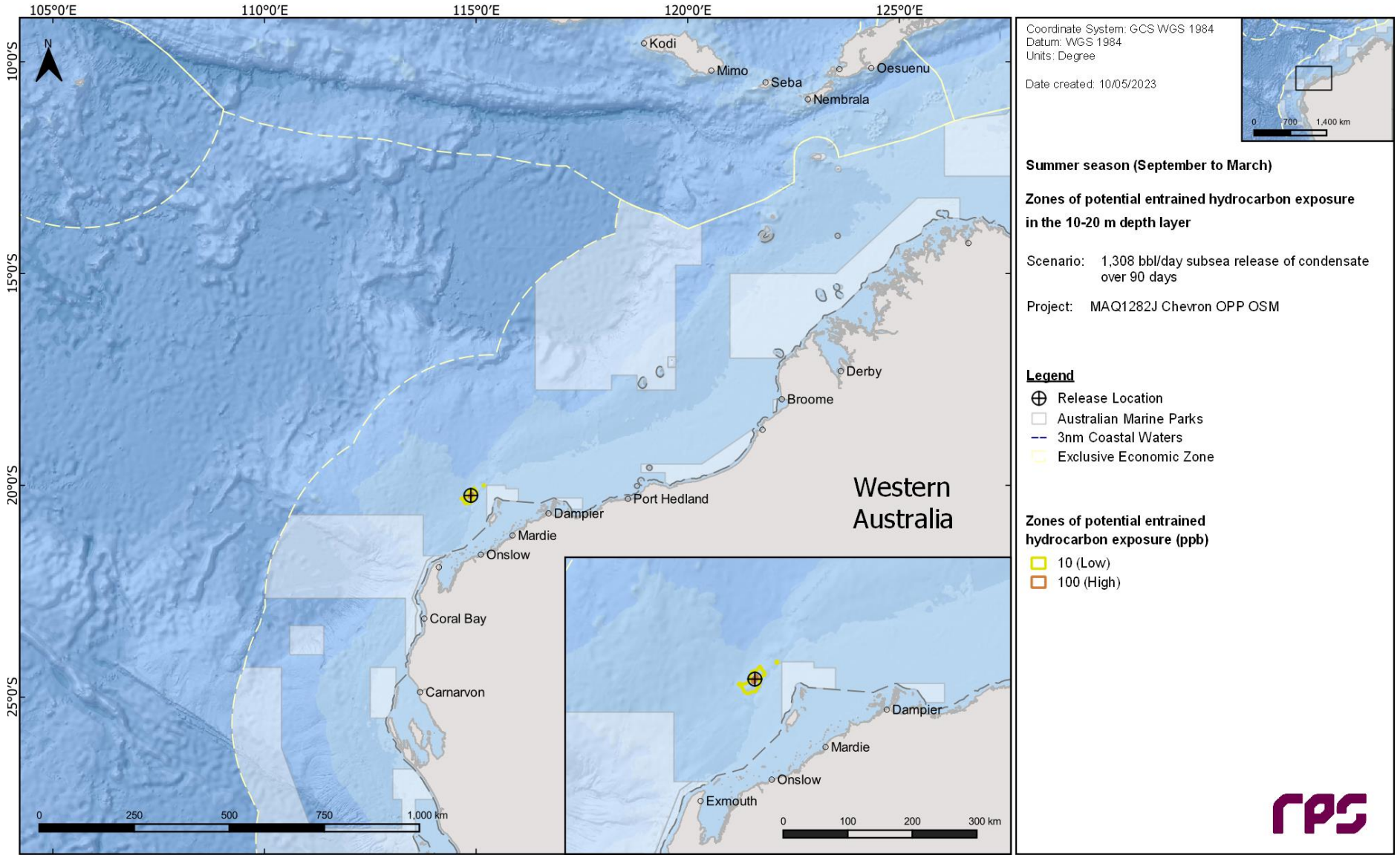


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

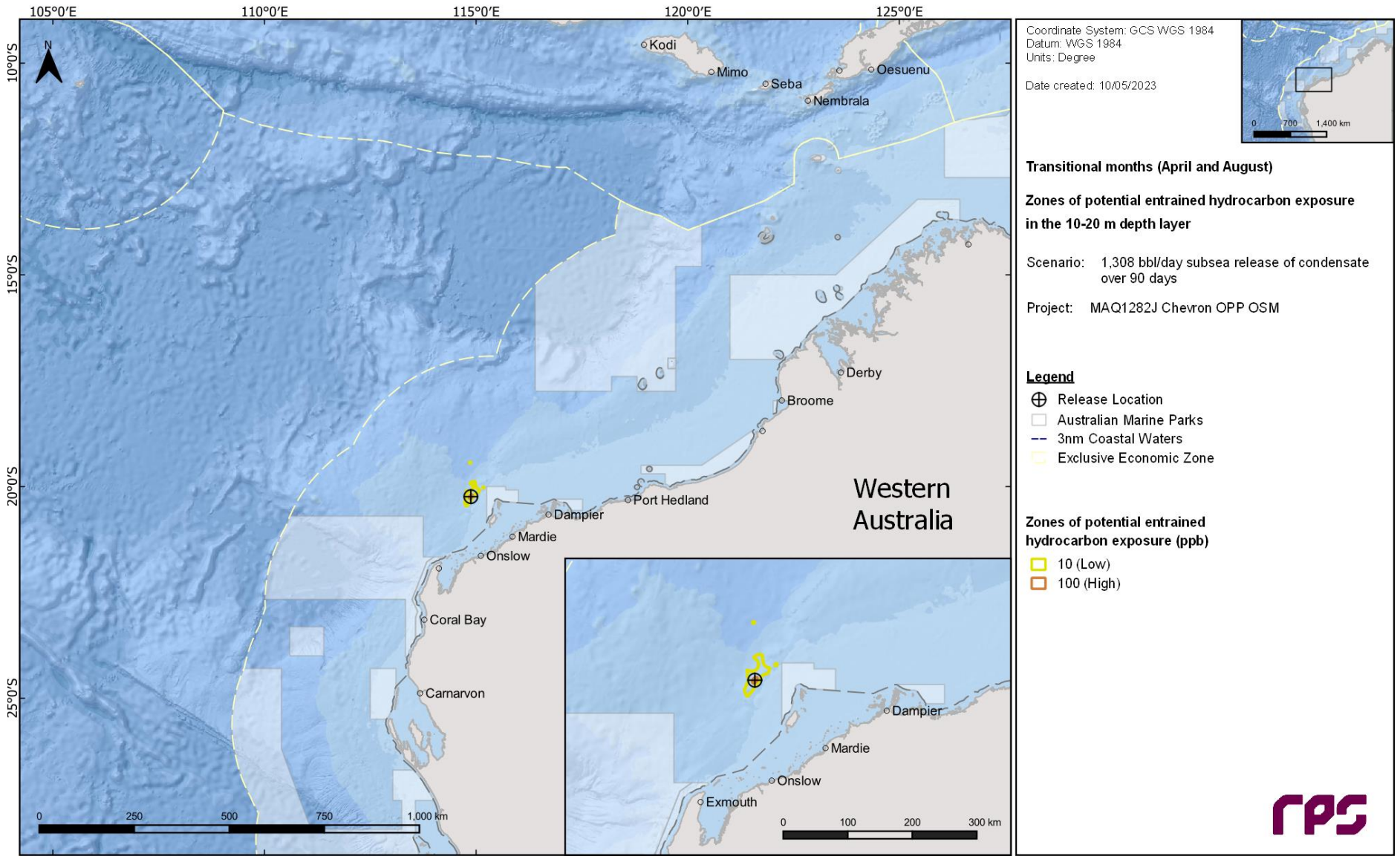


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

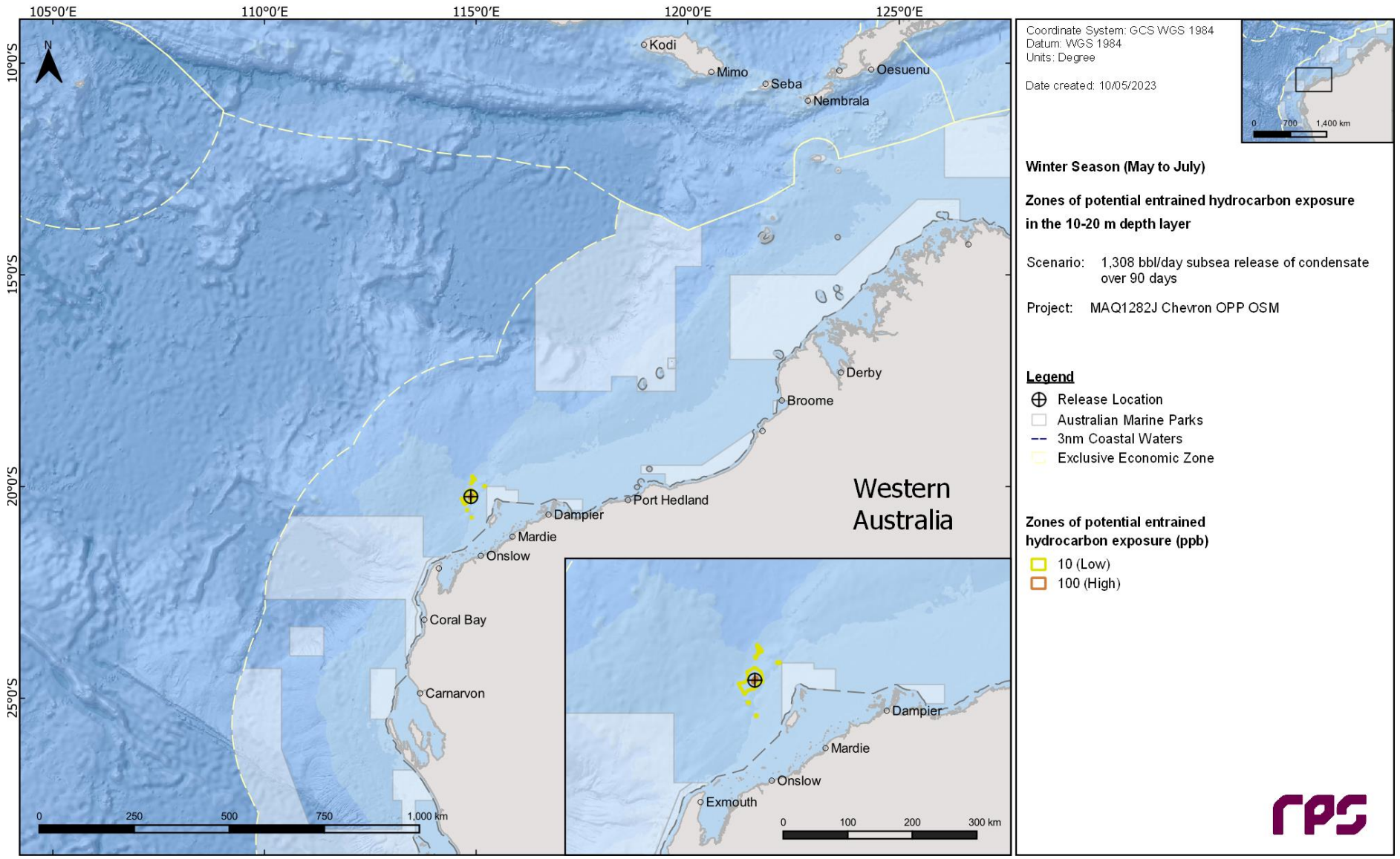


Figure 11.12 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), largest volume of oil ashore (see Section 11.2.2), longest length of shoreline accumulation above 100 g/m^2 (see Section 11.2.2) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.8 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation and entrained hydrocarbon values at the assessed thresholds.

Note there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 481 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 27 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.8 Summary of the deterministic analysis following a subsea LOWC at Chrysaor Well 5.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m^2	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Transitional	Summer	Summer	Transitional
Run Number		78	80	46	55
Floating Oil (km^2)	1 g/m^2	481	322	294	251
	10 g/m^2	**7**	4	2	2
	50 g/m^2	-	-	-	-
Shoreline Length (km)	10 g/m^2	-	110	67	-
	100 g/m^2	-	3	**5**	-
	1,000 g/m^2	-	-	-	-
Minimum Time (days)		-	32.4	81.0	-
Maximum Volume (m^3)		-	**32**	29	-
Entrained Area (km^2)	10 ppb	49,383	78,046	79,755	105,594
	100 ppb	1,232	1,342	1,471	**2,628**
Dissolved Area (km^2)	10 ppb	-	-	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		1 April 2016	15 November 2010	27 September 2010	25 August 2013

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 78 during the transitional period.

Figure 11.13 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.14 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.15 presents the fates and weathering for the corresponding simulation and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.9 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	175	55	2
Entrained (m^3)	1,679	90	1,161
Dissolved (m^3)	2	48	0
Evaporation (m^3)	14,634	104	14,634
Decay (m^3)	3,015	104	3,015
Ashore (m^3)	0	0	0

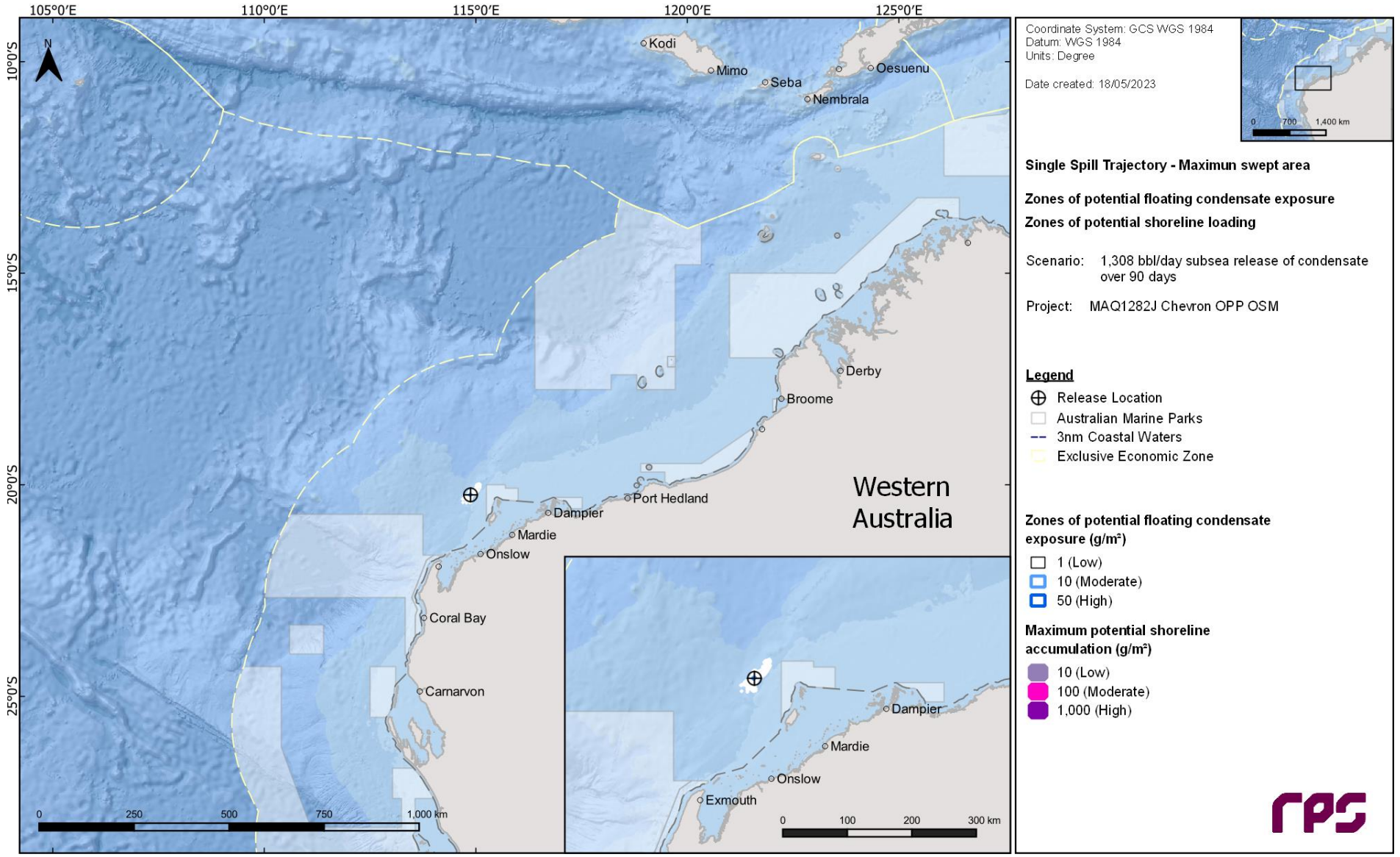


Figure 11.13 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Chrysaor Well 5.

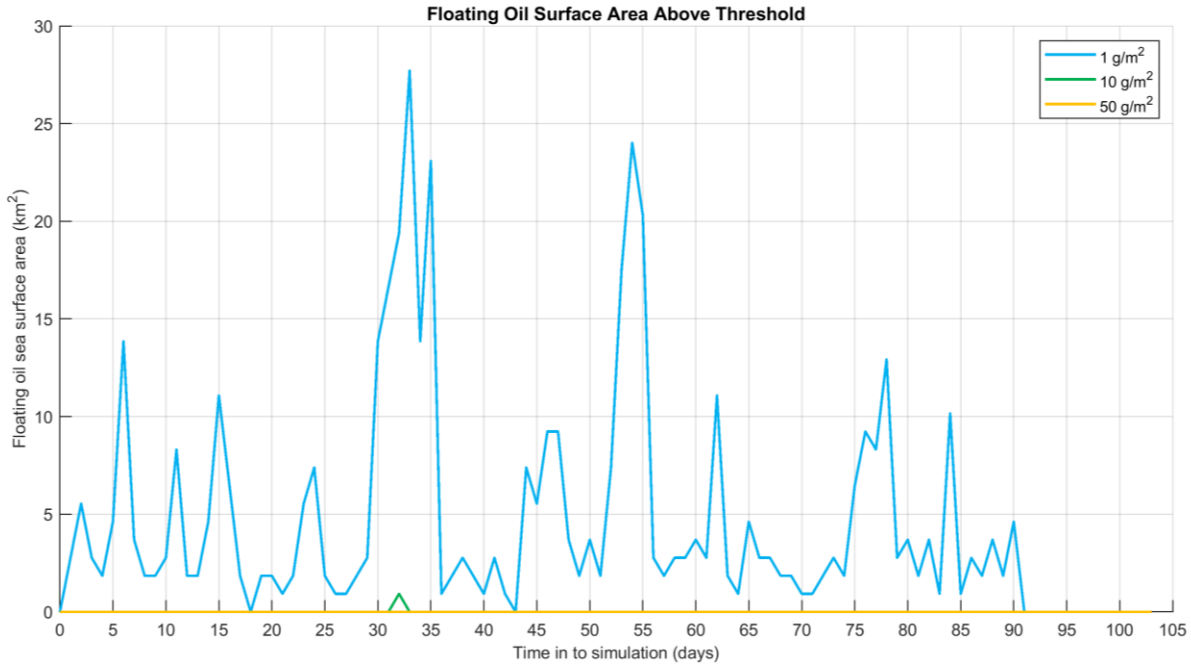


Figure 11.14 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chrysaor Well 5.

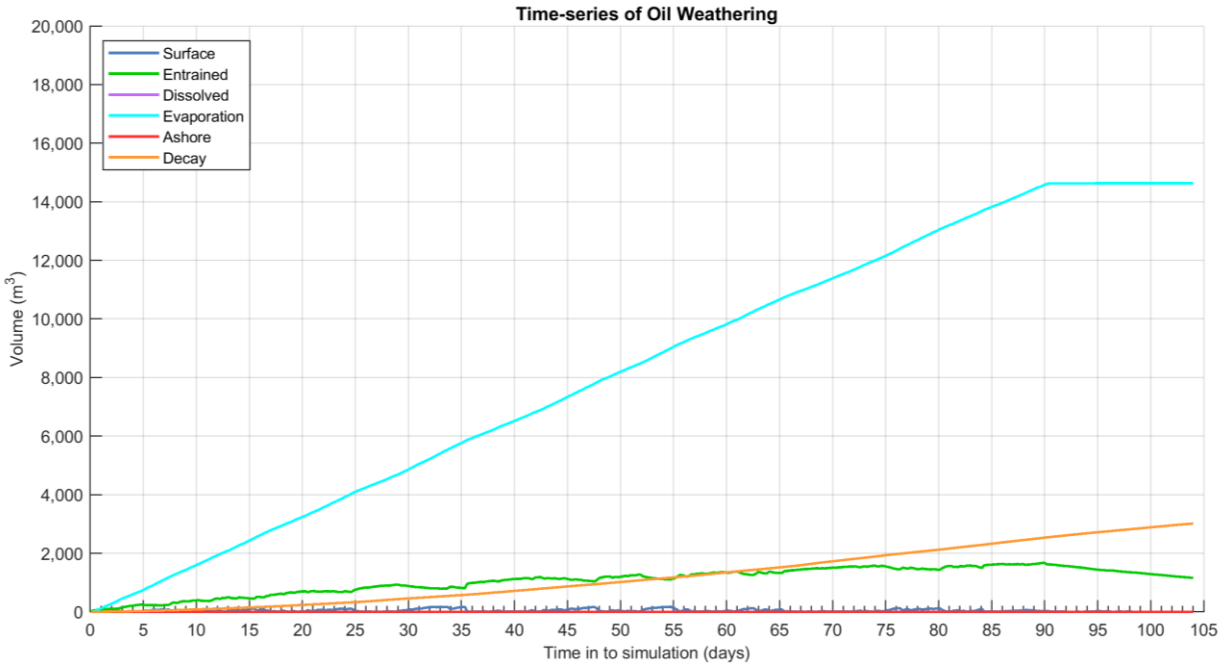


Figure 11.15 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chrysaor Well 5.

11.2.2 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 80, during the summer season.

Figure 11.16 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.17 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.18 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	130	75	0
Entrained (m^3)	1,668	88	1,153
Dissolved (m^3)	2	59	0
Evaporation (m^3)	14,494	104	14,494
Decay (m^3)	3,138	104	3,138
Ashore (m^3)	32	103	31

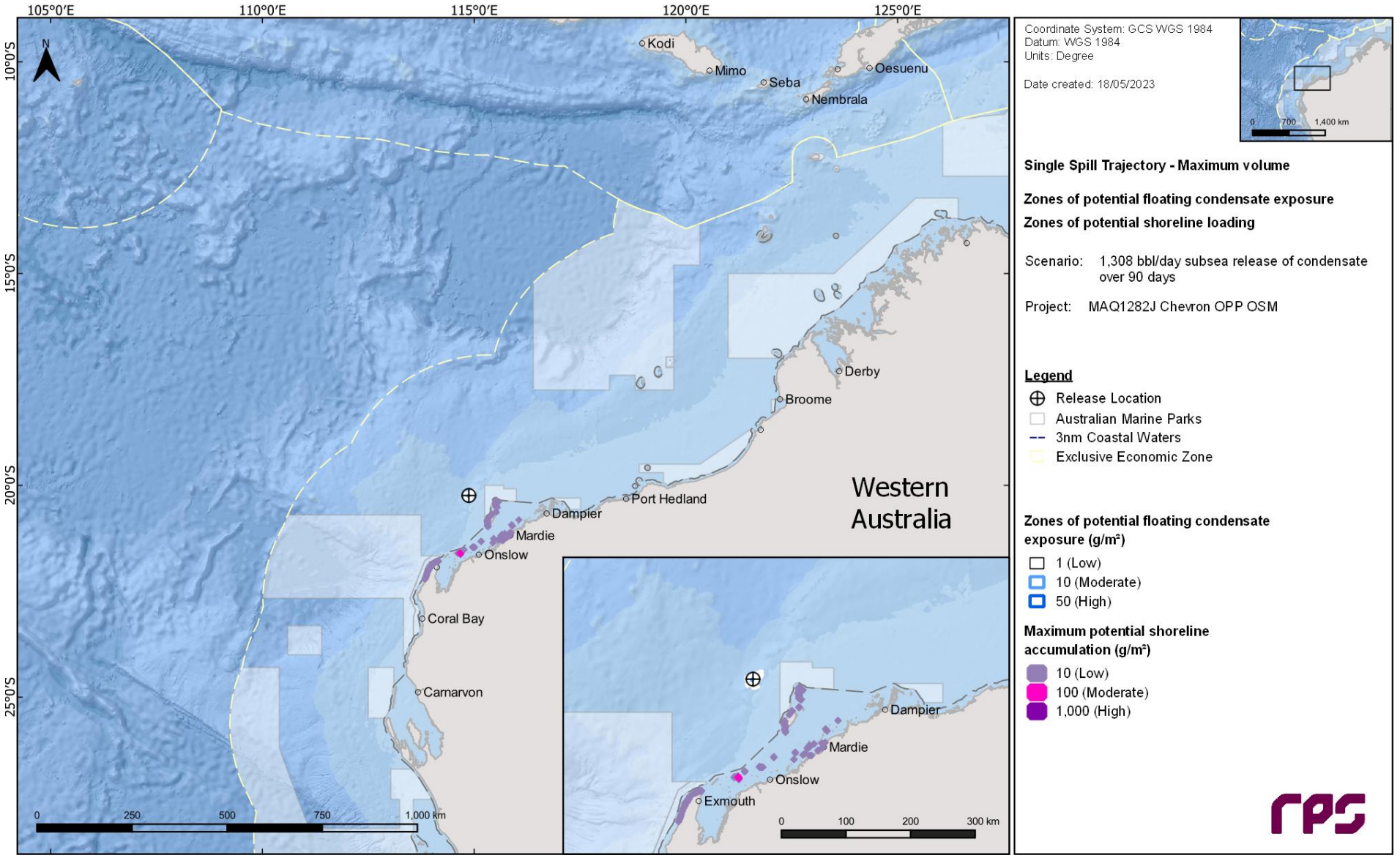


Figure 11.16 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a LOWC at Chrysaor Well 5.

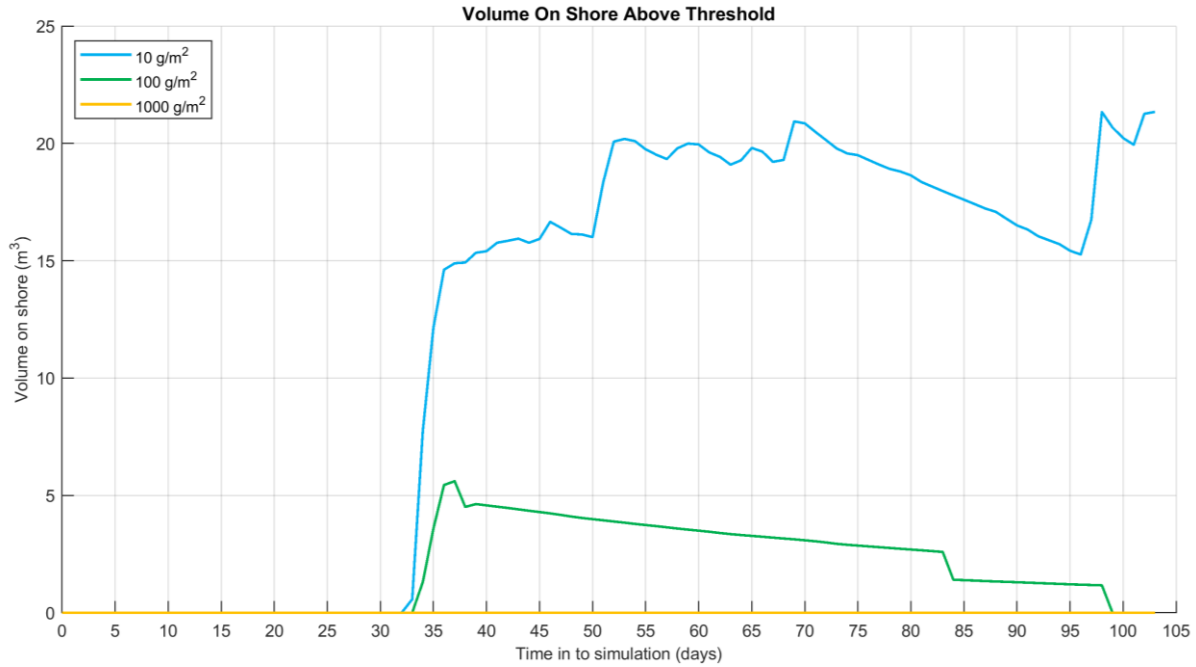


Figure 11.17 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore following a LOWC at Chrysaor Well 5.

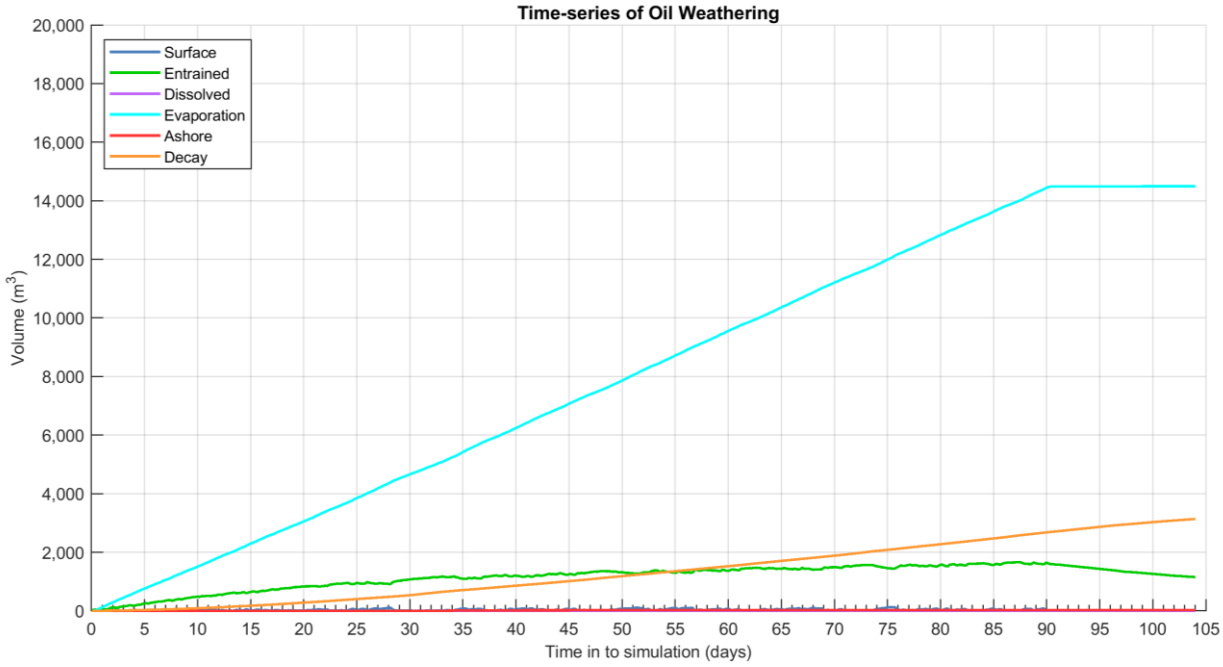


Figure 11.18 Predicted weathering and fates for the simulation with the largest volume of oil ashore following a LOWC at Chrysaor Well 5.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 46 during the summer period.

Figure 11.16 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.17 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.18 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	134	23	8
Entrained (m^3)	1,788	82	1,219
Dissolved (m^3)	2	33	0
Evaporation (m^3)	14,203	104	14,203
Decay (m^3)	3,357	104	3,357
Ashore (m^3)	29	101	29

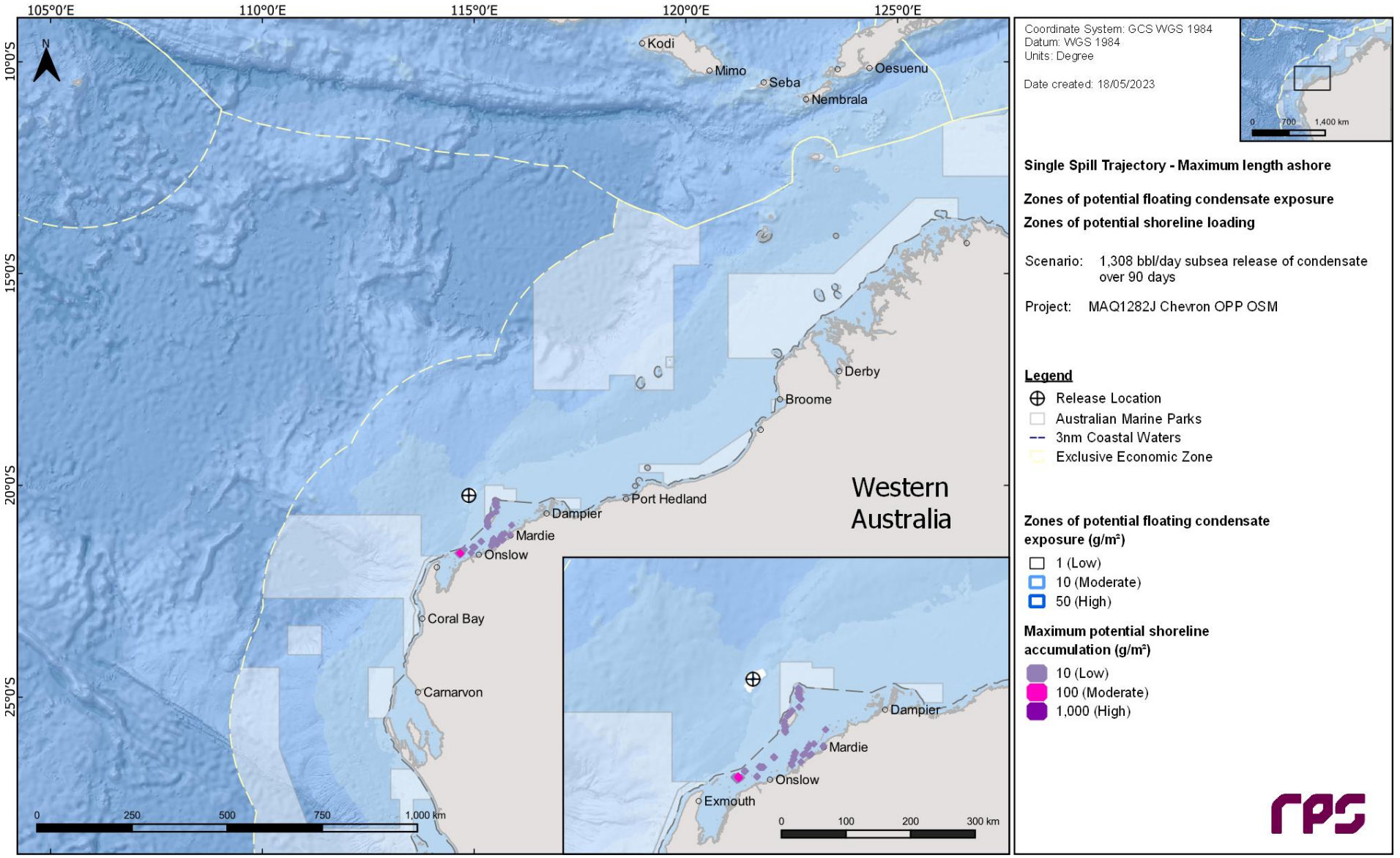


Figure 11.19 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Chrysaor Well 5.

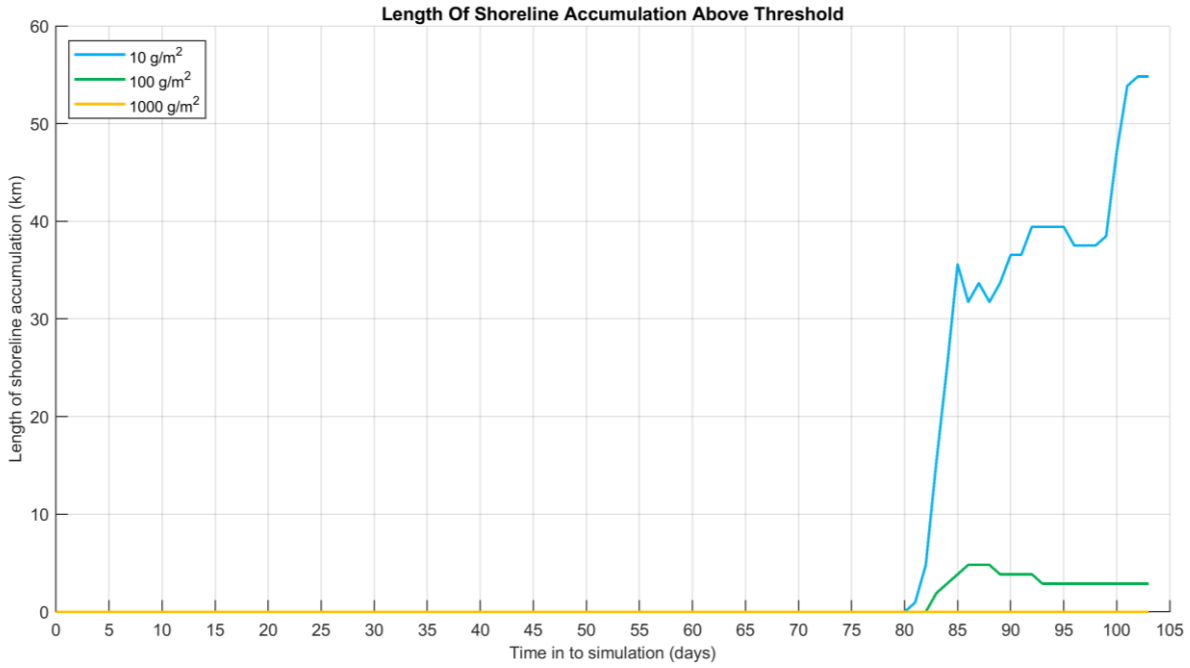


Figure 11.20 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Chrysaor Well 5.

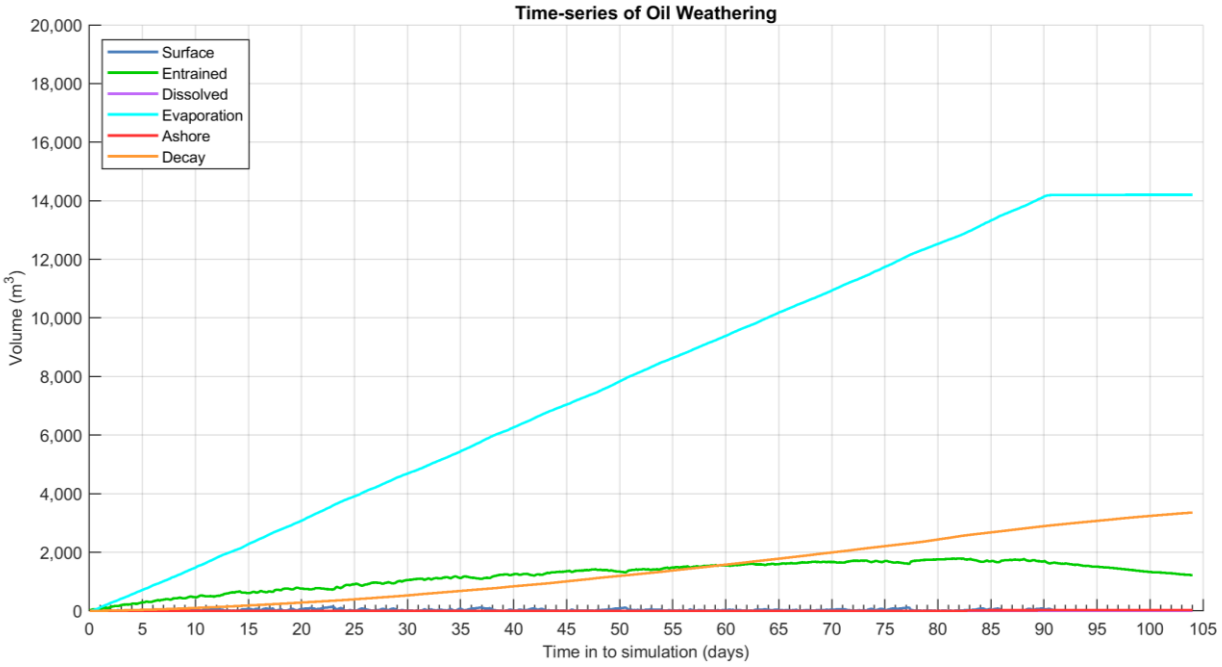


Figure 11.21 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Chrysaor Well 5.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (moderate threshold) was identified as run number 55 during the transitional period.

Figure 11.22 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.23 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.24 presents the fates and weathering for the corresponding single spill trajectory and Table 11.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.12 Summary of the peak volumes and times of occurrence for each oil phase and the volumes at day 104, for the trajectory with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	113	38	8
Entrained (m^3)	1,902	90	1,336
Dissolved (m^3)	2	81	0
Evaporation (m^3)	13,817	104	13,817
Decay (m^3)	3,656	104	3,656
Ashore (m^3)	0	0	0

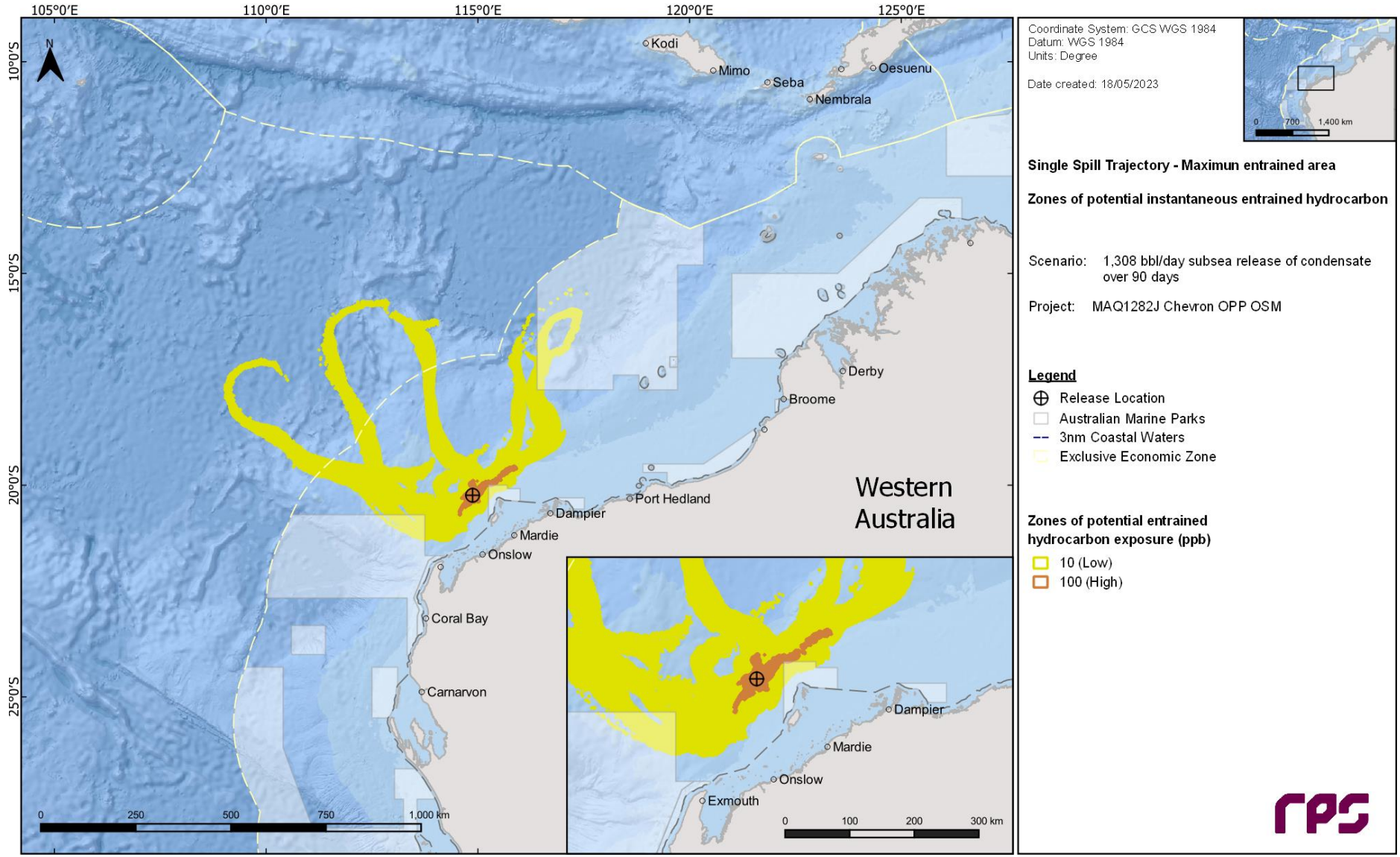


Figure 11.22 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

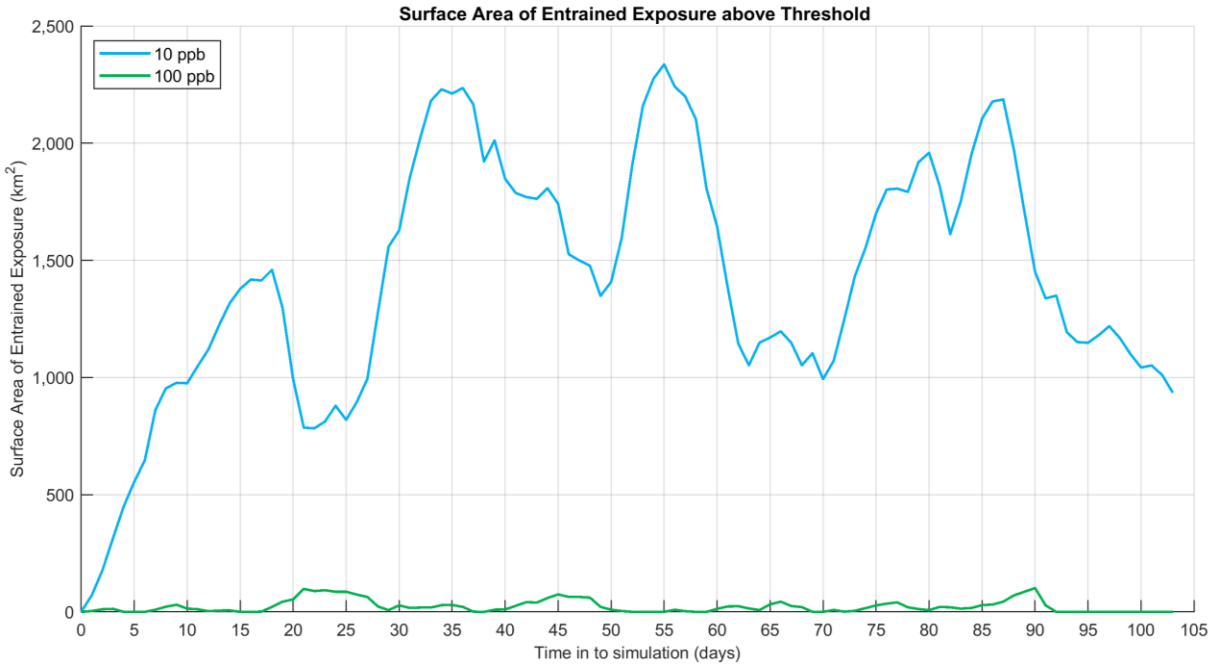


Figure 11.23 Time series of the area of entrained hydrocarbons for each threshold for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

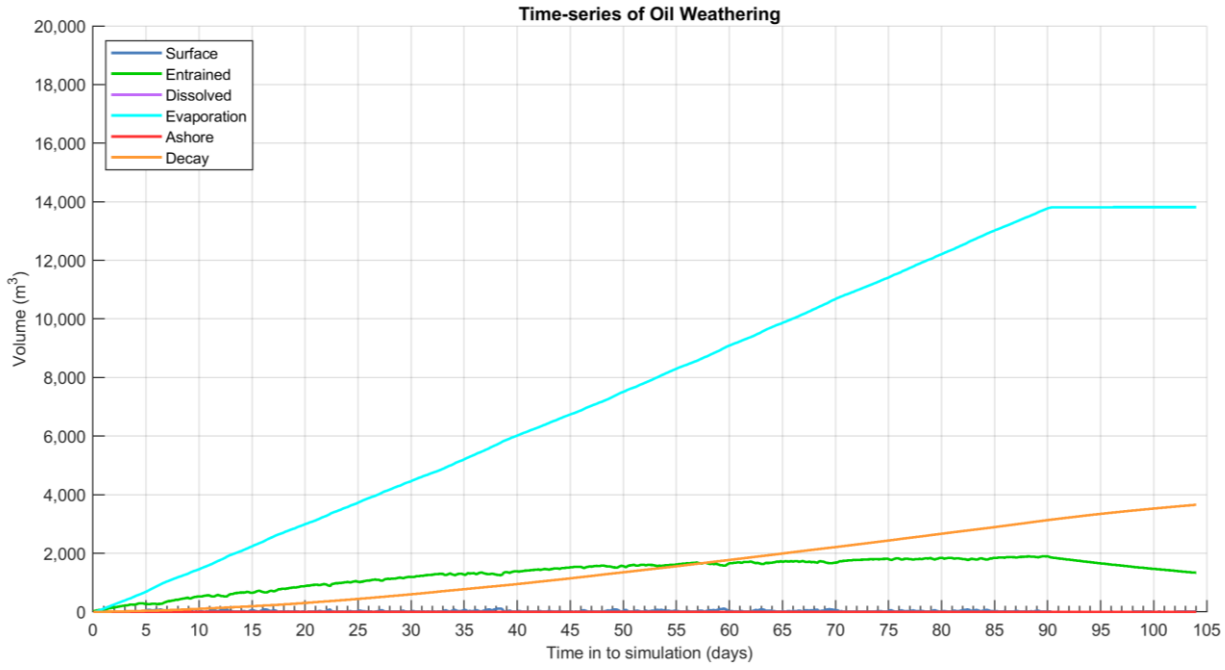


Figure 11.24 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

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appendix c.5—semele LOWC (condensate)

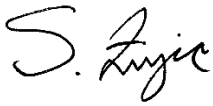
GREATER GORGON – SEMELE

Oil Spill Modelling

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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
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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating condensate 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
g/m^2	Grams per square meter (unit of surface area density)
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.
IAA	Impact Assessment Area

IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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
SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Semele field situated within the Northern Carnarvon Basin in Permit area WA-15-R, northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 2,441 stb/day (388.1 m^3/day) subsea release of condensate over 90 days (totalling 219,690 stb or 34,927 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Semele condensate has an API of 41.9, a density of 816 kg/m^3 (at 15ºC) and a viscosity value of 6.7 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 33% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 32.5% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (27.9%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 6.5% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. For this condensate, the aromatic hydrocarbons contribute 3.9% and are all contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 144.5 km southwest (summer) and 2.2 km west southwest (winter and transitional), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Wedge-tailed Shearwater – Breeding BIA which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probability for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 6% (summer) and 18% (transitional).

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 27%, while the minimum time before shoreline accumulation was 13.7 days and the maximum volume of condensate ashore above the low threshold was 29.0 m^3.

- No high (≥ 1,000 g/m^2) shoreline threshold accumulation was observed in the modelling results.

- During summer conditions, condensate had accumulated on 62 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (19%). In comparison, during transitional and winter conditions condensate had accumulated on 10 and 4 shoreline receptors, respectively. During transitional conditions, the greatest probabilities had occurred at Cunningham Island (Imperieuse Reef), Argo-Rowley Terrace IAAs and Imperieuse Reef, all 3% probability. While for the winter season, the same three receptors recorded a 9% probability.

- There were several receptors exposed at or above the low threshold for dissolved hydrocarbons (≥ 10 ppb) during summer and winter, however they were all 1% occurrence.

- In the 0-10 m depth layer, a total of 34, 22 and 21 BIAs were shown to be exposed at or above the low threshold during summer, transitional and winter seasons respectively. Excluding the receptors that the release location resides within, the highest probabilities of exposure were shown for the Flatback Turtle – Internesting Buffer BIA during summer (100%), transitional (97%) and winter (90%) conditions.

- Across the three seasons, 6 Australian Marine Parks (AMP) were predicted to be exposed at, or above the low threshold for entrained hydrocarbons, with the highest probabilities predicted at the Gascoyne AMP (81% summer, 82% transitional and 74% winter).

- A total of 6 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Continental Slope Demersal Fish Communities KEF that the release site is located within. Excluding that receptor, probabilities of exposure ranged between 6–80%, 1–92% and 1–80%, for summer, transitional and winter, respectively.

- A total of 37 IAAs were shown to be exposed to entrained hydrocarbons at low threshold.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Semele field situated within the Northern Carnarvon Basin in Permit area WA-15-R, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the Semele field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 2,441 stb/day (388.1 m^3/day) subsea release of condensate over 90 days (totalling 219,690 stb or 34,927 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 Semele release location.

Location	Latitude	Longitude	Depth (mLAT)
Semele Well 5	19.99726° S	114.94312° E	800

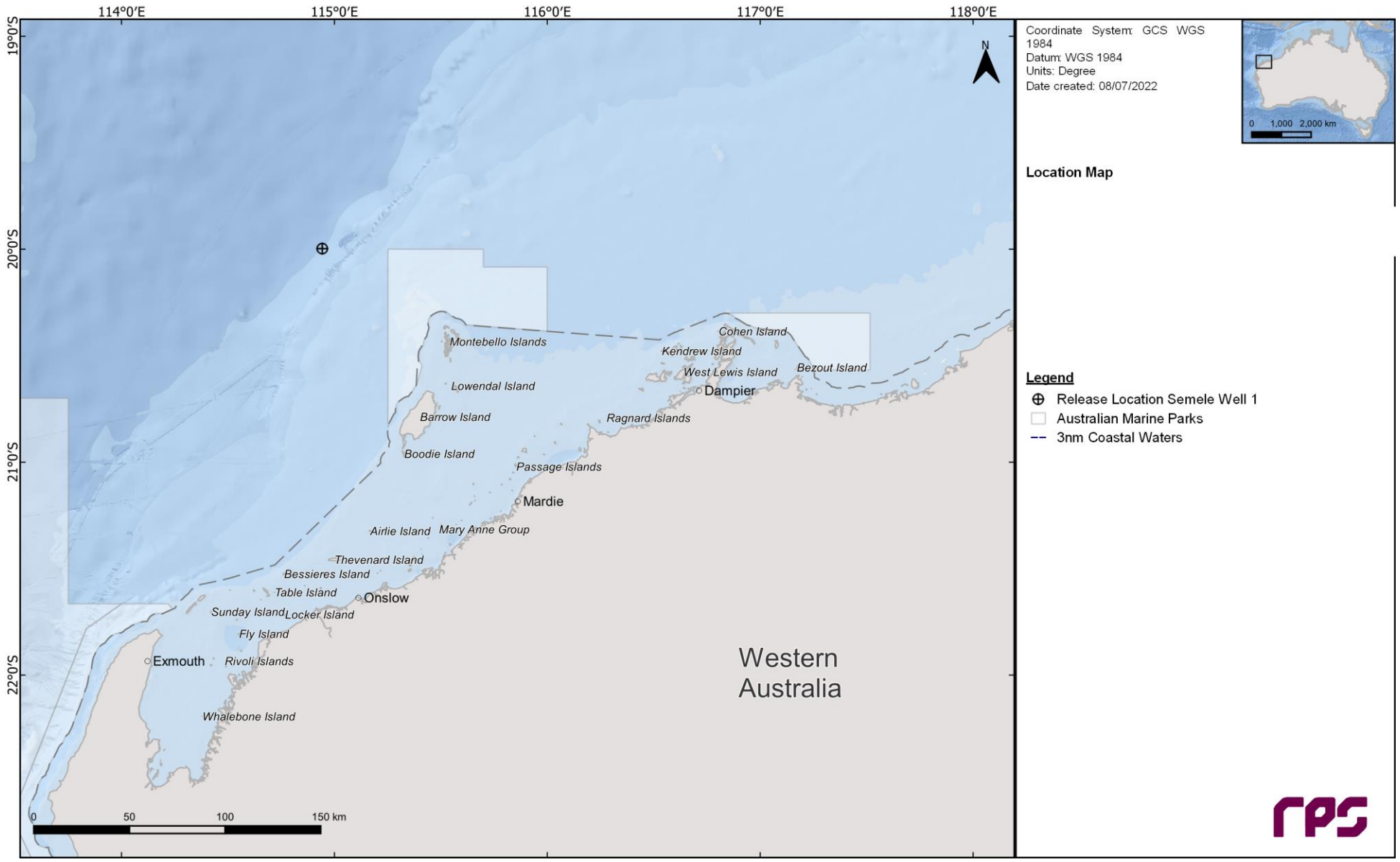


Figure 1.1 Semele hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
    a. Largest swept area of floating hydrocarbon above 10 g/m^2
    b. Largest swept area of floating hydrocarbon above 50 g/m^2
    c. Largest volume of condensate ashore
    d. Longest length of shoreline accumulation above 100 g/m^2
    e. Largest area of entrained hydrocarbons above 100 ppb
    f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

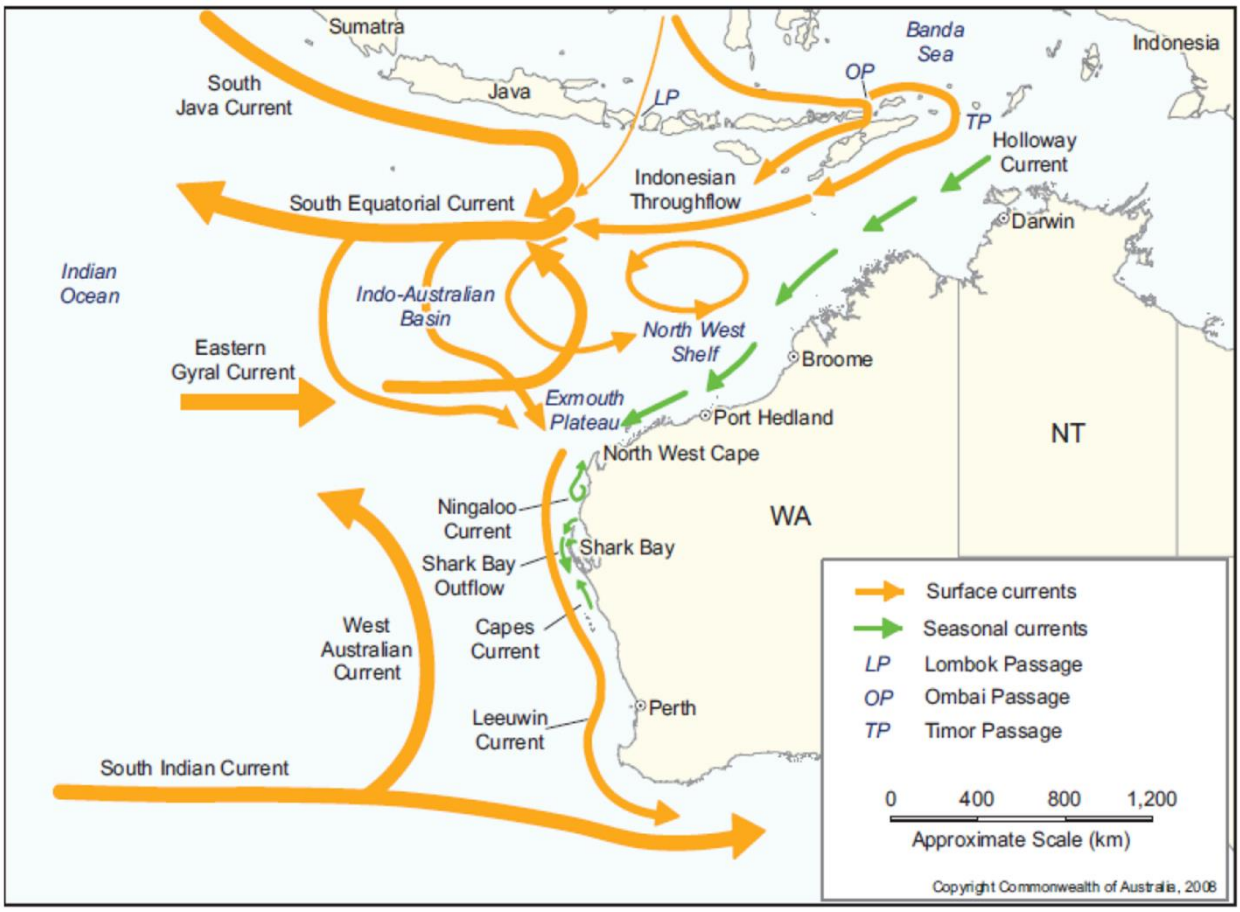


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

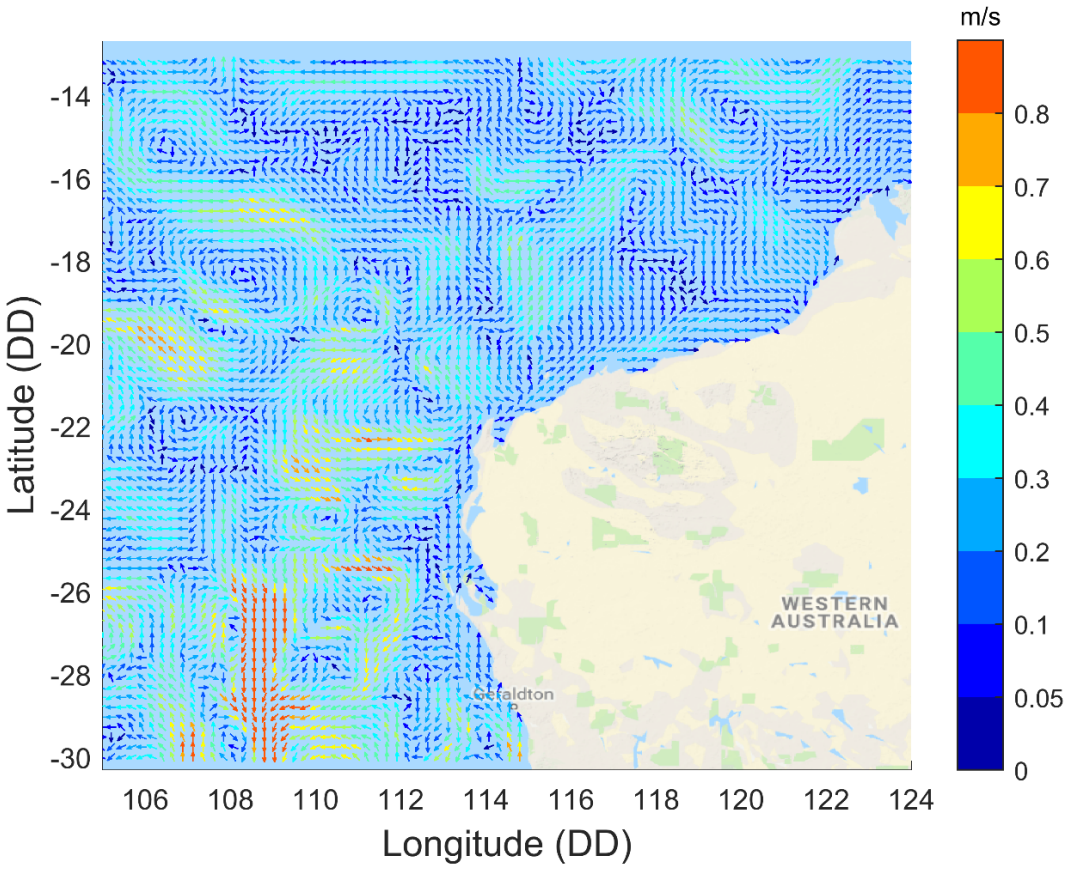


Figure 3.2 Typical ocean current circulation pattern during the summer months.

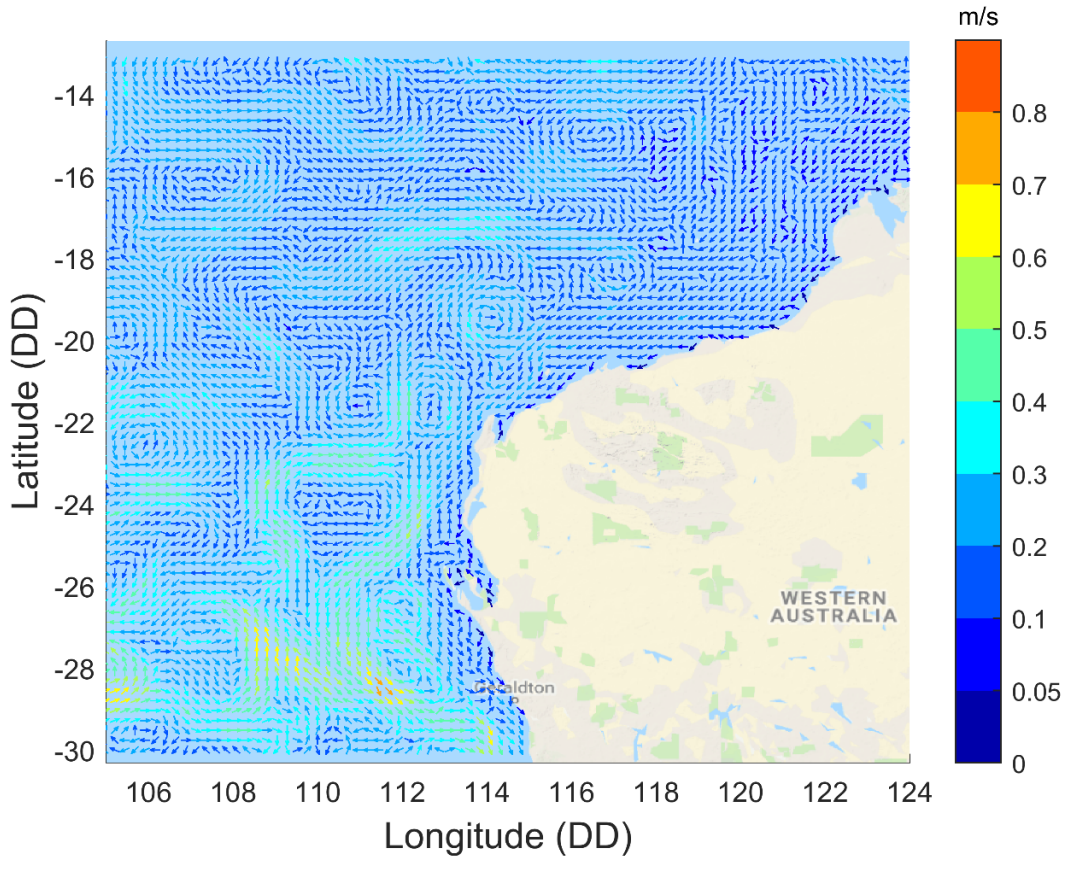


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

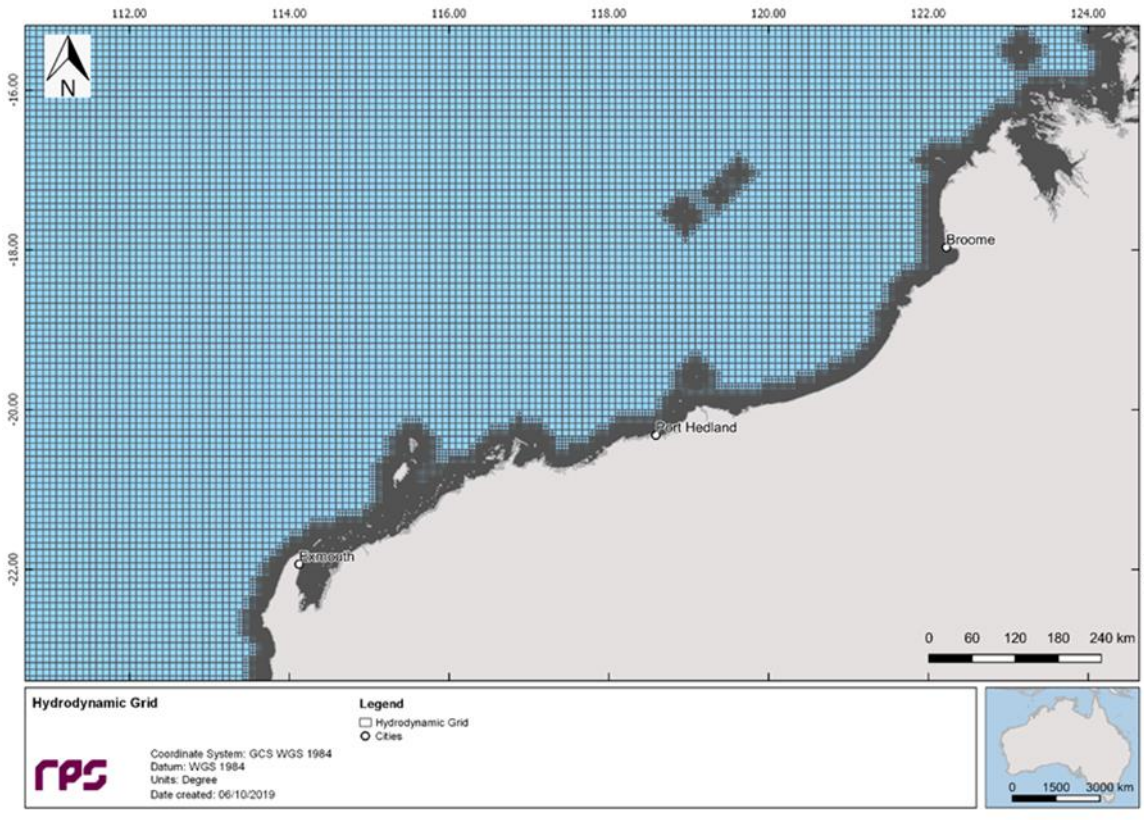


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

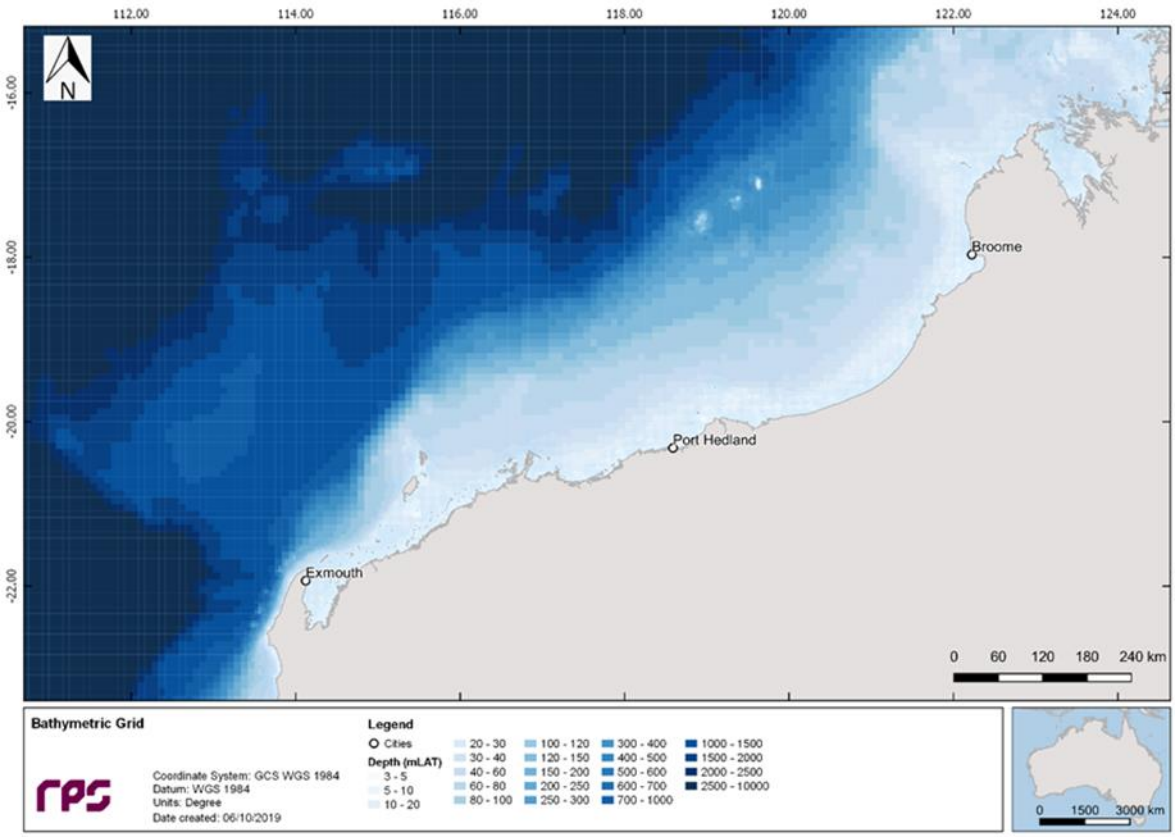


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.18 m/s (November) and 0.26 m/s (June). Additionally, the maximums ranged between 0.57 m/s (November) and 1.63 m/s (January). The general current directions were predominately southwest and then northeast throughout the year. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.21	1.63	Northeast and Southwest
	February	0.19	1.09	Northeast and Southwest
	March	0.21	1.50	Southwest
Transitional	April	0.23	1.02	Southwest
Winter	May	0.24	0.78	Southwest
	June	0.26	1.01	Southwest
	July	0.22	0.98	Southwest
Transitional	August	0.19	0.60	Northeast and Southwest
Summer	September	0.20	0.87	Northeast and Southwest
	October	0.20	0.67	Northeast and Southwest
	November	0.18	0.57	Southwest
	December	0.20	0.69	Southwest
Minimum		**0.18**	**0.57**	
Maximum		**0.26**	**1.63**	

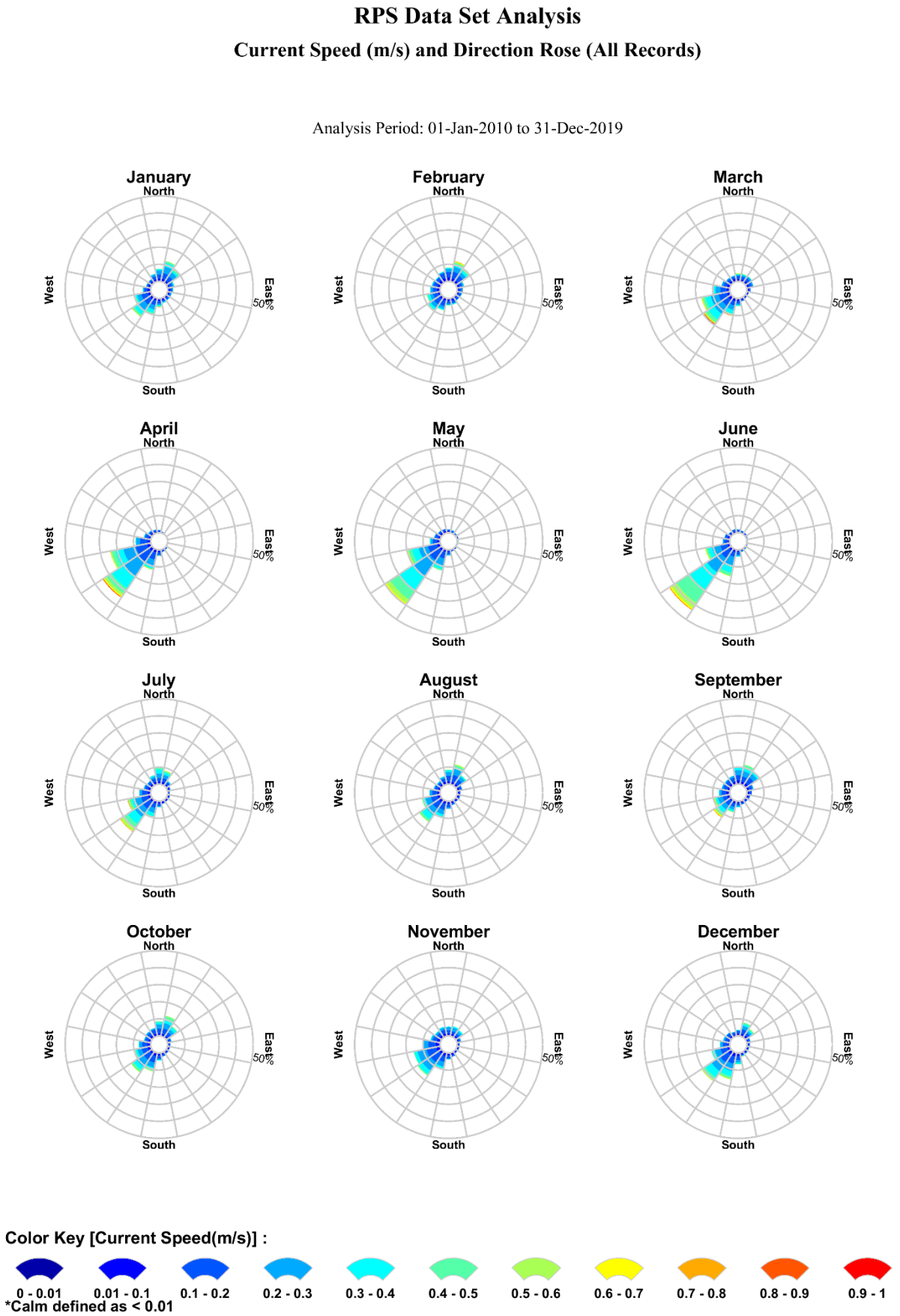


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

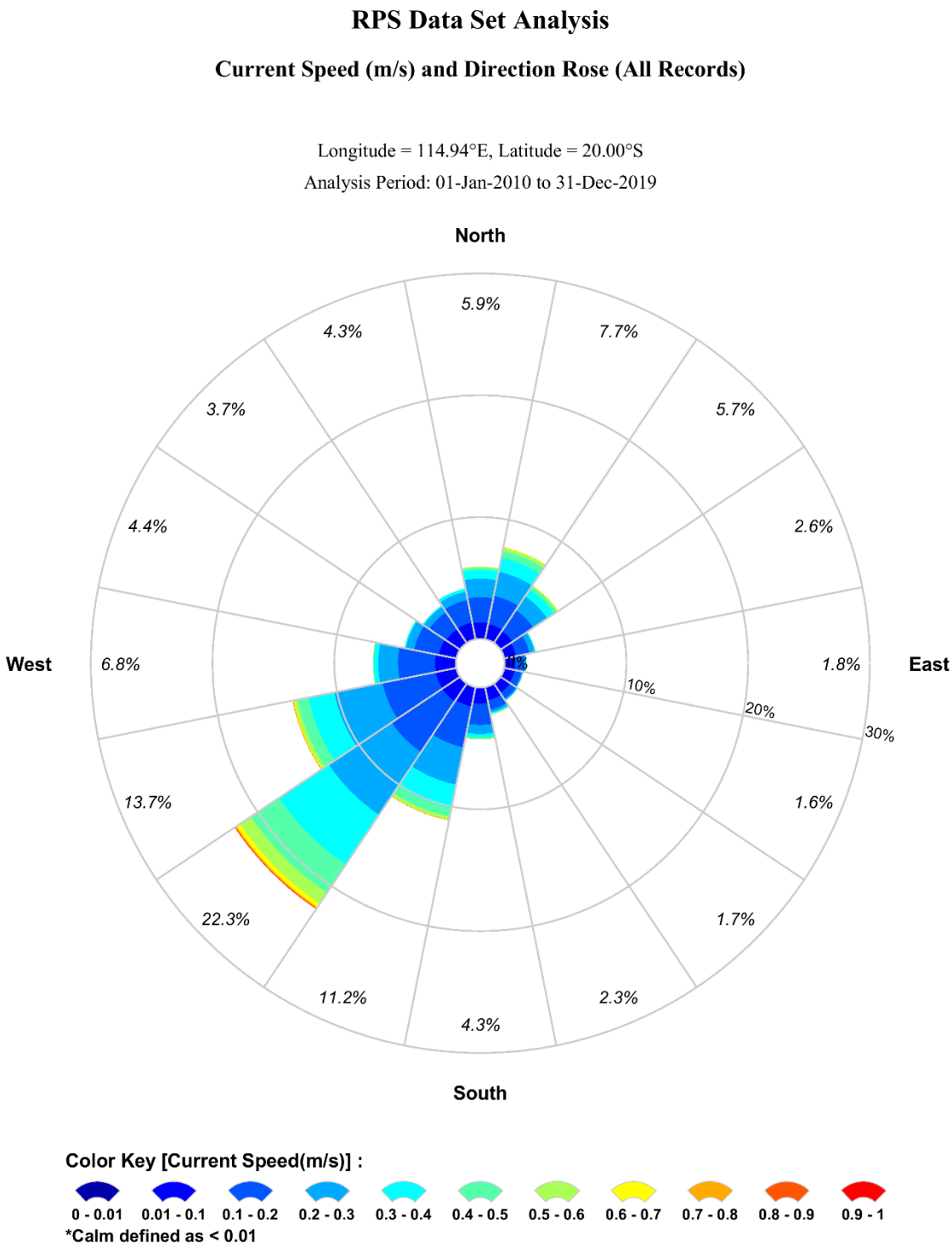


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 46 knots (February). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

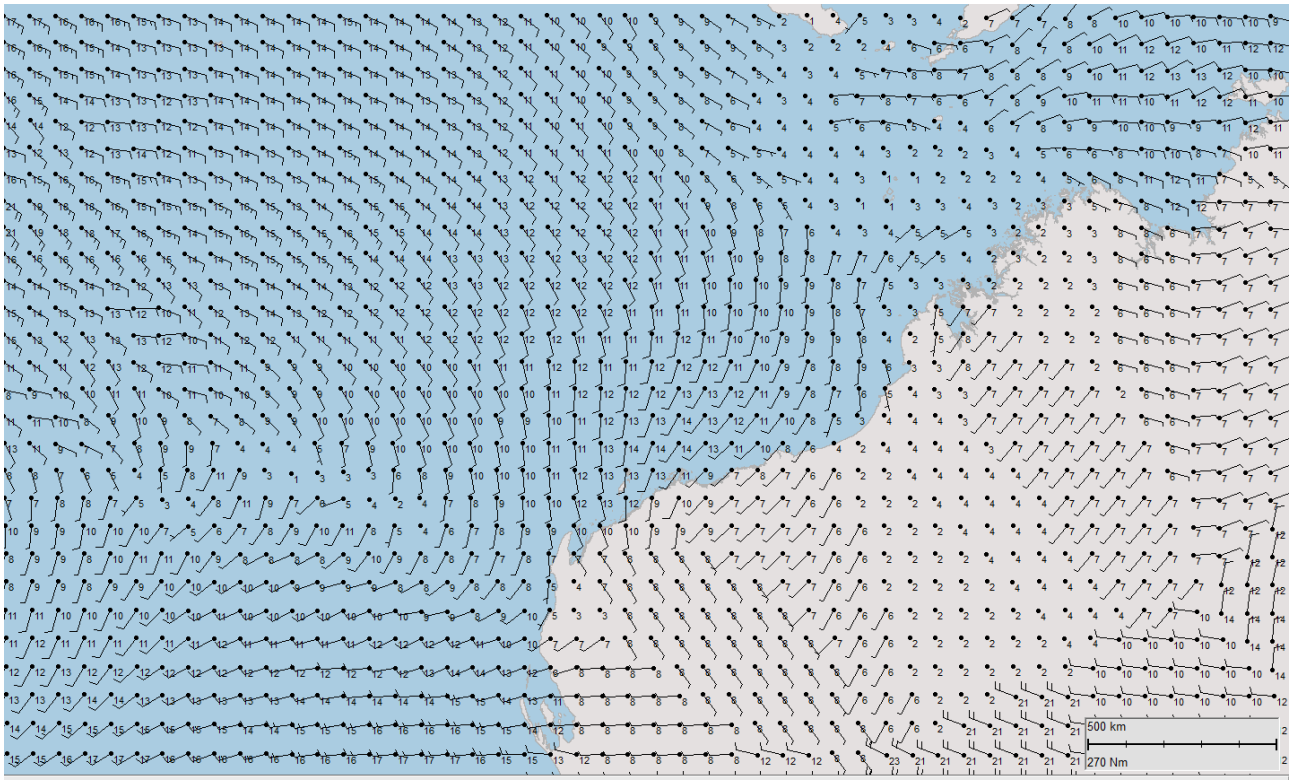


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	45	Southwest
	February	11	46	Southwest
	March	10	34	Southwest
Transitional	April	10	39	South
Winter	May	12	43	East
	June	14	29	East
	July	13	48	Southeast
Transitional	August	11	30	South
Summer	September	12	27	Southwest
	October	13	27	Southwest
	November	13	25	Southwest
	December	13	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**46**	

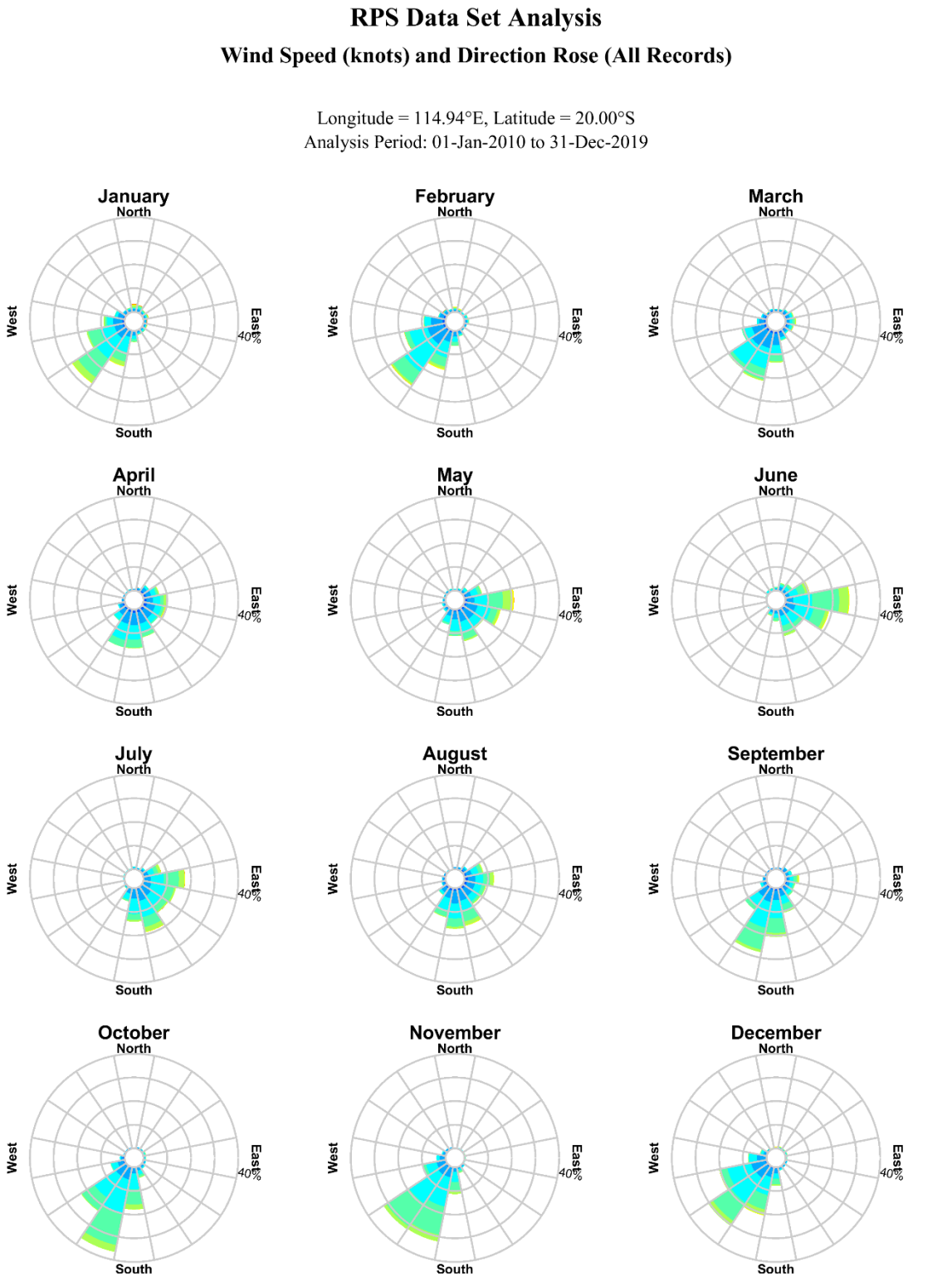


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

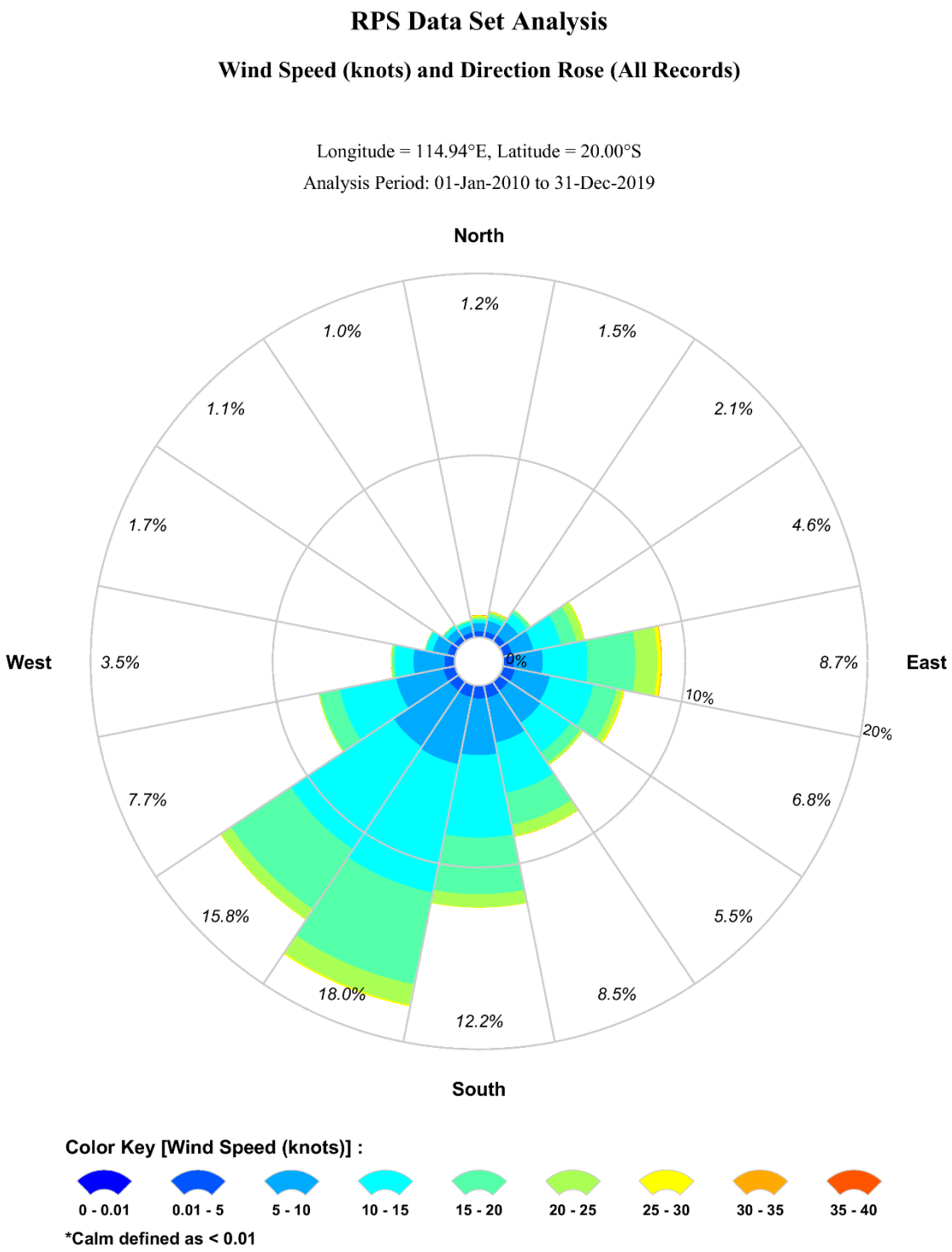


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.3°C (September) to 29.5°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.1 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.9	28.7	29.5	28.9	28.0	26.7	25.6	24.7	24.3	25.1	27.2	27.1
Salinity (psu)	35.1	34.7	34.8	34.9	35.1	35.1	34.9	34.8	34.8	34.8	34.6	34.9

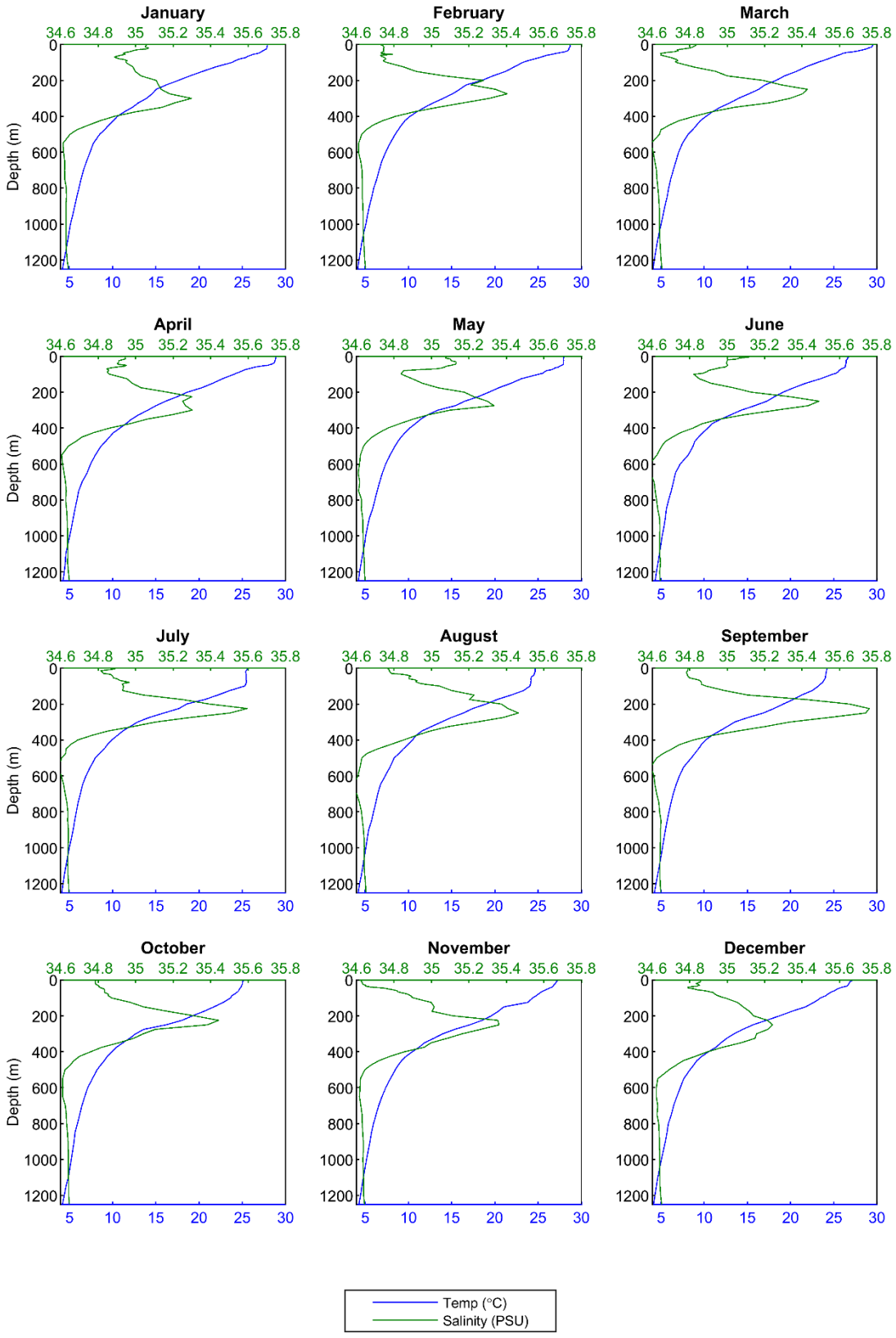


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

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).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 424 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which are predicted to range in size from 115 to 496 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Semele Well 5
Water depth (m)	800
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	2,441
Gas rate (MMscf/day)	428
Gas to condensate ratio (scf/bbl)	175,338
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,646
Key results	
Plume execution depth (m BMSL)	424
Droplet sizes (µm)	115 to 496

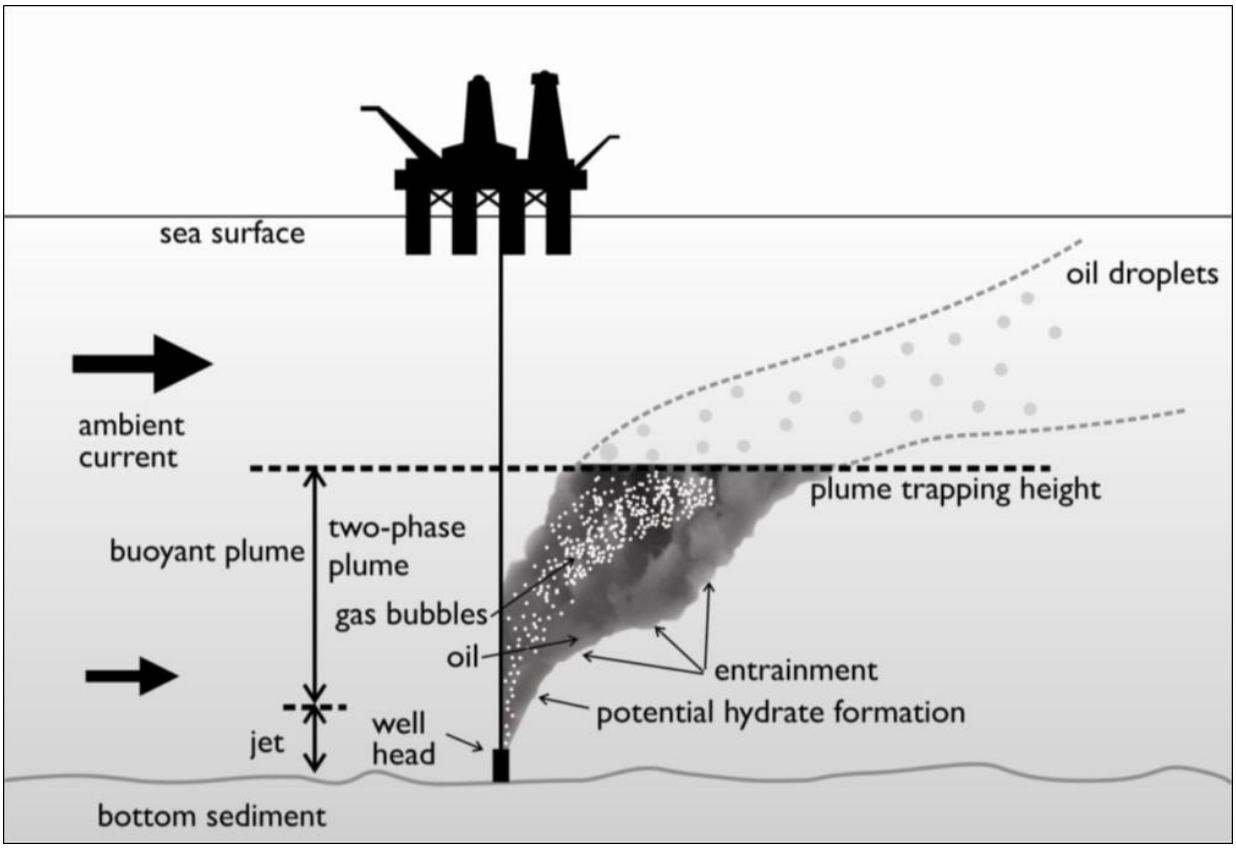


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

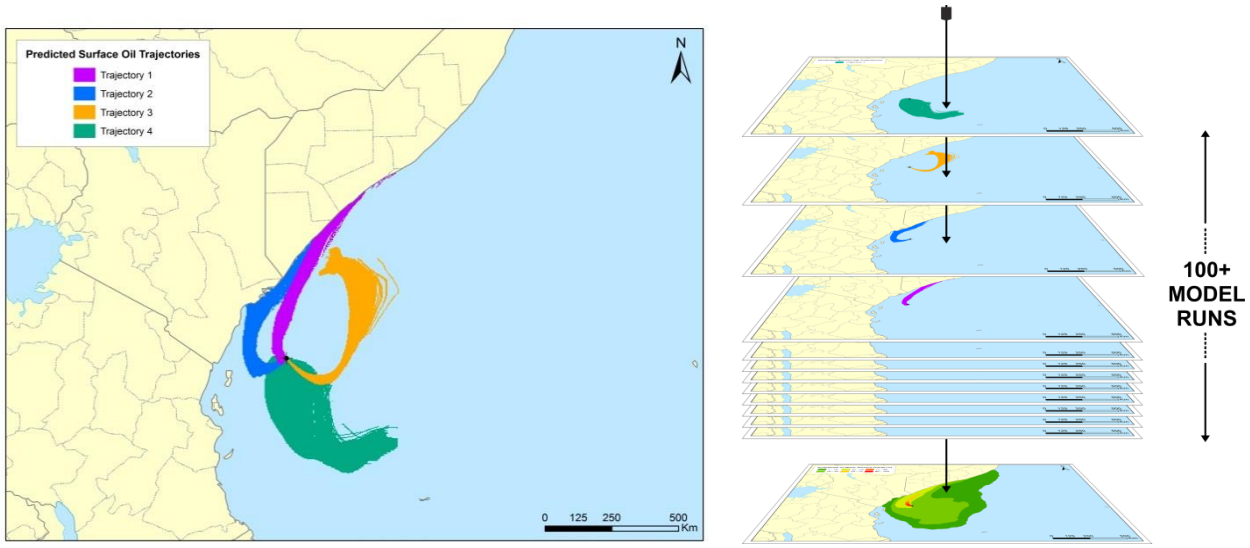


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating condensate exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating condensate exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating condensate exposure reported herein.

Table 7.1 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

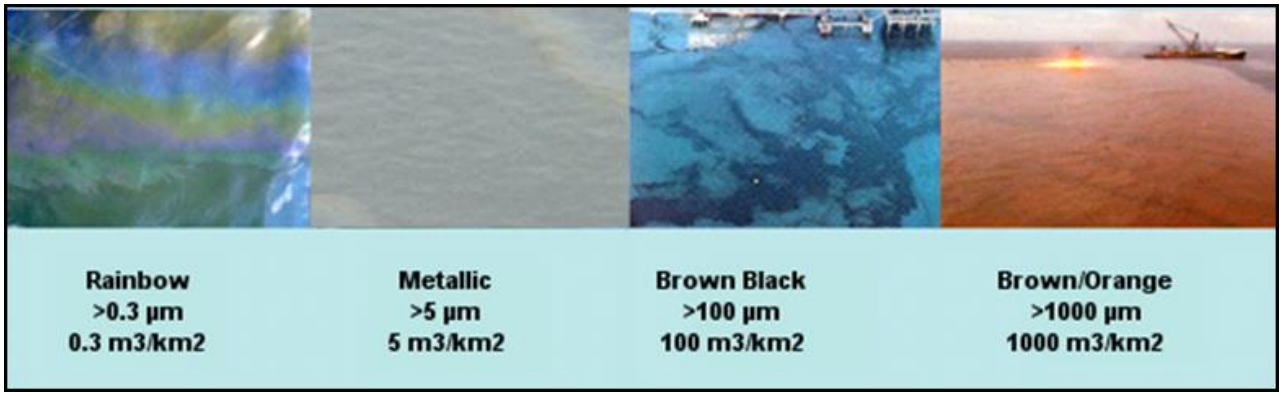


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating condensate exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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 In-water Exposure 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 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on 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 & ARMCANZ (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.

This exposure zone 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 7.4), 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 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

Semele condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

Semele condensate has an API of 41.9, a density of 816 kg/m^3 (at 15ºC) and a viscosity value of 6.7 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 33% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 32.5% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (27.9%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 6.5% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble aromatic hydrocarbons contribute approximately 3.9% by mass of the whole oil, which is contained in the volatile fractions and are highly soluble. The process of evaporation will be grater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of Semele condensate.

Characteristic	Semele Condensate
Density (kg/m^3)	816 (at 15°C)
API	41.9
Dynamic viscosity (cP)	6.7 (at 15°C)
Pour point (°C)	-9
Surface tension (dyne/cm)	22
Hydrocarbon property category	Group I
Hydrocarbon property classification	Non-persistent

Table 8.2 Boiling point ranges of Semele condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Semele Condensate	% of total	33.0	32.5	27.9	6.5
	% of aromatics	3.9	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 66% of the condensate is predicted to evaporate within 24 hours. The majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Semele condensate into the water column was shown to increase. Approximately 24 hours after the spill, 49% of the condensate mass was shown to entrain and a further 49% had evaporated, leaving only a small portion of the condensate floating on the water surface (<0.8%). The residual compounds will tend to remain entrained during conditions that generate wind-waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case would result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.5% per day with an accumulated total of ~11.5% after 7 days, in comparison to a rate of ~0.1% per day and an accumulated total of ~0.7% after 7 days in the constant-wind case. Given the portion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

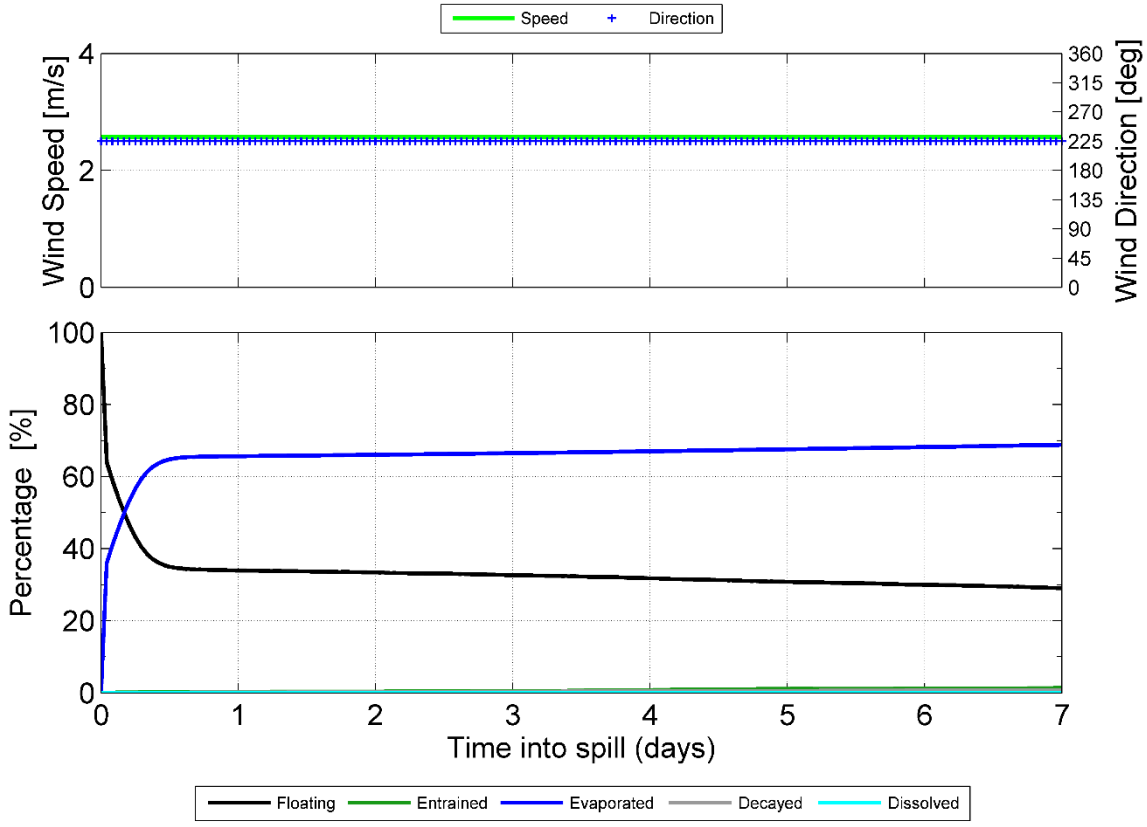


Figure 8.1 Proportional mass balance plot representing the weathering of Semele condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

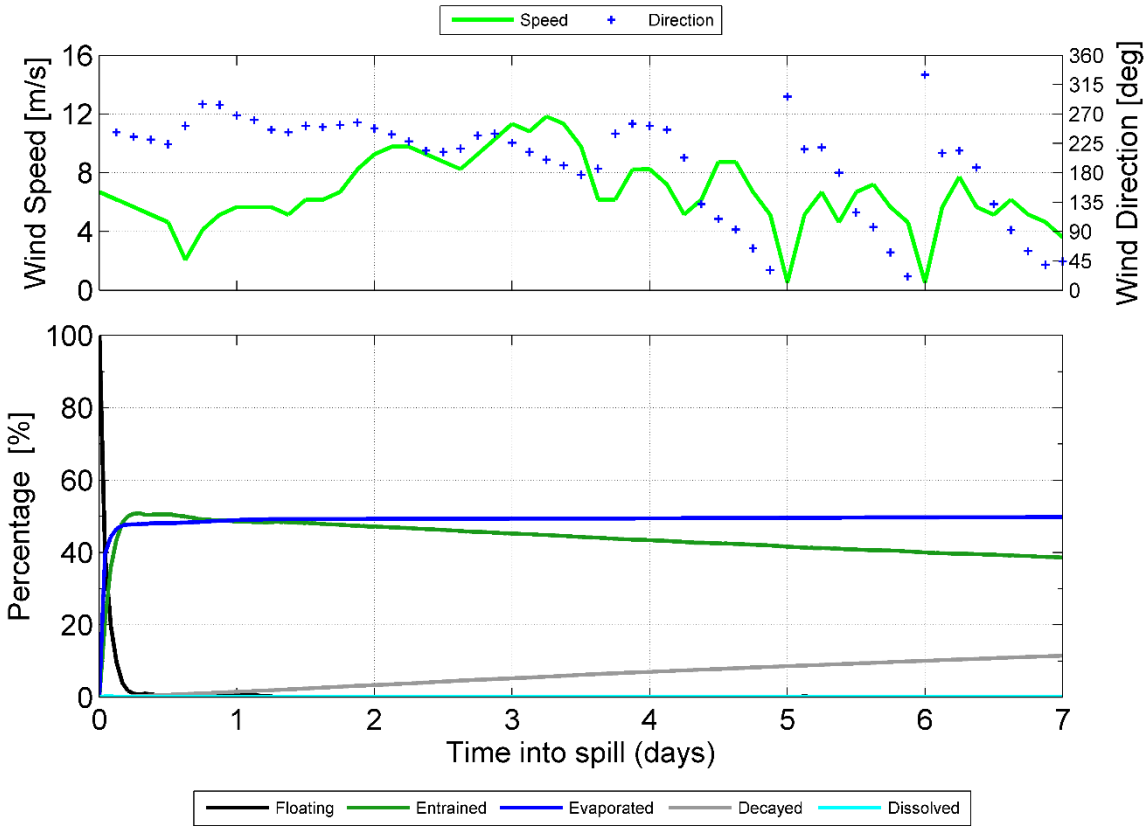


Figure 8.2 Proportional mass balance plot representing the weathering of Semele condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Semele Well 5 (Semele)
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	34,927 [219,690]
Condensate type	Semele condensate
Release type (depth)	Subsea (800 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of condensate ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb; and
f. Largest area of dissolved hydrocarbons above 50 ppb

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Key Ecological Feature	KEF	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
Nature Reserve	NR	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Ramsar Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓
Continental Slope Demersal Fish Communities*	KEF	✓

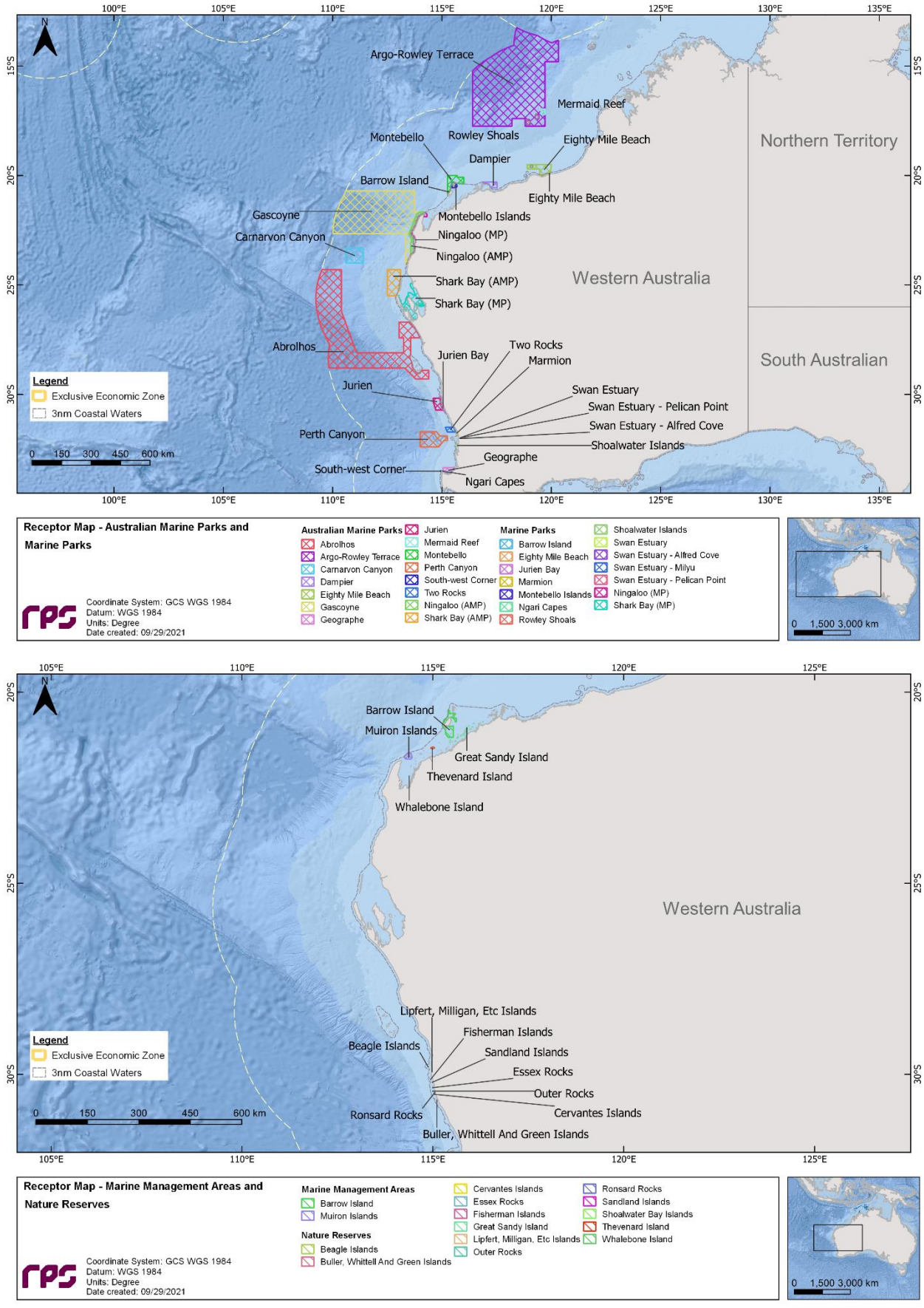


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

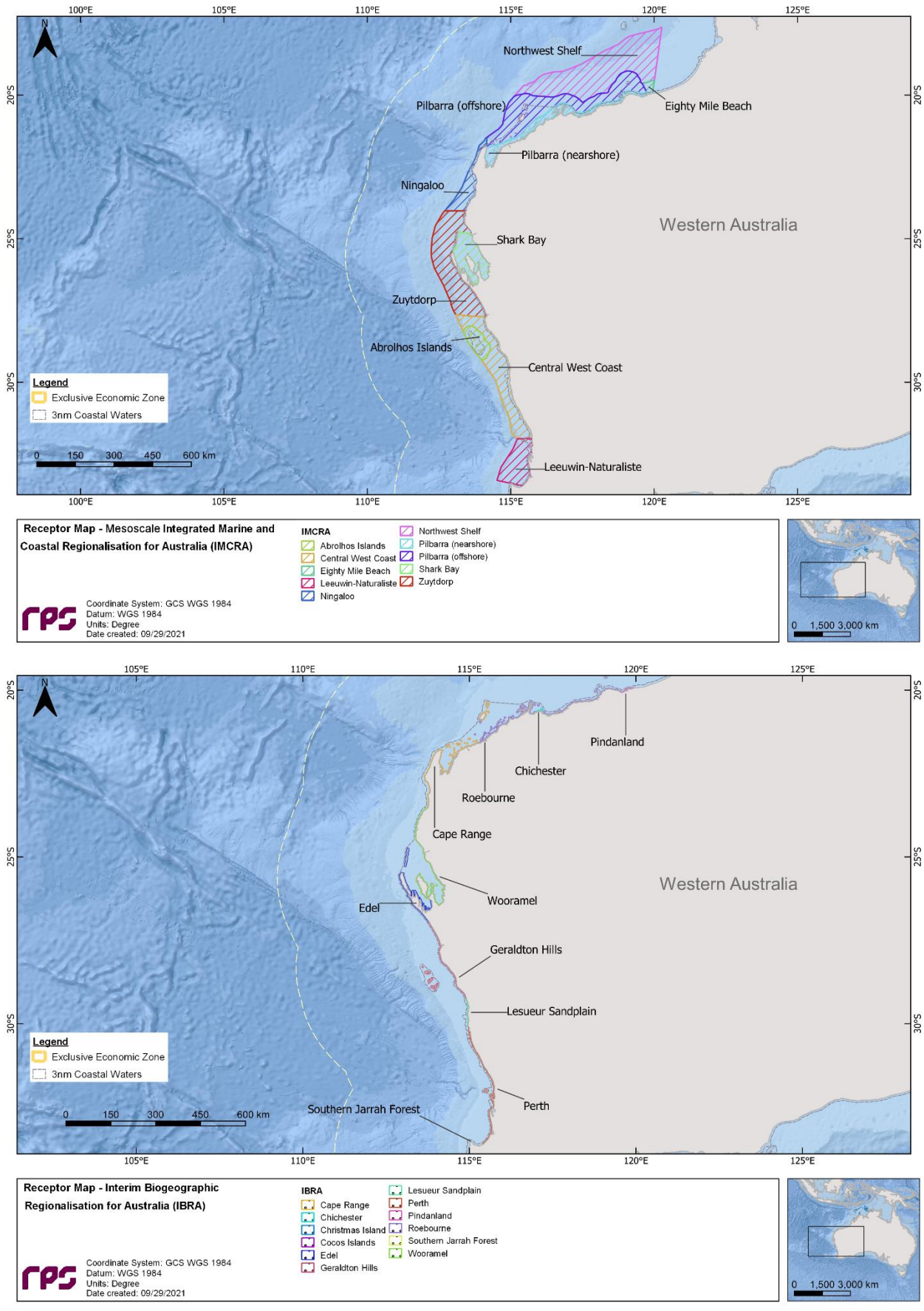


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

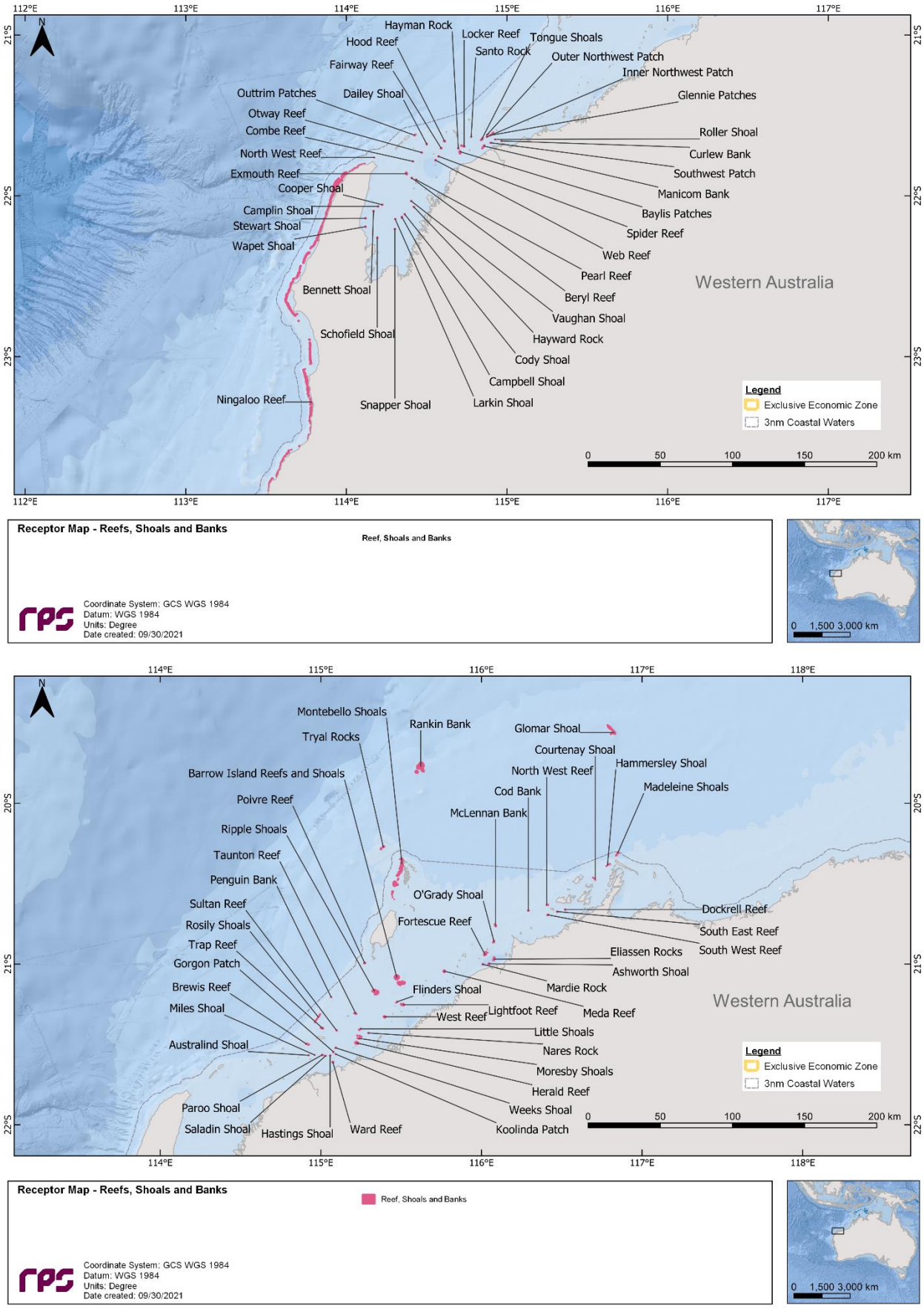


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

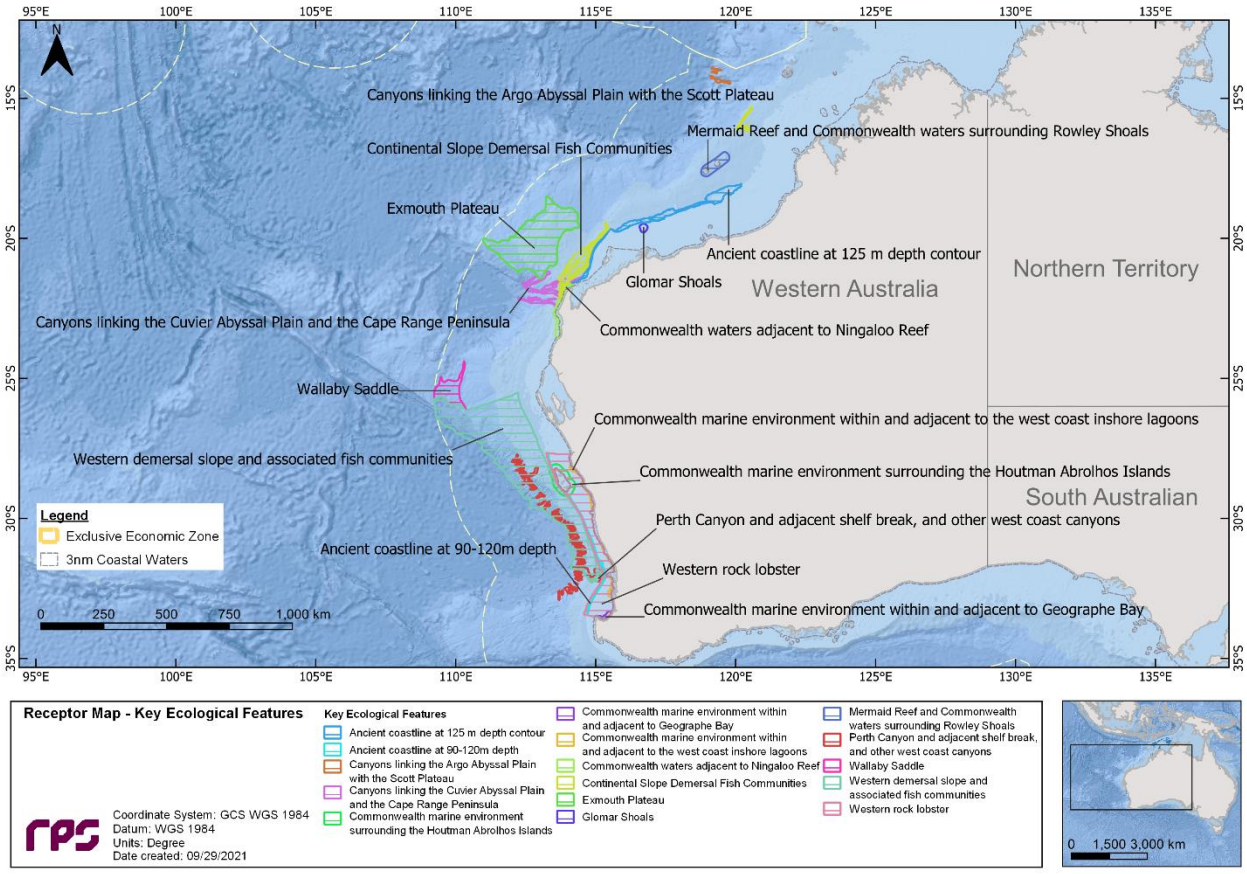


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

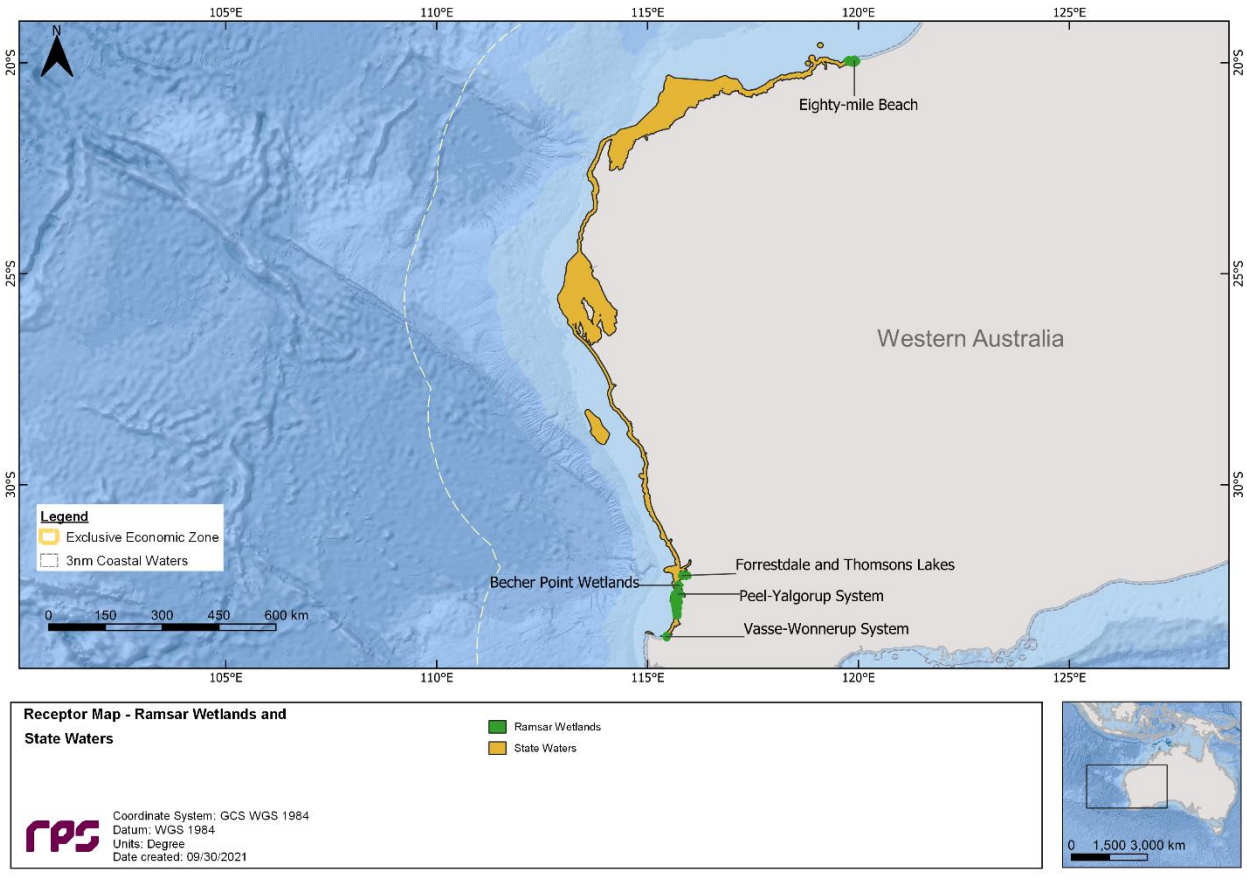


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

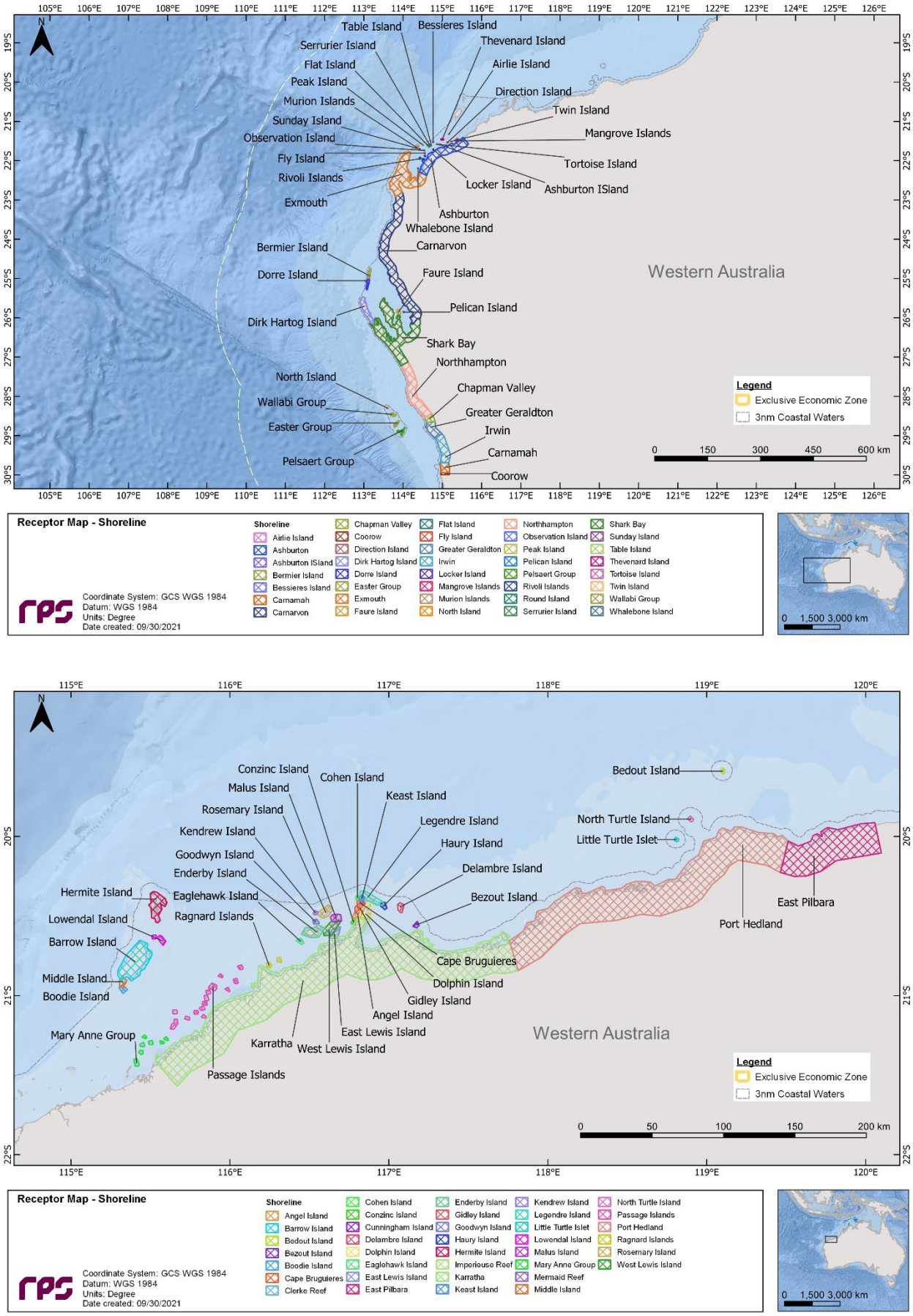


Figure 10.6 Receptor maps for Shorelines (1 of 2).

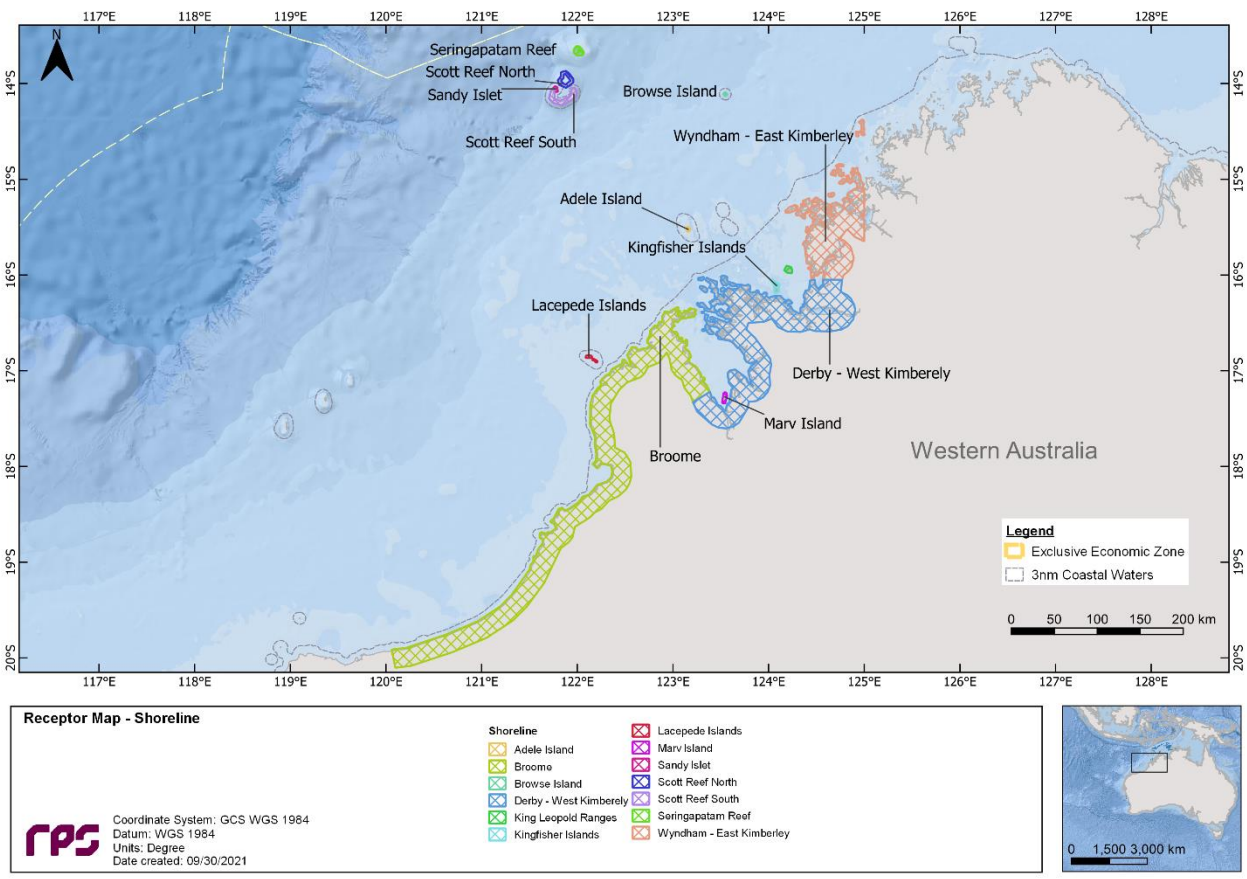


Figure 10.7 Receptor maps for Shorelines (2 of 2).

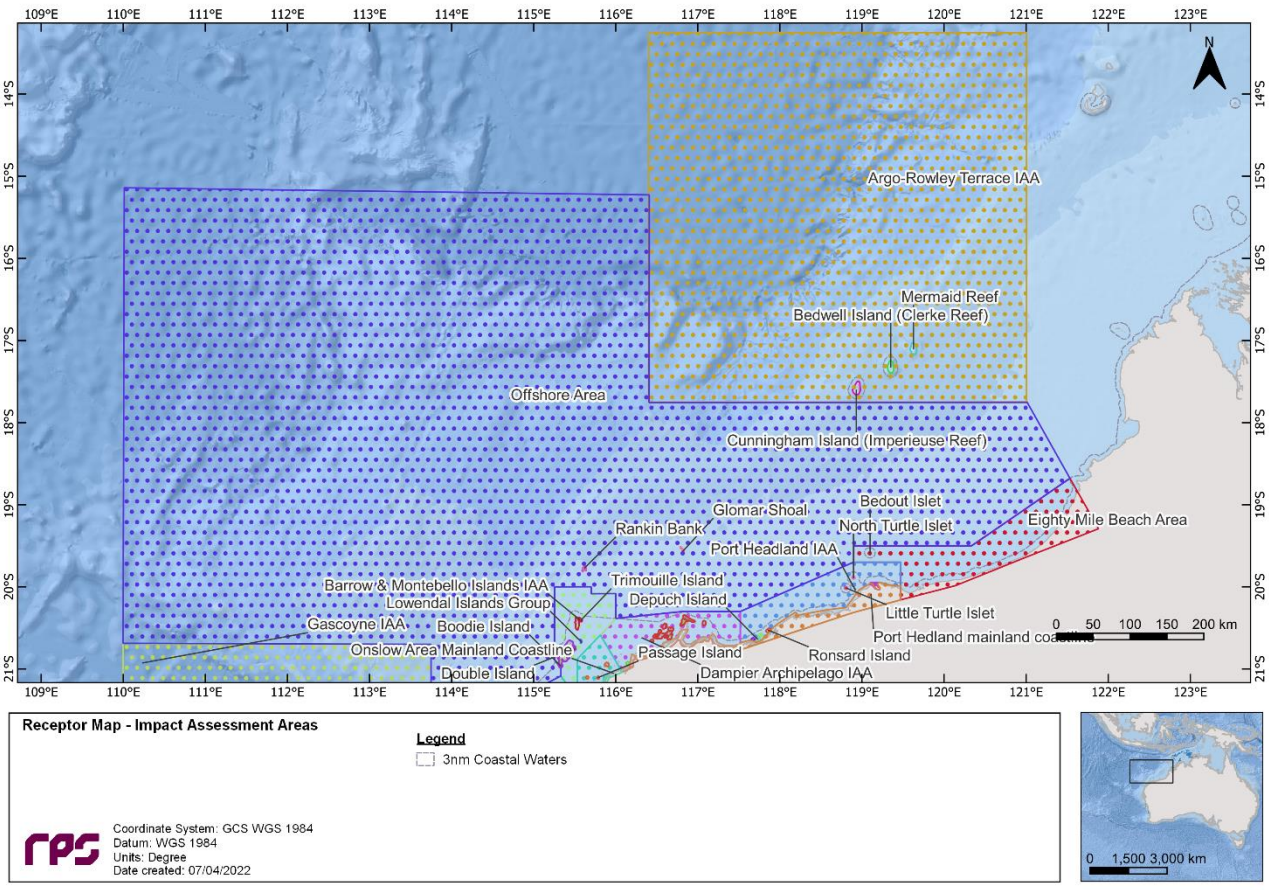


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

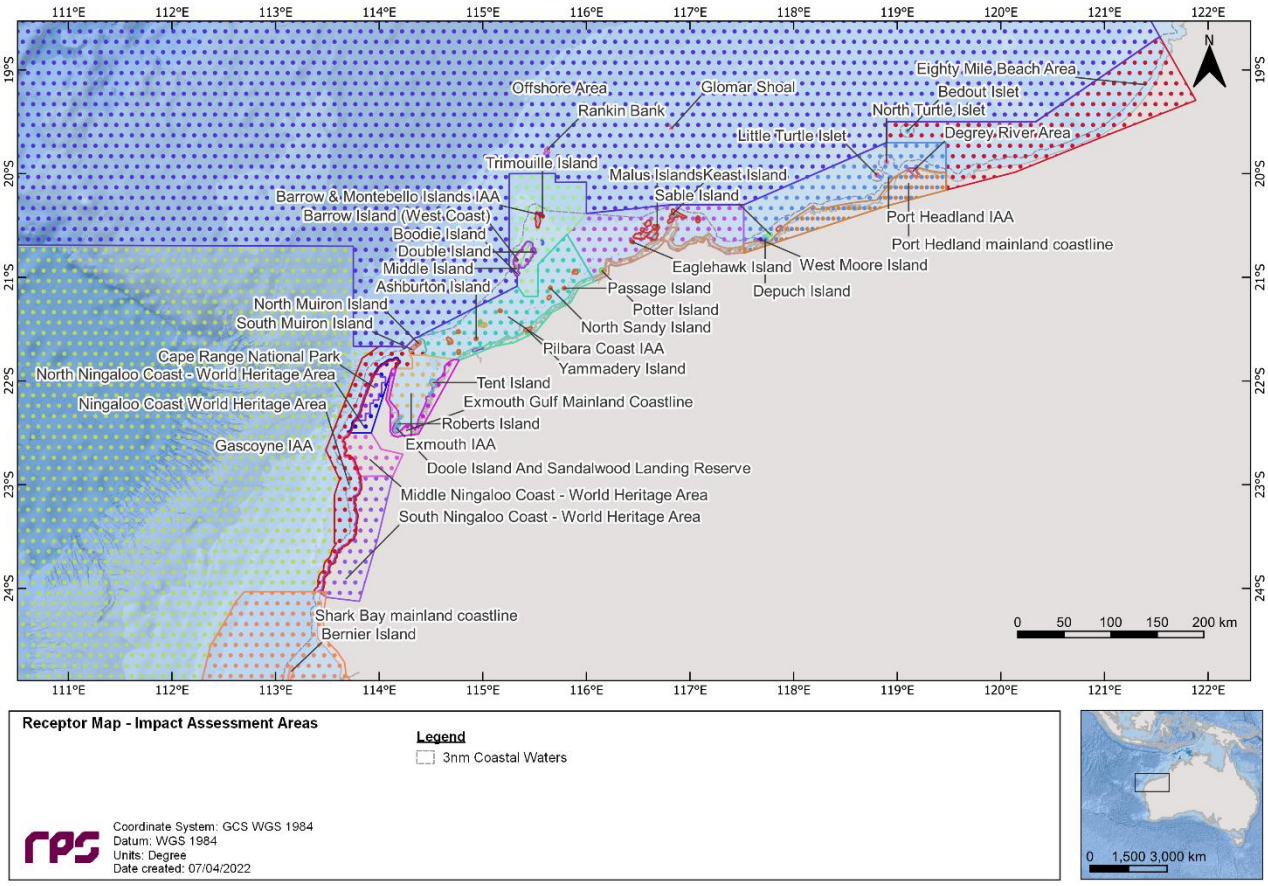


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

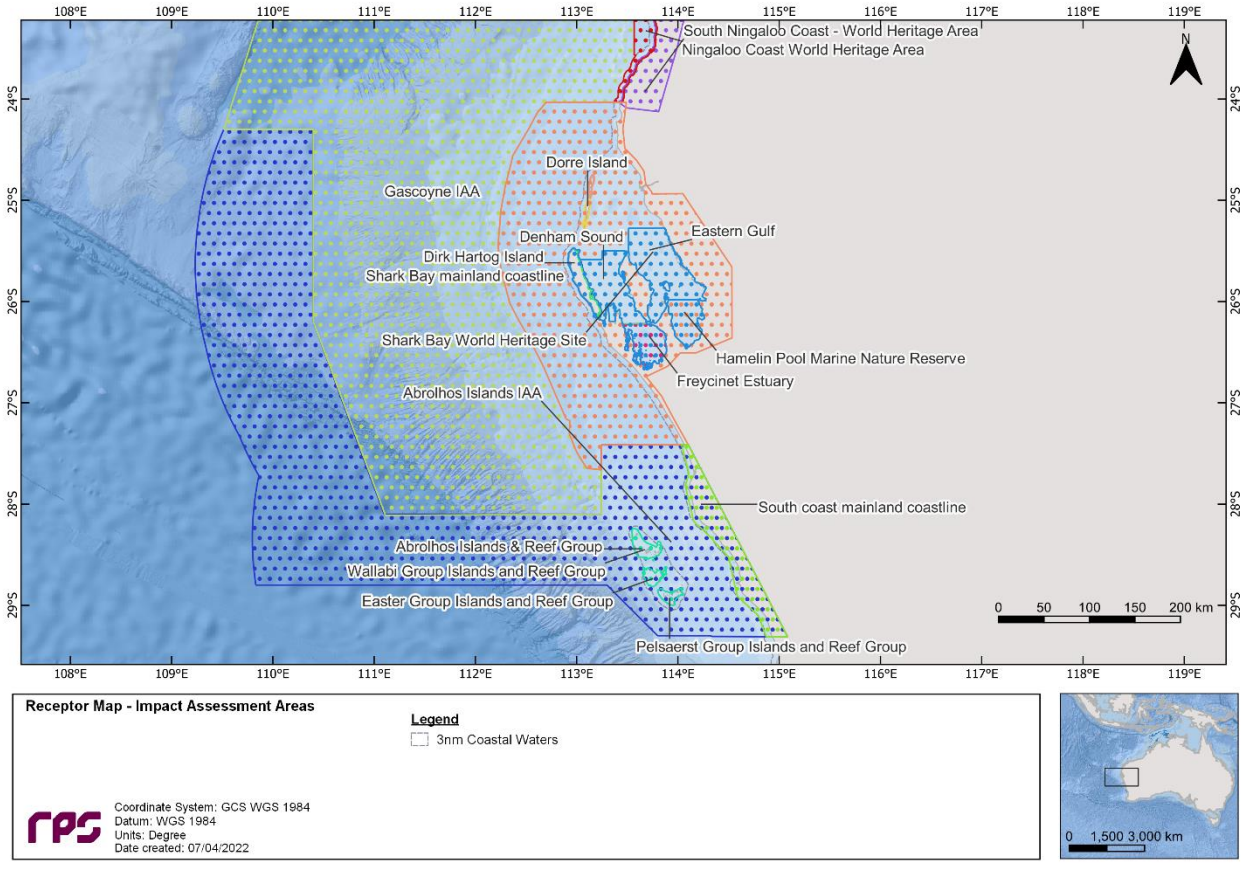


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: SEMELE LOSS OF WELL CONTROL

This scenario examined a 219,690 bbl subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run across the three seasons; summer, winter and transitional (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season.

The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 144.5 km southwest (summer) and 2.2 km west southwest (winter and transitional), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Wedge-tailed Shearwater – Breeding BIA which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probability for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 6% (summer) and 18% (transitional).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	144.5	1.4	-
	Max. distance from release site (km) (99th percentile)	80.6	1.4	-
	Direction	Southwest	Southwest	-
Transitional	Max. distance from release site (km)	134.6	2.2	-
	Max. distance from release site (km) (99th percentile)	73.9	2.2	-
	Direction	North-northeast	West-southwest	-
Winter	Max. distance from release site (km)	103.2	2.2	-
	Max. distance from release site (km) (99th percentile)	74.1	2.2	-
	Direction	Northeast	West-southwest	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Flatback Turtle - Internesting Buffer	3	-	-	29.88	-	-	21	-	-	1.71	-	-	31	-	-	12.88	-	-
	Humpback Whale - Migration	2	-	-	46.25	-	-	1	-	-	20.63	-	-	1	-	-	78.96	-	-
	Pygmy Blue Whale – Distribution*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
	Wedge-tailed Shearwater – Breeding*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
	Whale Shark - Foraging	-	-	-	-	-	-	14	-	-	2.38	-	-	26	-	-	13.04	-	-
EEZ	Australian Exclusive Economic Zone*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
IAA	Offshore Area*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
IMCRA	Northwest Shelf	-	-	-	-	-	-	5	-	-	7.13	-	-	6	-	-	13.13	-	-
	Pilbara (offshore)	-	-	-	-	-	-	12	-	-	5.79	-	-	24	-	-	13.21	-	-
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	5	-	-	8.92	-	-	11	-	-	28.67	-	-
	Continental Slope Demersal Fish Communities*	100	-	-	0.88	-	-	98	-	-	1.13	-	-	98	-	-	1.71	-	-

*The release location resides within the receptor boundaries.

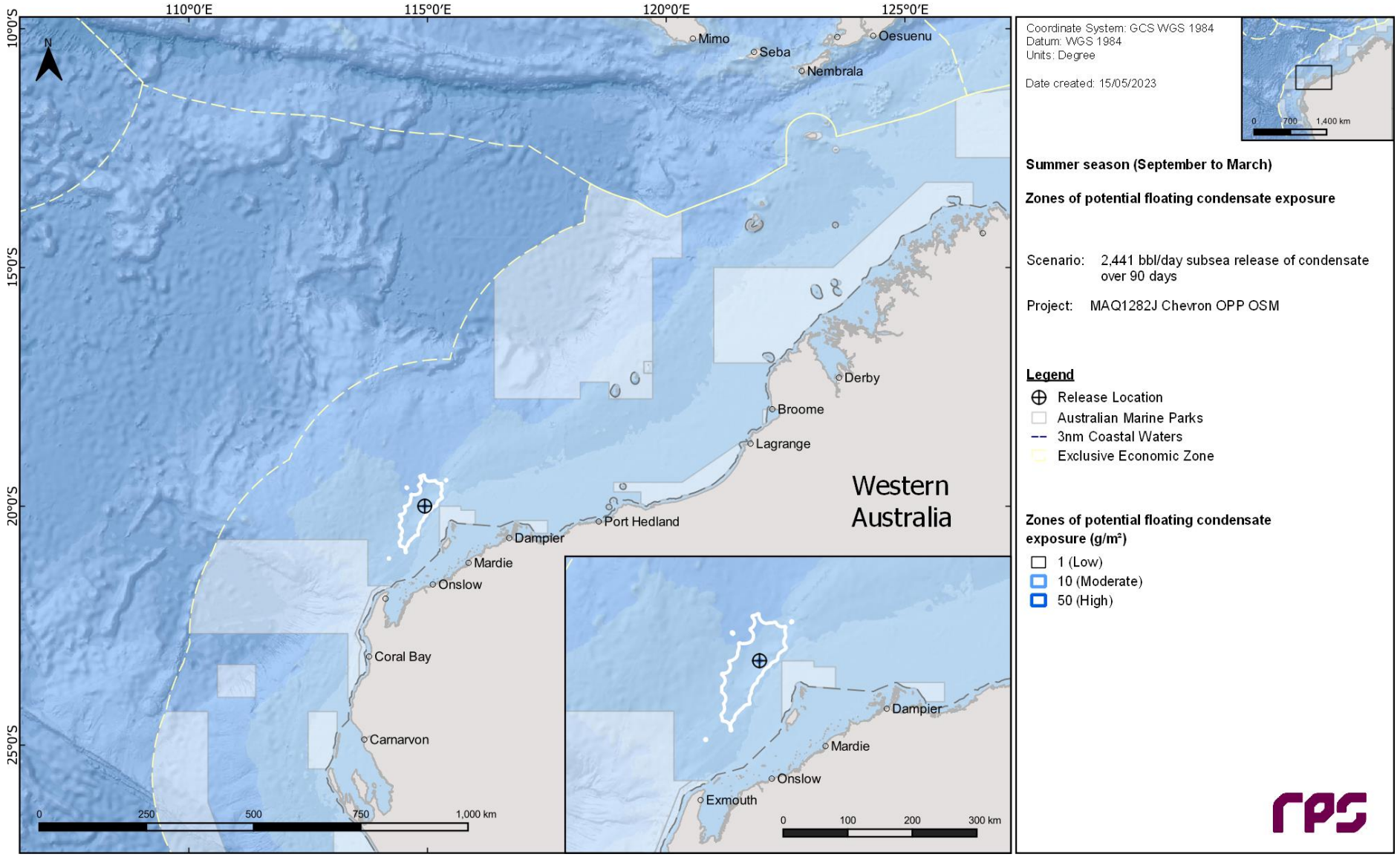


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

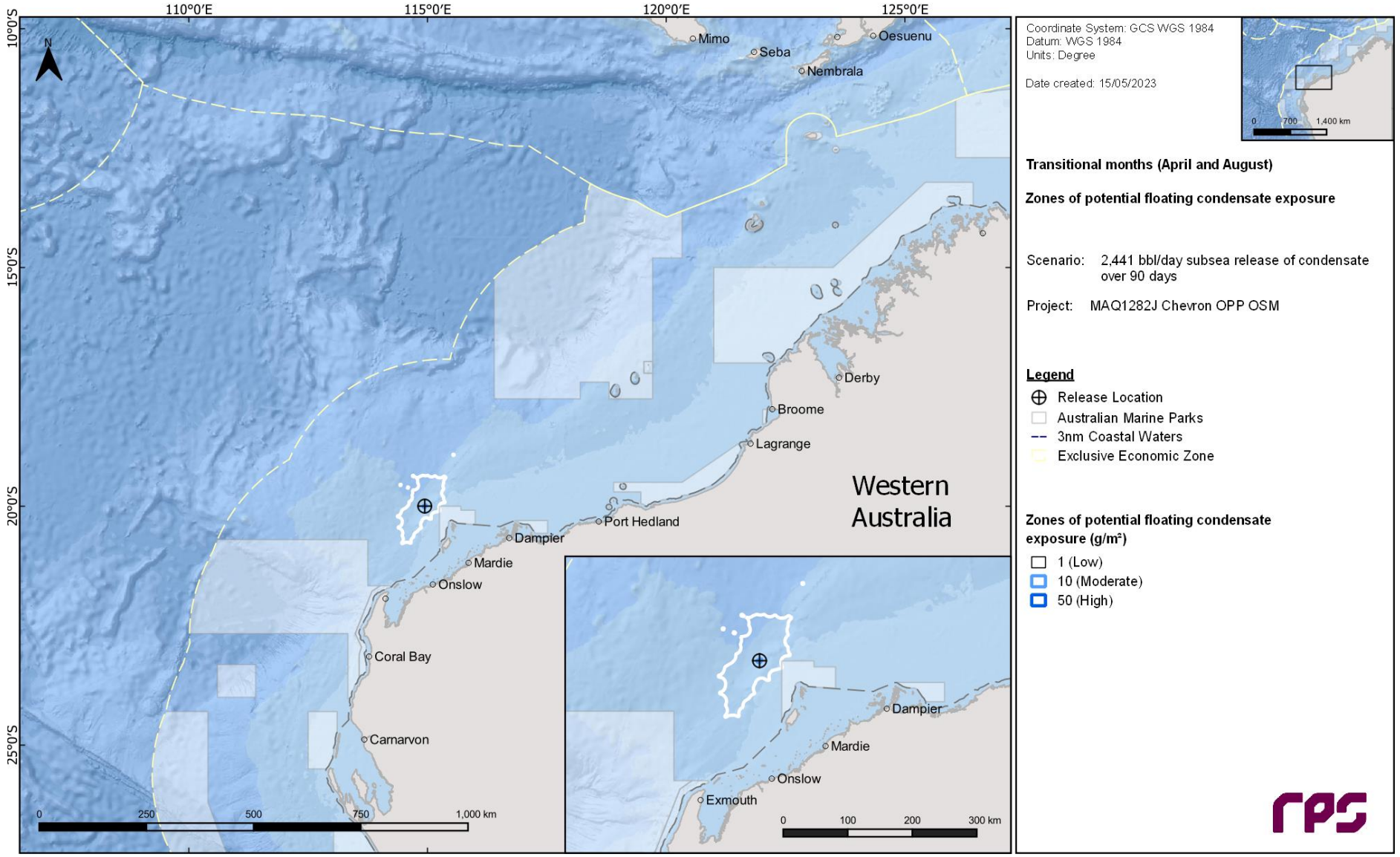


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

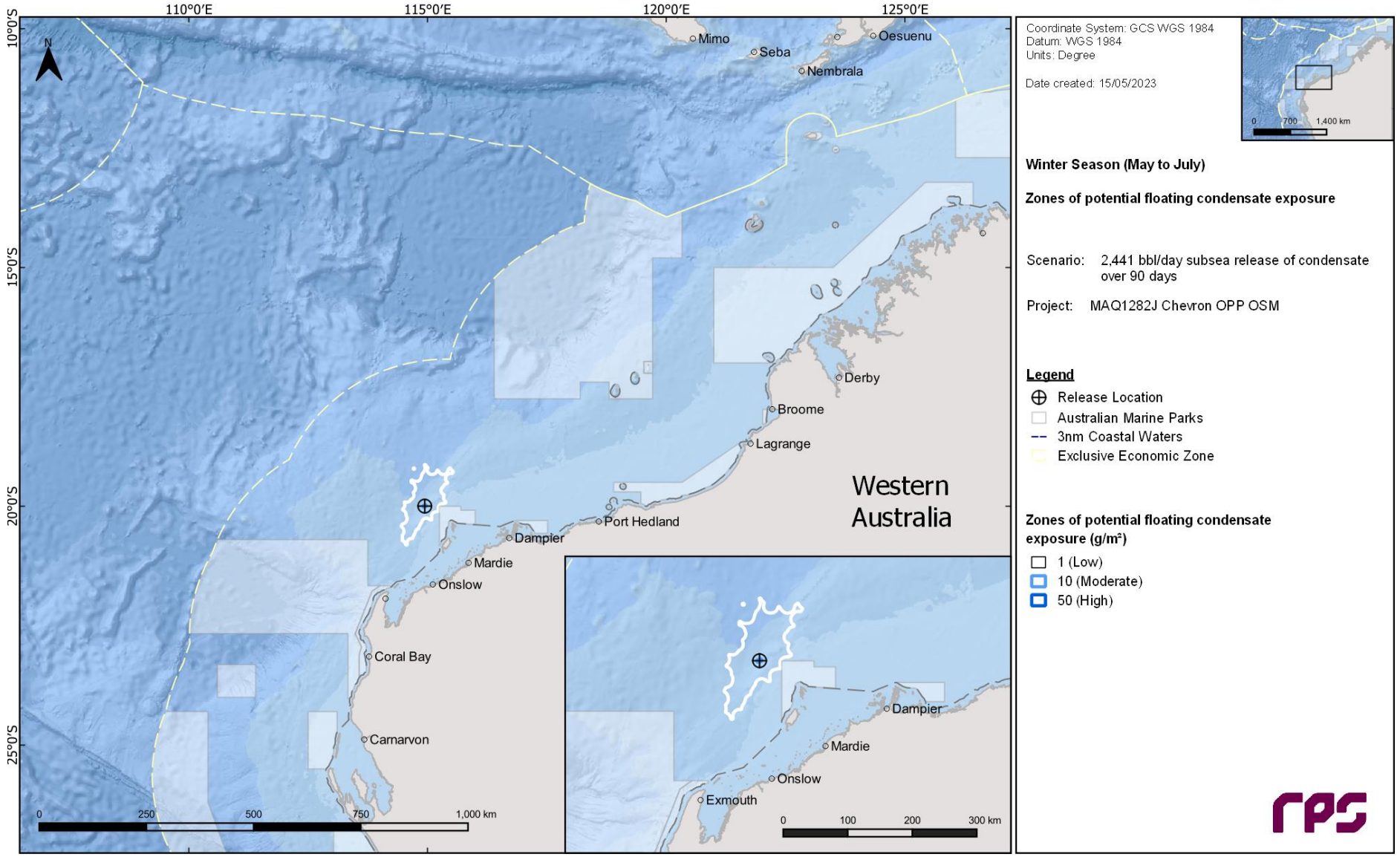


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 27%, while the minimum time before shoreline accumulation was 13.7 days and the maximum volume of condensate ashore above the low threshold was 29.0 m^3.

No accumulation at the high (≥ 1,000 g/m^2) shoreline threshold was observed.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, condensate had accumulated on 62 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (19%). In comparison, during transitional and winter conditions condensate had accumulated on 10 and 4 shoreline receptors, respectively. During transitional conditions, the greatest probabilities had occurred at Cunningham Island (Imperieuse Reef), Argo-Rowley Terrace IAAs and Imperieuse Reef, all 3% probability. While for the winter season, the same three receptors recorded a 9% probability.

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.5.

Table 11.3 Summary of oil accumulation across all shorelines for each season and threshold, following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	27	4	9
Absolute minimum time for visible oil to shore (days)	13.7	29.0	45.4
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	29.0	2.1	2.4
Average volume of hydrocarbons ashore (m^3) above the low threshold	6.9	0.3	0.5
Maximum length of the shoreline at **10 g/m^2** (km)	142	8	7
Average shoreline length (km) at **10 g/m^2** (km)	35.2	5	4.9
Maximum length of the shoreline at **100 g/m^2** (km)	2.9	-	-
Average shoreline length (km) at **100 g/m^2** (km)	2.1	-	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	8	2	-	33.58	59.54	-	27	110	1	2.5	2.4	1	-	2.9	1	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	19	5	-	18.67	21.21	-	7	209	5	25.6	22.3	2.5	-	56.8	2.9	-
	Barrow Island (West Coast)	13	-	-	18.67	-	-	9	79	2.7	9.2	14.6	-	-	22.1	-	-
	Barrow Island Group	14	5	-	18.67	21.21	-	10	209	4.8	19.2	21.2	2.5	-	33.7	2.9	-
	Bessieres Island	7	-	-	15.08	-	-	9	45	0.3	0.9	2.1	-	-	2.9	-	-
	Boodie Island	12	5	-	20.25	21.21	-	24	209	1.4	5.1	3.3	1.2	-	3.8	1.9	-
	Cape Range National Park	8	-	-	15.08	-	-	4	38	1.1	4.4	9.1	-	-	15.4	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	5	-	-	40.67	-	-	4	39	4.1	8.7	12.9	-	-	19.2	-	-
	Dampier Archipelago Island Group	3	-	-	44.67	-	-	4	17	1.3	2.5	3.8	-	-	4.8	-	-
	Dampier mainland coastline	4	-	-	45.88	-	-	5	21	2.4	3.2	4.3	-	-	4.8	-	-
	Eaglehawk Island	1	-	-	45.33	-	-	4	17	0.3	0.5	1	-	-	1	-	-
	Enderby Island	3	-	-	45.46	-	-	5	17	0.4	0.8	1.6	-	-	1.9	-	-
	Exmouth IAA	2	-	-	19.63	-	-	3	17	0.4	0.7	1.4	-	-	1.9	-	-
	Great Sandy Island	5	-	-	40.71	-	-	7	24	0.3	0.7	2.5	-	-	2.9	-	-
	Hermite Island	15	-	-	20.42	-	-	5	45	0.8	4.2	4.7	-	-	12.5	-	-
	Malus Islands	1	-	-	88.42	-	-	4	14	0.2	0.4	1	-	-	1	-	-
	Middle Island	10	4	-	20.63	21.75	-	18	143	1.6	5.9	6.7	1.7	-	7.7	1.9	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Shoreline	Middle Ningaloo Coast - World Heritage Area	8	-	-	14.75	-	-	4	29	1.3	2.9	4.3	-	-	9.6	-	-
	Montebello Islands Group	15	-	-	20.42	-	-	5	45	0.9	4.6	4.8	-	-	13.5	-	-
	Muiron Islands	15	-	-	13.67	-	-	8	97	1.4	7.7	4.7	-	-	15.4	-	-
	Ningaloo Coast World Heritage Area	16	-	-	13.67	-	-	5	97	2.7	16.5	13	-	-	41.4	-	-
	North Muiron Island	7	-	-	13.67	-	-	8	97	0.5	3	3.3	-	-	5.8	-	-
	North Ningaloo Coast - World Heritage Area	10	-	-	14.63	-	-	4	66	1.2	5.4	6.6	-	-	15.4	-	-
	North Sandy Island	6	-	-	44.13	-	-	9	21	0.2	0.5	1.3	-	-	1.9	-	-
	Onslow Area Mainland Coastline	3	-	-	43.38	-	-	3	13	0.9	2.9	1.9	-	-	3.8	-	-
	Passage Island	1	-	-	102.21	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Pilbara Coast IAA	11	2	-	14.88	59.54	-	5	110	3.2	13.5	15.6	1	-	32.7	1	-
	Pilbara Coast Islands Group	11	2	-	14.88	59.54	-	8	110	2.1	5.7	8.6	1	-	15.4	1	-
	Pilbara Mainland Coast	3	-	-	43.38	-	-	3	13	0.9	2.9	1.9	-	-	3.8	-	-
	Potter Island	2	-	-	50.54	-	-	7	13	0.3	0.4	1.4	-	-	1.9	-	-
	Rosemary Island	2	-	-	44.67	-	-	4	15	0.4	0.6	2.4	-	-	2.9	-	-
	Serrurier Island	9	-	-	14.88	-	-	5	30	0.6	1.6	2.7	-	-	7.7	-	-
	Sholl Island	5	-	-	40.67	-	-	7	30	0.5	1.2	3.1	-	-	5.8	-	-
	South Muiron Island	15	-	-	13.71	-	-	8	82	0.9	4.7	3.2	-	-	9.6	-	-
	Thevenard Island	9	-	-	22.5	-	-	6	36	0.5	1	2.1	-	-	3.8	-	-
	Trimouille Island	1	-	-	62.92	-	-	4	12	0.2	0.5	1	-	-	1	-	-
	Airlie Island	8	2	-	33.58	59.54	-	27	110	1	2.5	2.4	1	-	2.9	1	-
	Barrow Island	13	-	-	18.67	-	-	8	94	3	10.6	15.8	-	-	24	-	-
	Bessieres Island	7	-	-	15.08	-	-	9	45	0.3	0.9	2.1	-	-	2.9	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	12	5	-	20.25	21.21	-	24	209	1.7	6.7	4.1	1.7	-	4.8	1.9	-
Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eaglehawk Island	1	-	-	45.33	-	-	4	17	0.3	0.5	1	-	-	1	-	-
Enderby Island	3	-	-	45.46	-	-	5	17	0.4	0.8	1.6	-	-	1.9	-	-
Exmouth	10	-	-	14.63	-	-	4	66	2.3	12.4	17.4	-	-	35.6	-	-
Flat Island	5	-	-	16.46	-	-	5	17	0.2	0.4	1.2	-	-	1.9	-	-
Fly Island	2	-	-	19.63	-	-	8	17	0.2	0.3	1.4	-	-	1.9	-	-
Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	4	-	-	43.38	-	-	3	29	2.3	6.4	7.5	-	-	8.7	-	-
Kendrew Island	3	-	-	55.5	-	-	6	12	0.1	0.2	1	-	-	1	-	-
Lowendal Island	7	-	-	22.38	-	-	5	47	0.4	1.5	2.2	-	-	3.8	-	-
Malus Island	1	-	-	88.42	-	-	4	14	0.2	0.4	1	-	-	1	-	-
Mary Anne Group	7	-	-	38.08	-	-	6	29	0.6	1.5	2.7	-	-	4.8	-	-
Middle Island	10	4	-	20.63	21.75	-	17	143	1.9	7.5	8.4	1.7	-	9.6	1.9	-
Montebello Islands	15	-	-	20.42	-	-	5	45	1.3	7.4	7.5	-	-	22.1	-	-
Murion Islands	15	-	-	13.67	-	-	8	97	1.4	7.7	4.7	-	-	15.4	-	-
Observation Island	1	-	-	35.54	-	-	4	10	< 0.1	0.2	1	-	-	1	-	-
Passage Islands	7	-	-	40.67	-	-	6	45	2	6	11.1	-	-	20.2	-	-
Peak Island	3	-	-	15.08	-	-	6	14	< 0.1	0.2	1	-	-	1	-	-
Ragnard Islands	4	-	-	50.17	-	-	8	22	0.5	0.6	1.4	-	-	1.9	-	-
Rosemary Island	3	-	-	44.67	-	-	4	15	0.4	0.7	1.9	-	-	2.9	-	-
Round Island	1	-	-	19.79	-	-	5	12	< 0.1	0.2	1	-	-	1	-	-
Serrurier Island	9	-	-	14.88	-	-	5	30	0.6	1.6	2.7	-	-	7.7	-	-
Sunday Island	5	-	-	30.42	-	-	7	21	0.2	0.5	1.2	-	-	1.9	-	-
Thevenard Island	9	-	-	22.5	-	-	6	36	0.5	1	2.1	-	-	3.8	-	-

Table 11.5 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	3	-	-	29.04	-	-	3	23	0.7	2	5.8	-	-	7.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	3	-	-	29.04	-	-	5	23	0.7	1.7	5.8	-	-	7.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Shoreline	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	1	-	-	31.42	-	-	3	11	0.1	0.5	1.9	-	-	1.9	-	-
	Pilbara Coast Islands Group	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Potter Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	1	-	-	31.42	-	-	3	11	0.1	0.2	1	-	-	1	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunningham Island	2	-	-	39.46	-	-	5	20	0.4	0.9	2.9	-	-	3.8	-	-
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	3	-	-	29.04	-	-	5	23	0.6	1.5	5.1	-	-	5.8	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	1	-	-	31.42	-	-	3	11	0.1	0.2	1	-	-	1	-	-

Table 11.6 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	9	-	-	45.42	-	-	5	37	1.1	2.3	4.7	-	-	6.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	9	-	-	45.42	-	-	6	37	1	1.8	4.7	-	-	6.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Shoreline	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Potter Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunningham Island	8	-	-	49	-	-	6	36	0.5	1	2.2	-	-	2.9	-	-
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	9	-	-	45.42	-	-	7	37	0.8	1.5	4.1	-	-	5.8	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

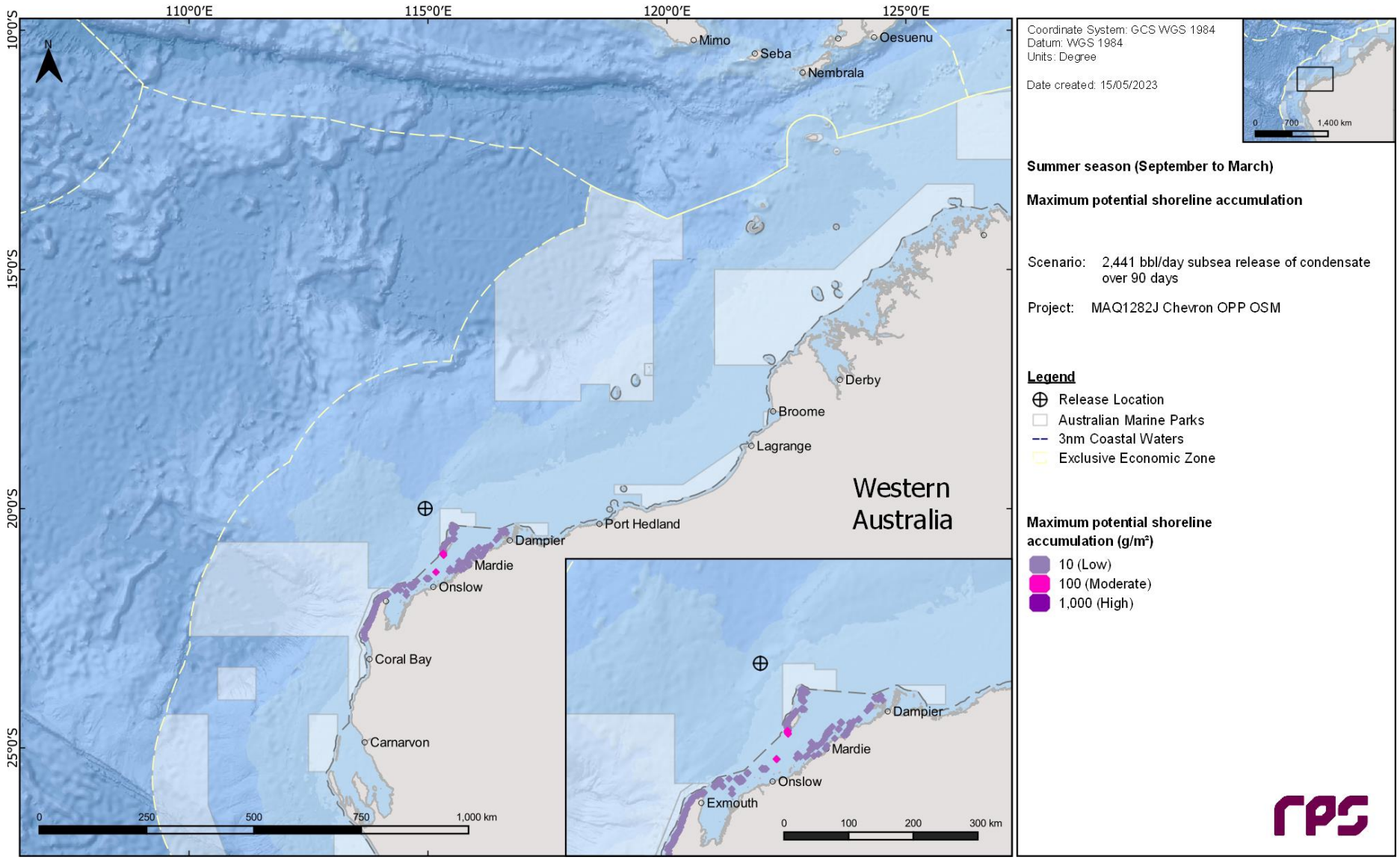


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at Semele Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

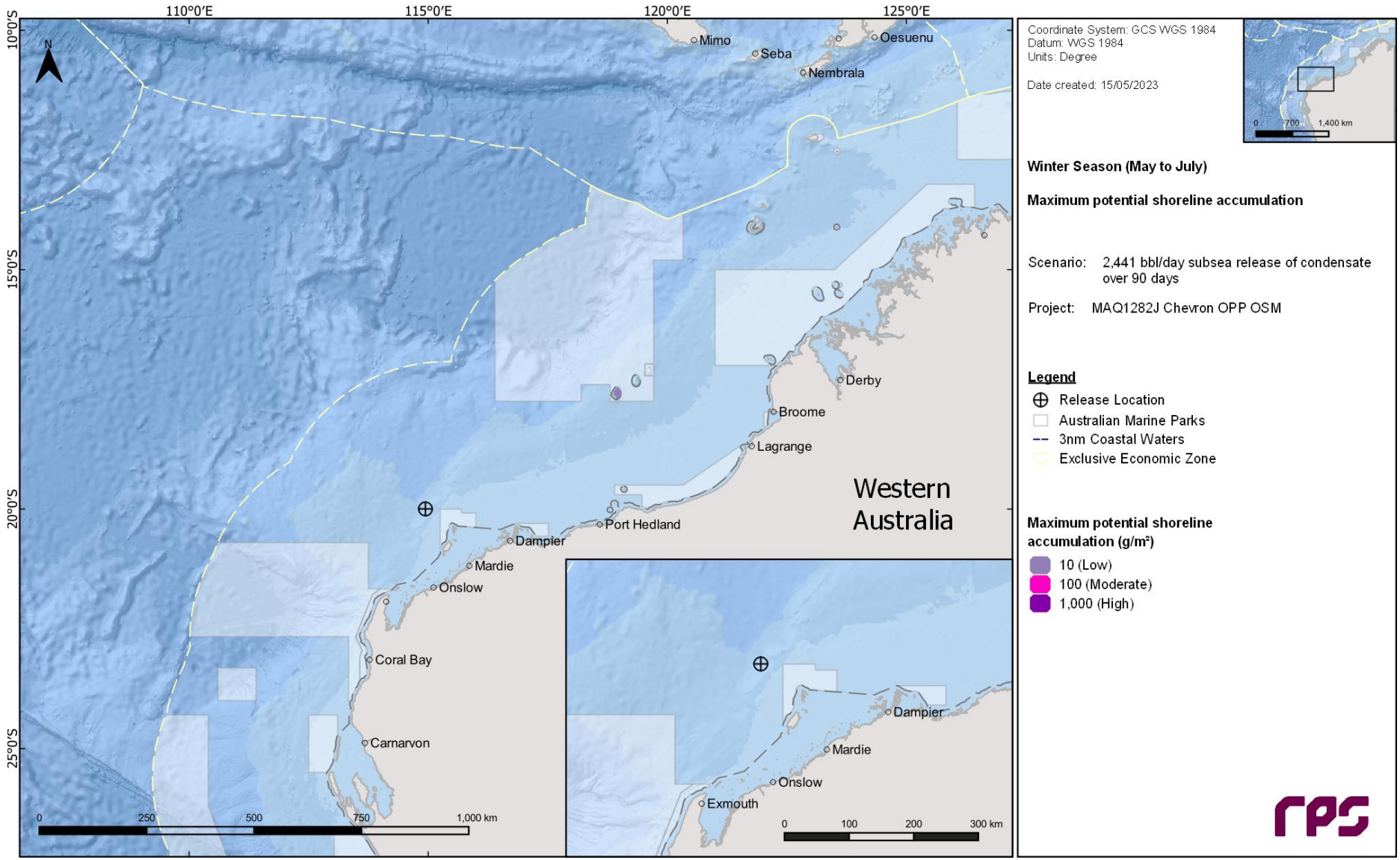


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.7 summarises the maximum instantaneous exposure to dissolved hydrocarbons and the probability for individual receptors in the 0-10 m depth layer.

There were several receptors exposed at or above the low threshold during summer and winter, however they were all 1% occurrence.

Figure 11.6 to Figure 11.7 illustrate the extent of the predicted dissolved hydrocarbon exposure in the 0-10 m depth layer for each season.

Table 11.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
BIA	Flatback Turtle - Internesting Buffer	10.8	1	-	-	5.46	-	-	2.6	-	-	-	4.08	7.63	-	13.8	1	-	-	4.29	-	-
	Flatback Turtle - Nesting	0.6	-	-	-	-	-	-	0.6	-	-	-	5.46	-	-	10.4	1	-	-	8.54	-	-
	Humpback Whale - Migration	0.6	-	-	-	-	-	-	1.5	-	-	-	6.33	-	-	13.8	1	-	-	6	-	-
	Pygmy Blue Whale – Distribution*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
	Wedge-tailed Shearwater – Breeding*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
	Whale Shark - Foraging	9	-	-	-	5.5	-	-	2.4	-	-	-	4.13	7.63	-	13.8	1	-	-	4.38	-	-
EEZ	Australian Exclusive Economic Zone	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
IAA	Offshore Area*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
IMCRA	Pilbara (offshore)	9	-	-	-	7.04	-	-	2.2	-	-	-	4.42	9	-	13.8	1	-	-	4.38	-	-

*The release location resides within the receptor boundaries.

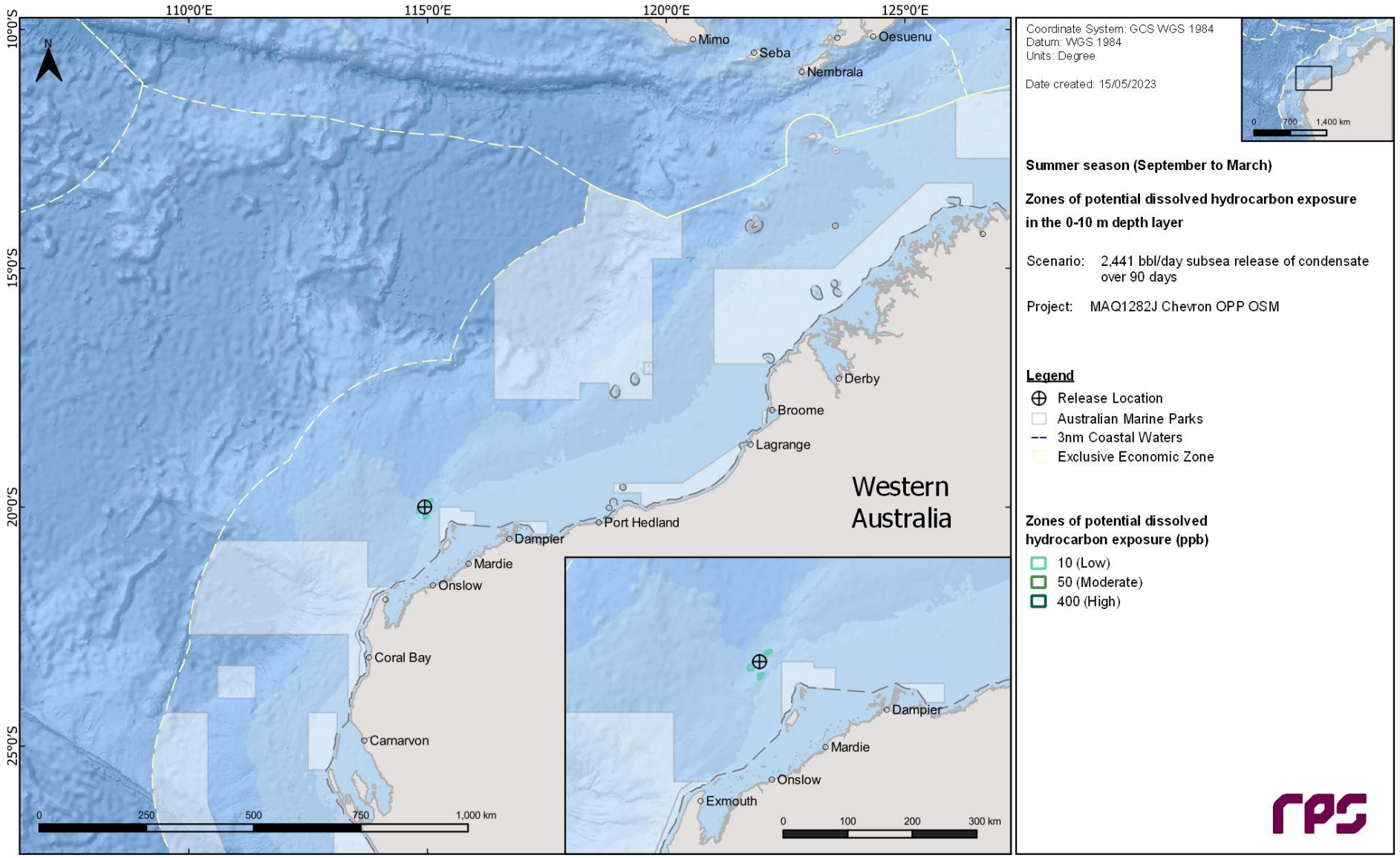


Figure 11.6 Zones of potential dissolved hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

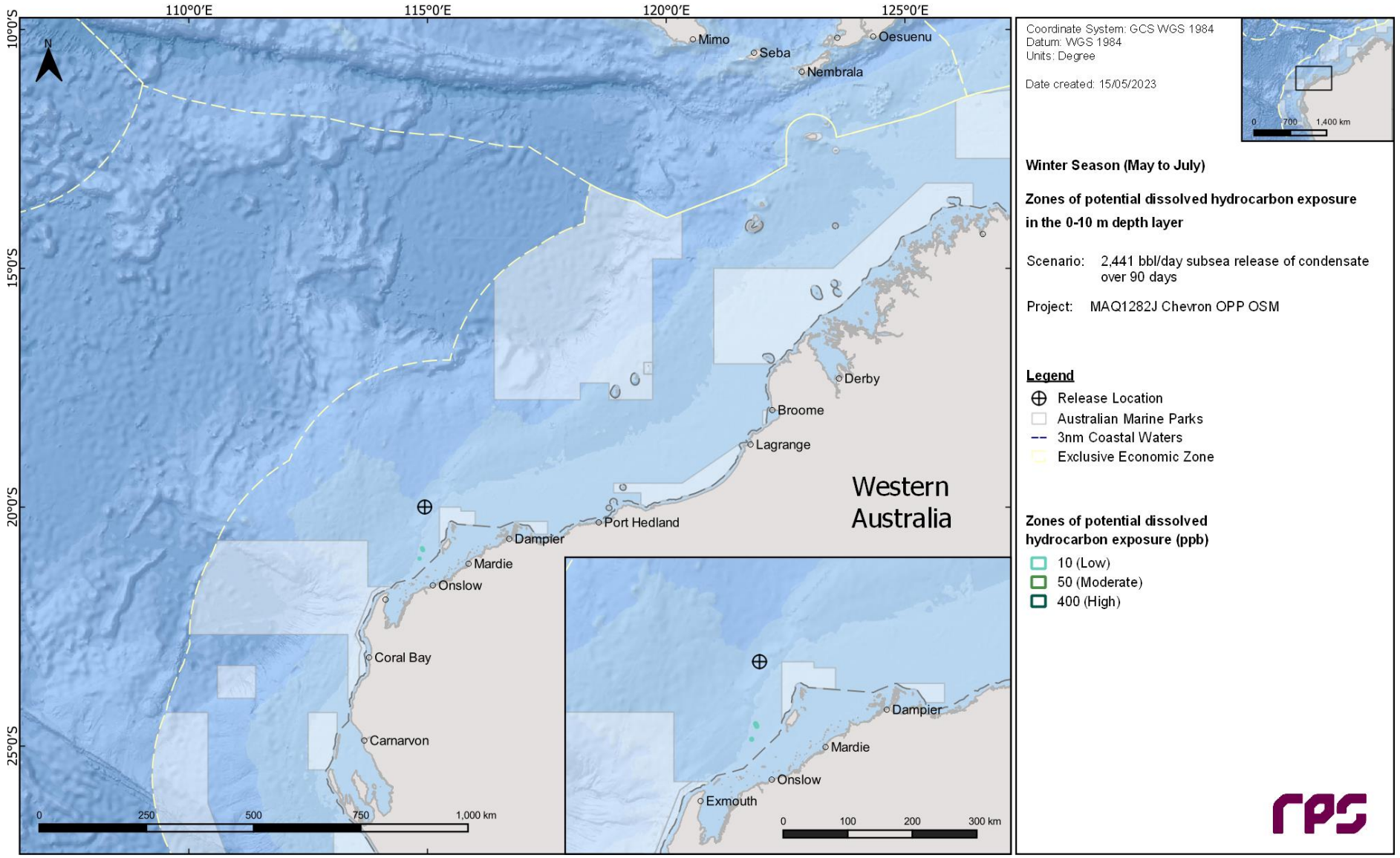


Figure 11.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.8 summarises the maximum exposure to entrained hydrocarbons and the probability for individual receptors in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 34, 22 and 21 BIAs were shown to be exposed at or above the low threshold during summer, transitional and winter seasons respectively. Excluding the receptors that the release location resides within, the highest probabilities of exposure were shown for the Flatback Turtle – Internesting Buffer BIA during summer (100%), transitional (97%) and winter (90%) conditions.

Across the three seasons, 6 AMPs were predicted to be exposed at, or above the low threshold, with the highest probabilities predicted at the Gascoyne AMP (81% summer, 82% transitional and 74% winter).

A total of 6 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Continental Slope Demersal Fish Communities KEF that the release site is located within. Excluding that receptor, probabilities of exposure ranged between 6–80%, 1–92% and 1–80%, for summer, transitional and winter, respectively.

Additionally, 37 IAA, were shown to be exposed to entrained hydrocarbons at low threshold.

Furthermore, 36 RSBs were shown to be exposed to entrained hydrocarbons at the low threshold.

Figure 11.8 to Figure 11.10 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.11 to Figure 11.13.

Table 11.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill simulations per season.

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
	Argo-Rowley Terrace	18.5	10	-	27.71	-	25.8	10	-	18.79	-	32.8	20	-	40.17	-
	Carnarvon Canyon	19	2	-	100.33	-	19.8	8	-	70.33	-	19.7	7	-	38.04	-
	Gascoyne	64	81	-	4.42	-	61	82	-	5.67	-	61.2	74	-	6	-
	Montebello	58.9	43	-	3.17	-	53.5	34	-	4.79	-	55.6	48	-	7.71	-
	Ningaloo	56.6	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	Shark Bay	10.4	1	-	100.96	-	8.3	-	-	-	-	3.4	-	-	-	-
BIA	Dugong - Breeding	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Calving	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Foraging	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Nursing	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Fairy Tern - Breeding	90.4	16	-	12.54	-	20.2	9	-	16.54	-	19.8	7	-	22.21	-
	Flatback Turtle - Aggregation	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Flatback Turtle - Foraging	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Flatback Turtle - Internesting	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Flatback Turtle - Internesting Buffer	149.6	100	12	1.04	9.75	130.3	97	6	1.5	5.79	200	90	17	1	6.75
	Flatback Turtle - Mating	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Flatback Turtle - Nesting	104.8	71	2	3.17	30.58	64.9	39	-	3.38	-	66.6	48	-	6.08	-
	Green Turtle - Aggregation	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Green Turtle - Basking	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Foraging	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Internesting	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Internesting Buffer	66.4	18	-	4.54	-	16.8	8	-	10.21	-	23.6	11	-	9.63	-
	Green Turtle - Mating	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Nesting	93.3	21	-	5	-	20.2	10	-	12.63	-	20.7	8	-	10.08	-
	Hawksbill Turtle - Foraging	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Hawksbill Turtle - Internesting	14.4	5	-	38.67	-	0.3	-	-	-	-	1.5	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	90.4	20	-	4.67	-	20.2	10	-	11.13	-	24	12	-	8.63	-
	Hawksbill Turtle - Mating	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Hawksbill Turtle - Nesting	93.3	21	-	5	-	15.5	5	-	12.67	-	20.7	6	-	10.08	-
	Humpback Whale - Migration	122.1	97	6	2.96	29.75	97.4	86	-	2.96	-	91.6	94	-	2.42	-
	Humpback Whale - Resting	28.9	4	-	14.25	-	4.6	-	-	-	-	4.9	-	-	-	-
	Lesser Crested Tern - Breeding	93.3	22	-	12.63	-	14.3	1	-	28.29	-	9.2	-	-	-	-
	Little Tern - Resting	3.7	-	-	-	-	11.3	3	-	43.46	-	11.7	4	-	58.21	-
	Loggerhead Turtle - Internesting Buffer	66.4	20	-	10.88	-	20.2	10	-	14.42	-	19.8	12	-	13.25	-
	Loggerhead Turtle - Nesting	66.4	18	-	12.29	-	20.2	10	-	16	-	19.8	8	-	14.63	-
	Pygmy Blue Whale – Distribution*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Pygmy Blue Whale - Foraging	40.1	53	-	11.38	-	33.5	32	-	7.96	-	31.7	20	-	9.83	-
	Roseate Tern - Breeding	81.1	26	-	12.71	-	15.3	3	-	21.92	-	30.1	13	-	17.08	-
	Wedge-tailed Shearwater – Breeding*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
	Whale Shark - Foraging	138.5	98	7	1.17	21.33	120.4	95	5	1.63	6.04	184.2	90	17	1.08	7.04
	White-tailed Tropicbird - Breeding	16	3	-	31.67	-	16.1	3	-	37.67	-	16.4	6	-	44.5	-
CP	Montebello Islands	15	4	-	33.54	-	0.2	-	-	-	-	1.7	-	-	-	-
EEZ	Australian Exclusive Economic Zone*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
IAA	Abrolhos Islands IAA	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
	Airlie Island	52.2	6	-	33.46	-	1.6	-	-	-	-	1.7	-	-	-	-
	Argo-Rowley Terrace IAA	18.5	10	-	27.71	-	25.8	10	-	18.79	-	32.8	20	-	40.17	-
	Barrow & Montebello Islands IAA	58.9	43	-	3.17	-	53.5	34	-	4.79	-	55.6	48	-	7.71	-
	Barrow Island (East Coast)	23.5	10	-	23.83	-	0.2	-	-	-	-	2.4	-	-	-	-
	Barrow Island (West Coast)	37.9	11	-	22.96	-	0.6	-	-	-	-	2.9	-	-	-	-
	Barrow Island Group	37.9	12	-	17.75	-	0.6	-	-	-	-	2.9	-	-	-	-
	Bessieres Island	59.4	10	-	18.63	-	6.2	-	-	-	-	5.6	-	-	-	-
	Boodie Island	36.6	12	-	17.75	-	0.5	-	-	-	-	2.9	-	-	-	-
	Cape Range National Park	24.7	5	-	14.42	-	8.6	-	-	-	-	7.8	-	-	-	-
	Cunningham Island (Imperieuse Reef)	2.9	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.67	-
	Dampier Archipelago IAA	28.5	5	-	40.71	-	0.9	-	-	-	-	1	-	-	-	-
	Dampier mainland coastline	12.3	4	-	52.58	-	0.1	-	-	-	-	0.2	-	-	-	-
	Exmouth IAA	28.2	11	-	13.75	-	5.2	-	-	-	-	7	-	-	-	-
	Gascoyne IAA	64	81	-	4.42	-	61	82	-	5.67	-	61.2	74	-	6	-
	Glomar Shoal	16.1	5	-	22.21	-	0.8	-	-	-	-	1.4	-	-	-	-
	Great Sandy Island	16.4	5	-	40.71	-	0.2	-	-	-	-	0.4	-	-	-	-
	Hermite Island	16.3	4	-	53.04	-	0.3	-	-	-	-	1.7	-	-	-	-
	Middle Island	37.7	11	-	17.75	-	0.5	-	-	-	-	2.7	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	21.3	8	-	15.79	-	6.3	-	-	-	-	5.9	-	-	-	-
	Montebello Islands Group	16.3	4	-	53.04	-	0.3	-	-	-	-	1.7	-	-	-	-
	Muiron Islands	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Ningaloo Coast World Heritage Area	66.4	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	North Muiron Island	60.5	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	North Ningaloo Coast - World Heritage Area	27.5	5	-	13.75	-	5.6	-	-	-	-	5.9	-	-	-	-
	North Sandy Island	12.9	5	-	40.29	-	0.2	-	-	-	-	0.3	-	-	-	-
	Offshore Area*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
	Onslow Area Mainland Coastline	15.7	4	-	49.54	-	0.4	-	-	-	-	0.4	-	-	-	-
	Pilbara Coast IAA	90.4	17	-	12.46	-	14.8	4	-	16.33	-	14.7	4	-	68.58	-
	Pilbara Coast Islands Group	59.4	10	-	17.33	-	7.1	-	-	-	-	5.6	-	-	-	-
	Pilbara Mainland Coast	15.7	4	-	49.54	-	0.4	-	-	-	-	0.4	-	-	-	-
	Potter Island	11.2	3	-	52.67	-	0.1	-	-	-	-	0.1	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Rankin Bank	84.1	34	-	4.88	-	20.8	21	-	8.38	-	21.7	32	-	18.92	-
	Serrurier Island	35.4	9	-	17.33	-	7.1	-	-	-	-	5.1	-	-	-	-
	Shark Bay mainland coastline	10.8	1	-	36.38	-	9.2	-	-	-	-	4.5	-	-	-	-
	Sholl Island	20.9	5	-	42.29	-	0.1	-	-	-	-	0.3	-	-	-	-
	South Muiron Island	66.4	13	-	13.17	-	10.6	1	-	37.04	-	10	-	-	-	-
	Thevenard Island	59.5	9	-	32.46	-	6.3	-	-	-	-	3.2	-	-	-	-
	Trimouille Island	10.5	2	-	81.13	-	0.2	-	-	-	-	1	-	-	-	-
IBRA	Cape Range	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Roebourne	50.9	11	-	17.75	-	1.6	-	-	-	-	2.9	-	-	-	-
IMCRA	Ningaloo	48.5	21	-	12.08	-	19.5	13	-	10.71	-	18.5	8	-	14	-
	Northwest Shelf	111.5	62	4	1.71	41.71	125.1	62	6	3.04	30.29	127.5	81	6	6.25	60.08
	Pilbara (nearshore)	30.5	6	-	14.25	-	4.8	-	-	-	-	7	-	-	-	-
	Pilbara (offshore)	140.3	97	7	1.13	21.33	119	95	3	1.63	6.04	184.2	84	17	1.08	6.92
	Zuytdorp	10.8	1	-	36.38	-	9.2	-	-	-	-	4.5	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	116.2	80	6	1.71	30.04	96.2	64	-	2.17	-	97.5	65	-	3.67	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	66.2	64	-	7.71	-	64.1	48	-	7.29	-	63.1	43	-	7.04	-
	Commonwealth waters adjacent to Ningaloo Reef	56.6	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	Continental Slope Demersal Fish Communities*	212.3	100	39	0.67	4.29	243.6	100	49	0.75	4.46	266.7	100	48	0.75	4.42
	Exmouth Plateau	73.7	70	-	4.71	-	77.2	92	-	4.71	-	96.7	80	-	5.54	-
	Glomar Shoals	17.1	6	-	20.13	-	1.3	-	-	-	-	1.4	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	4.2	-	-	-	-	11.3	3	-	43.08	-	11.7	4	-	58.21	-
	Wallaby Saddle	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
MMA	Barrow Island	52.3	13	-	17.17	-	0.8	-	-	-	-	3.8	-	-	-	-
	Muiron Islands	66.4	15	-	12.54	-	13.3	5	-	17.38	-	13.3	5	-	69.92	-
MP	Barrow Island	20.1	11	-	23.92	-	0.5	-	-	-	-	2.5	-	-	-	-
	Montebello Islands	22	6	-	32.88	-	0.7	-	-	-	-	2.6	-	-	-	-
	Ningaloo	56.4	12	-	13.21	-	15.6	4	-	17.13	-	15.5	5	-	69.79	-
	Rowley Shoals	3.4	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.54	-
NR	Great Sandy Island	39	6	-	34.38	-	0.2	-	-	-	-	1	-	-	-	-
	Thevenard Island	43	6	-	32.96	-	3.2	-	-	-	-	2.4	-	-	-	-
RSB	Ashworth Shoal	13.8	4	-	51.17	-	0	-	-	-	-	0.2	-	-	-	-
	Australind Shoal	15.5	5	-	56.88	-	0.5	-	-	-	-	0.7	-	-	-	-
	Barrow Island Reefs and Shoals	41.7	6	-	34	-	0.3	-	-	-	-	1.2	-	-	-	-
	Brewis Reef	33	6	-	32.63	-	3.6	-	-	-	-	2	-	-	-	-
	Cod Bank	14.2	4	-	44.29	-	0.1	-	-	-	-	0.2	-	-	-	-
	Combe Reef	11.4	1	-	97.63	-	2.8	-	-	-	-	3.5	-	-	-	-
	Dailey Shoal	15.3	4	-	15.21	-	5.6	-	-	-	-	5.8	-	-	-	-
	Eliassen Rocks	12.1	3	-	51.63	-	0	-	-	-	-	0.1	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Fairway Reef	11.7	2	-	33.38	-	3.5	-	-	-	-	2.2	-	-	-	-
	Flinders Shoal	20.5	6	-	37.13	-	0.2	-	-	-	-	0.5	-	-	-	-
	Fortescue Reef	16.3	4	-	47	-	0.1	-	-	-	-	0.2	-	-	-	-
	Glomar Shoal	16.1	5	-	22.21	-	0.8	-	-	-	-	1.4	-	-	-	-
	Hood Reef	13.6	8	-	17.92	-	5.5	-	-	-	-	3.9	-	-	-	-
	Imperieuse Reef	2.9	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.67	-
	Lightfoot Reef	20.8	6	-	38.17	-	0.2	-	-	-	-	0.5	-	-	-	-
	Little Shoals	14.5	4	-	59.58	-	0.2	-	-	-	-	0.4	-	-	-	-
	Mardie Rock	13	4	-	49.54	-	0	-	-	-	-	0.1	-	-	-	-
	McLennan Bank	25.8	5	-	42.21	-	0.1	-	-	-	-	0.2	-	-	-	-
	Meda Reef	11.1	1	-	89.96	-	0.1	-	-	-	-	0.2	-	-	-	-
	Montebello Shoals	20.1	6	-	32.96	-	0.7	-	-	-	-	2.2	-	-	-	-
	Moresby Shoals	11.1	2	-	60.71	-	0.3	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	24.8	8	-	14.42	-	9.6	-	-	-	-	8.3	-	-	-	-
	North West Reef	29.9	9	-	13.67	-	6.3	-	-	-	-	6.6	-	-	-	-
	O'Grady Shoal	18.5	4	-	44.25	-	0.1	-	-	-	-	0.1	-	-	-	-
	Otway Reef	12.9	4	-	18.88	-	3.7	-	-	-	-	4.5	-	-	-	-
	Outtrim Patches	44.8	13	-	13.17	-	10	2	-	37.13	-	9.8	-	-	-	-
	Penguin Bank	50.3	11	-	18.67	-	2.9	-	-	-	-	5.7	-	-	-	-
	Poivre Reef	41.9	13	-	17.92	-	0.4	-	-	-	-	2.3	-	-	-	-
	Rankin Bank	84.1	34	-	4.88	-	23	21	-	8.13	-	21.7	32	-	18.92	-
	Ripple Shoals	40.7	6	-	33.04	-	0.5	-	-	-	-	1.6	-	-	-	-
	Rosily Shoals	73.8	14	-	20.75	-	11.9	1	-	31.29	-	6	-	-	-	-
	South West Reef	10.2	1	-	59.42	-	0.1	-	-	-	-	0	-	-	-	-
	Sultan Reef	31.5	6	-	33.5	-	0.9	-	-	-	-	1.5	-	-	-	-
	Taunton Reef	46.9	6	-	34.42	-	0.8	-	-	-	-	1.5	-	-	-	-
	Trap Reef	58.4	6	-	32.58	-	4.8	-	-	-	-	2.2	-	-	-	-
	Tryal Rocks	20.7	4	-	32.92	-	4.7	-	-	-	-	3.8	-	-	-	-
	West Reef	13.8	6	-	39.42	-	0.5	-	-	-	-	0.5	-	-	-	-
Nearshore Waters	Airlie Island	52.2	6	-	33.46	-	1.6	-	-	-	-	1.7	-	-	-	-
	Barrow Island	37.9	11	-	22.96	-	0.6	-	-	-	-	2.9	-	-	-	-
	Bessieres Island	59.4	10	-	18.63	-	6.2	-	-	-	-	5.6	-	-	-	-
	Boodie Island	36.1	11	-	17.75	-	0.4	-	-	-	-	2.9	-	-	-	-
	Cunningham Island	2.3	-	-	-	-	10.3	1	-	54.33	-	10	1	-	63.21	-
	Exmouth	27.5	8	-	13.75	-	9.6	-	-	-	-	7.8	-	-	-	-
	Flat Island	24.2	10	-	14.33	-	6.9	-	-	-	-	6.3	-	-	-	-
	Imperieuse Reef	2.3	-	-	-	-	10.5	1	-	54.88	-	11.2	3	-	59.17	-
	Karratha	15.7	4	-	45.46	-	0.1	-	-	-	-	0.4	-	-	-	-
	Lowendal Island	14.4	5	-	40.21	-	0.3	-	-	-	-	1.4	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Mary Anne Group	20.4	6	-	37.54	-	0.2	-	-	-	-	0.5	-	-	-	-
	Middle Island	37.7	11	-	17.75	-	0.5	-	-	-	-	2.7	-	-	-	-
	Montebello Islands	17.6	4	-	33.42	-	0.5	-	-	-	-	2.1	-	-	-	-
	Murion Islands	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Observation Island	12	3	-	34.29	-	4.2	-	-	-	-	2.5	-	-	-	-
	Passage Islands	23	5	-	40.29	-	0.2	-	-	-	-	0.4	-	-	-	-
	Peak Island	25.5	9	-	13.29	-	8.6	-	-	-	-	8.4	-	-	-	-
	Ragnard Islands	12.4	4	-	56.21	-	0.1	-	-	-	-	0.1	-	-	-	-
	Round Island	21.4	9	-	19.75	-	5.2	-	-	-	-	3.8	-	-	-	-
	Serrurier Island	33.1	9	-	17.33	-	6.5	-	-	-	-	4.8	-	-	-	-
	Sunday Island	20	11	-	13.71	-	6	-	-	-	-	7.1	-	-	-	-
	Table Island	31.9	9	-	18.33	-	5.1	-	-	-	-	2.9	-	-	-	-
	Thevenard Island	47.4	7	-	32.96	-	3.4	-	-	-	-	1.9	-	-	-	-
	Tortoise Island	18.1	6	-	33.13	-	1.7	-	-	-	-	2.9	-	-	-	-
State Waters	Western Australia State Waters	90.4	17	-	12.46	-	15.6	5	-	16.63	-	15.5	5	-	58.54	-

*The release location resides within the receptor boundaries.

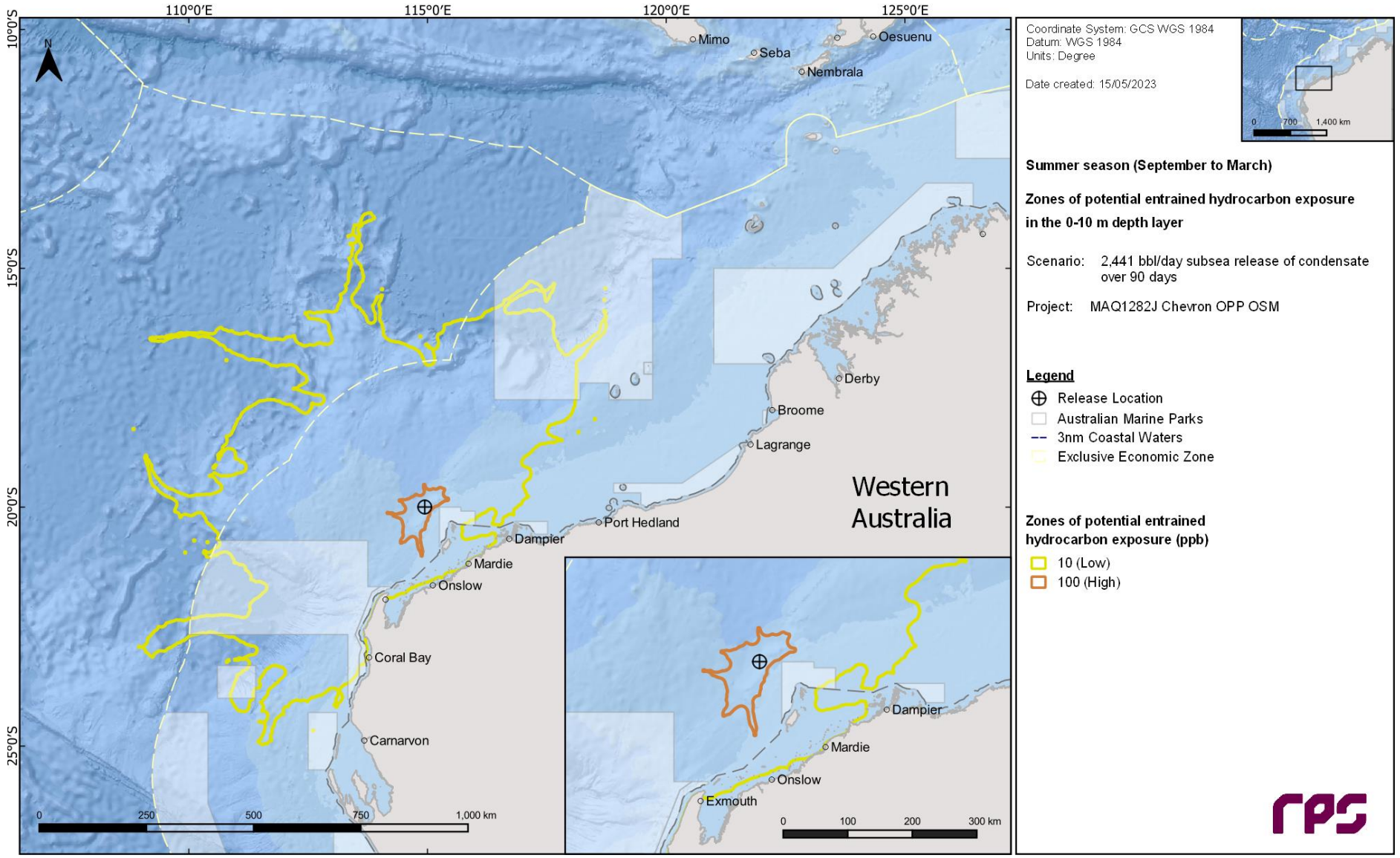


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

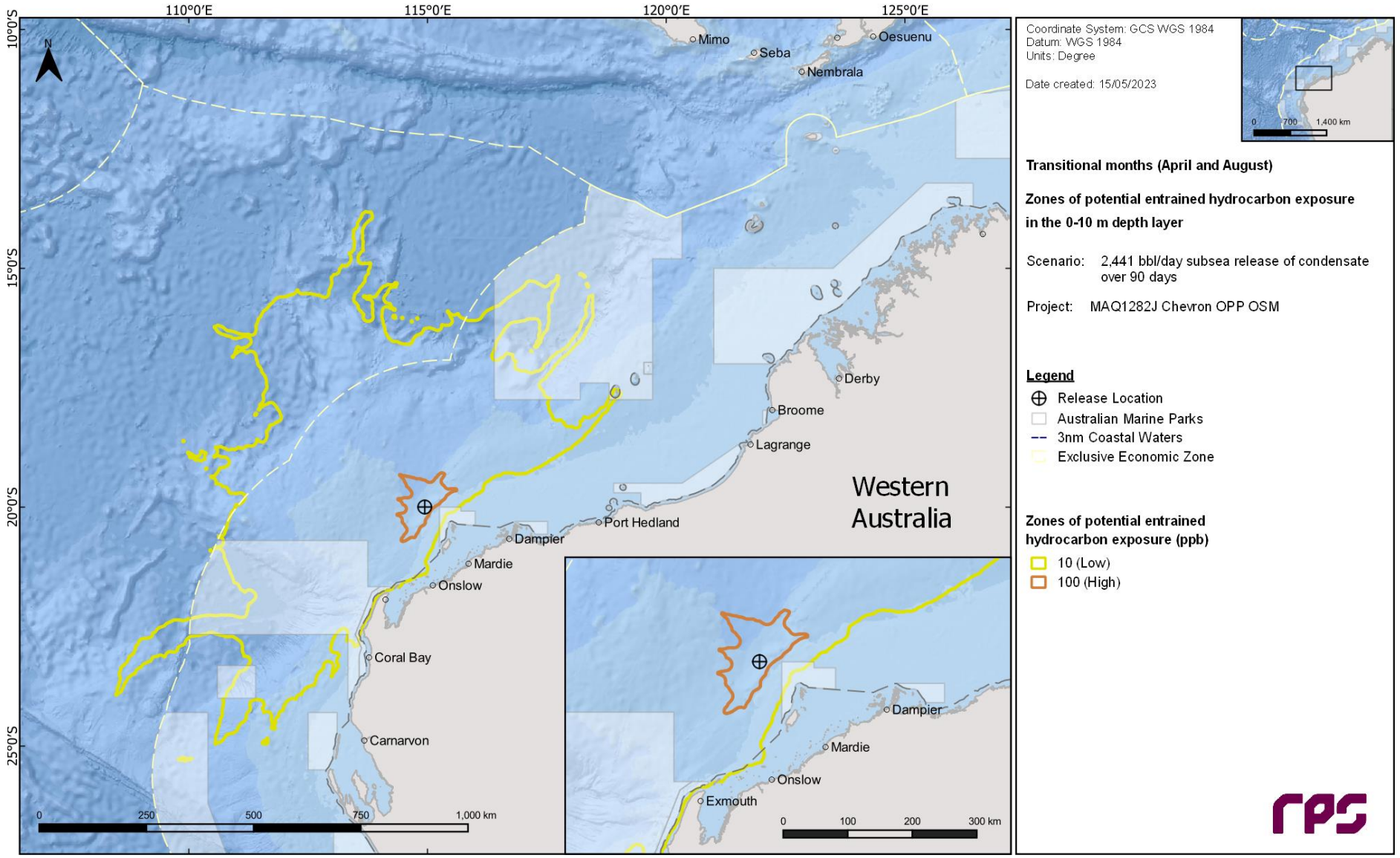


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

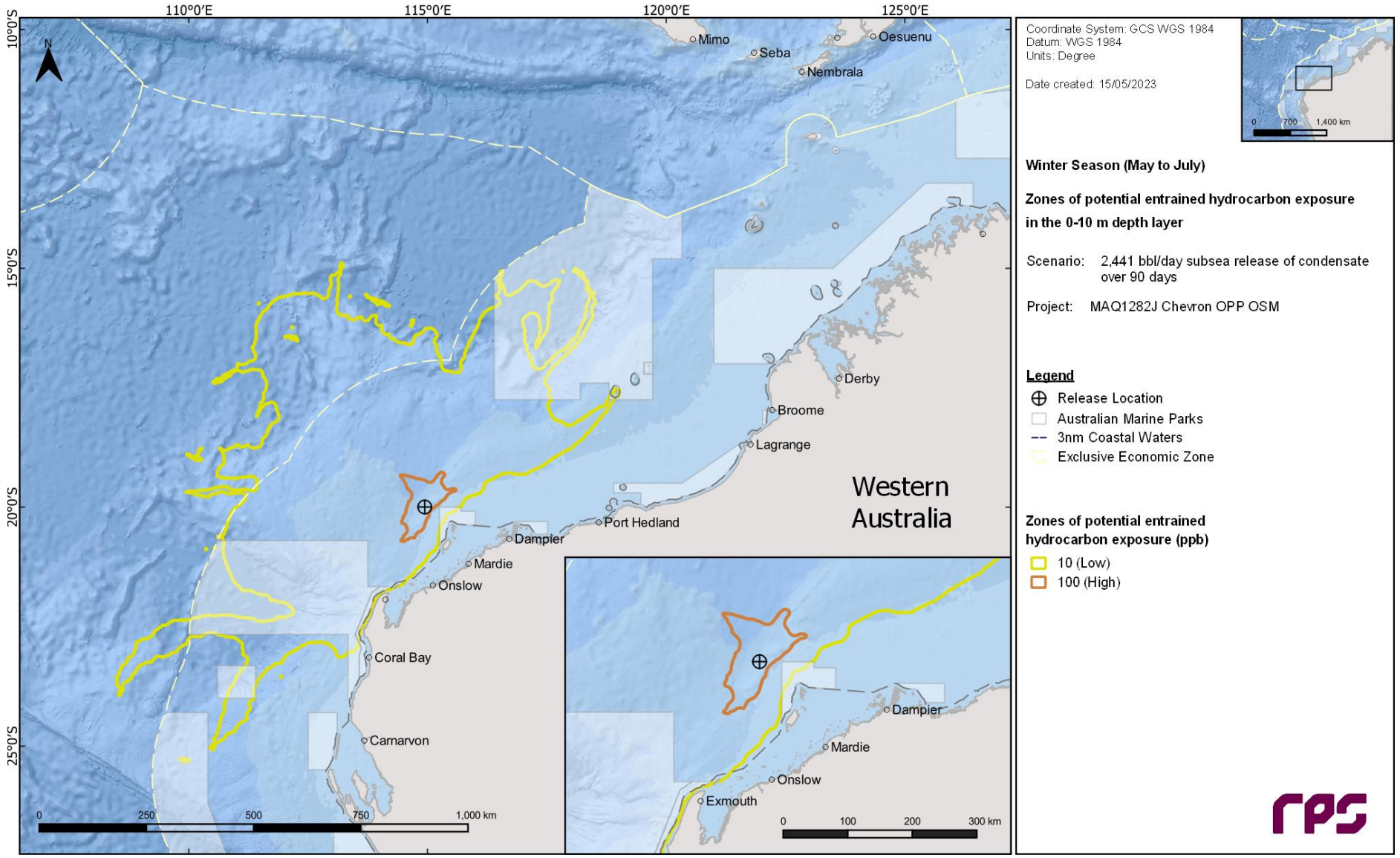


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

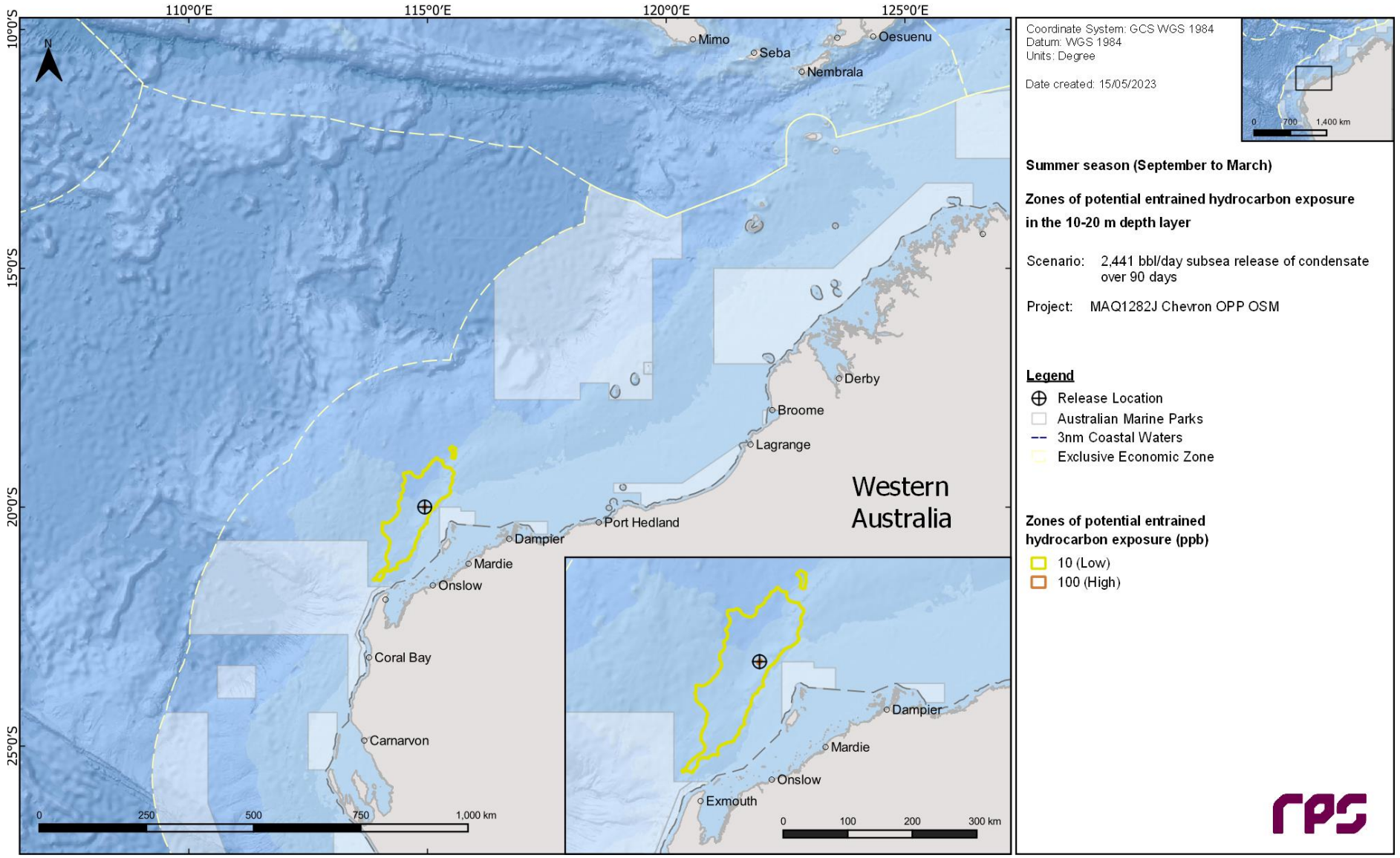


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

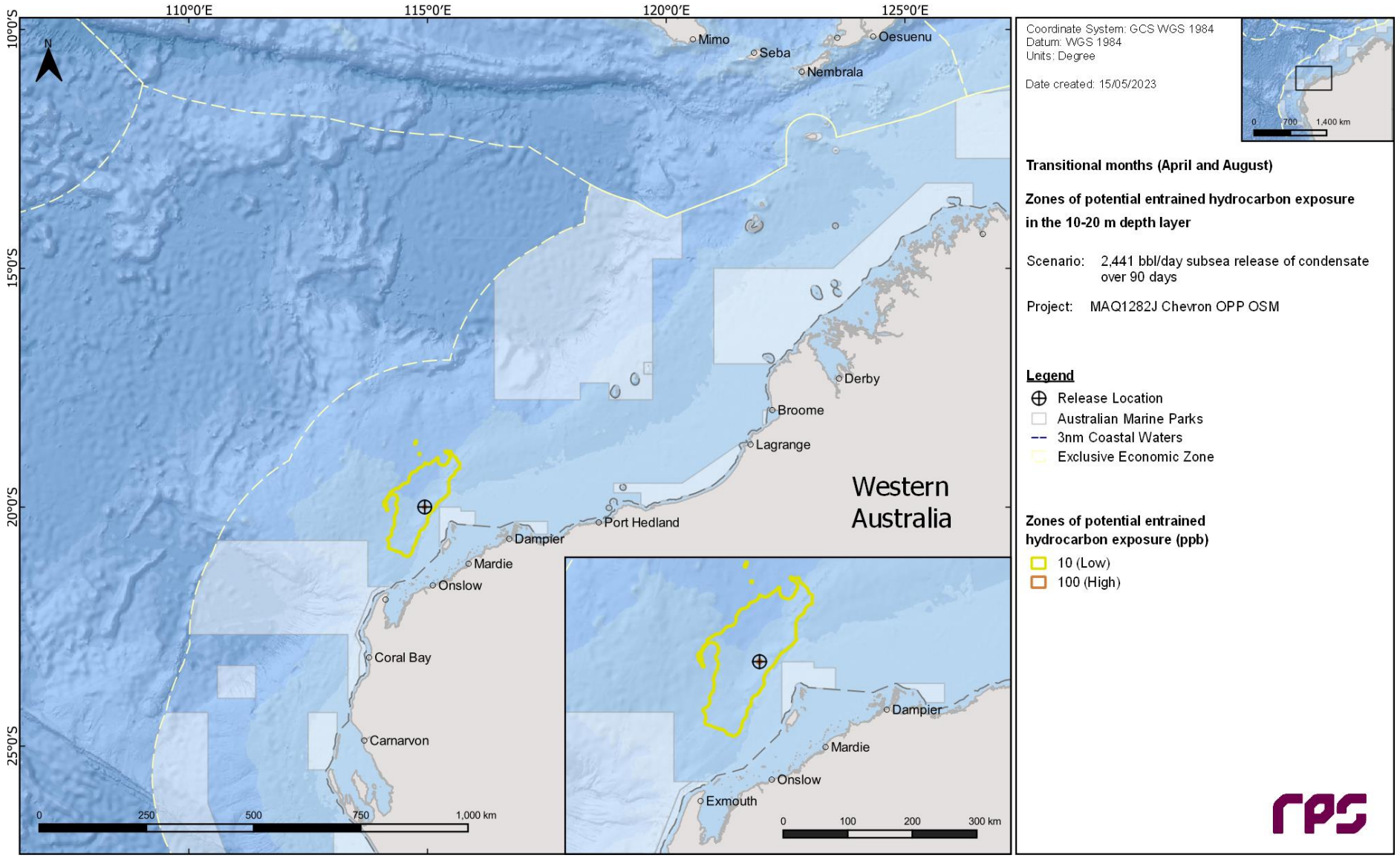


Figure 11.12 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

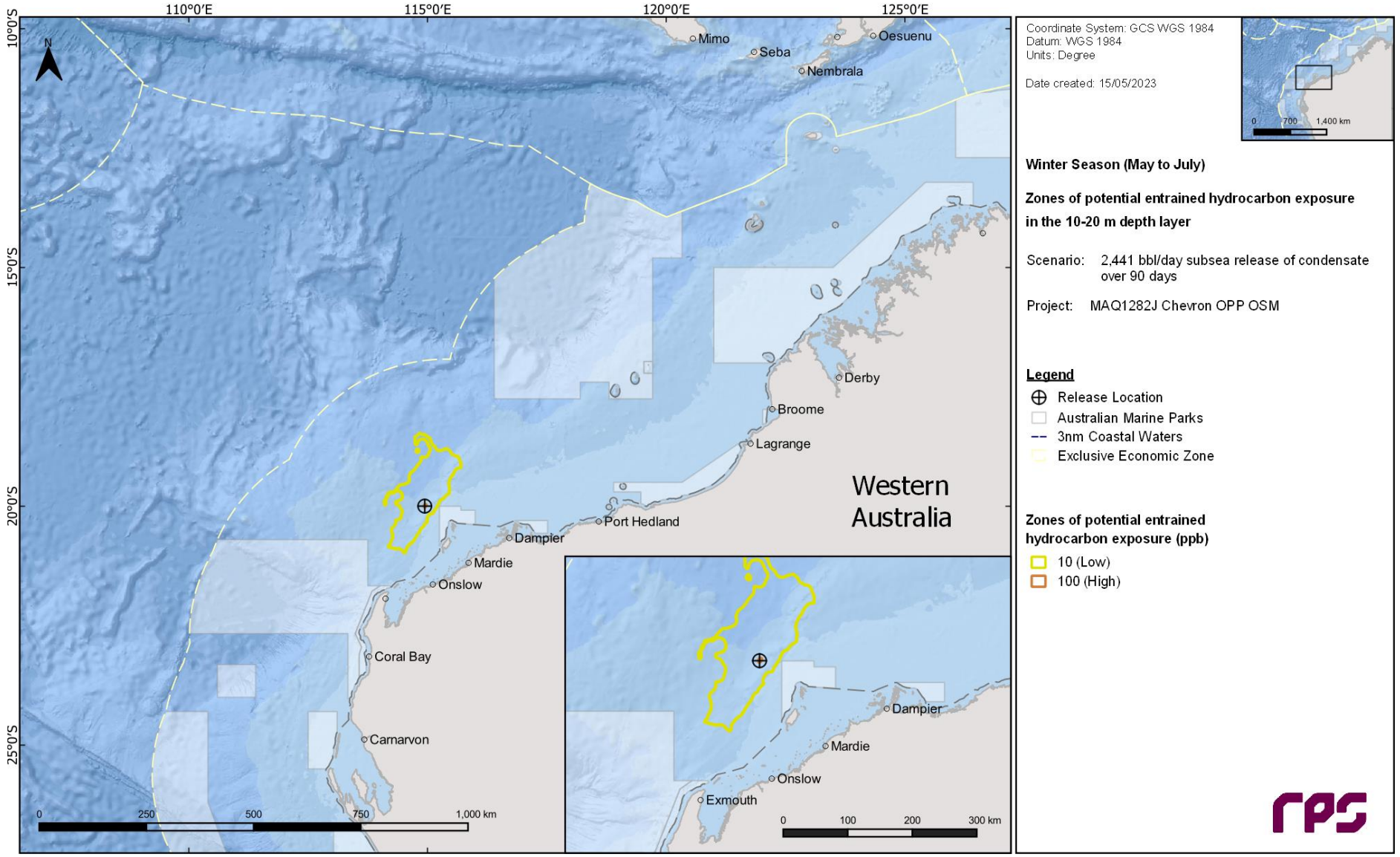


Figure 11.13 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), and the largest volume of condensate ashore (see Section 11.2.2), the longest length of shoreline with accumulation above 100 g/m2 (see Section 11.2.3) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.9 presents a summary of all deterministic analysis criteria and the corresponding values at the assessed thresholds.

Note that there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 564 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 36 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.9 Summary of the deterministic analysis following a subsea LOWC at Semele Well 5.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m^2	Largest volume of condensate ashore	Longest length of shoreline with accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Winter	Summer	Summer	Winter
Run Number		43	18	8	48
Floating Oil (km^2)	1 g/m^2	564	489	814	598
	10 g/m^2	**4**	-	-	-
	50 g/m^2	-	-	-	-
Shoreline Length (km)	10 g/m^2	-	137	38	-
	100 g/m^2	-	1	**3**	-
	1,000 g/m^2	-	-	-	-
Minimum Time (days)		-	33	20.3	-
Maximum Volume (m^3)		-	**29**	8	-
Entrained Area (km^2)	10 ppb	68,367	78,433	75,220	96,269
	100 ppb	1,015	1,169	505	**2,351**
Dissolved Area (km^2)	10 ppb	4	5	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		30 June 2011	16 November 2010	27 December 2011	31 July 2013

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 43 during the winter period.

Figure 11.14 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.15 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.16 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	325	43	1
Entrained (m^3)	2,703	90	1,561
Dissolved (m^3)	61	78	2
Evaporation (m^3)	23,577	104	23,577
Decay (m^3)	9,937	104	9,937
Ashore (m^3)	0	0	0

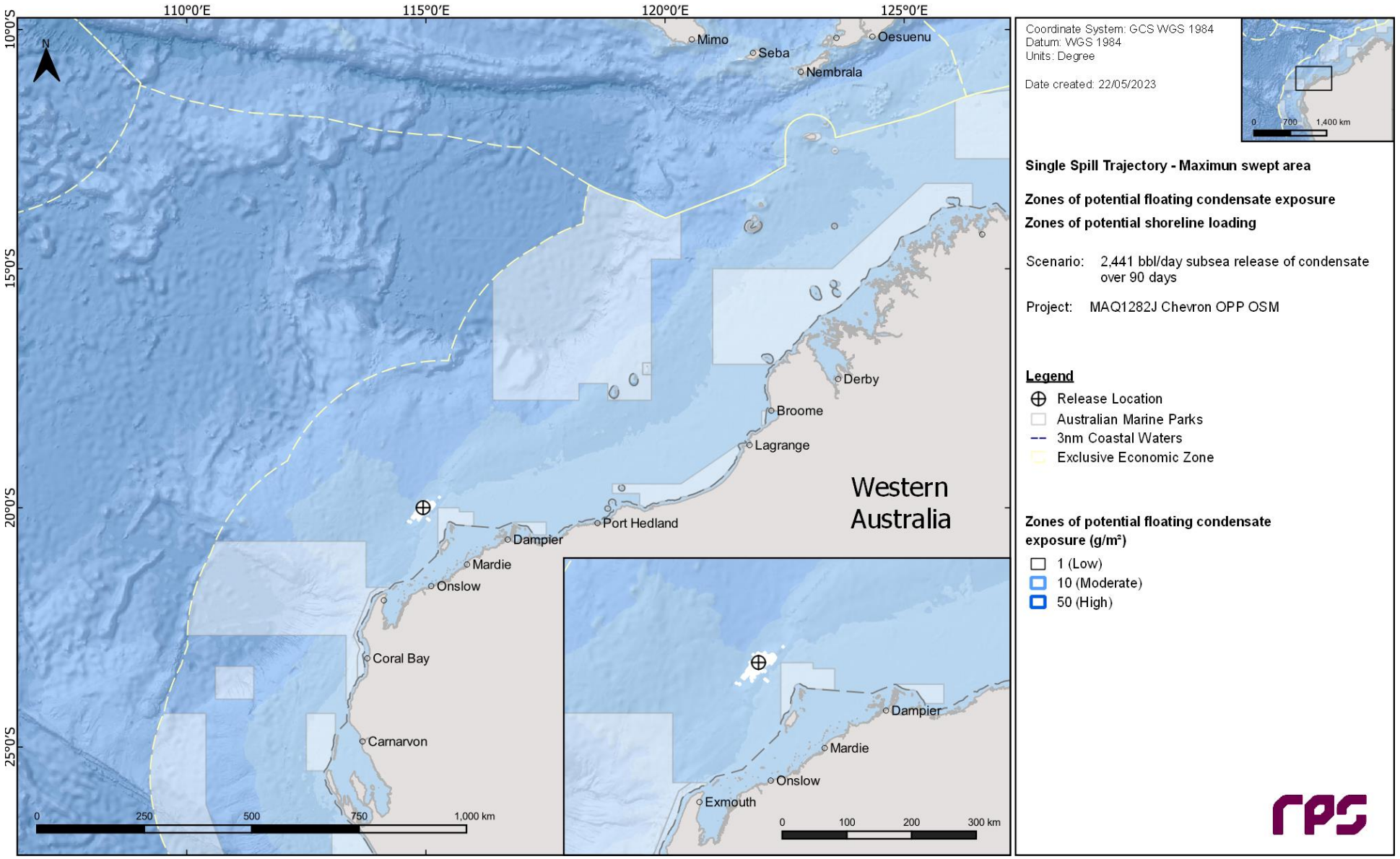


Figure 11.14 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Semele Well 5.

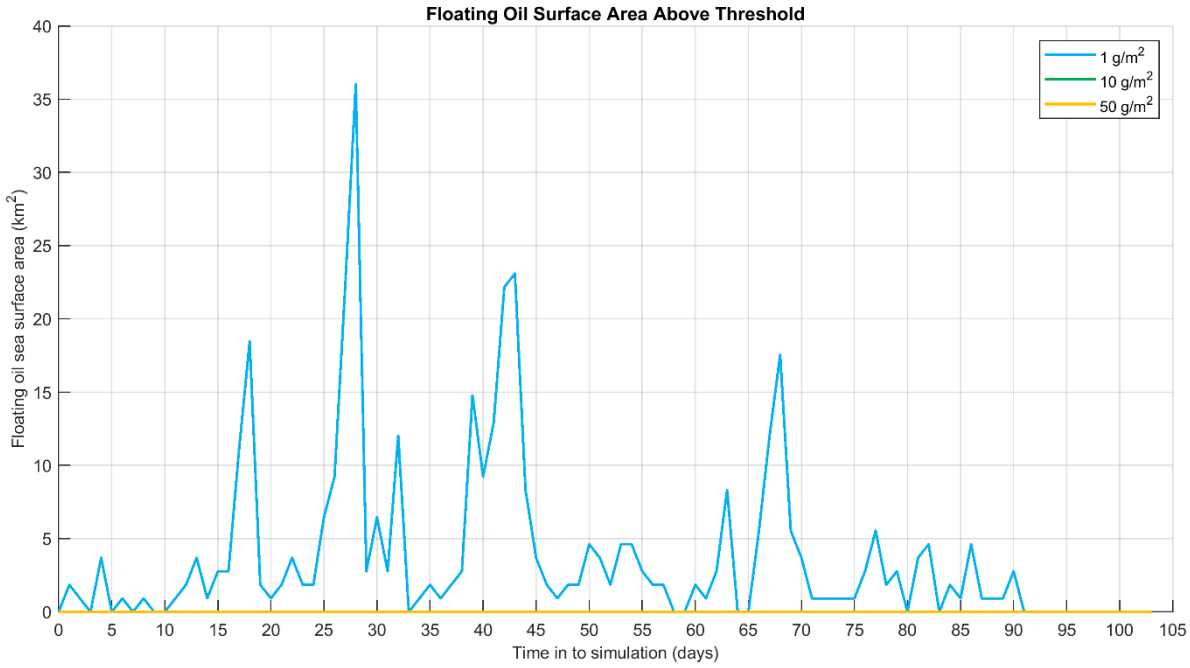


Figure 11.15 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Semele Well 5.

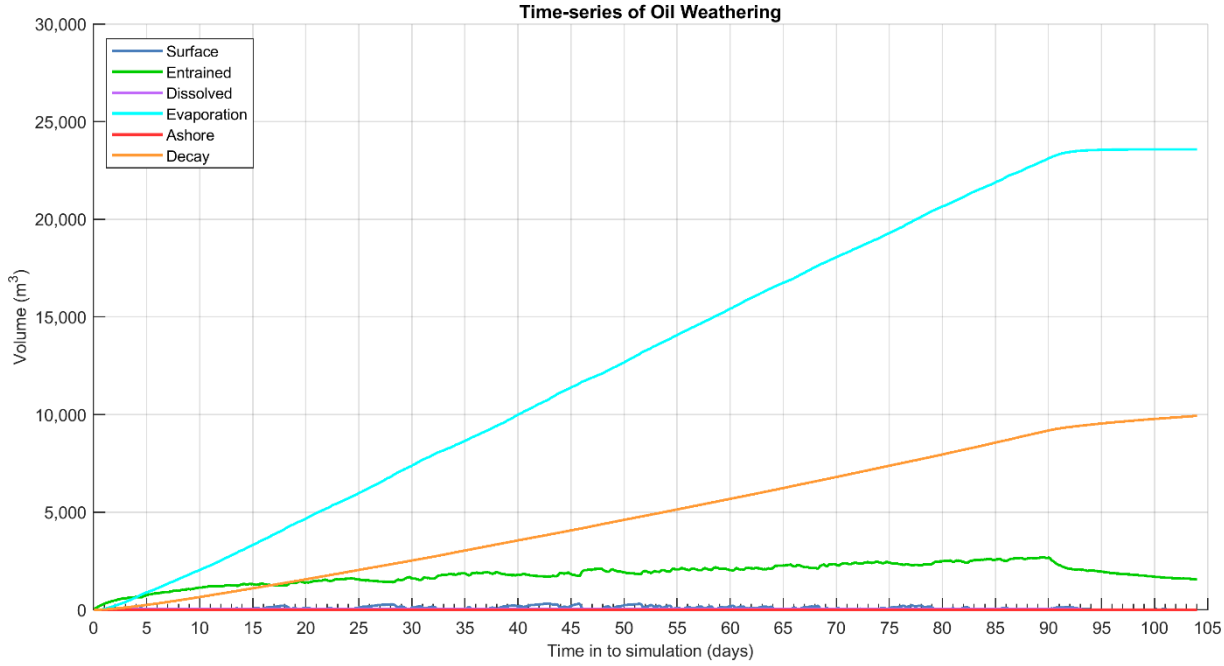


Figure 11.16 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Semele Well 5.

11.2.2 Deterministic Case: Largest volume of condensate ashore

The deterministic simulation that resulted in the largest volume of condensate ashore was identified as run number 18, during the summer season.

Figure 11.17 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.18 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.19 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of condensate ashore following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	196	75	1
Entrained (m^3)	2,518	87	1,458
Dissolved (m^3)	61	52	2
Evaporation (m^3)	23,753	104	23,753
Decay (m^3)	9,826	104	9,826
Ashore (m^3)	43	103	43

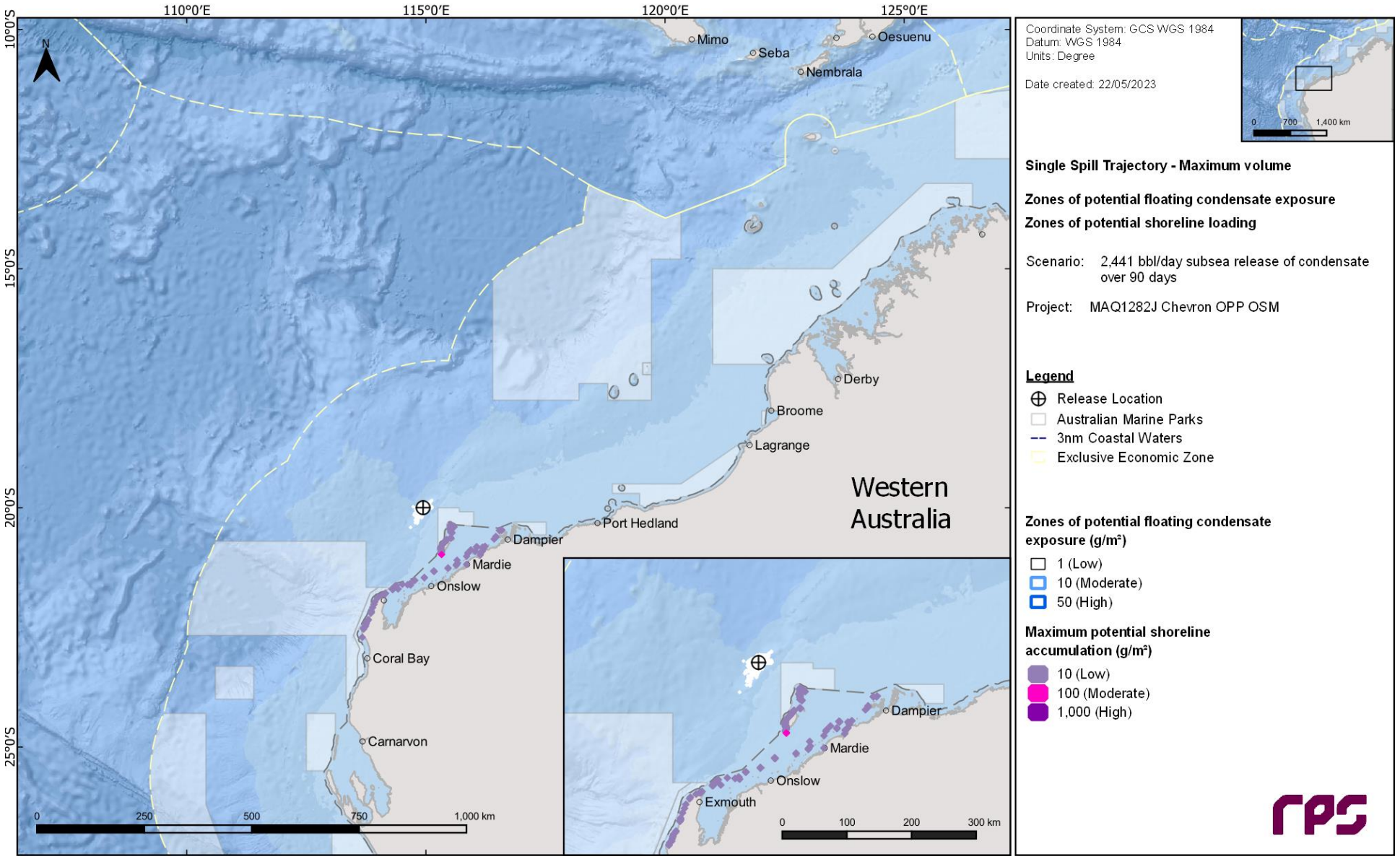


Figure 11.17 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of condensate ashore following a LOWC at Semele Well 5.

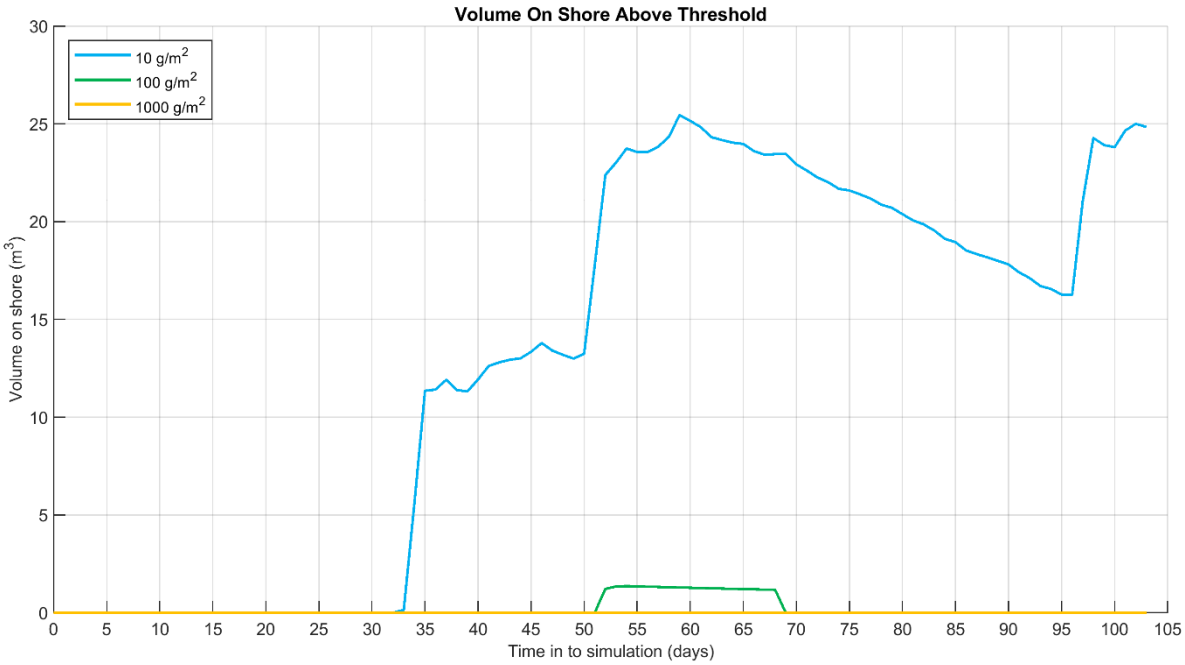


Figure 11.18 Time series of the volume of condensate ashore at each threshold for the simulation with the largest volume ashore following a LOWC at Semele Well 5.

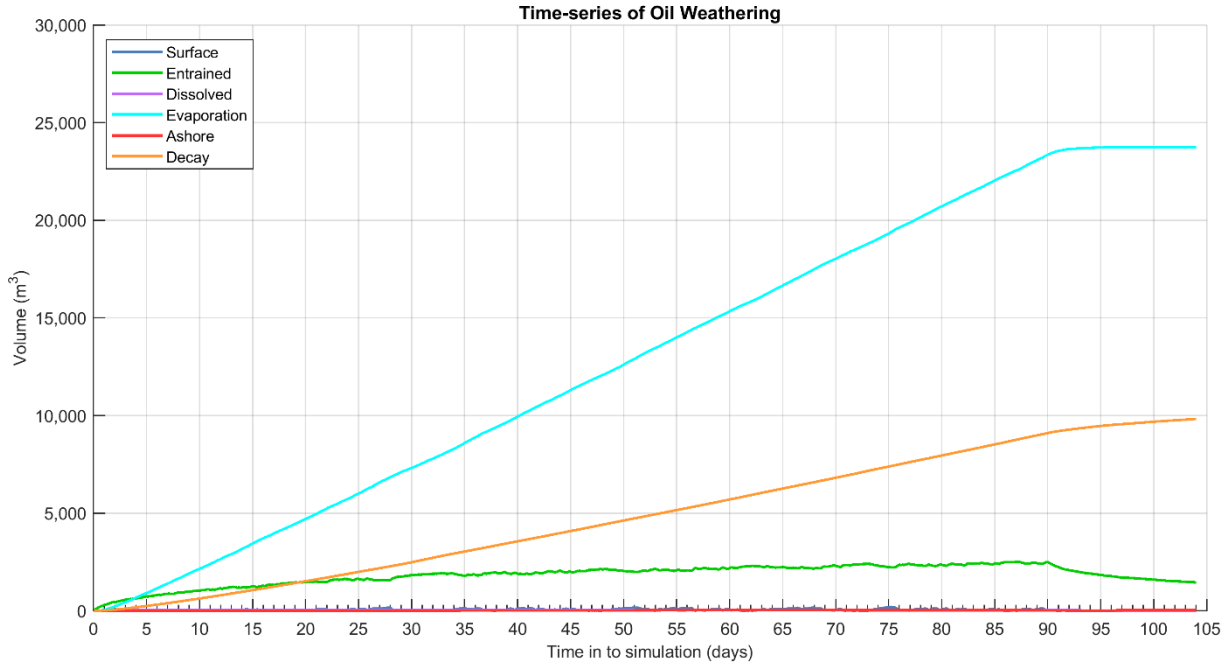


Figure 11.19 Predicted weathering and fates for the simulation with the largest volume of condensate ashore following a LOWC at Semele Well 5.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 8 during the summer period.

Figure 11.17 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.18 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.19 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.12 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	274	22	35
Entrained (m^3)	2,525	82	1,399
Dissolved (m^3)	61	73	2
Evaporation (m^3)	24,037	104	24,037
Decay (m^3)	9,599	104	9,599
Ashore (m^3)	19	42	10

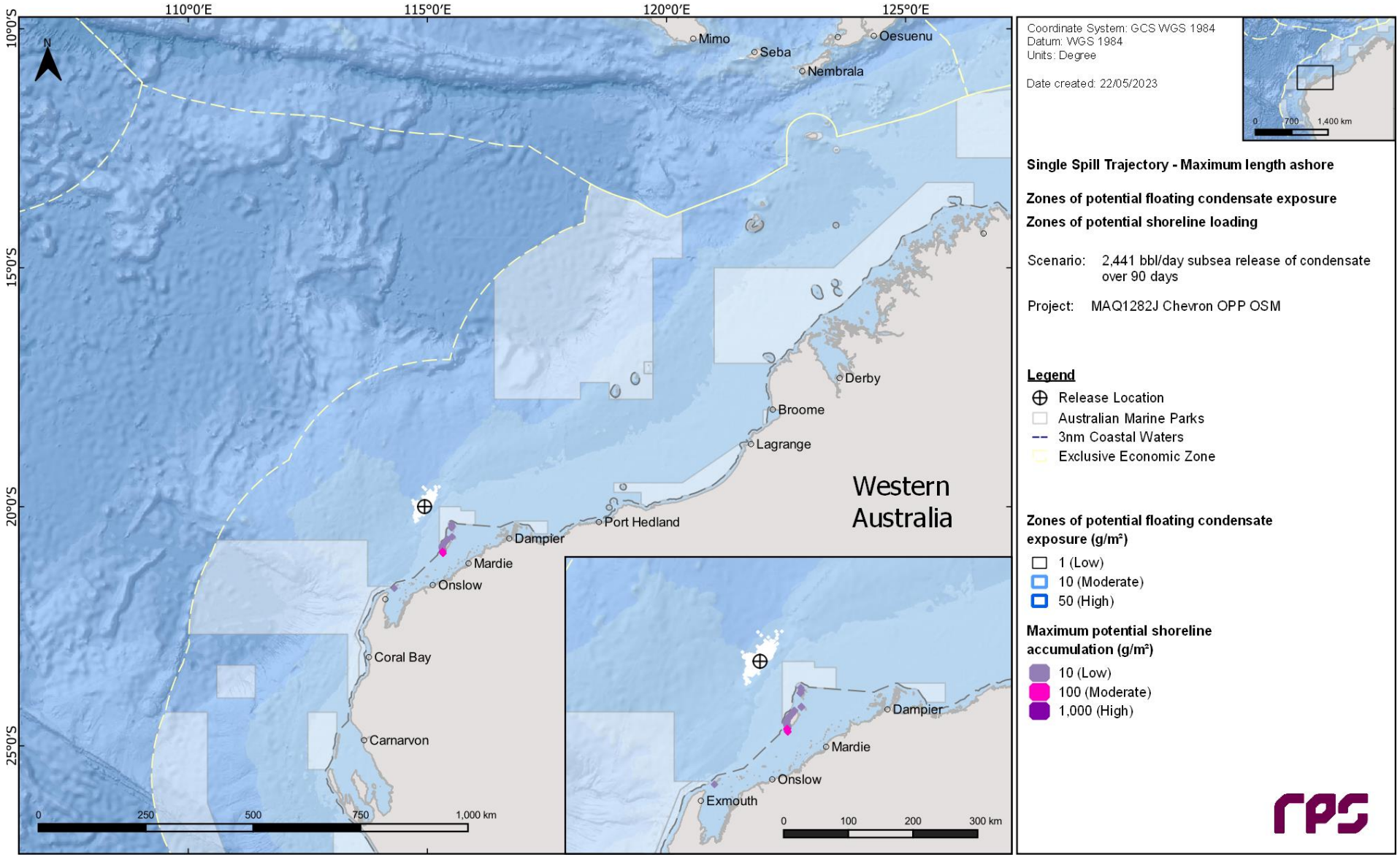


Figure 11.20 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Semele Well 5.

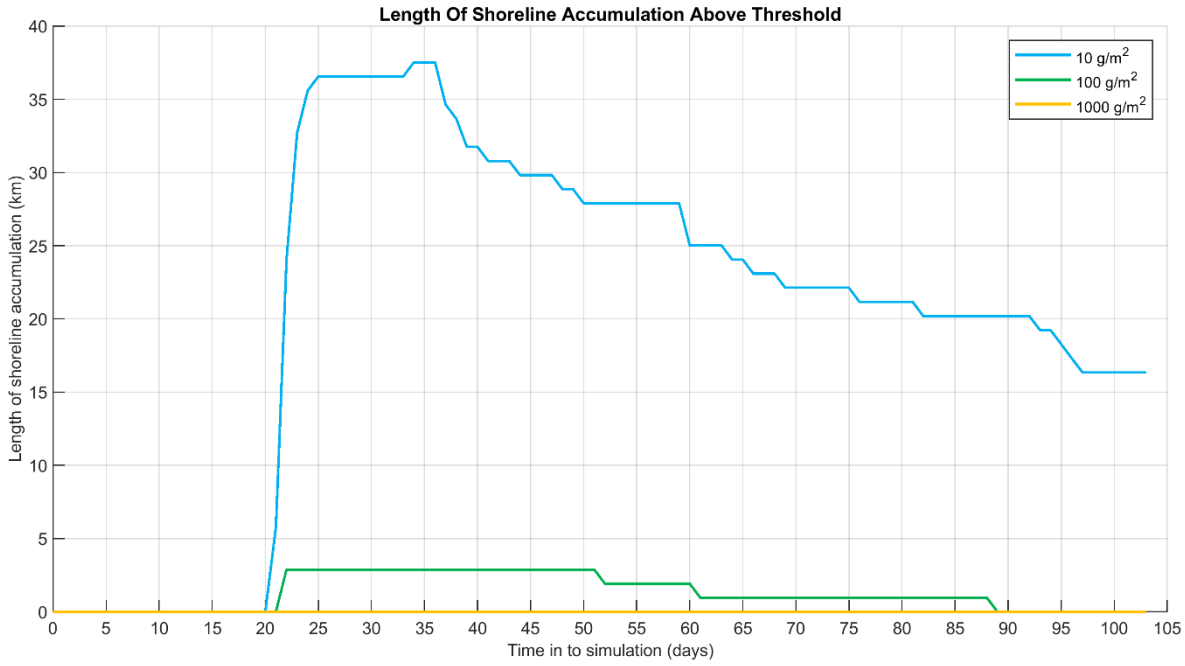


Figure 11.21 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Semele Well 5.

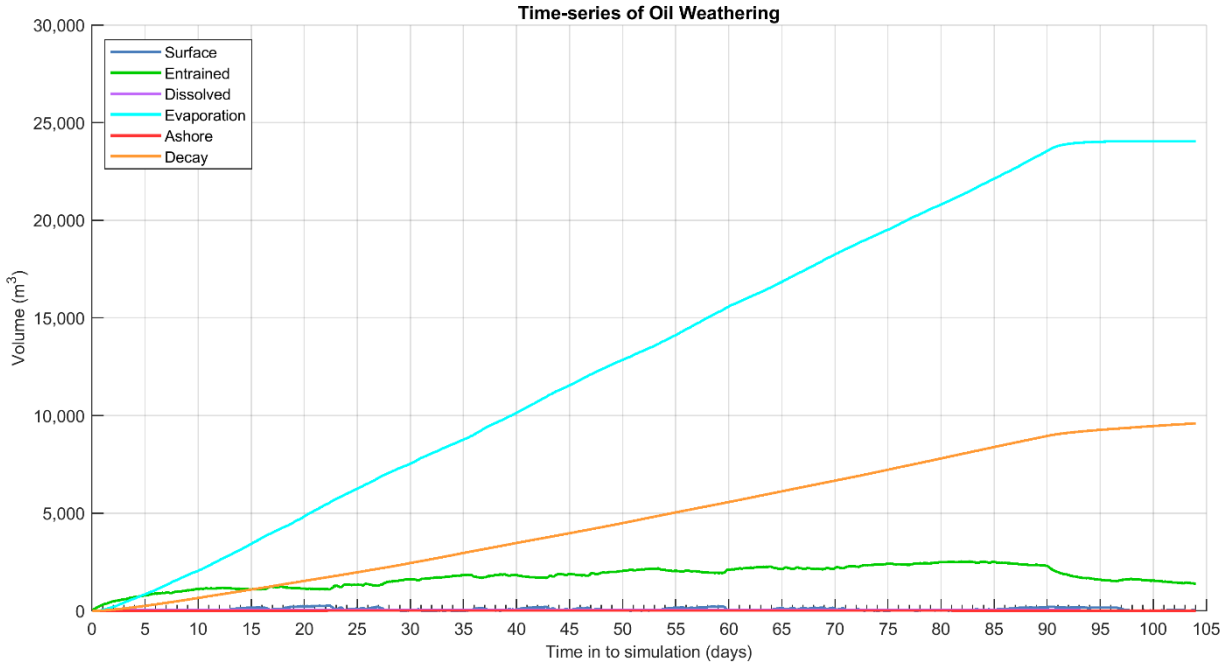


Figure 11.22 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Semele Well 5.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 48 during the winter period.

Figure 11.23 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.24 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.25 presents the fates and weathering for the corresponding single spill trajectory and Table 11.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	244	15	7
Entrained (m^3)	2,860	87	1,701
Dissolved (m^3)	61	37	2
Evaporation (m^3)	23,134	104	23,134
Decay (m^3)	10,246	104	10,246
Ashore (m^3)	0	43	0

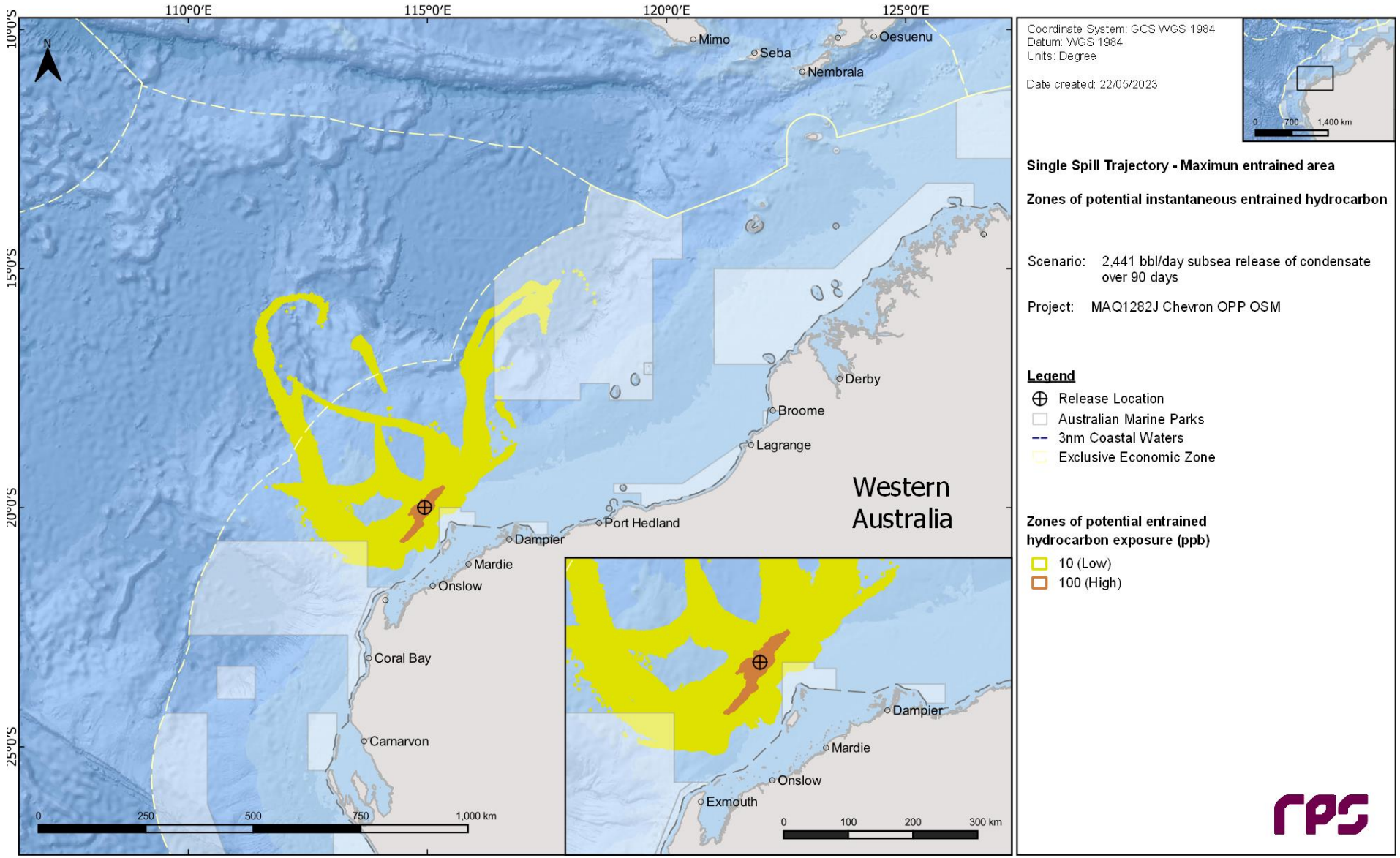


Figure 11.23 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

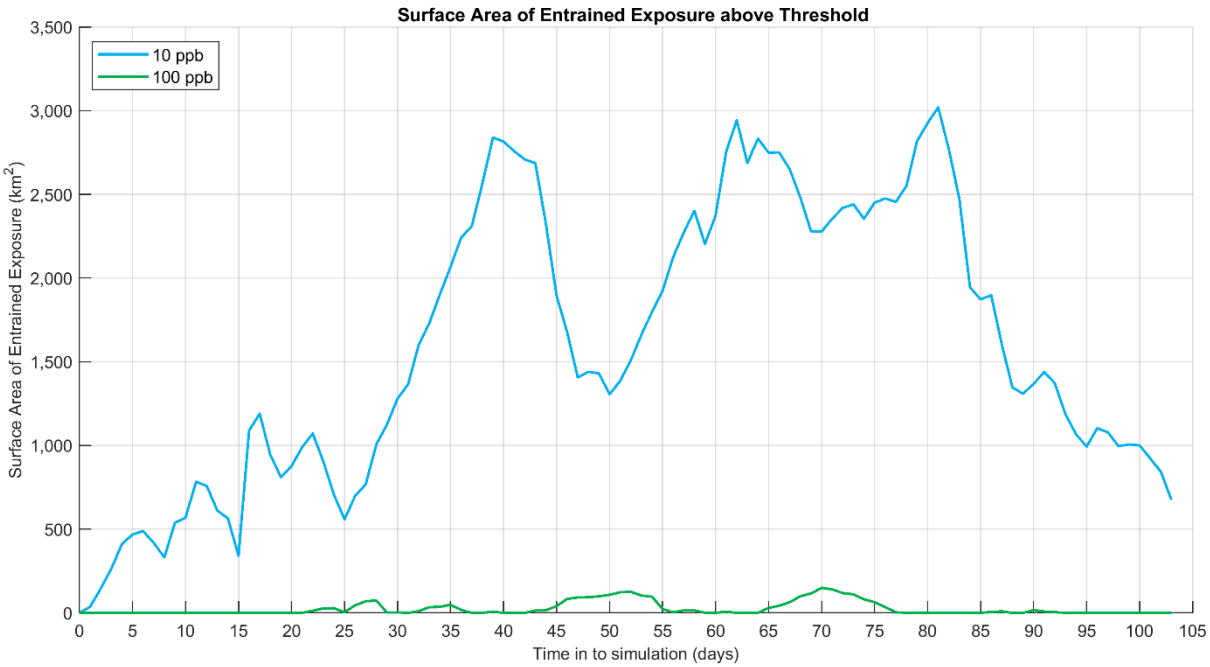


Figure 11.24 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

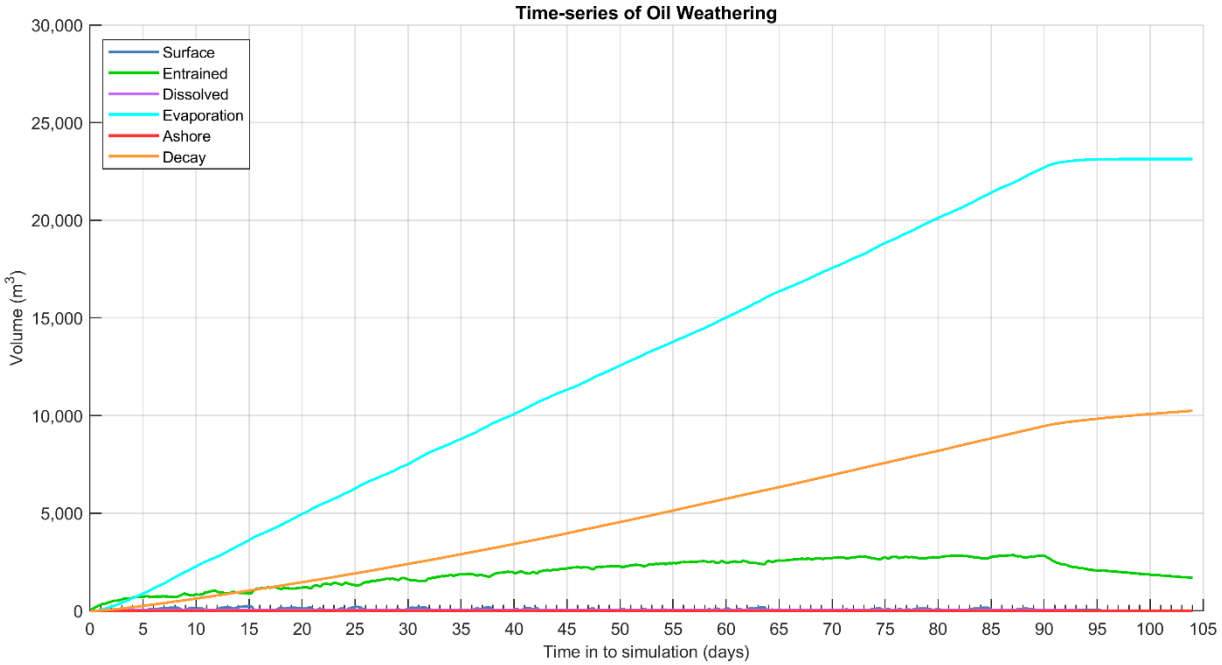


Figure 11.25 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

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appendix c.6—chandon LOWC (condensate)

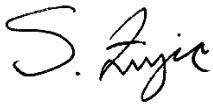
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TERMS AND ABBREVIATIONS

°	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

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.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
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.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
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.
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.
Floating condensate 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
g/m^2	Grams per square meter (unit of surface area density)
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.

IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
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 2 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, 2017). 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
SRTM	Shuttle Radar Topography Mission
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 environment that maybe affected (EMBA) and indicates which 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 will encompass 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 region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) 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
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chandon field situated within the Northern Carnarvon Basin in Permit area WA-53-R, northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 5,214 stb/day (829 m^3/day) subsea release of condensate over 90 days (totalling 469,260 stb or 74,604 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) 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, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Chandon condensate physical properties and boiling point distributions were provided by Chevron. The condensate has an API of 47.80, a density of 789 kg/m^3 (at 15ºC) and a viscosity value of 2.6 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 45.9% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 26.3% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (22.4%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 5.4% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. For this condensate, the aromatic hydrocarbons contribute 2.5% and are all contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 102.9 km south (transitional) and 5.2 km west (transitional and winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- Other than the receptors that the release location resides within (Offshore Area Impact Assessment Area (IAA), Pygmy Blue Whale – Distribution Biologically Important Area (BIA) and Exmouth Plateau Key Ecological Feature (KEF)), the Wedge-tailed Shearwater – Breeding BIA was the only other receptor to exposed above the low threshold, but only for the transitional season and a 1% probability.

- No shoreline accumulation at or above the low (≥ 10 g/m^2) shoreline contact threshold was recorded for any of the spill simulations.

- There was no exposure to any other receptors by dissolved hydrocarbons in the 0-10 m depth layer, other than those that the release location resides within, being Offshore Area IAA and Pygmy Blue Whale – Distribution BIA.

- In the 0-10 m depth layer, a total of 16 BIAs were shown to be exposed to entrained hydrocarbons at, or above, the low threshold (≥10 ppb) during all 3 seasons. Across the three seasons, 5 Australian Marine Parks (AMPs) were predicted to be exposed at, or above the low threshold, with the highest probabilities predicted at the Gascoyne AMP (63% summer, 65% transitional and 68% winter). Furthermore, during summer conditions the Gascoyne AMP was shown to be exposed to entrained hydrocarbons at the high threshold above 100 ppb (5%). Additionally, 5 KEFs were shown to be exposed to entrained hydrocarbons at or above the low threshold. Furthermore, the Rankin Bank was shown to be exposed to entrained hydrocarbons at the low threshold only during the summer season.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chandon field situated within the Northern Carnarvon Basin in Permit area WA-53-R, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the Chandon field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 5,214 stb/day (829 m^3/day) subsea release of condensate over 90 days (totalling 469,260 stb or 74,604 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, 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.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis 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.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, 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 Chandon release location.

Location	Latitude	Longitude	Depth (mLAT)
Chandon Well 1	19.56712° S	114.12603° E	1,100

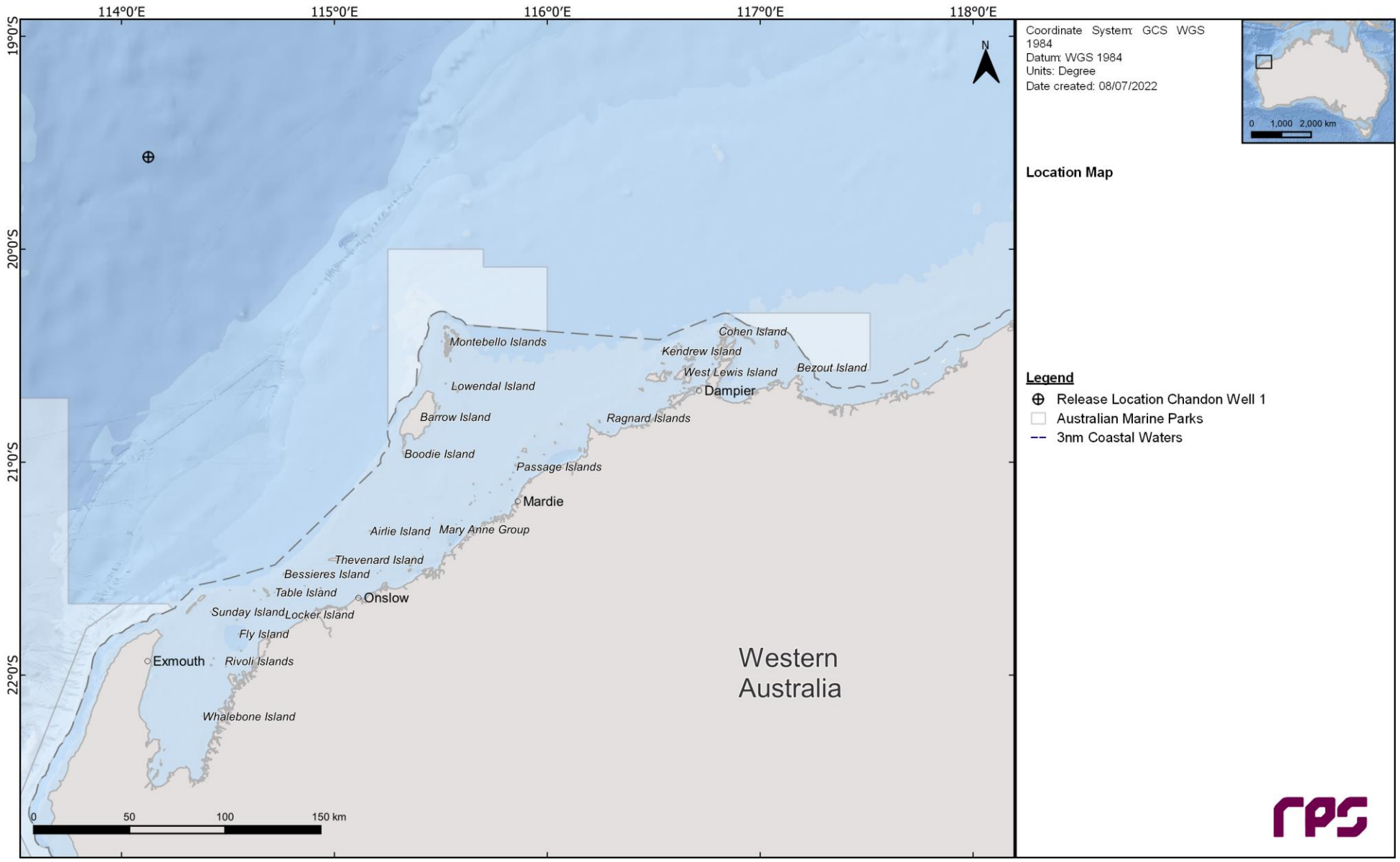


Figure 1.1 Chandon hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
    a. Largest swept area of floating hydrocarbon above 10 g/m^2
    b. Largest swept area of floating hydrocarbon above 50 g/m^2
    c. Largest volume of oil ashore
    d. Longest length of shoreline accumulation above 100 g/m^2
    e. Largest area of entrained hydrocarbons above 100 ppb
    f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2, no dissolved hydrocarbon exposure at or above 50 ppb, and no shoreline accumulation at or above any threshold, for any of the 300 simulations, the deterministic results are presented based on criteria a, and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

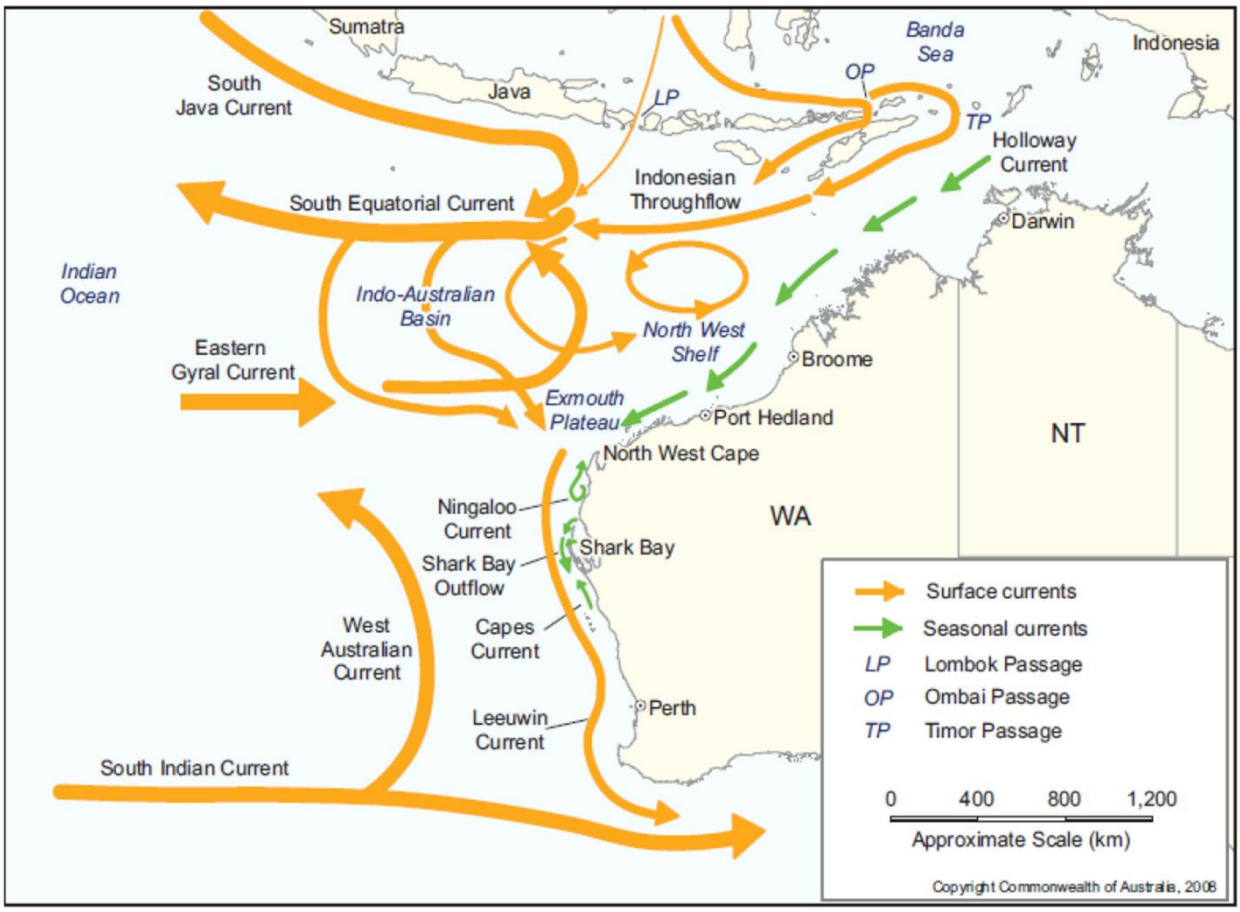


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

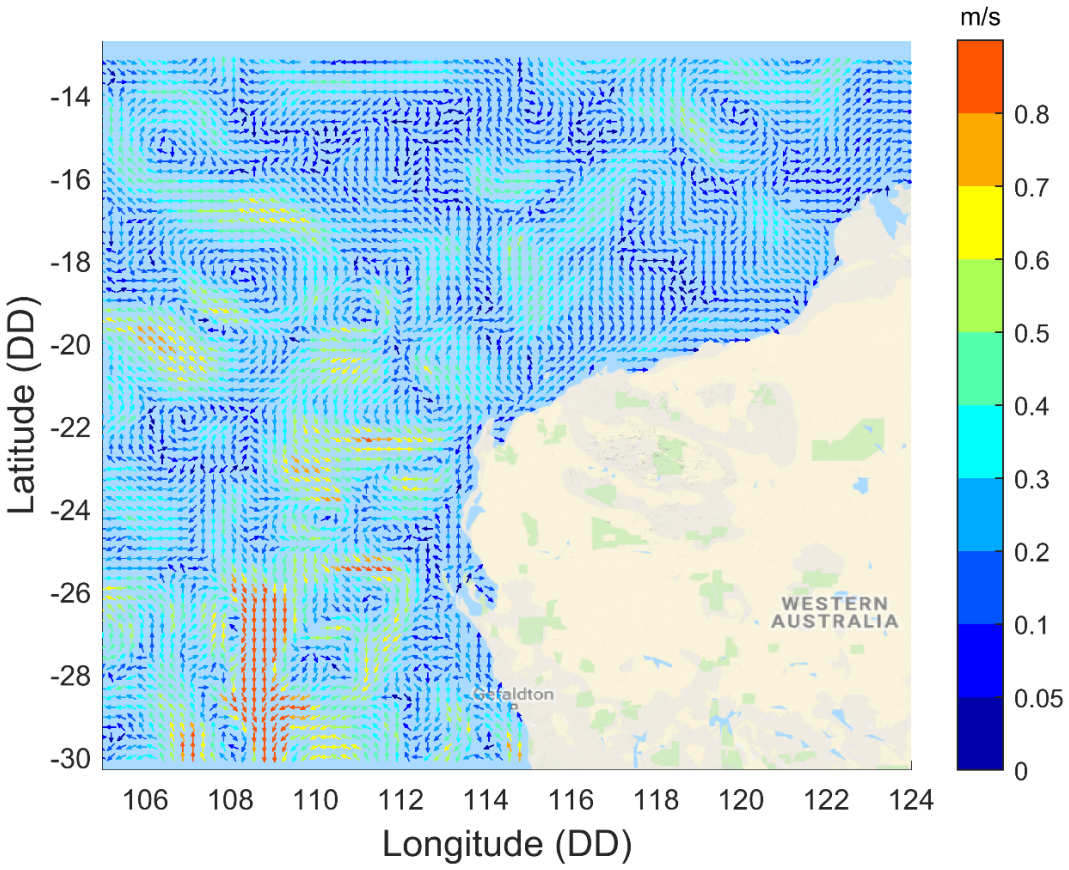


Figure 3.2 Typical ocean current circulation pattern during the summer months.

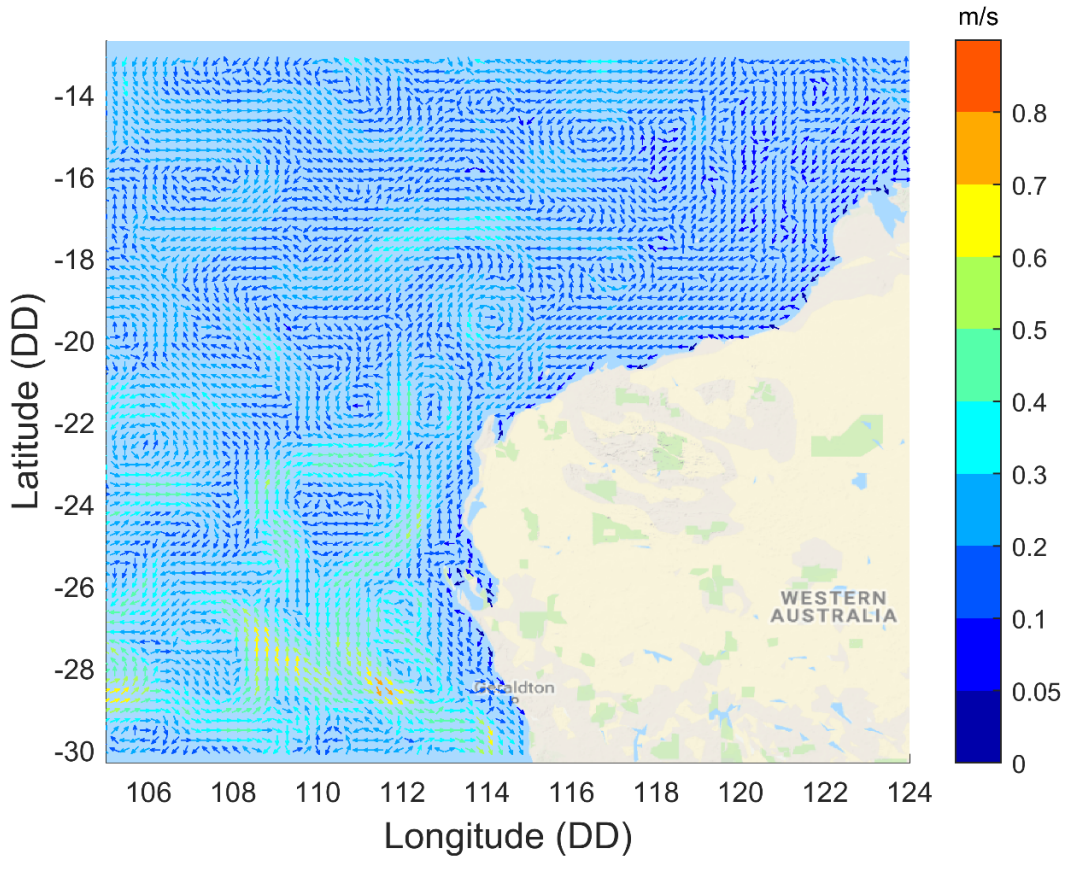


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 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 and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded 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 regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

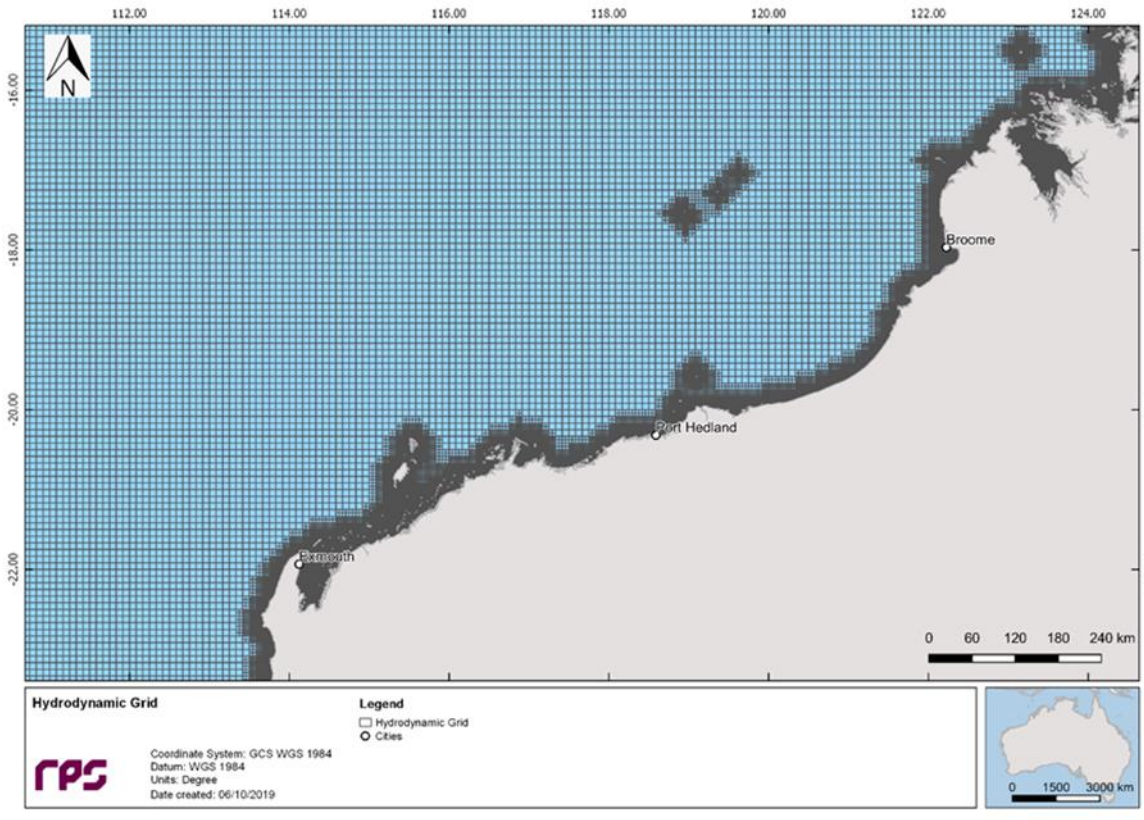


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

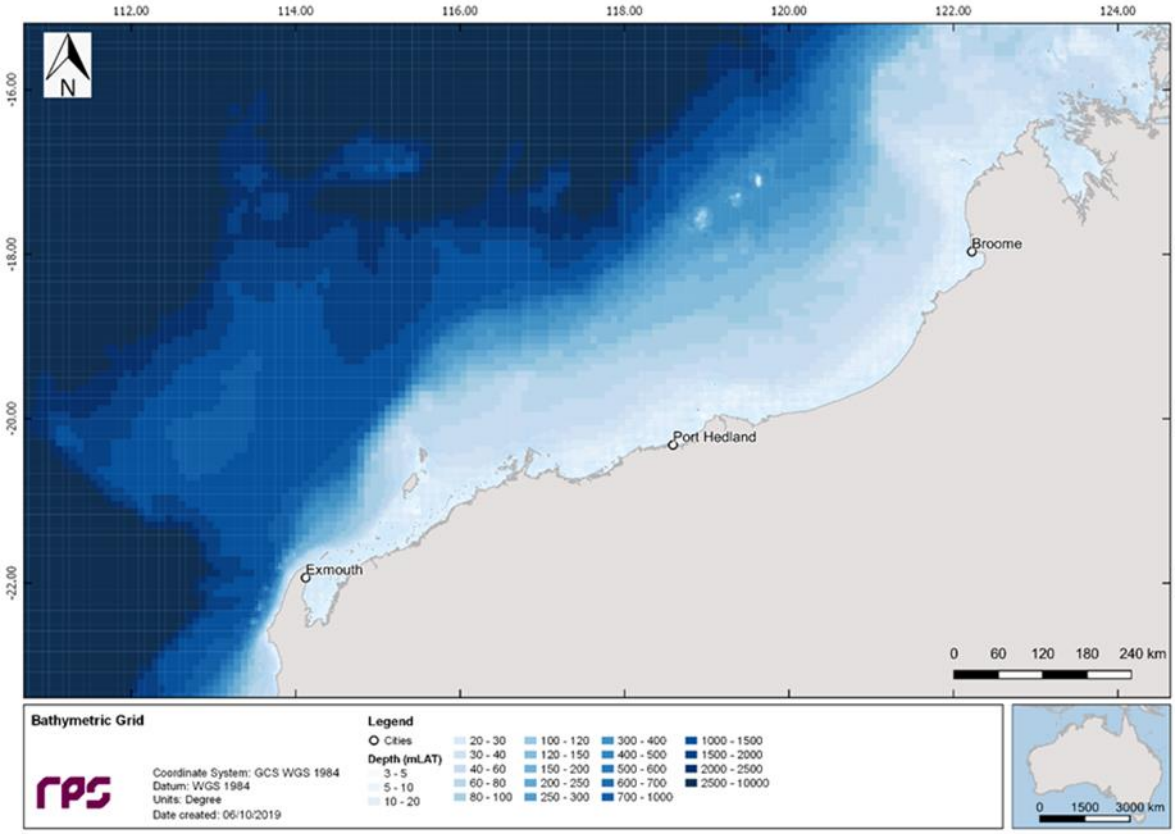


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. 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.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.23 m/s (February). Additionally, the maximums ranged between 0.55 m/s (November) and 1.36 m/s (January). The general current directions were quite variable throughout the year. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.22	1.36	Northeast
	February	0.23	0.97	Variable
	March	0.18	0.57	Westerly
Transitional	April	0.21	1.15	Westerly
Winter	May	0.22	0.90	Westerly
	June	0.21	0.60	Northwest
	July	0.20	0.90	Westerly
Transitional	August	0.17	0.59	North
Summer	September	0.19	0.93	Variable
	October	0.20	0.74	Northwest
	November	0.16	0.55	Variable
	December	0.21	0.73	North
Minimum		**0.16**	**0.55**	
Maximum		**0.23**	**1.36**	

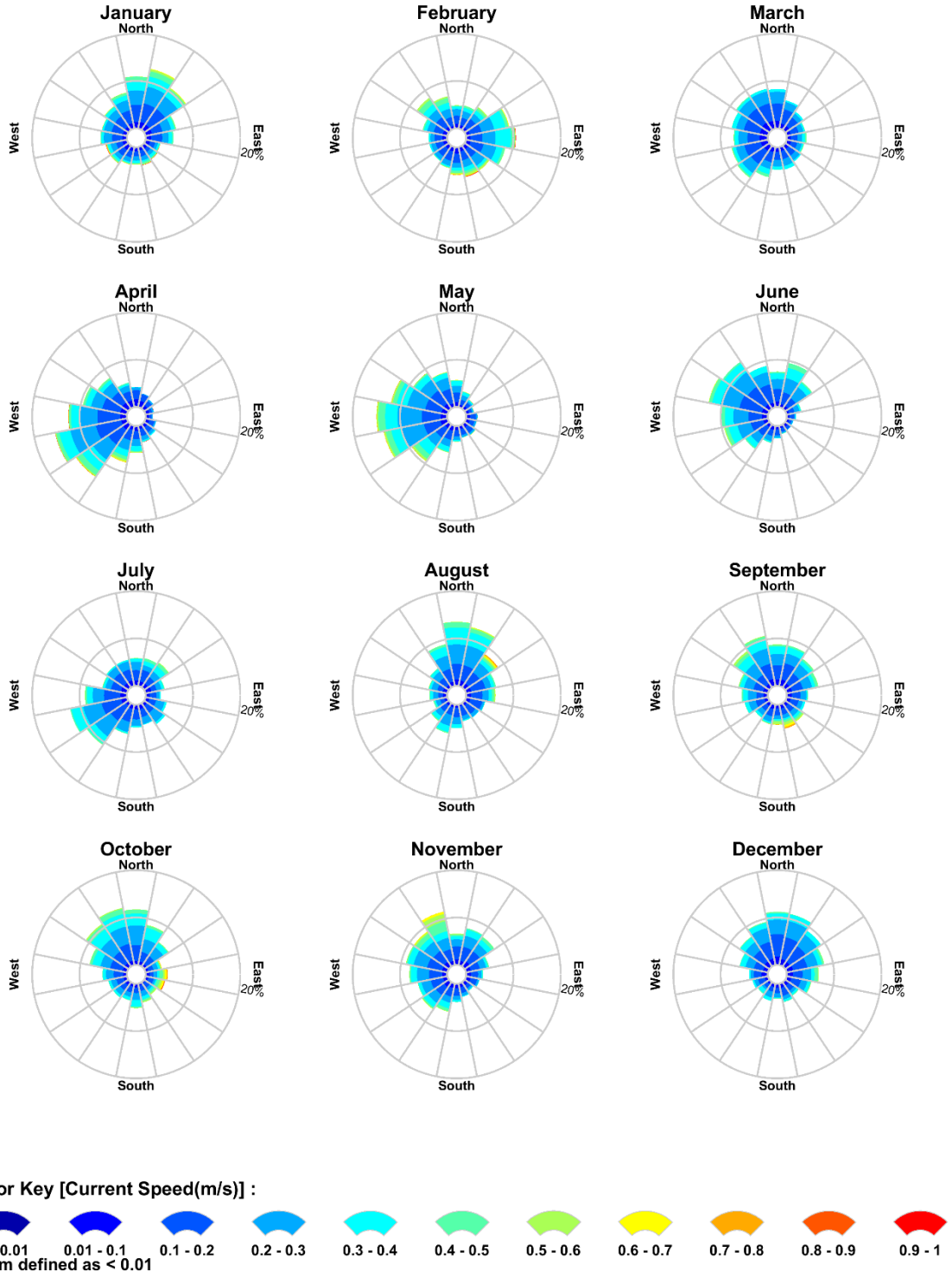


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

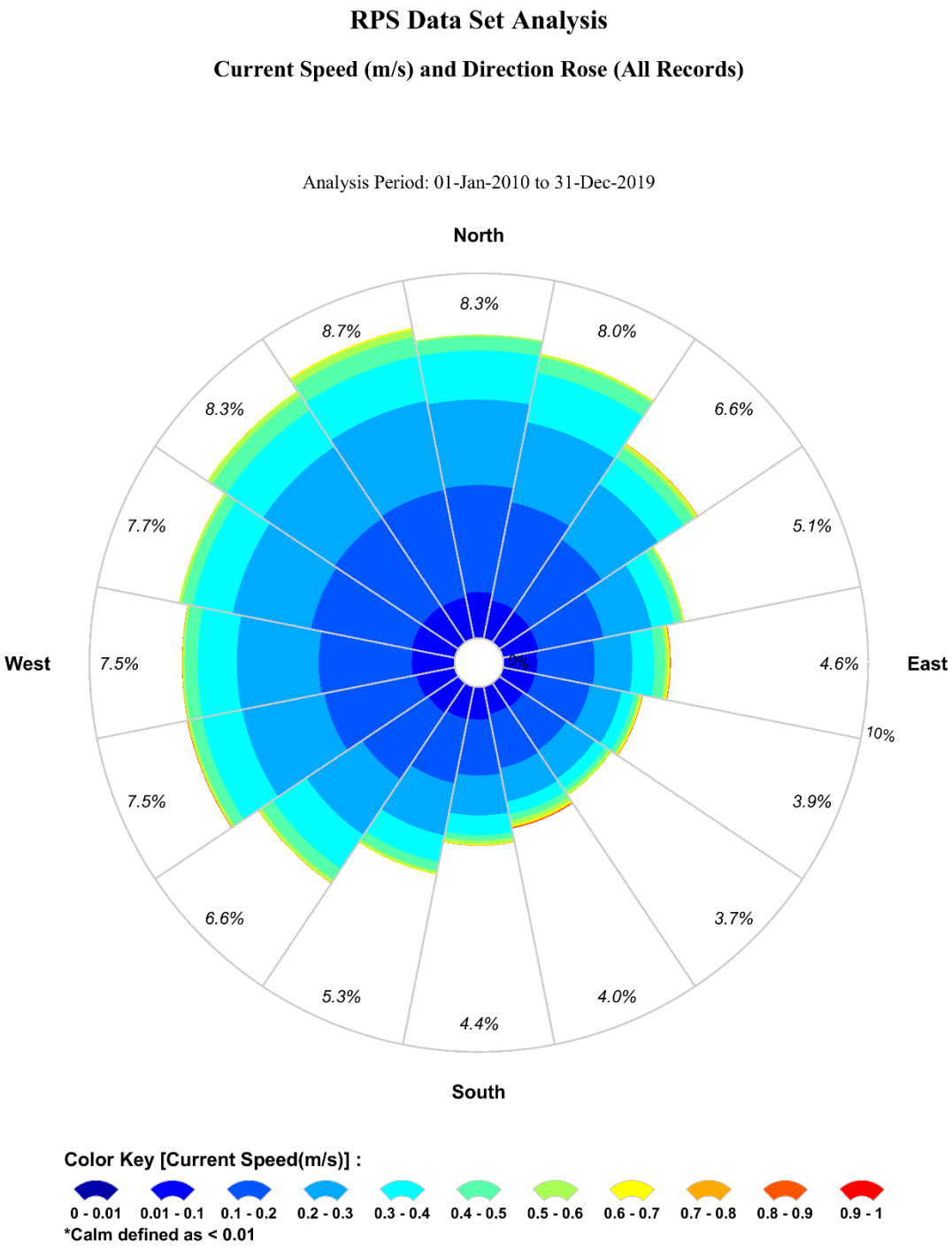


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 45 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

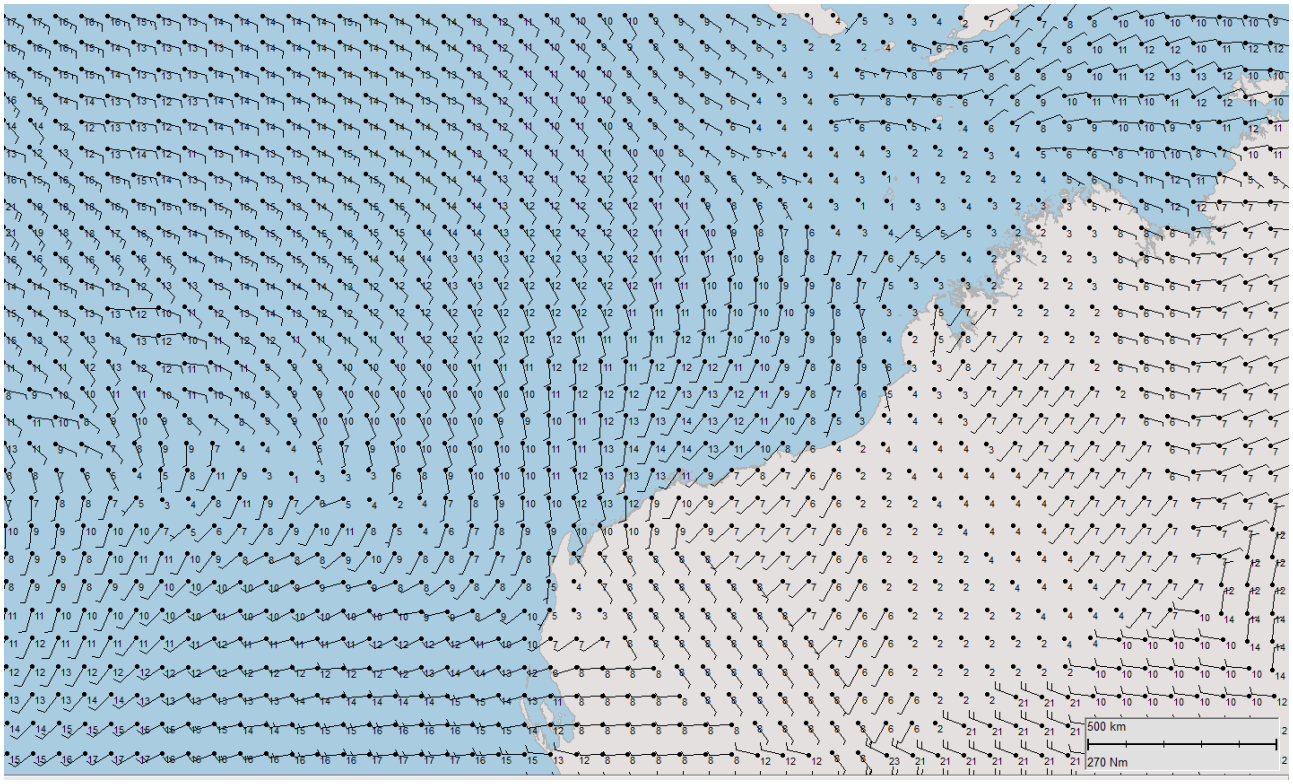


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	44	Southwest
	February	11	36	Southwest
	March	10	33	Southwest
Transitional	April	11	42	South
Winter	May	12	37	East
	June	14	30	East
	July	13	45	Southeast
Transitional	August	11	30	Southeast
Summer	September	12	25	South
	October	13	25	South
	November	13	24	South
	December	12	31	Southwest
Minimum		**10**	**24**	
Maximum		**14**	**45**	

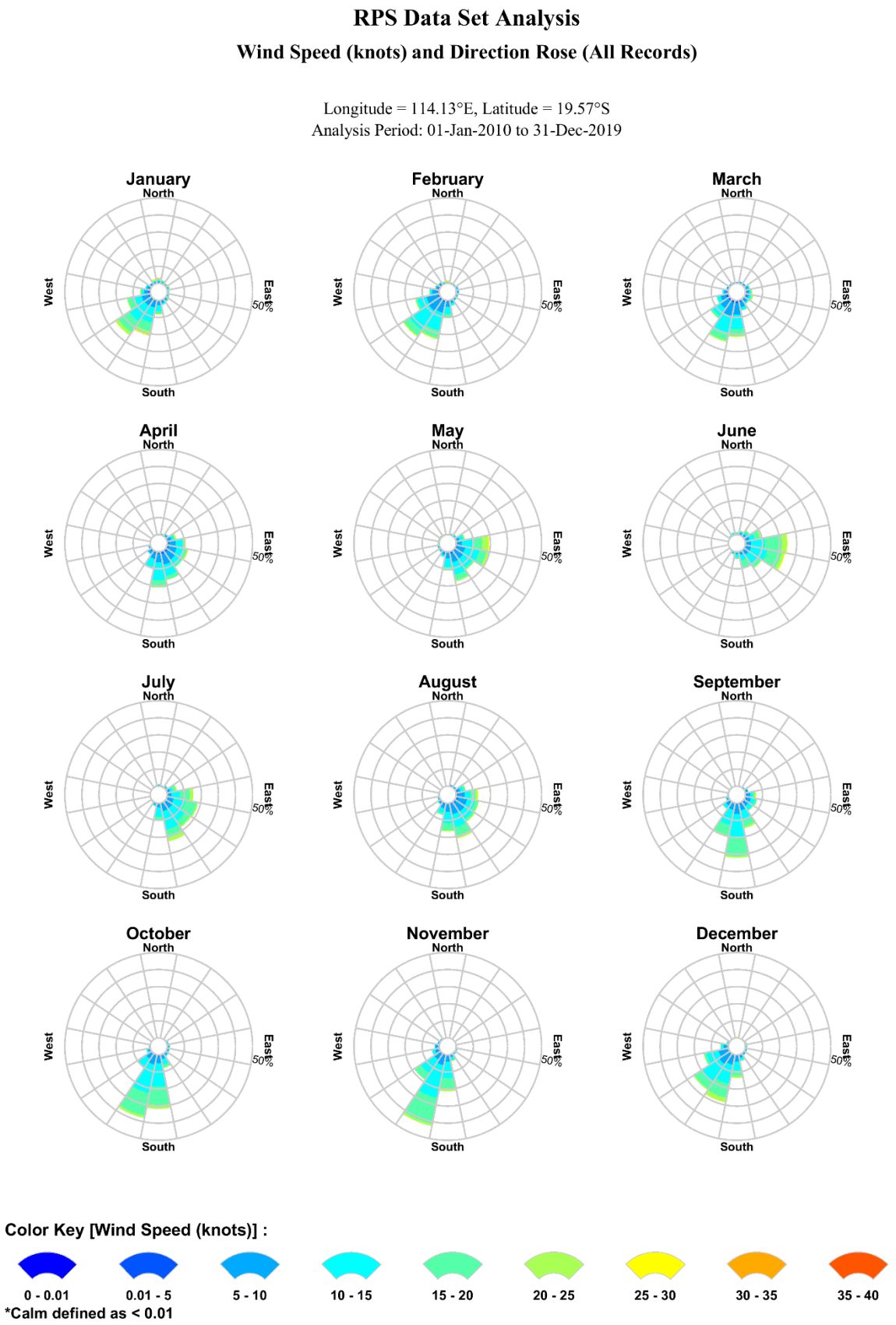


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

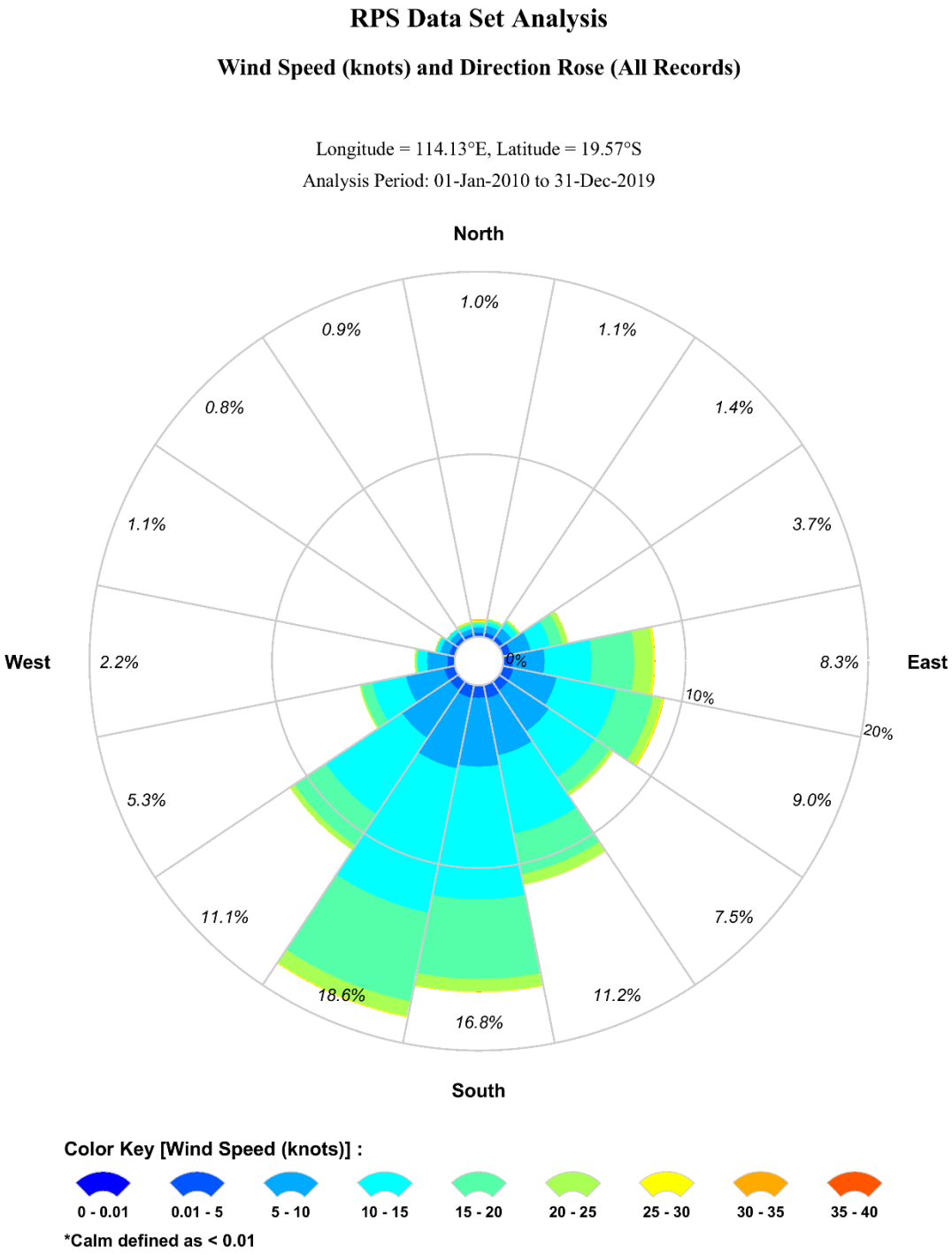


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.3°C (September) to 29.4°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	28.3	28.8	29.4	28.9	27.7	26.2	25.3	24.5	24.3	24.9	26.8	27.3
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

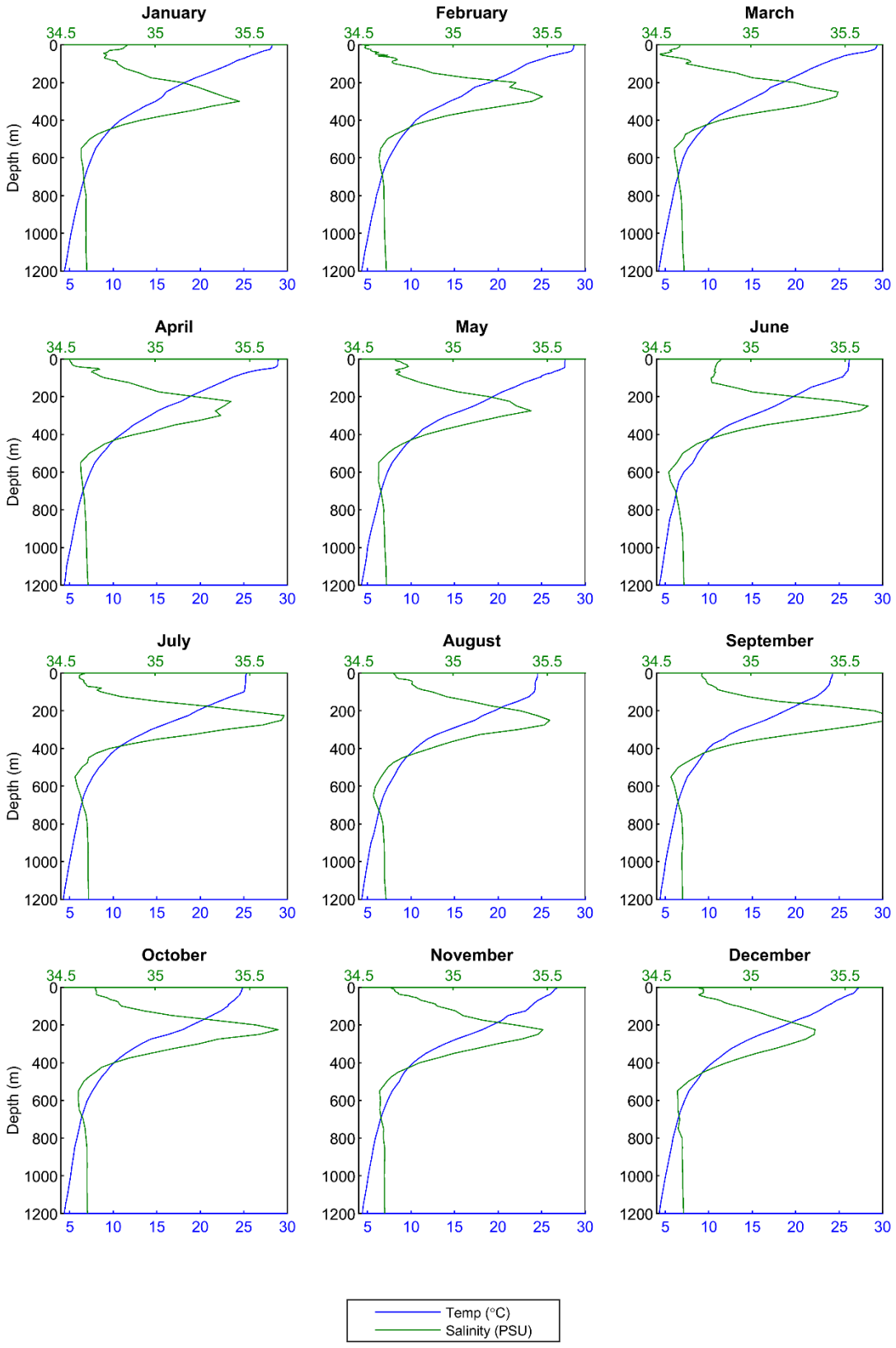


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

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).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 753 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which are predicted to range in size from 135 to 548 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Chandon Well 1
Water depth (m)	1,100
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	5,214
Gas rate (MMscf/day)	356
Gas to condensate ratio (scf/bbl)	68,278
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,296
Key results	
Plume execution depth (m BMSL)	753
Droplet sizes (µm)	135 to 584

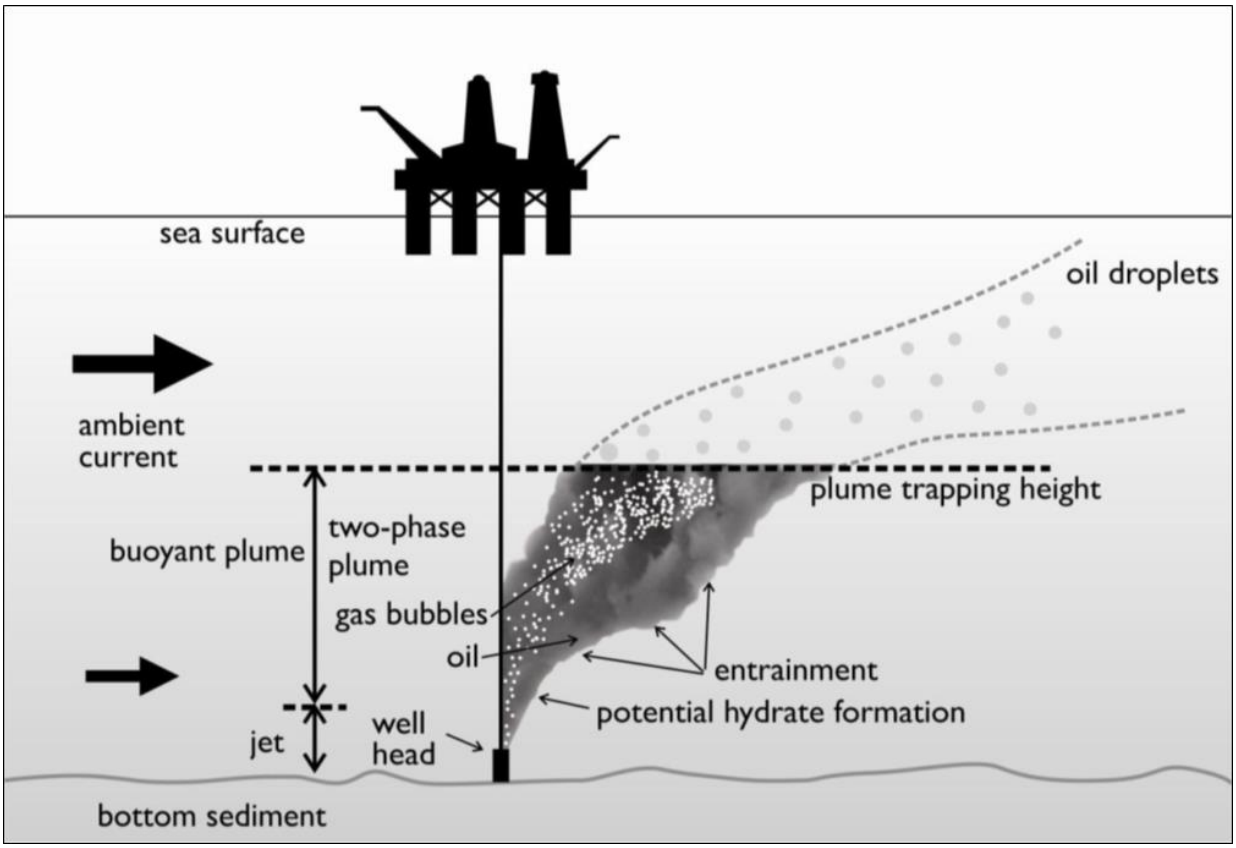


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

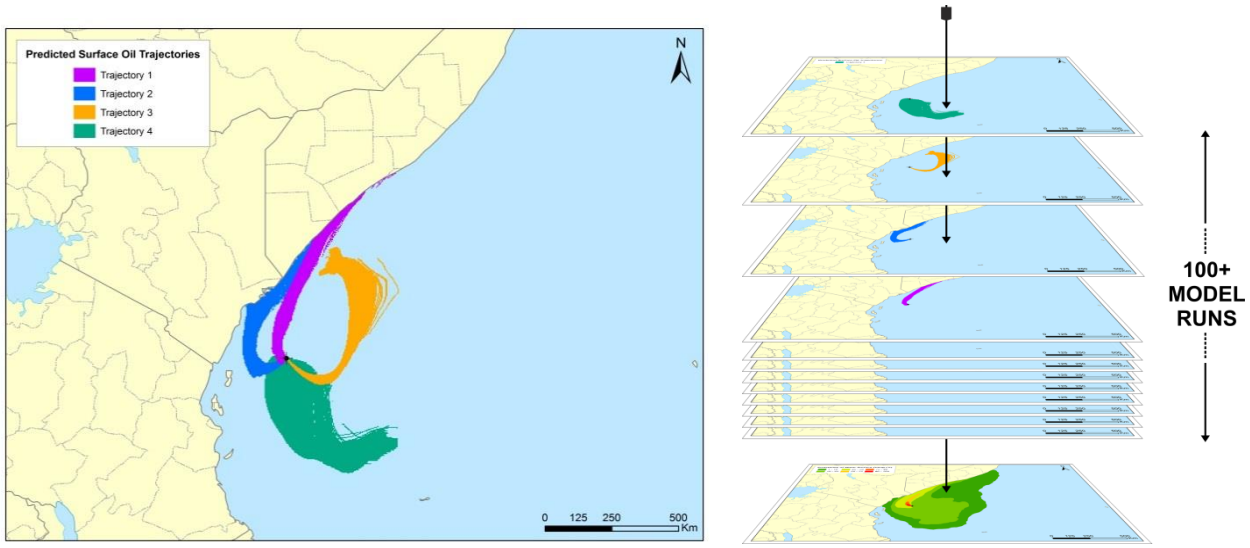


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating condensate exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating condensate exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil 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; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. 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 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil 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). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at 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). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating condensate exposure reported herein.

Table 7.1 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

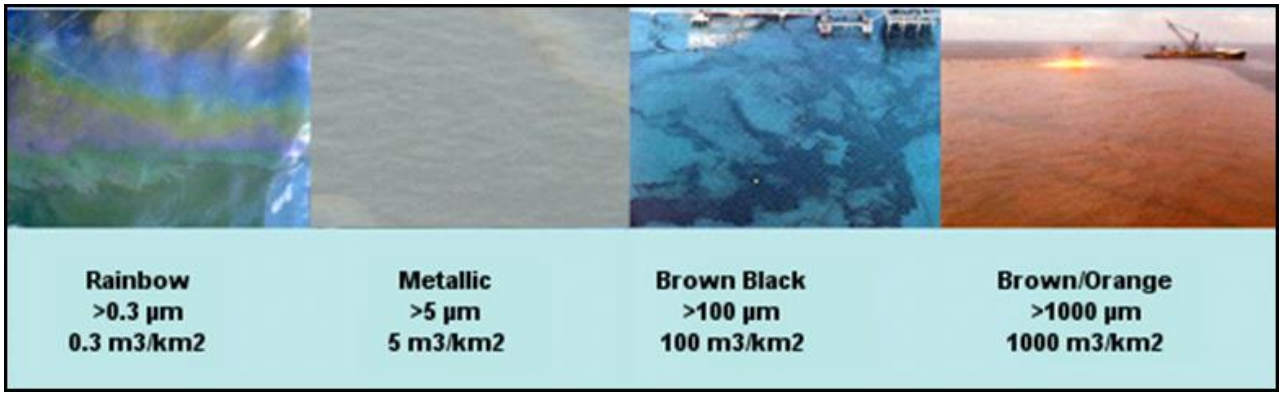


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating condensate exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (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

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential "low 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 to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential "moderate shoreline accumulation".

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential "high shoreline accumulation". It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	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 In-water Exposure 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 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on 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 & ARMCANZ (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.

This exposure zone 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 7.4), 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 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

Chandon condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

Chandon condensate has an API of 47.80, a density of 789 kg/m^3 (at 15ºC) and a viscosity value of 2.6 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 45.9% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 26.3% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (22.4%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 5.4% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble aromatic hydrocarbons contribute approximately 2.5% by mass of the whole oil, which is contained in the volatile fractions and are highly soluble. The process of evaporation will be grater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of Chandon condensate.

Characteristic	Chandon Condensate
Density (kg/m^3)	789 (at 15°C)
API	47.8
Dynamic viscosity (cP)	2.6 (at 15°C)
Pour point (°C)	<-20
Surface tension (dyne/cm)	21
Hydrocarbon property category	Group I
Hydrocarbon property classification	Non-persistent

Table 8.2 Boiling point ranges of Chandon condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Chandon Condensate	% of total	45.9	26.3	22.4	5.4
	% of aromatics	2.5	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 72% of the condensate is predicted to evaporate within 24 hours. The majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Chandon condensate into the water column was shown to increase. Approximately 24 hours after the spill, 38% of the condensate mass was shown to entrain and a further 60% had evaporated, leaving only a small portion of the condensate floating on the water surface (<0.3%). The residual compounds will tend to remain entrained during conditions that generate wind-waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case would result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.1% per day with an accumulated total of ~8.6% after 7 days, in comparison to a rate of <0.1% per day and an accumulated total of 0.7% after 7 days in the constant-wind case. Given the portion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

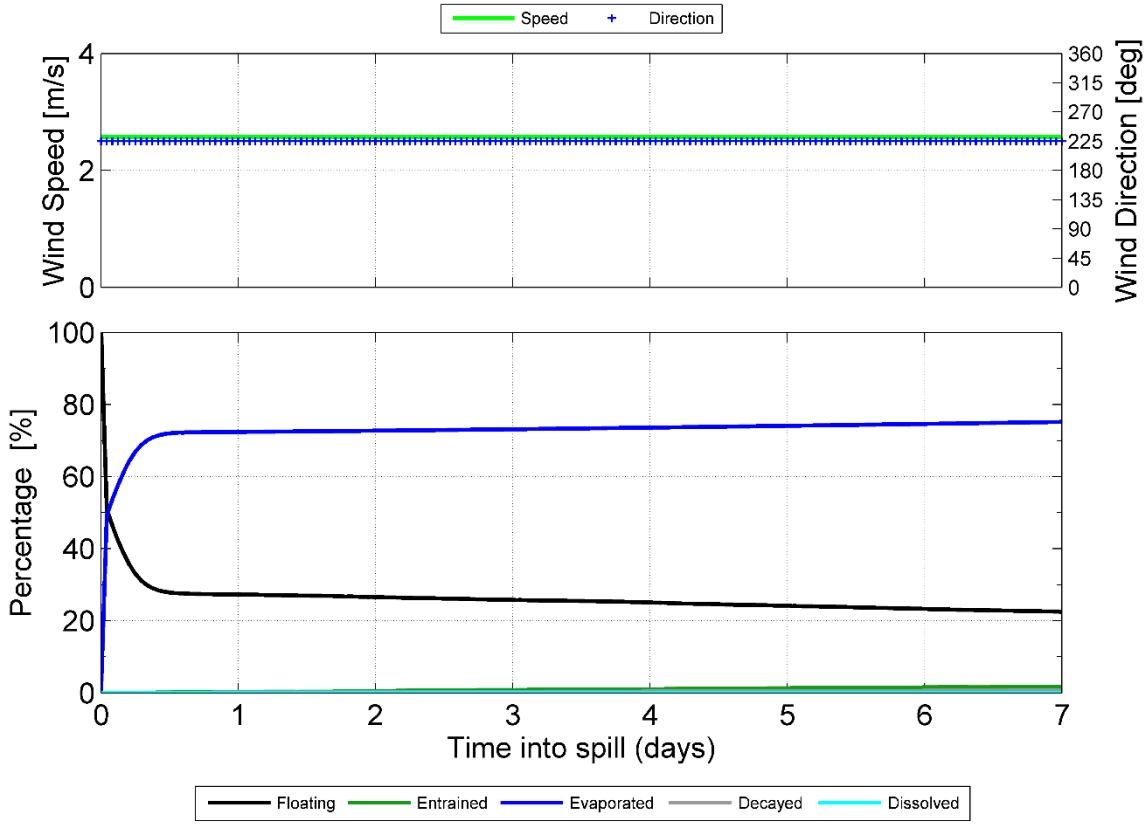


Figure 8.1 Proportional mass balance plot representing the weathering of Chandon condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

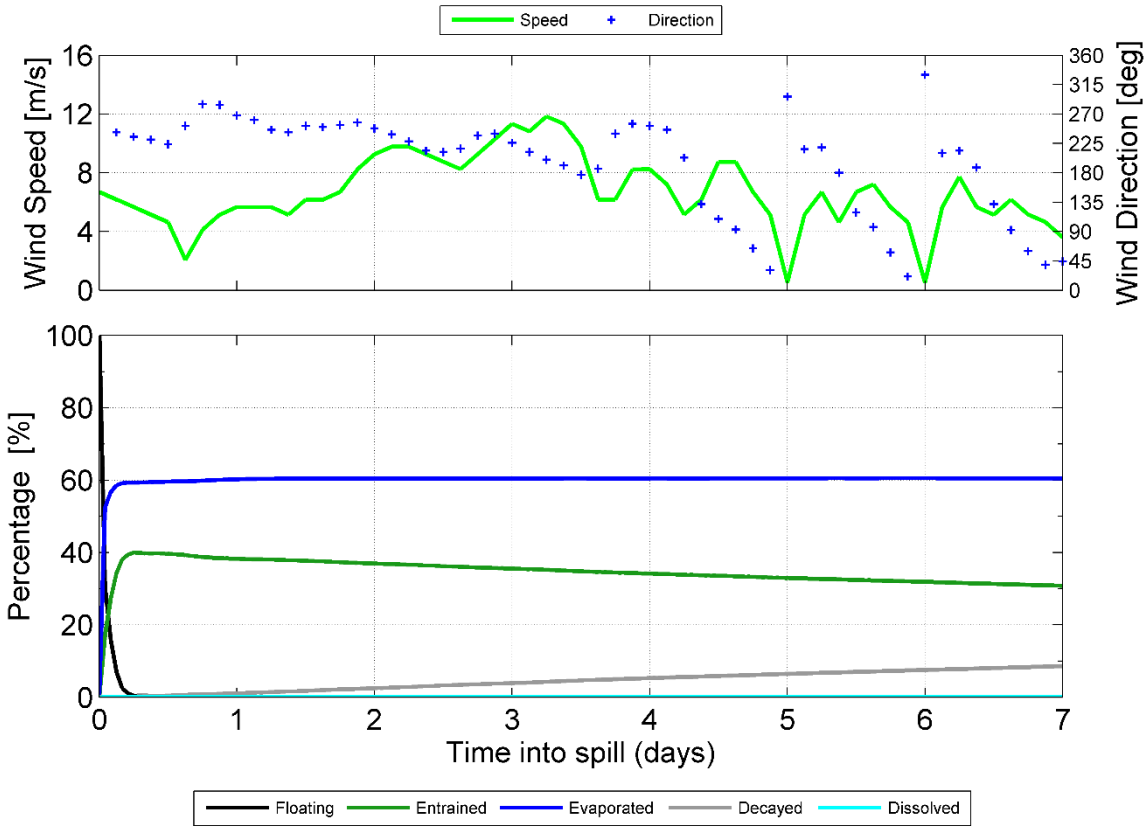


Figure 8.2 Proportional mass balance plot representing the weathering of Chandon condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Chandon Well 1 (Chandon)
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	74,604 [469,260]
Condensate type	Chandon condensate
Release type (depth)	Subsea (1,100 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2, no dissolved hydrocarbon exposure at or above 50 ppb, and no shoreline accumulation at or above any threshold, for any of the 300 simulations, the deterministic results are presented based on criteria a, and e only.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than the submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Key Ecological Feature	KEF	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
Nature Reserve	NR	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Ramsar Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Offshore Area	IAA	✓
Exmouth Plateau	KEF	✓

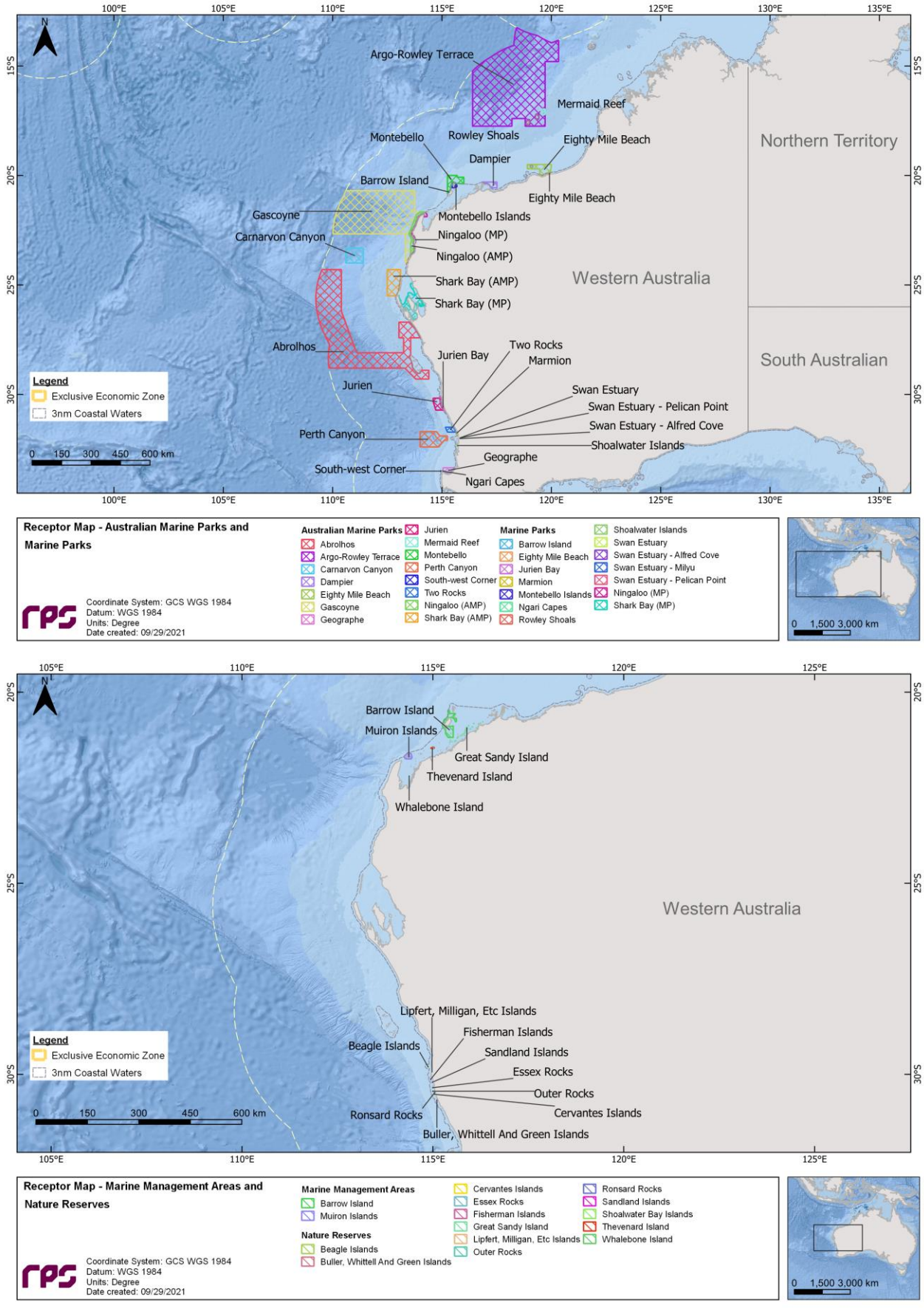


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

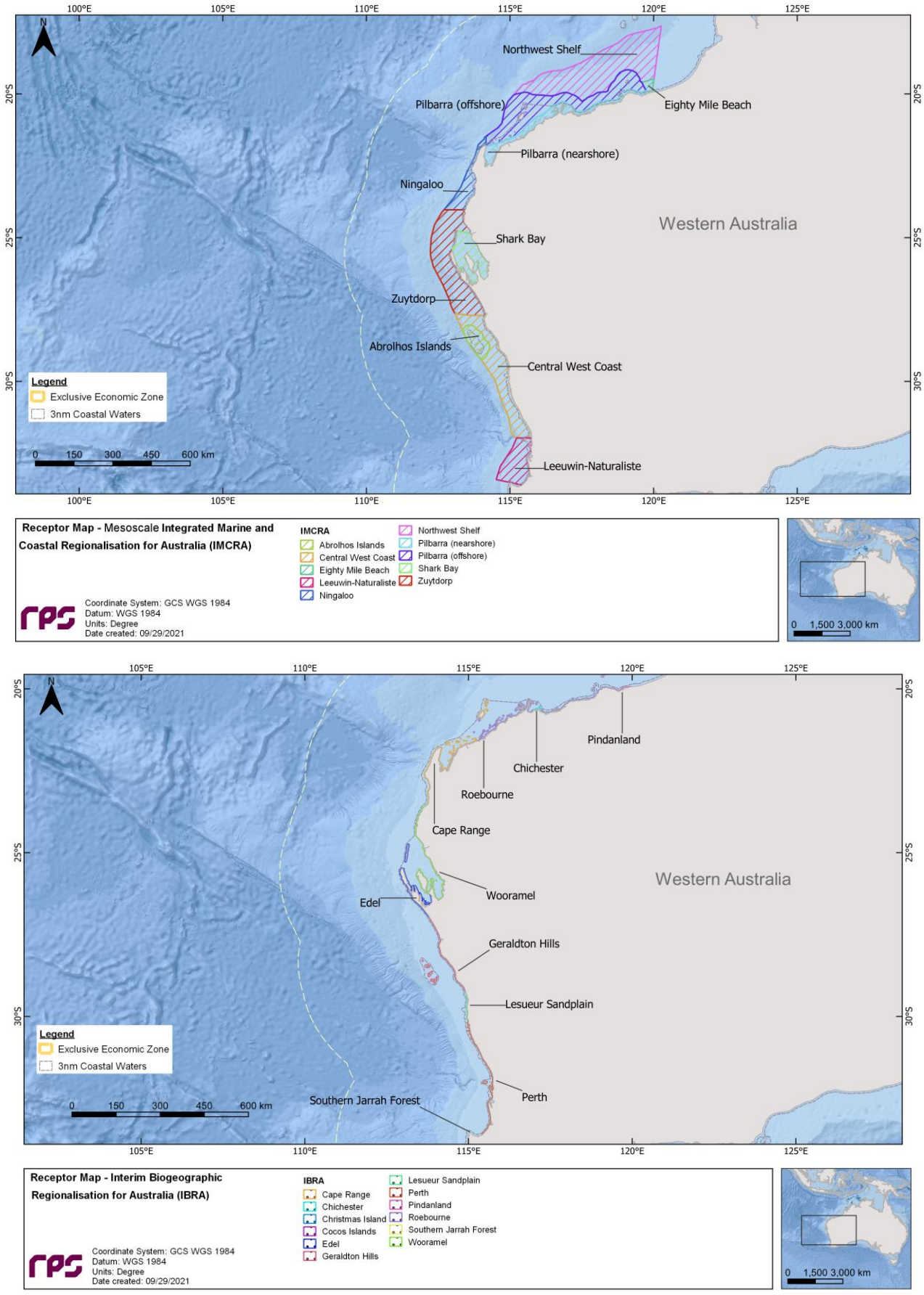


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

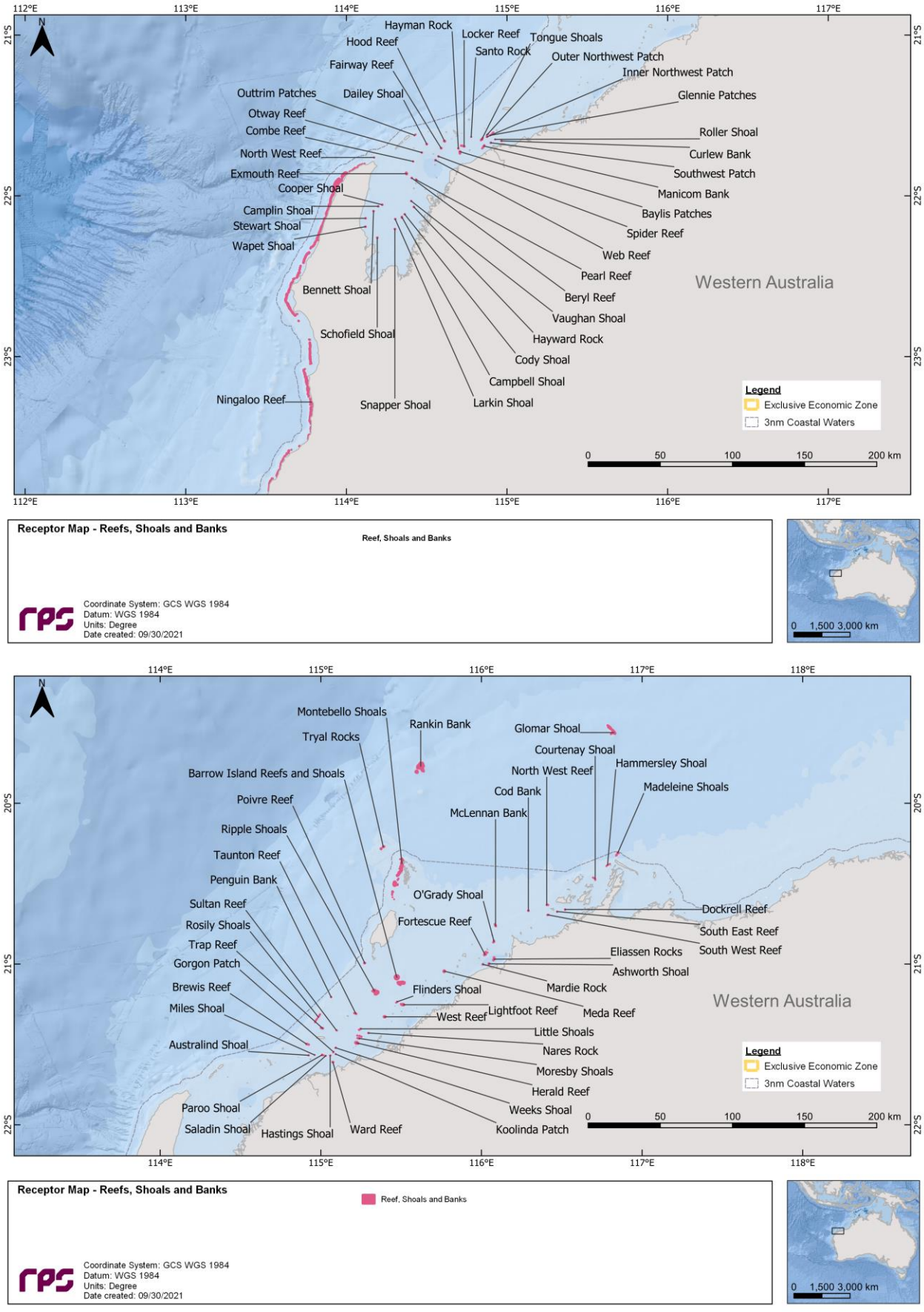


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

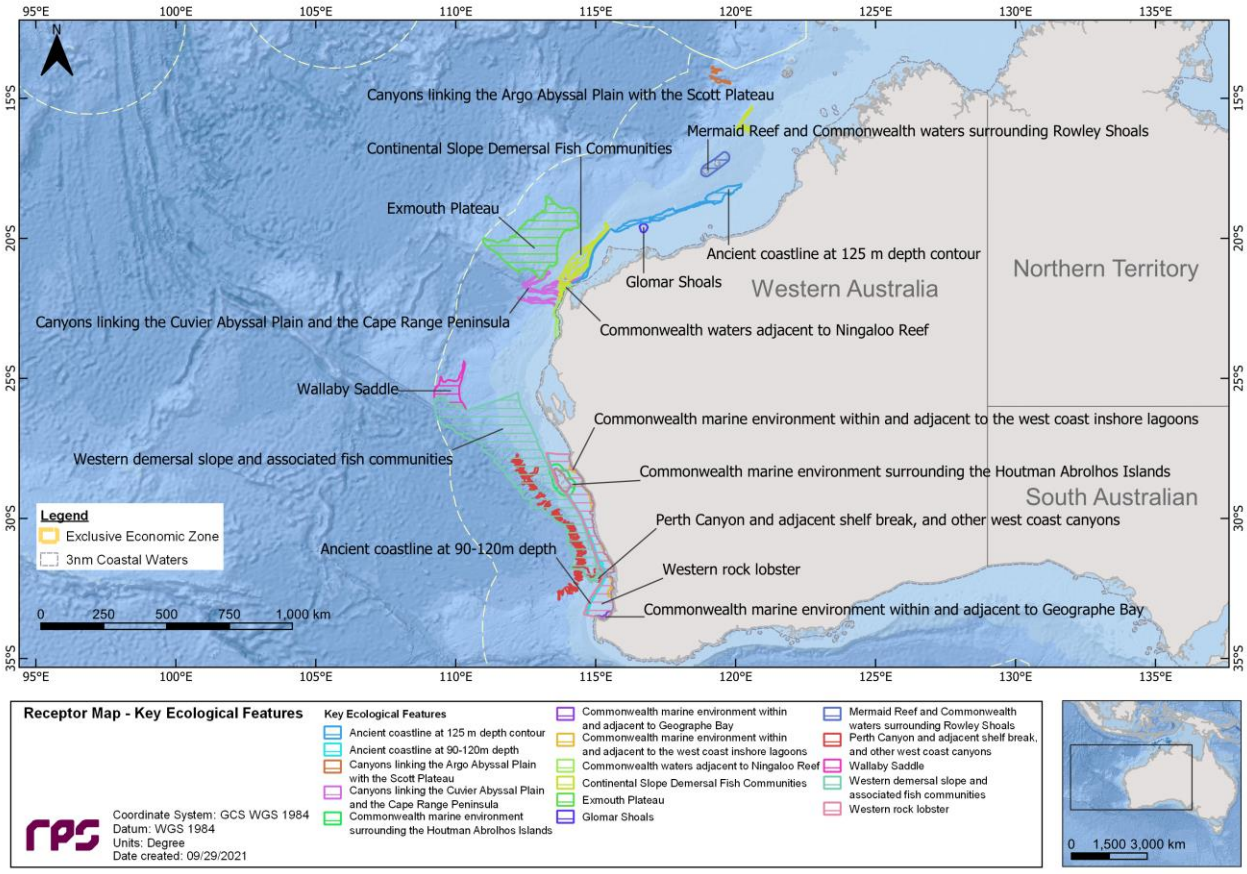


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

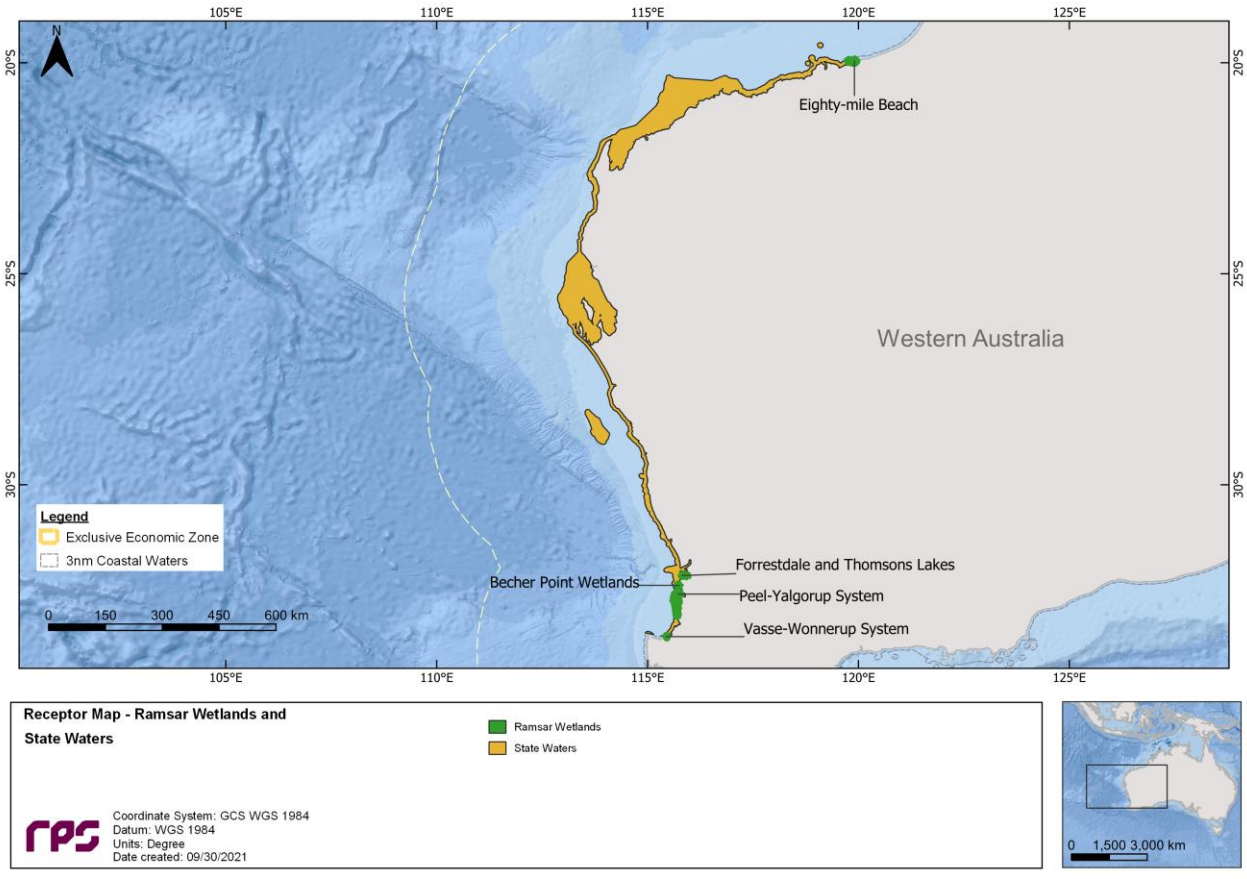


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

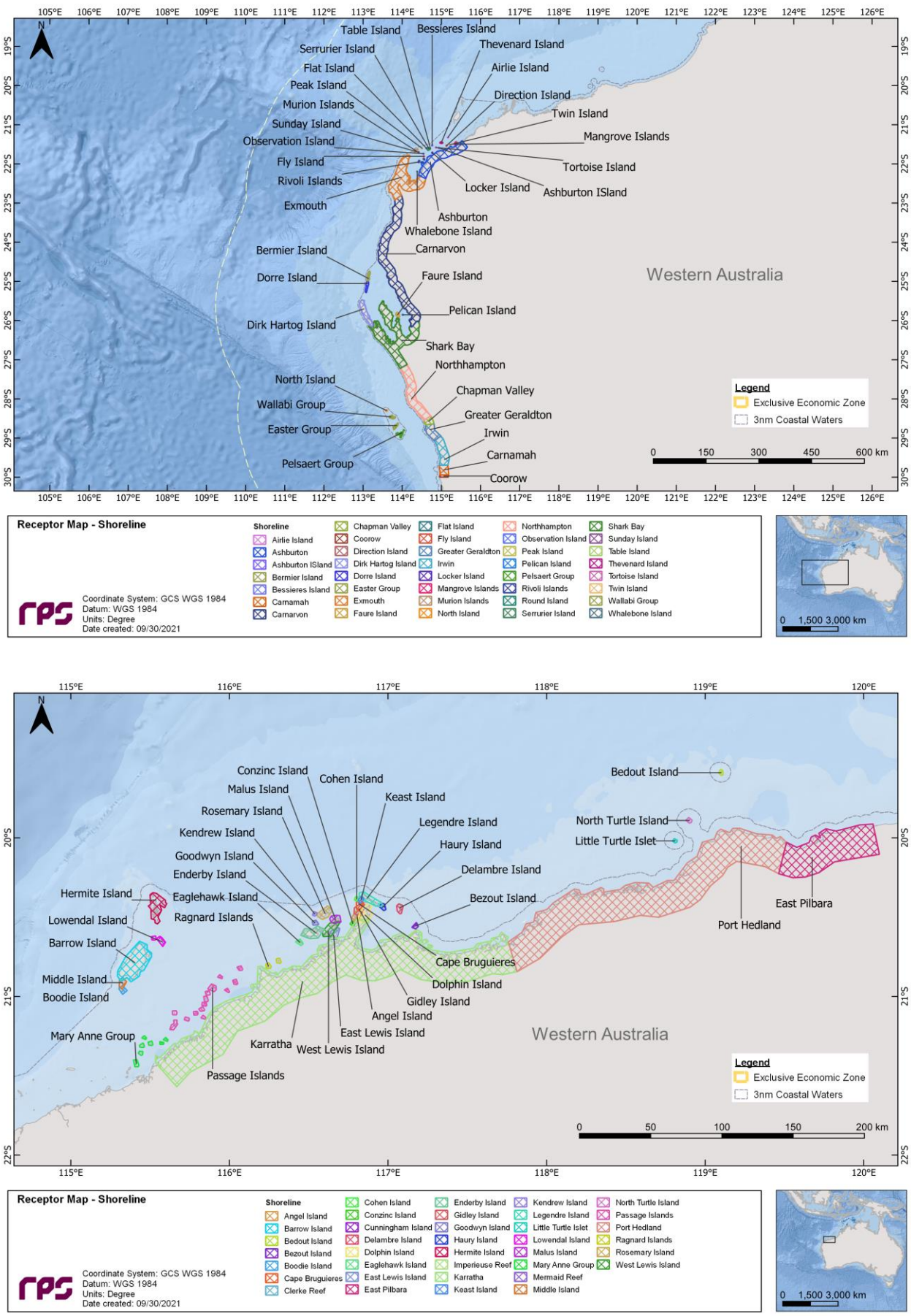


Figure 10.6 Receptor maps for Shorelines (1 of 2).

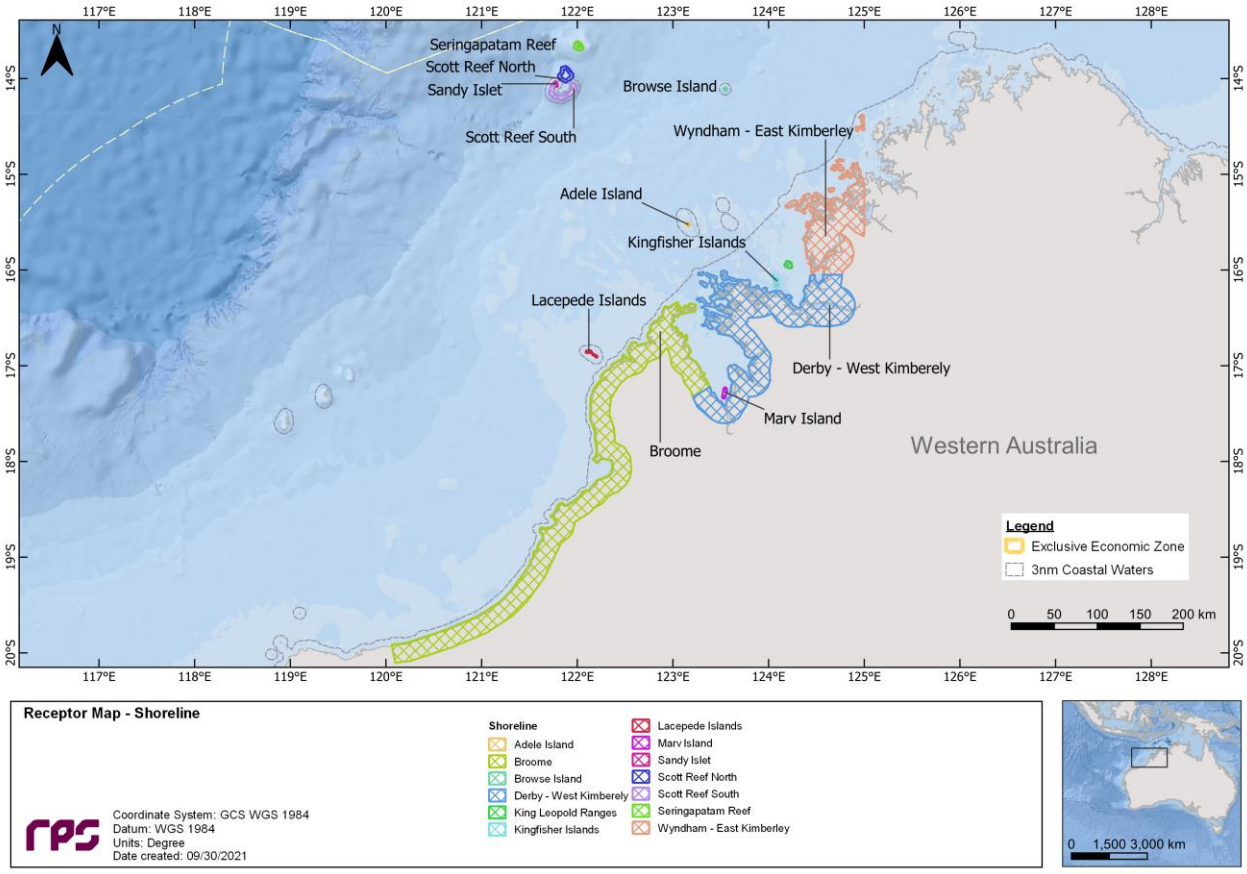


Figure 10.7 Receptor maps for Shorelines (2 of 2).

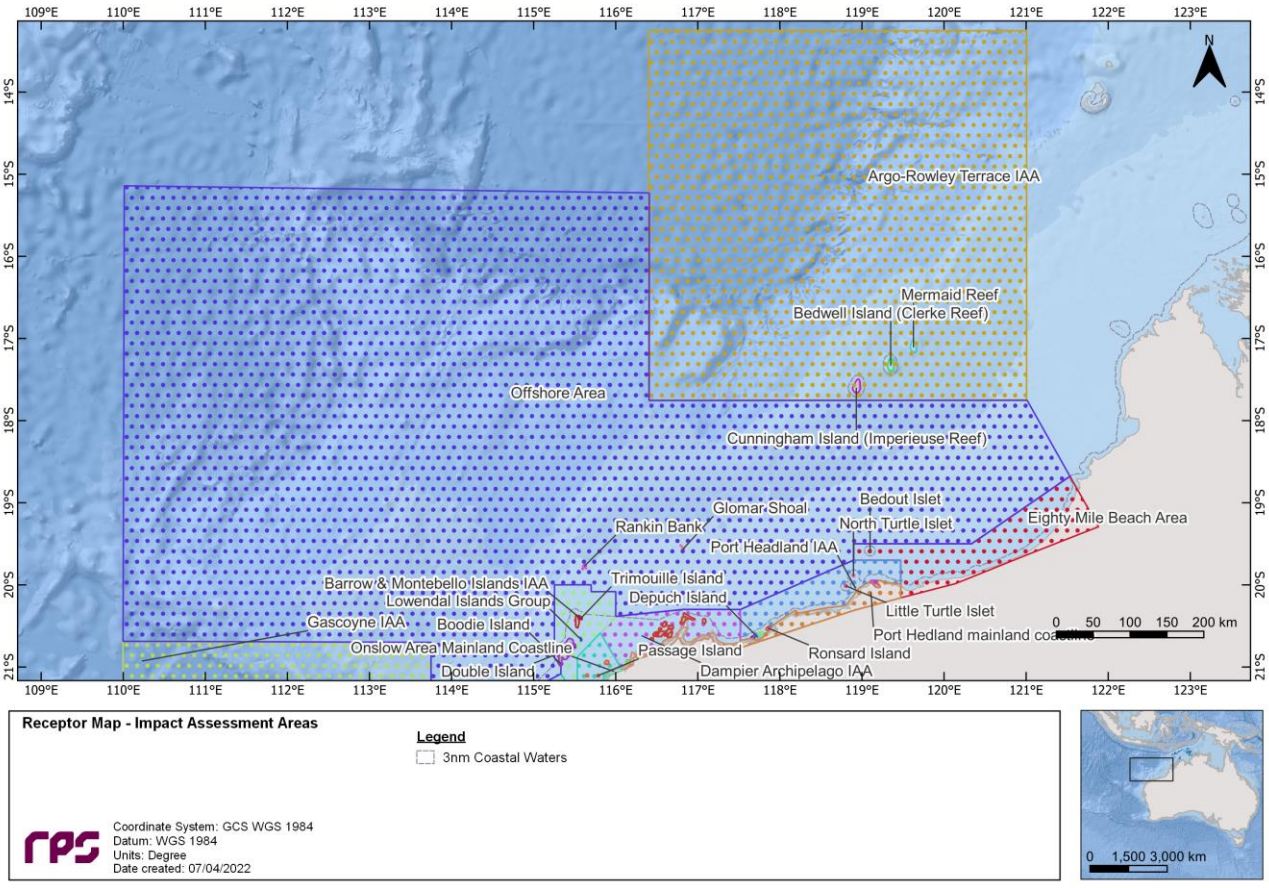


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

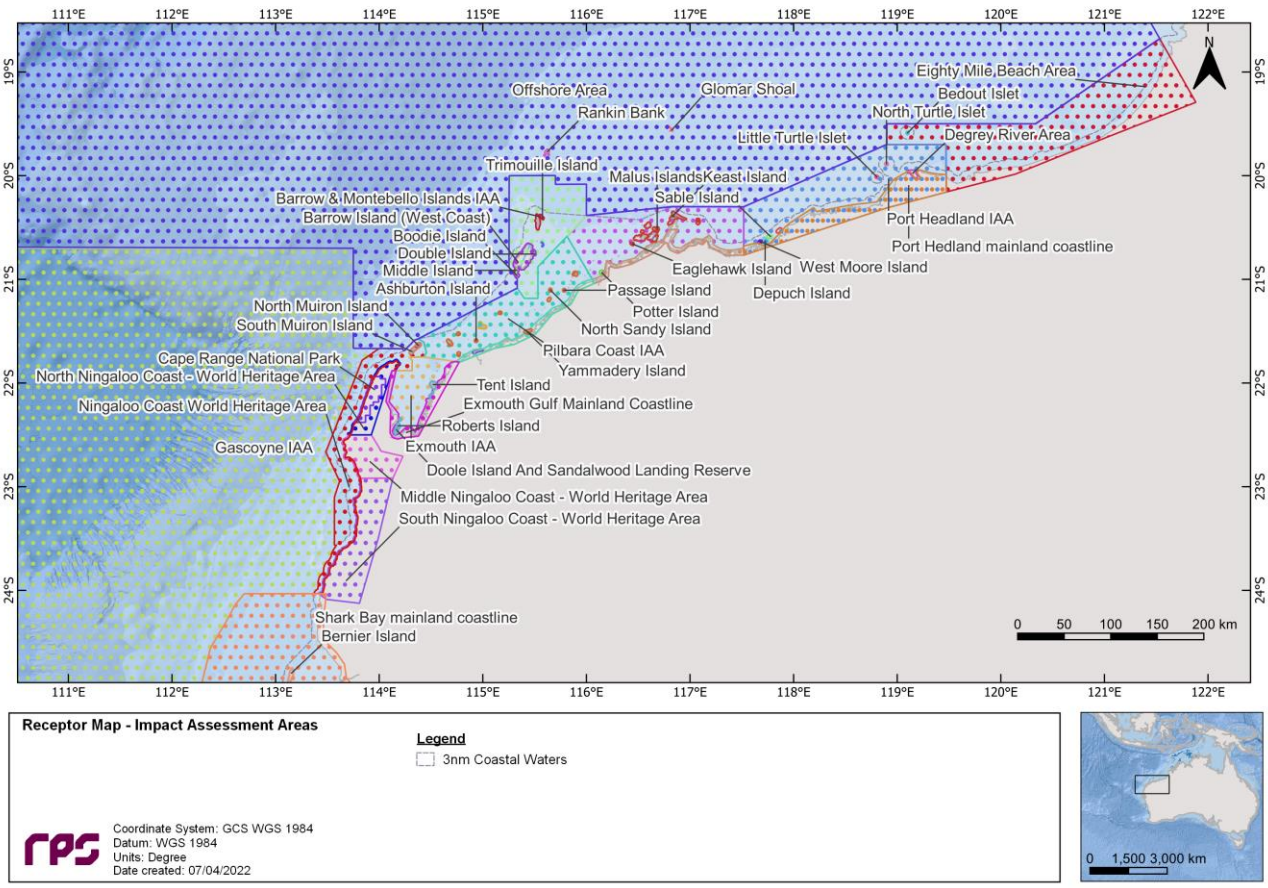


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

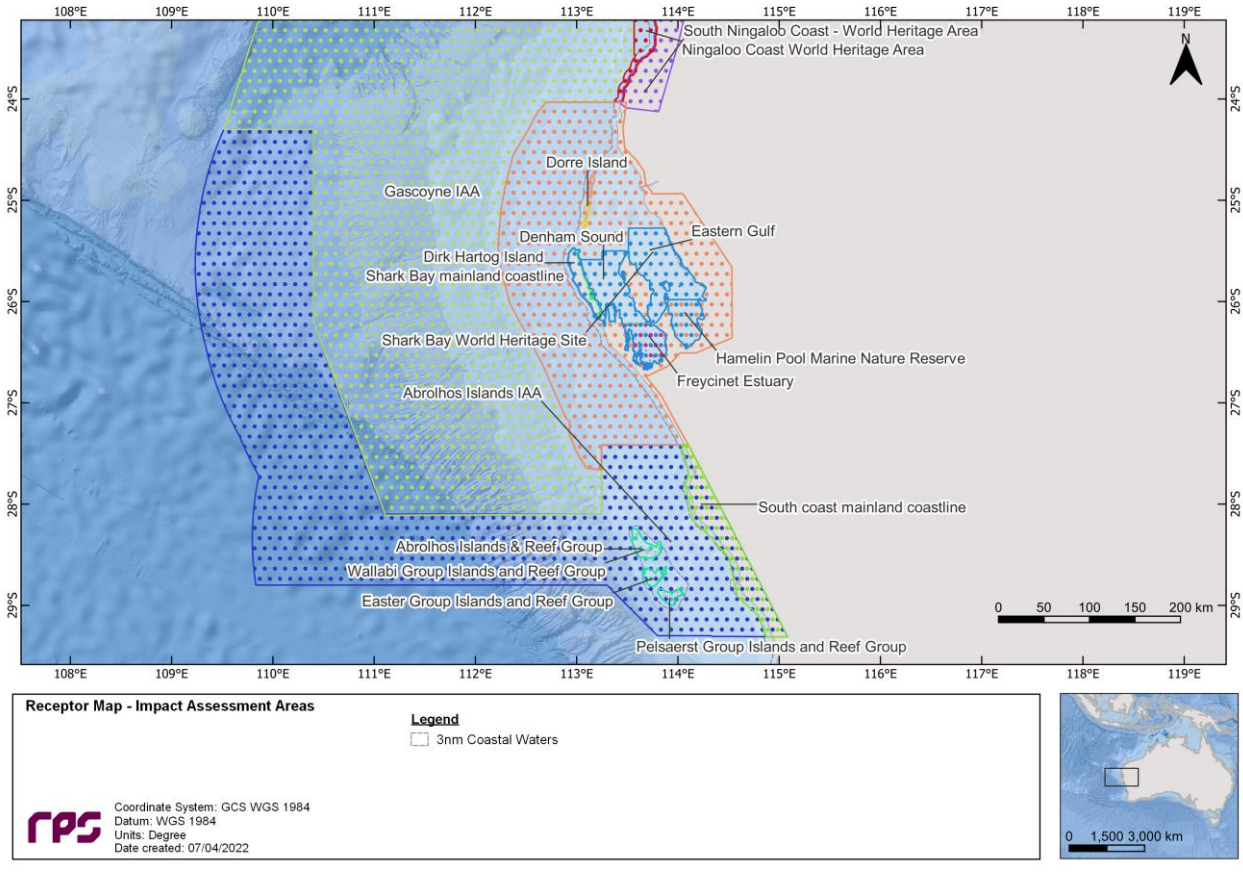


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: CHANDON LOSS OF WELL CONTROL

This scenario examined a 469,260 stb (or 74,604 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons; summer (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 102.9 km south (transitional) and 5.2 km west (transitional and winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Exmouth Plateau KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 27% (winter) and 37% (summer and transitional).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	91.0	3.7	-
	Max. distance from release site (km) (99th percentile)	60.4	3.7	-
	Direction	West-northwest	North-northeast	-
Transitional	Max. distance from release site (km)	102.9	5.2	-
	Max. distance from release site (km) (99th percentile)	64.5	5.2	-
	Direction	Southwest	West	-
Winter	Max. distance from release site (km)	88.0	5.2	-
	Max. distance from release site (km) (99th percentile)	61.0	5.2	-
	Direction	West-northwest	West	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Chandon Well 1. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Pygmy Blue Whale – Distribution*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
EEZ	Australian Exclusive Economic Zone	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
IAA	Offshore Area*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
KEF	Exmouth Plateau*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-

*The release location resides within the receptor boundaries.

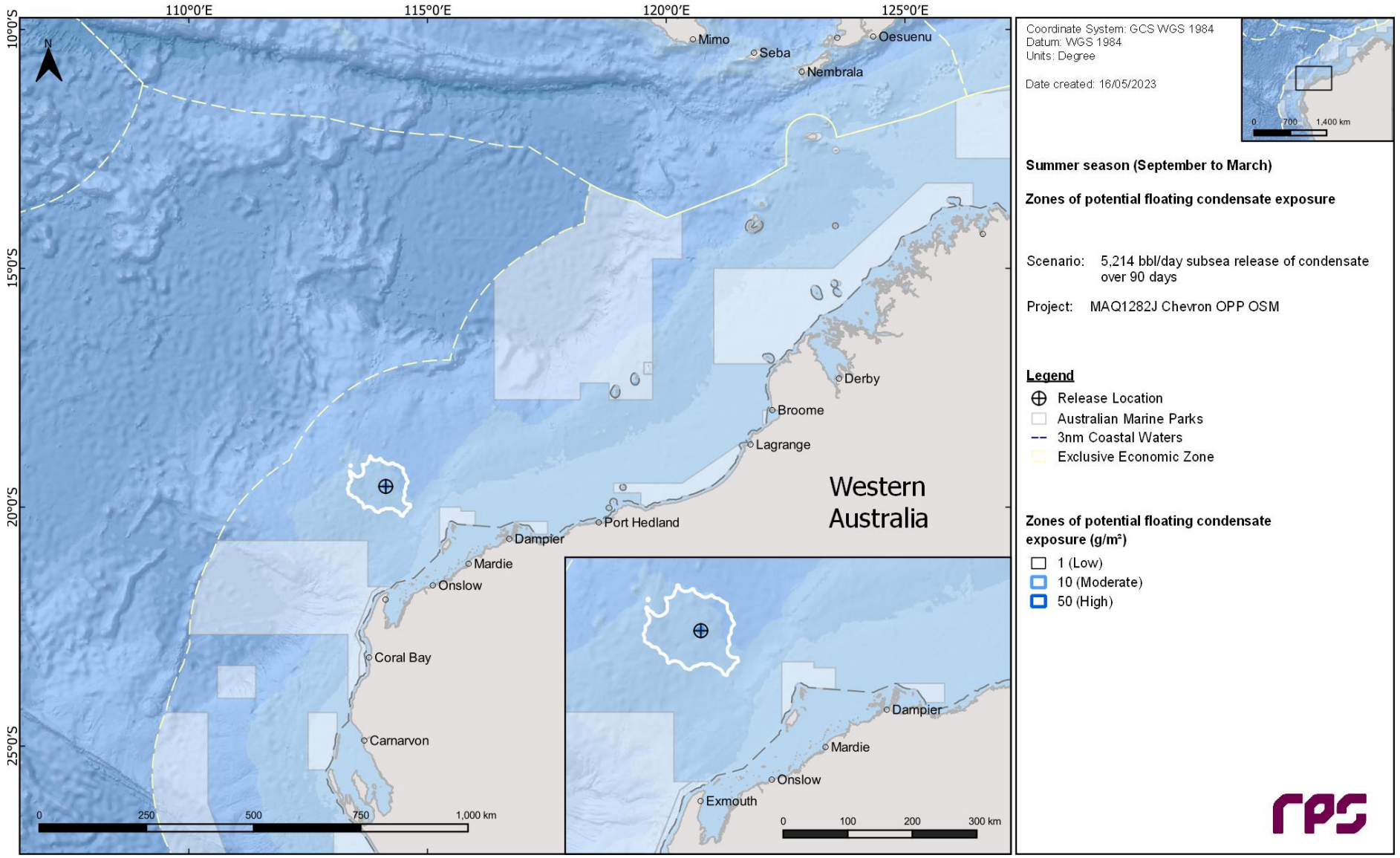


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

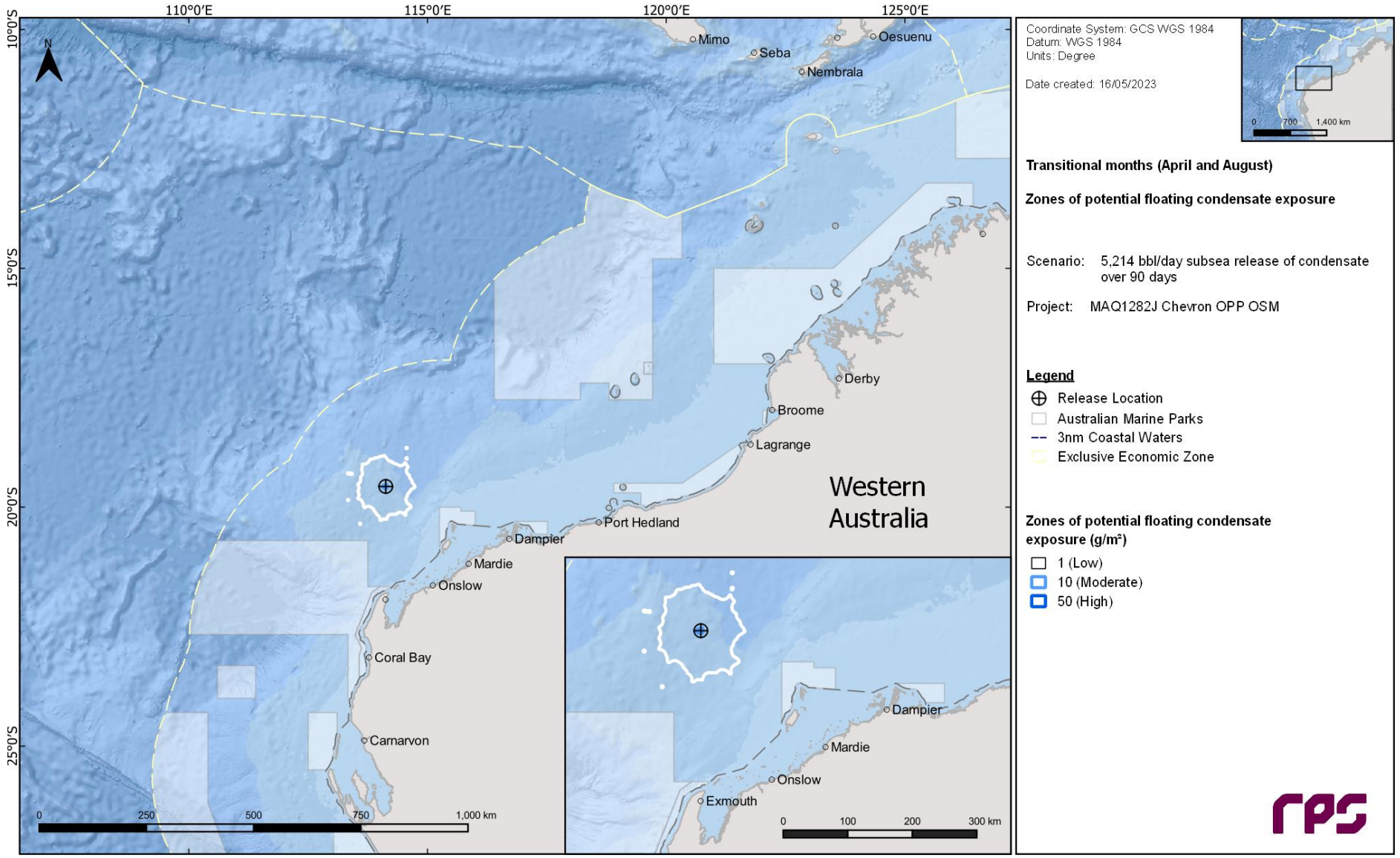


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

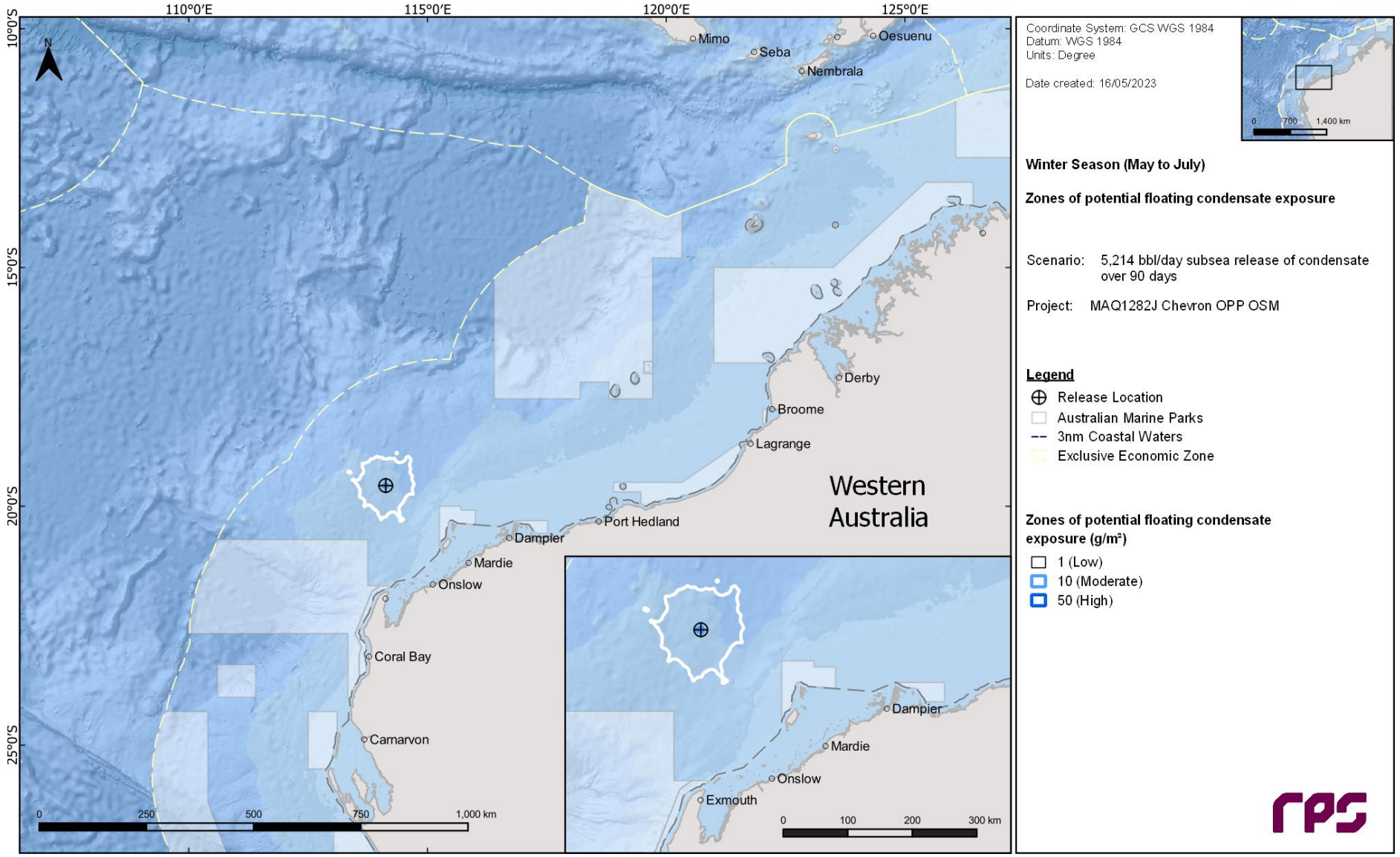


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

No shoreline accumulation was predicted for this scenario above the low reporting threshold (≥10 g/m$_2$) during any of the seasons modelled. Consequently, no results are reported.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.3 summarises the maximum exposure to dissolved hydrocarbons and the probability for individual receptors in the 0-10 m depth layer.

The Offshore Area IAA and Pygmy Blue Whale – Distribution BIA, which the release location resides within, were the only receptors to be exposed at or above the low threshold exclusively in summer with 1% probability.

Figure 11.4 to Figure 11.5 illustrate the extent of the predicted dissolved hydrocarbon exposure in the 0-10 m depth layer for each season.

Table 11.3 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill simulations per season.

Receptor		Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
BIA	Pygmy Blue Whale – Distribution*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
EEZ	Australian Exclusive Economic Zone *	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
IAA	Offshore Area*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
KEF	Exmouth Plateau*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-

*The release location resides within the receptor boundaries.

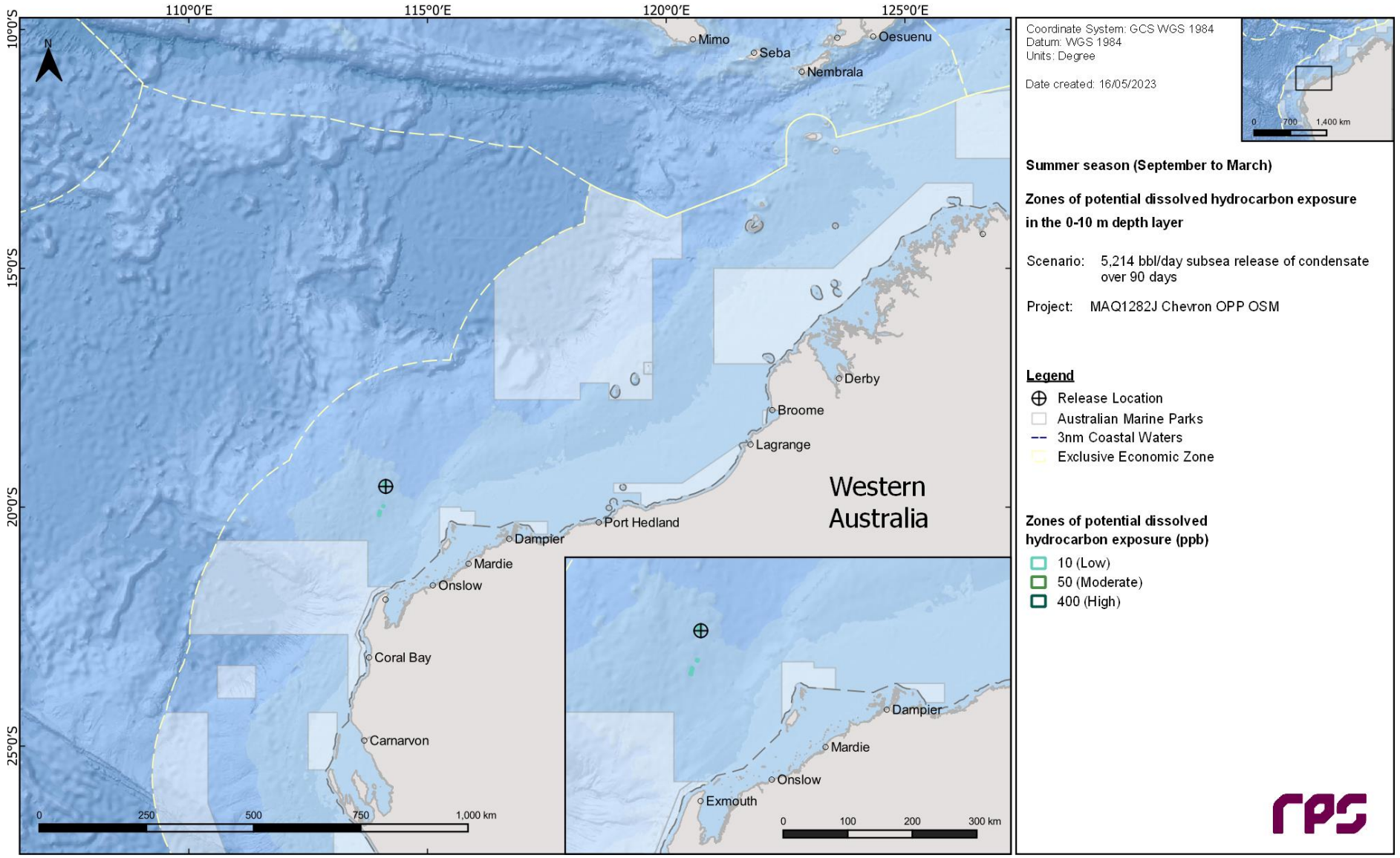


Figure 11.4 Zones of potential dissolved hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

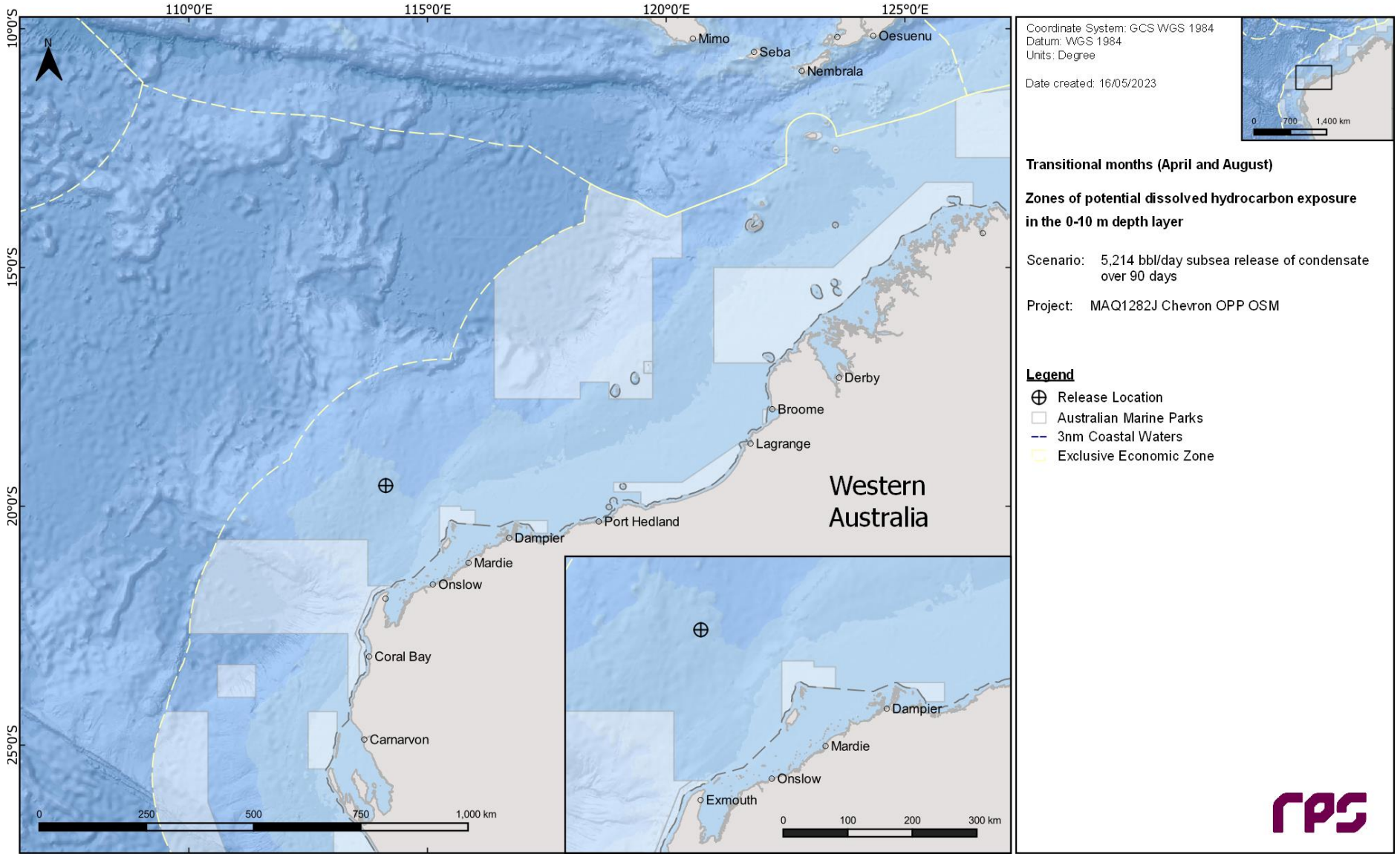


Figure 11.5 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.4 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 16 BIAs were shown to be exposed at or above the low threshold during summer, compared to 11 and 8 during transitional and winter seasons respectively. Excluding the Pygmy Blue Whale - Distribution BIA, which the release location resides within, the highest probabilities of exposure were predicted for the Wedge-tailed Shearwater - Breeding BIA during summer (60%), transitional (61%) and winter (57%) conditions.

During summer, 5 AMPs were predicted to be exposed at, or above the low threshold, whilst only 3 were predicted to be exposed at the same threshold during transitional and winter conditions. The highest probabilities predicted occurred at the Gascoyne AMP (63% summer, 65% transitional and 68% winter). Furthermore, during summer conditions the Gascoyne AMP was shown to be exposed to entrained hydrocarbons at the high threshold (5%).

A total of 5 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Exmouth Plateau KEF that the release site is located within. Excluding the Exmouth Plateau, probabilities of exposure ranged between 1–50%, 8–53% and 7–50%, for summer, transitional and winter, respectively.

Additionally, 6 IAA's (including the Offshore IAA that the release site is located within), were shown to be exposed to entrained hydrocarbons at low threshold during summer season, compared to 3 during transitional and winter seasons. Excluding the Offshore IAA, the probabilities for each season ranged between 1–63%, 7–65% and 4–68% under summer, transitional and winter conditions, respectively.

Furthermore, the Rankin Bank RSB was shown to be exposed to entrained hydrocarbons at the low threshold only during the summer conditions and an 8% probability.

Figure 11.6 to Figure 11.8 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.9 to Figure 11.11.

Table 11.4 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Argo-Rowley Terrace	47.6	12	-	22.29	-	25.6	7	-	41.17	-	24.7	4	-	53.04	-
	Carnarvon Canyon	13.1	1	-	101.42	-	14.2	8	-	61.92	-	14.2	3	-	40.83	-
	Gascoyne	115.8	63	5	5.25	22.13	109.2	65	2	4.29	45.21	81.6	68	-	6.25	-
	Montebello	22.4	8	-	8.83	-	1.6	-	-	-	-	3.4	-	-	-	-
	Ningaloo	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
BIA	Flatback Turtle - Internesting Buffer	31.6	15	-	8.08	-	35.4	12	-	40.29	-	34.3	20	-	11.29	-
	Flatback Turtle - Nesting	27.4	9	-	9	-	12.4	3	-	57.83	-	12.3	2	-	77.46	-
	Green Turtle - Internesting Buffer	17.6	5	-	10.5	-	6.1	-	-	-	-	6	-	-	-	-
	Green Turtle - Nesting	14.9	5	-	10.71	-	9.8	-	-	-	-	7.3	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	29.5	5	-	10.42	-	11.2	1	-	71.33	-	8.9	-	-	-	-
	Hawksbill Turtle - Nesting	14.9	5	-	10.71	-	5.5	-	-	-	-	6.3	-	-	-	-
	Humpback Whale - Migration	58.7	15	-	8.21	-	38.1	14	-	44.04	-	39.3	8	-	68.92	-
	Little Tern - Resting	11.1	1	-	79.96	-	3.1	-	-	-	-	1.8	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	29.5	3	-	52.29	-	11.2	1	-	71.33	-	8.9	-	-	-	-
	Loggerhead Turtle - Nesting	12.1	2	-	53.79	-	9.8	-	-	-	-	7.3	-	-	-	-
	Pygmy Blue Whale – Distribution*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Pygmy Blue Whale - Foraging	97.3	23	-	14.13	-	27.3	23	-	16.67	-	24.8	15	-	21.21	-
	Roseate Tern - Breeding	88.5	12	-	24.58	-	12.8	2	-	45.38	-	9.8	-	-	-	-
	Wedge-tailed Shearwater - Breeding	112.5	60	4	3.88	22.58	89.8	61	-	3.08	-	99.3	57	-	5.38	-
	Whale Shark - Foraging	31.6	15	-	8.13	-	35.4	12	-	31.58	-	34.3	19	-	26.42	-
	White-tailed Tropicbird - Breeding	38.6	10	-	33.96	-	12	2	-	51.67	-	10.7	1	-	83.75	-
EEZ	Australian Exclusive Economic Zone *	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Christmas Island Exclusive Economic Zone	18.7	4	-	58.58	-	19.3	4	-	93.83	-	8.1	-	-	-	-
	Indonesian Exclusive Economic Zone	15	2	-	61.58	-	11.3	3	-	42.88	-	13.7	8	-	54.83	-
IAA	Argo-Rowley Terrace IAA	47.6	12	-	22.29	-	25.6	7	-	41.17	-	24.7	4	-	53.04	-
	Barrow & Montebello Islands IAA	22.4	8	-	8.83	-	1.6	-	-	-	-	3.4	-	-	-	-
	Gascoyne IAA	115.8	63	5	5.25	22.13	109.2	65	2	4.29	45.21	81.6	68	-	6.25	-
	Ningaloo Coast World Heritage Area	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
	Offshore Area*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Rankin Bank	19.9	8	-	13.54	-	2.6	-	-	-	-	3.1	-	-	-	-
IMCRA	Northwest Shelf	28.2	15	-	8.63	-	25.9	6	-	31.67	-	24.2	11	-	63.17	-
	Pilbara (offshore)	31.6	10	-	8.13	-	33	12	-	44.29	-	34.3	19	-	26.38	-
KEF	Ancient coastline at 125 m depth contour	29.1	15	-	8.25	-	29.8	8	-	40.83	-	30.3	7	-	68.92	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	98.5	45	-	11.71	-	61.3	44	-	5.08	-	55.2	37	-	9.33	-
	Commonwealth waters adjacent to Ningaloo Reef	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
	Continental Slope Demersal Fish Communities	115	50	1	3.58	22.58	122.9	53	5	3.21	39.83	119.8	50	5	7.5	71.63

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Exmouth Plateau*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
RSB	Rankin Bank	19.9	8	-	13.54	-	2.8	-	-	-	-	3.1	-	-	-	-

*The release location resides within the receptor boundaries.

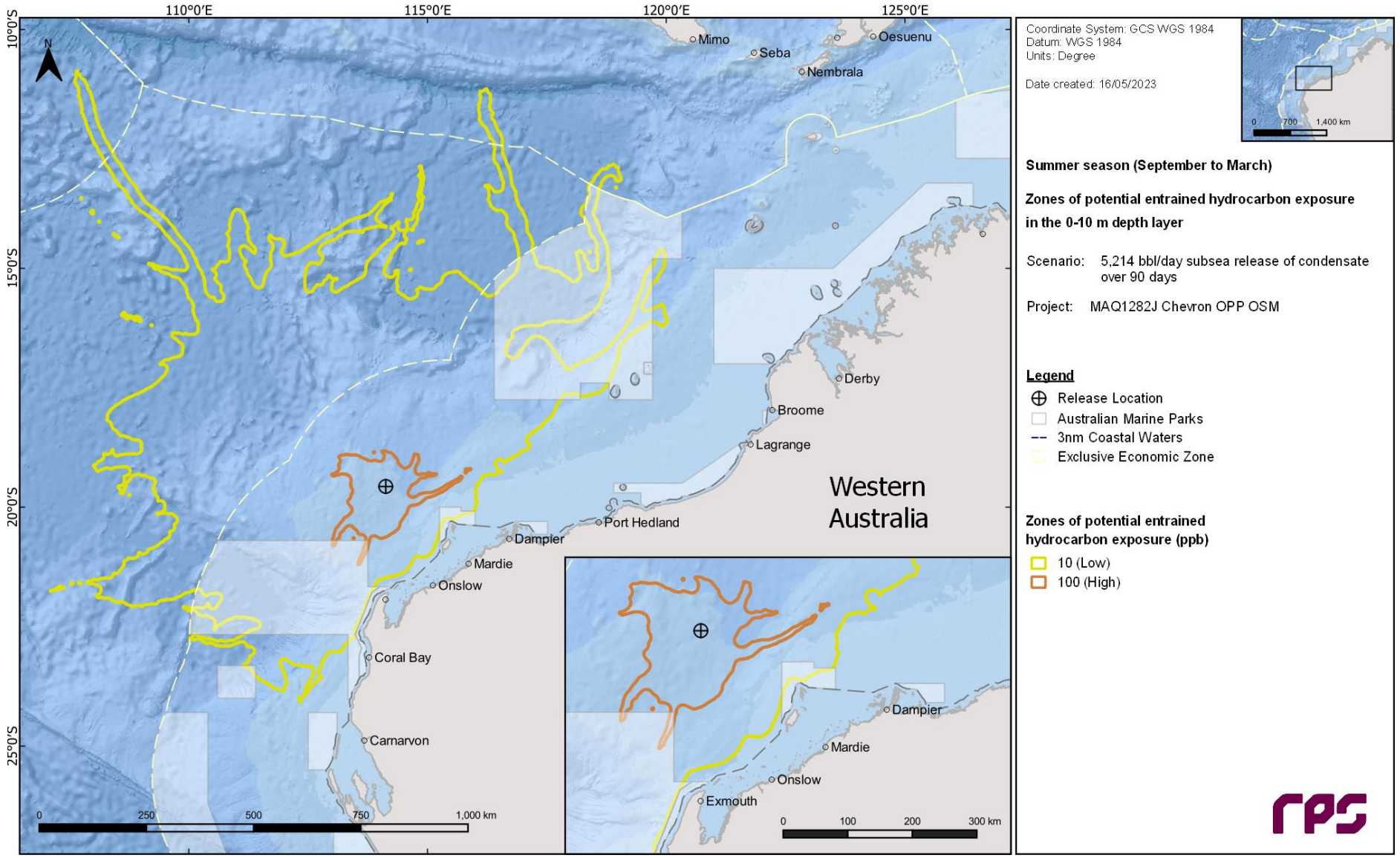


Figure 11.6 Zones of potential entrained hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

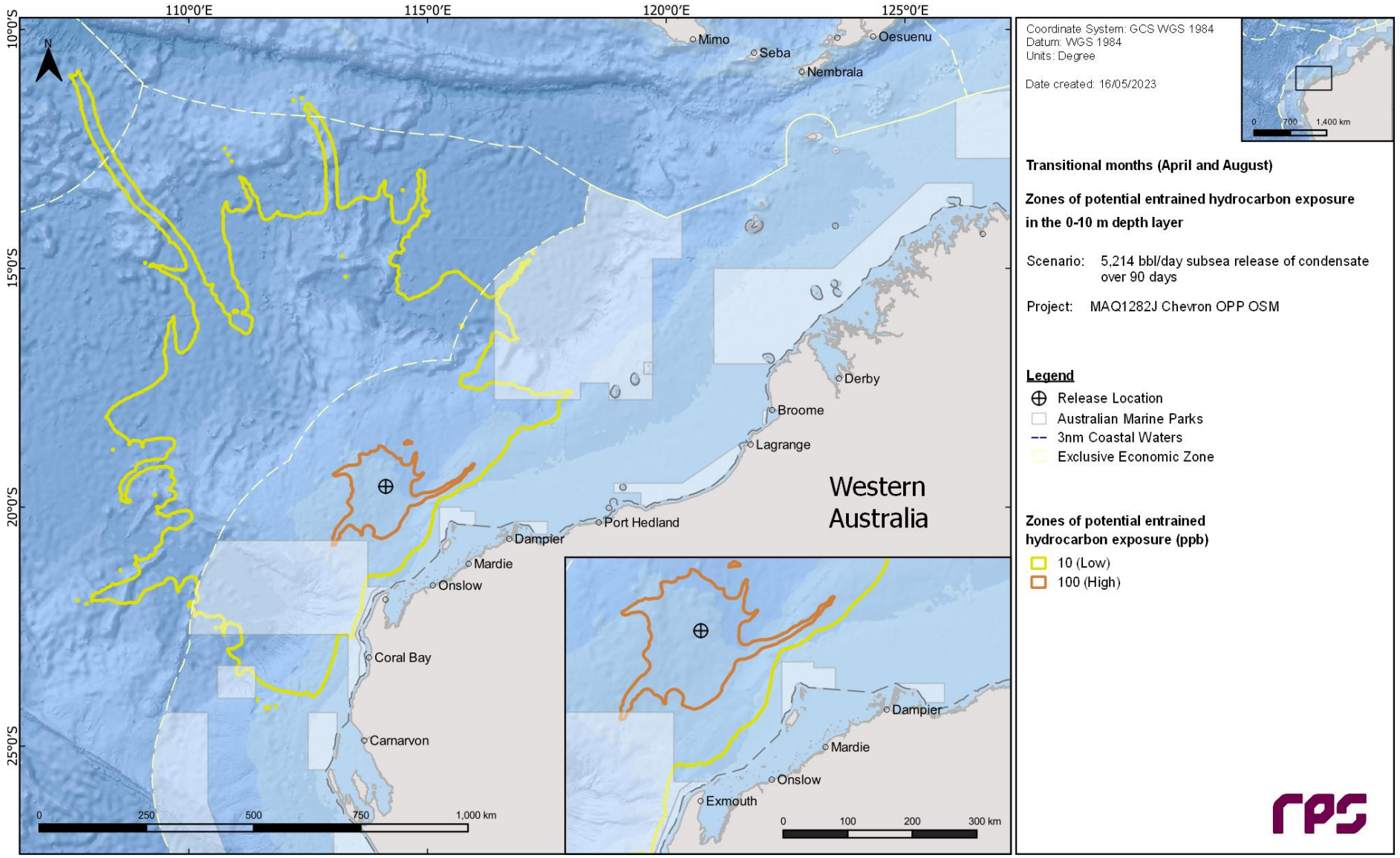


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

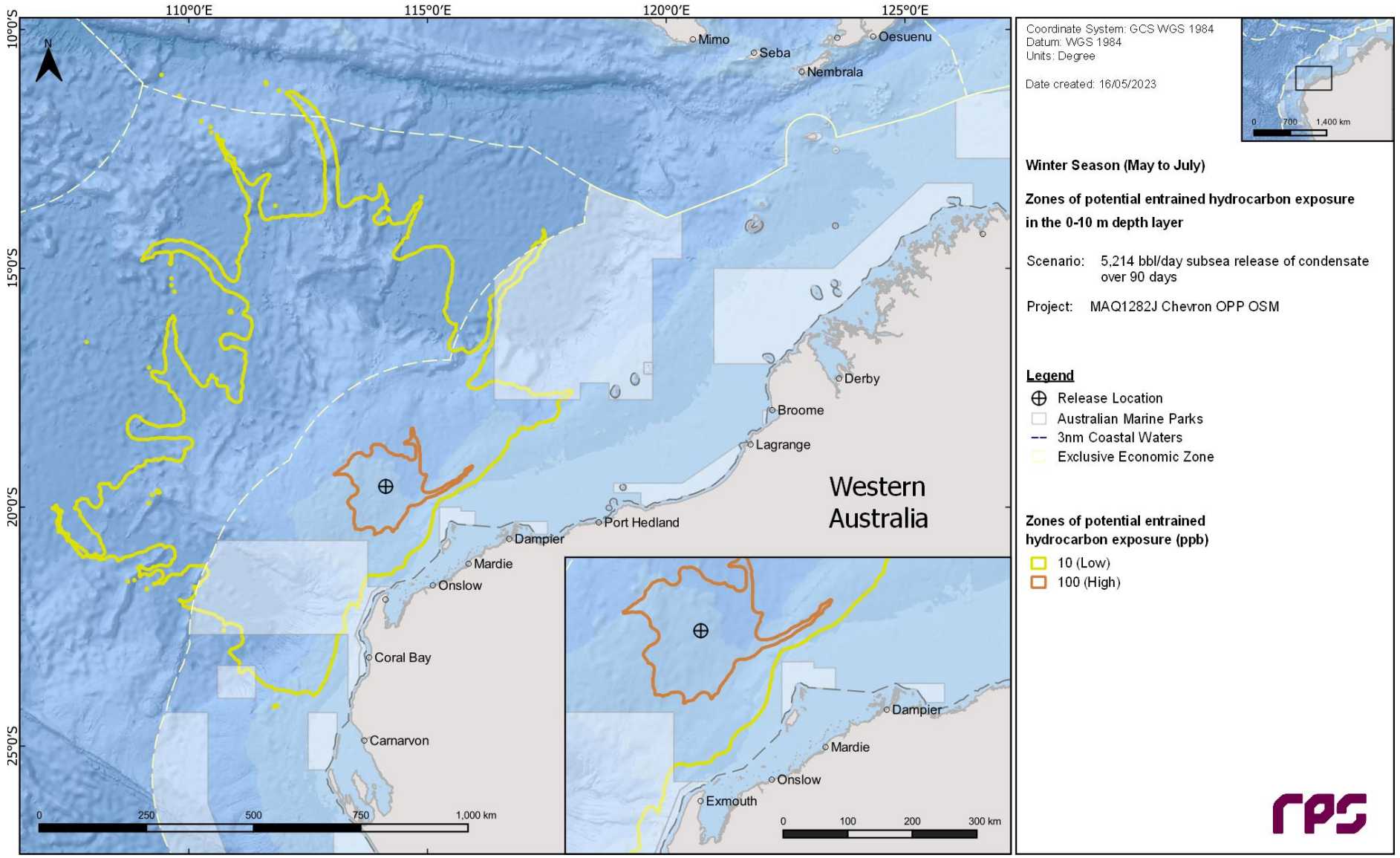


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

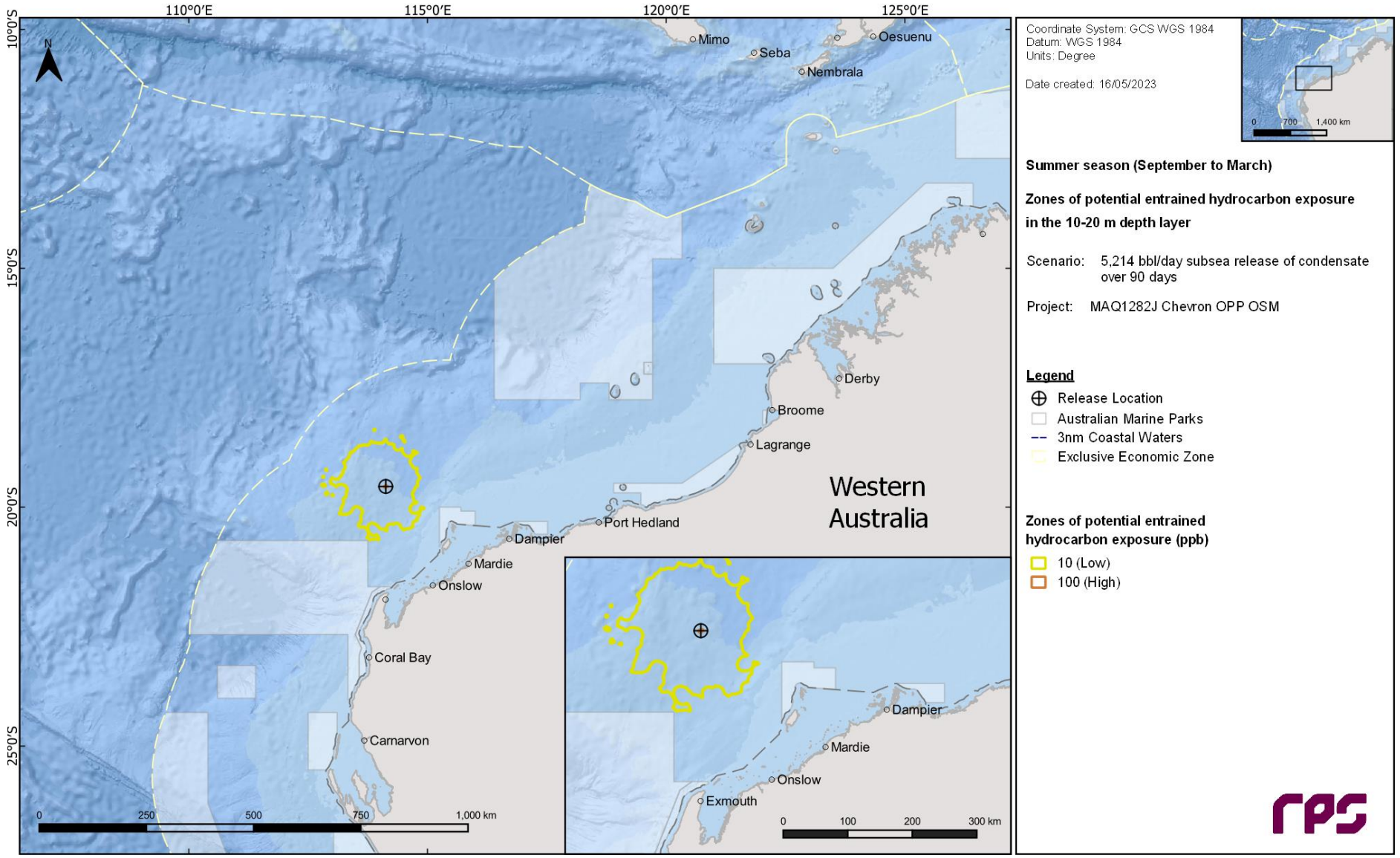


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 10-20 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

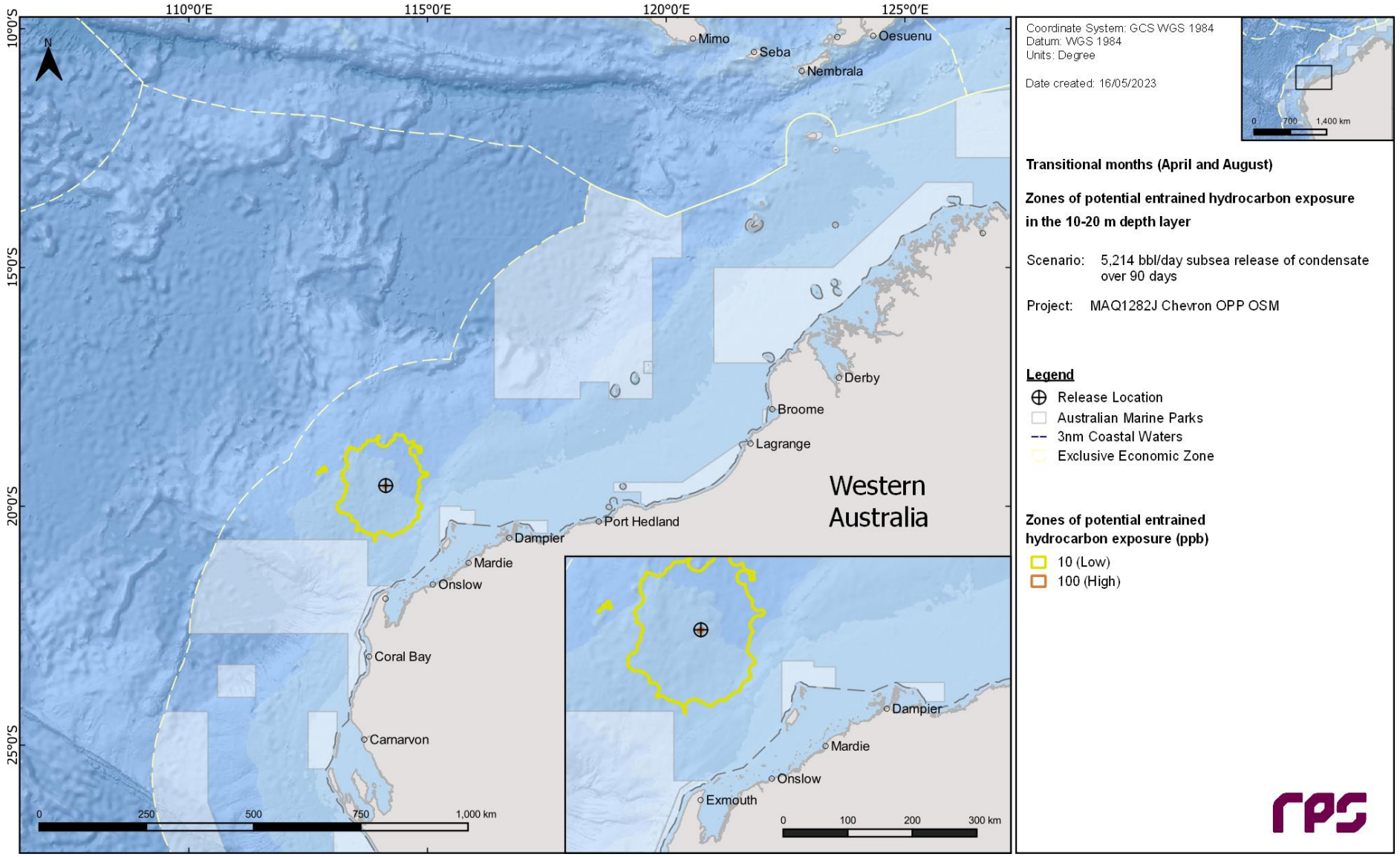


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

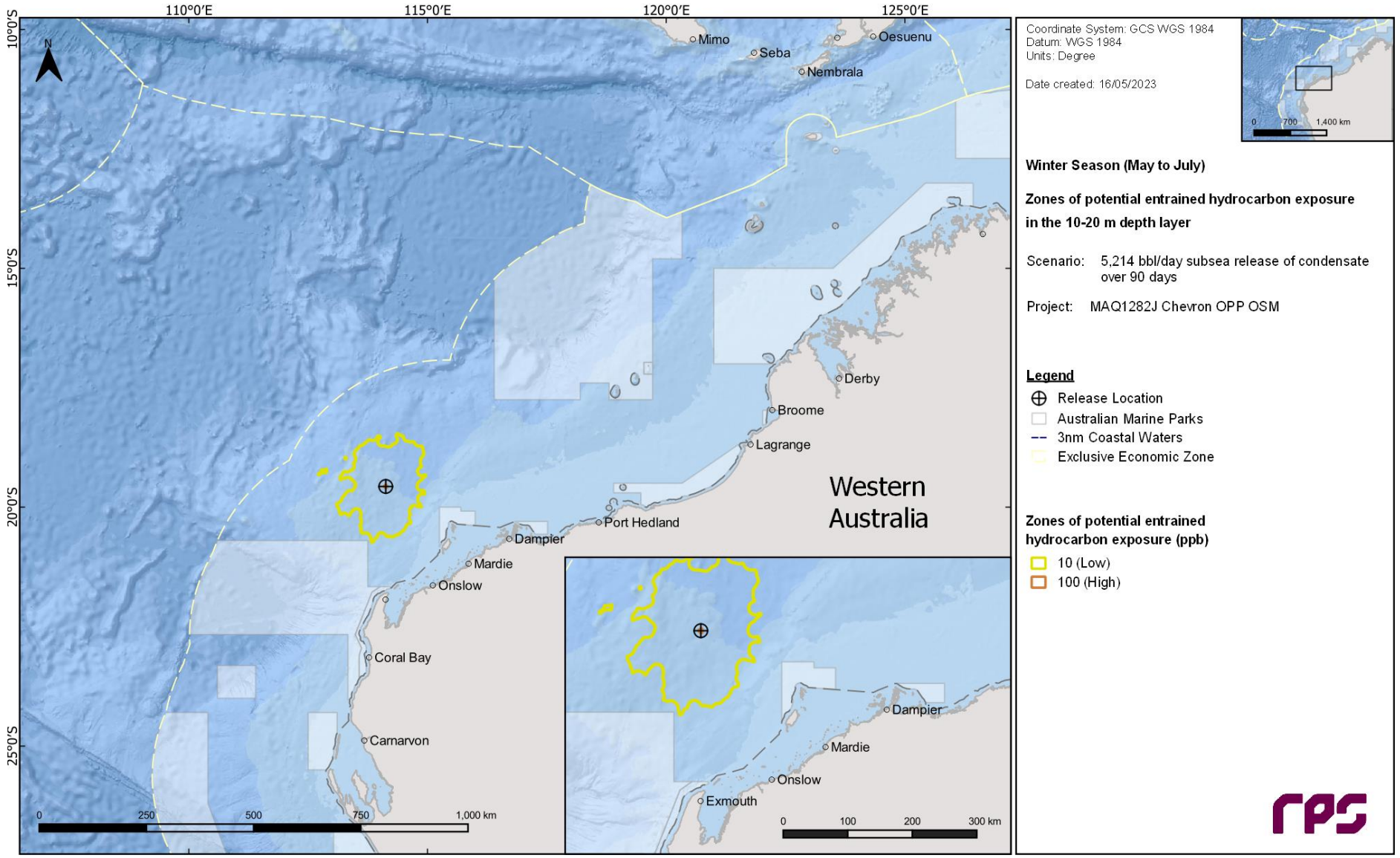


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.2).

Table 11.5 presents a summary of all deterministic analysis criteria and the corresponding values at the assessed thresholds.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 793 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 40 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.5 Summary of the deterministic analysis following a subsea LOWC at Chandon Well 1.

Variable	Threshold	Deterministic Analysis Criteria	
		Largest swept area of floating condensate above 10 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Transitional	Winter
Run Number		41	57
Floating Oil (km^2)	**1 g/m^2**	793	1,012
	10 g/m^2	**10**	-
	50 g/m^2	-	-
Shoreline Length (km)	**10 g/m^2**	-	-
	100 g/m^2	-	-
	1,000 g/m^2	-	-
Minimum Time (days)		-	-
Maximum Volume (m^3)		-	-
Entrained Area (km^2)	**10 ppb**	98,614	99,261
	100 ppb	3,030	**6,094**
Dissolved Area (km^2)	**10 ppb**	9	-
	50 ppb	-	-
	400 ppb	-	-
Start Date		28 April 2015	25 June 2011

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 41 during the transitional period.

Figure 11.12 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.13 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.14 presents the fates and weathering for the corresponding simulation and Table 11.6 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.6 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Chandon Well 1.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	234	52	0
Entrained (m^3)	5,305	90	2,817
Dissolved (m^3)	84	82	3
Evaporation (m^3)	47,176	104	47,176
Decay (m^3)	25,177	104	25,177
Ashore (m^3)	0	0	0

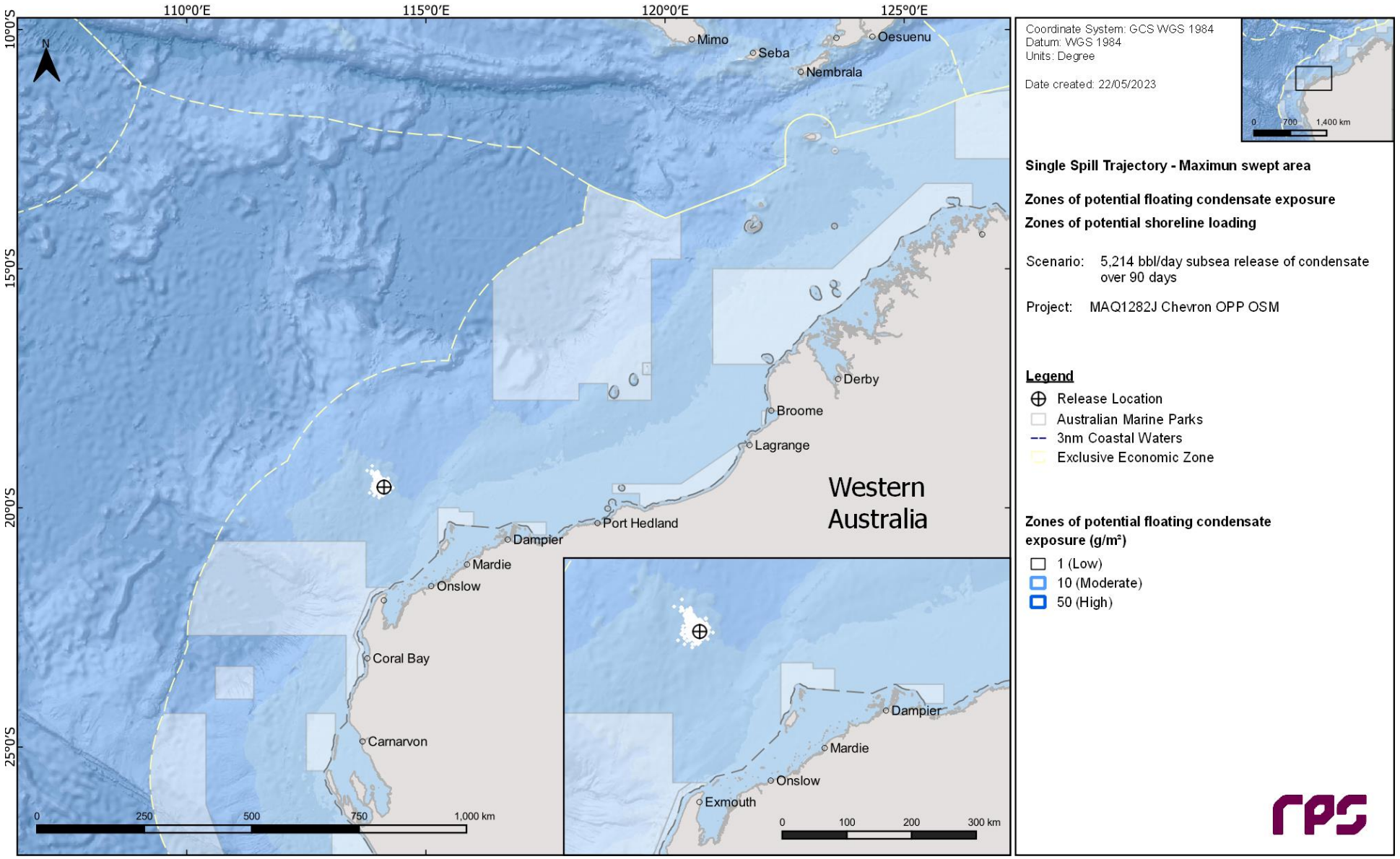


Figure 11.12 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Chandon Well 1.

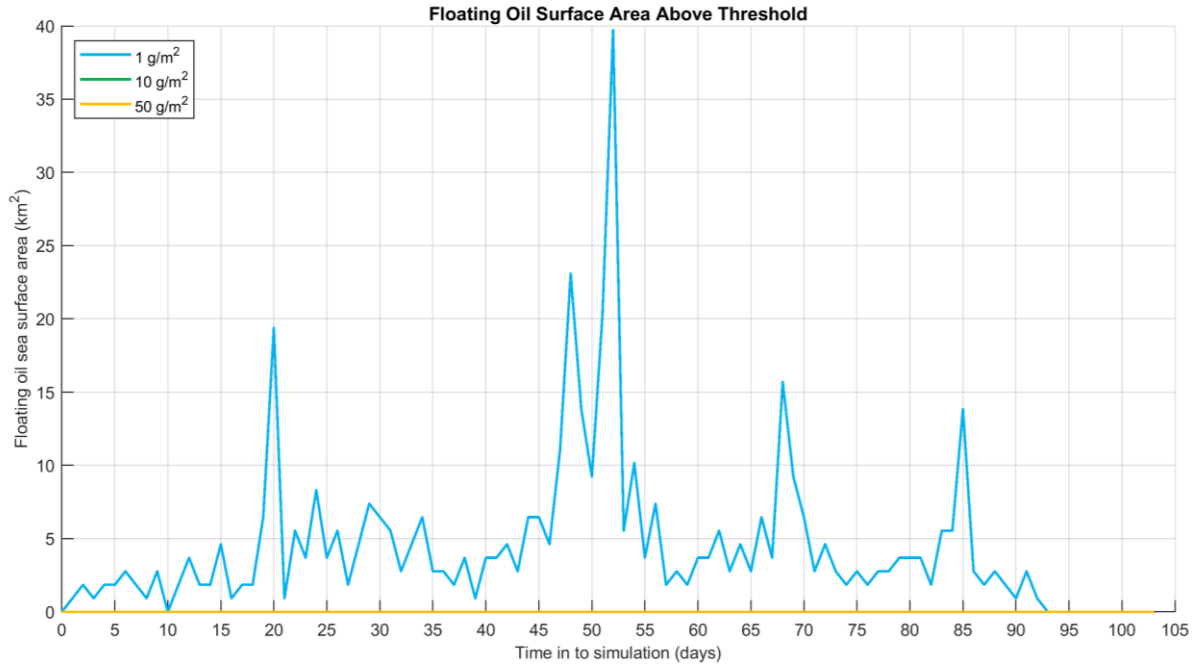


Figure 11.13 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chandon Well 1.

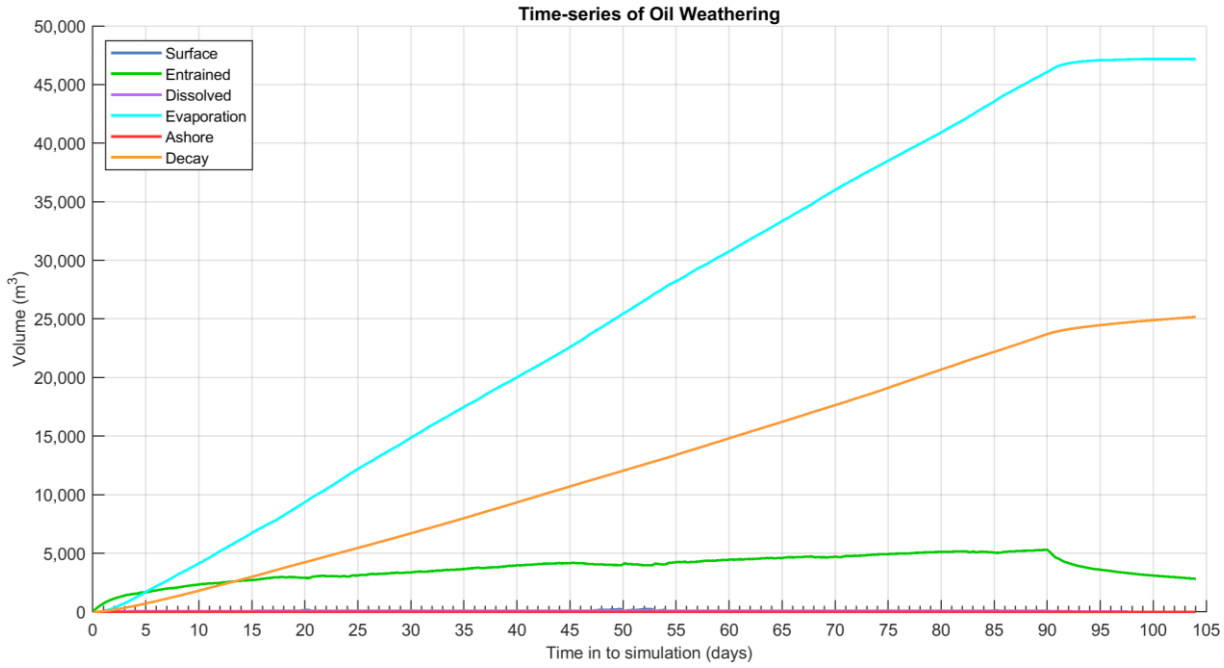


Figure 11.14 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chandon Well 1.

11.2.2 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 57 during the winter period.

Figure 11.15 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.16 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering for the corresponding single spill trajectory and Table 11.7 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.7 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	298	51	0
Entrained (m^3)	5,025	89	2,684
Dissolved (m^3)	84	68	3
Evaporation (m^3)	47,918	104	47,918
Decay (m^3)	24,575	104	24,575
Ashore (m^3)	0	0	0

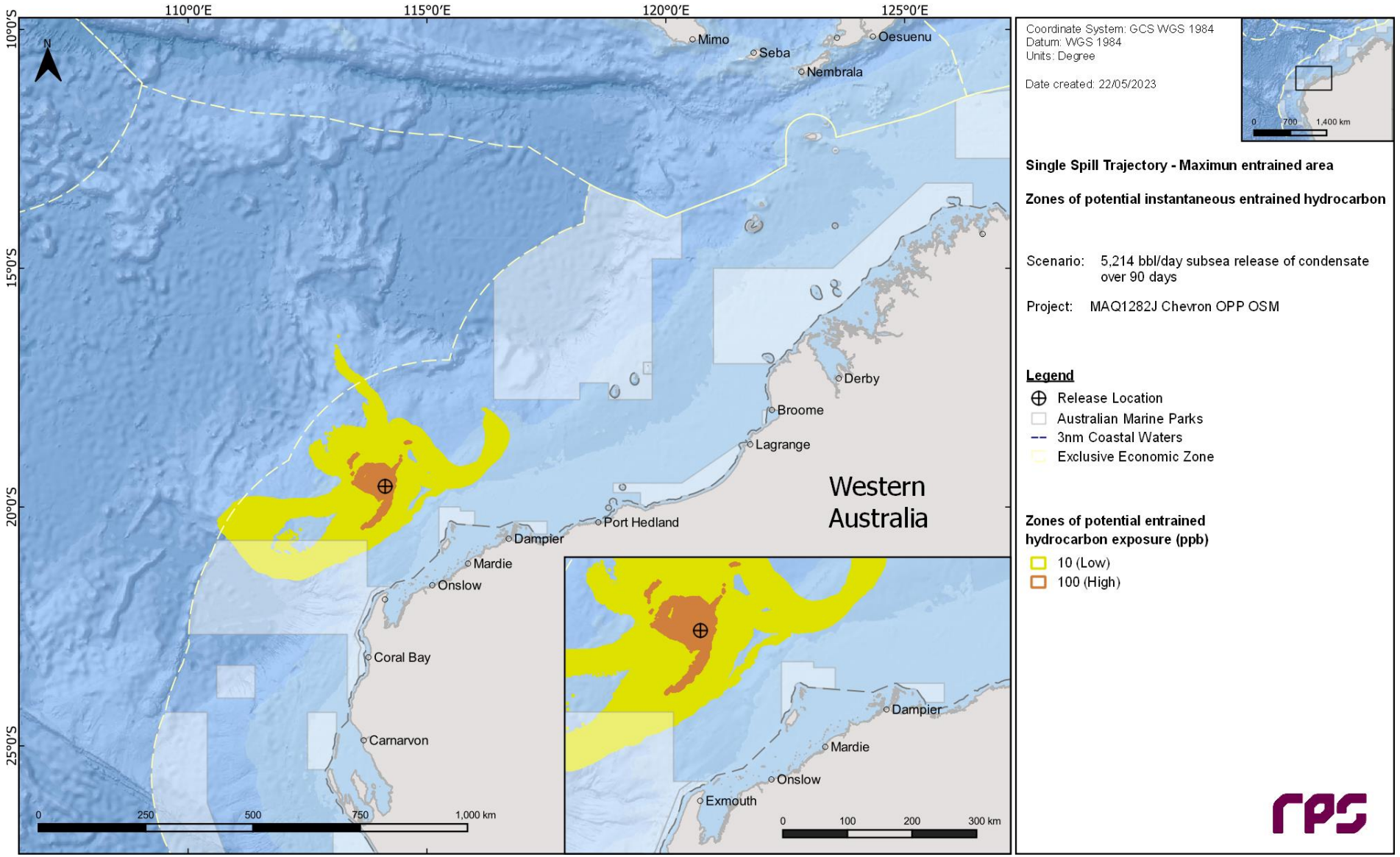


Figure 11.15 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

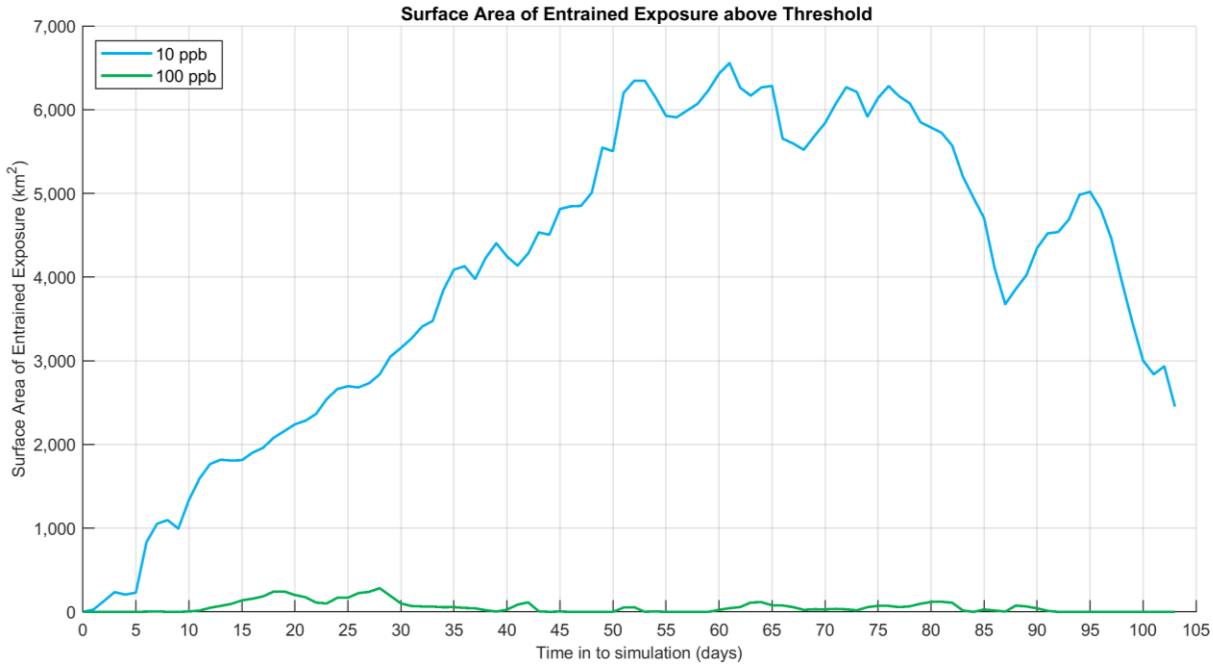


Figure 11.16 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

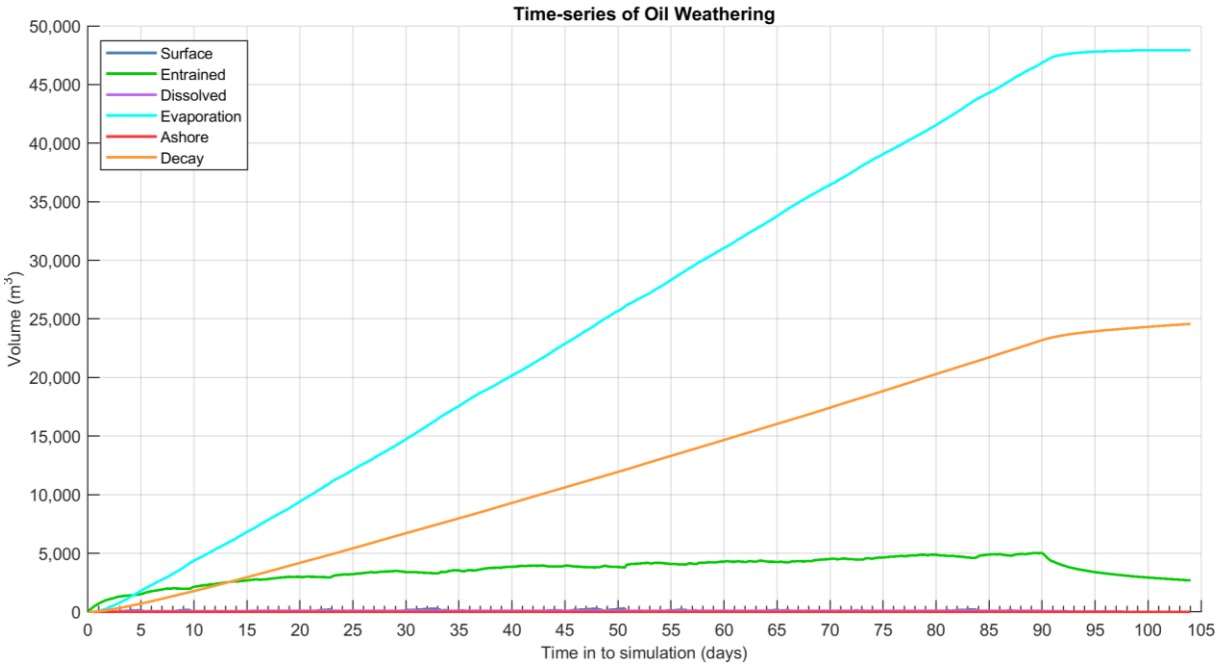


Figure 11.17 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

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appendix d gorgon gas development: backfill fields – acoustic and animal movement modelling for assessing marine fauna sound exposures

Gorgon Gas Development: Backfill Fields

Acoustic and Animal Movement Modelling for Assessing Marine Fauna Sound Exposures

JASCO Applied Sciences (Australia) Pty Ltd

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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

JASCO Applied Sciences (JASCO) undertook a modelling study of underwater sound levels associated with vessel activities and vertical seismic profiling (VSP) for the construction of the Chevron Gorgon Gas Development: Backfill Fields ('the Development'). This study considers representative noise sources in five representative areas across the Development (Areas 1 to 5). The five nominal areas were designated based upon bathymetry and proximity to each other to assist with the study. Some activities in Area 1, and all activities within Areas 2, 3 and 4 are within the pygmy blue whale migratory Biologically Important Area (BIA). Vessel activities comprise continuous non-impulsive noise sources, while VSP is an impulsive noise source.

Acoustic Modelling – Vessel Noise

The modelling study considers 36 individual vessel activity scenarios across the five Areas:

- Area 1 – Exmouth Plateau, furthest offshore
  - Scenario 1 - Drillship under dynamic positioning (DP)
  - Scenario 2 – Drillship under DP with an Offshore Support Vessel (OSV) (for 8 hours)
  - Scenario 3 – Pipelay under DP
  - Scenario 4 – Pipelay under DP with one resupply vessel
  - Scenario 5 – Pipelay under DP with one resupply vessel and one OSV
  - Scenario 6 – Inspection, Maintenance and Repair (IMR) vessel under DP
  - Scenario 7 – Offshore Construction Vessel (OCV) under DP
  - Scenario 8 – OCV under DP with three support vessels
- Area 2 – Between the Exmouth Plateau and the continental slope
  - Scenario 9 - Drillship under dynamic positioning (DP)
  - Scenario 10 – Drillship under DP with an OSV (for 8 hours)
  - Scenario 11 – Pipelay under DP
  - Scenario 12 – Pipelay under DP with one resupply vessel
  - Scenario 13 – Pipelay under DP with one resupply vessel and one OSV
  - Scenario 14 – IMR vessel under DP
  - Scenario 15 – OCV under DP
  - Scenario 16 – OCV under DP with three support vessels
- Area 3 – Immediately offshore of the continental slope
  - Scenario 17 - Drillship under dynamic positioning (DP)
  - Scenario 18 – Drillship under DP with an OSV (for 8 hours)
  - Scenario 19 – Pipelay under DP
  - Scenario 20 – Pipelay under DP with one resupply vessel
  - Scenario 21 – Pipelay under DP with one resupply vessel and one OSV
  - Scenario 22 – IMR vessel under DP
  - Scenario 23 – OCV under DP
  - Scenario 24 – OCV under DP with three support vessels
- Area 4 – Continental slope
  - Scenario 25 – Pipelay under DP
  - Scenario 26 – Pipelay under DP with one resupply vessel
  - Scenario 27 – Pipelay under DP with one resupply vessel and one OSV

  - Scenario 28 – IMR vessel under DP
- Area 5 – Continental shelf
  - Scenario 29 - Drillship under dynamic positioning (DP)
  - Scenario 30 – Drillship under DP with an OSV (for 8 hours)
  - Scenario 31 – Pipelay under DP
  - Scenario 32 – Pipelay under DP with one resupply vessel
  - Scenario 33 – Pipelay under DP with one resupply vessel and one OSV
  - Scenario 34 – IMR vessel under DP
  - Scenario 35 – OCV under DP
  - Scenario 36 – OCV under DP with three support vessels

Further to the 36 individual vessel activity scenarios, four combined scenarios have also been modelled, which consist of multiple vessel activities. The four combined scenarios consider the aggregate contribution of noise emissions from concurrent vessel activities, namely:

- Scenario 37 – Scenario 5 and 18 (Area 1 Pipelay with resupply vessel and OSV + Area 3 Drillship with OSV)
- Scenario 38 – Scenario 8, 14, and 18 (Area 1 OCV with three support vessels + Area 2 IMR vessel + Area 3 Drillship with OSV)
- Scenario 39 – Scenario 18 and 33 (Area 3 Drillship with OSV, Area 5 Pipelay with resupply vessel and OSV)
- Scenario 40 – Scenario 30 and 33 (Area 5 Drillship with OSV, Area 5 Pipelay with resupply vessel and OSV)

The study assessed distances from vessel activities where underwater sound levels reached thresholds corresponding to various levels of potential impact to marine fauna. The animals considered here included marine mammals, turtles, and fish. 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 scenario specific source levels and range-dependent environmental properties. Estimated underwater acoustic levels for non-impulsive (continuous) noise sources presented as sound pressure levels (SPL, L_p), and as accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. In this report, the duration of the SEL accumulation is defined as integrated over a 24 h period.

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. The corresponding SEL_{24h} radii represent an unlikely worst-case scenario. More realistically, marine mammals (as well as fish and turtles) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with impairment if it remained in that location for 24 hours.

Maps are provided in the report to assist with contextualising tabulated distances. The key results of this acoustic modelling study are summarised in Tables 1–5.

In Areas 1, 2, 3 and 5, the OCV with construction support vessels resulted in the longest distances to effect thresholds (Table 1). The 120 dB SPL marine mammal behavioural effect zone from construction activities with support vessels featured a radius of 15.7 km in Area 1, 15.4 km in Area 2, 14.0 km in Area 3, and 17.3km in Area 5. Construction activities were not modelled in Area 4, and in this Area the pipelay vessel with two support vessels resulted in the longest distances to effect

thresholds (120 dB marine mammal behavioural effect radii of 18.3 km). In every modelled Area, and for each activity, additional support vessels generated larger distances to effect thresholds (Table 1).

The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel; the largest marine mammal behavioural response zone for the IMR vessel was 3.76 km and the largest low-frequency (LF) cetacean TTS zone was 0.63 km (both in Area 5) (Table 1).

Offshore activities over deep water in Areas 1 and 2 generally featured smaller effect zones than equivalent activities in Areas 3, 4 and 5 where the continental shelf environment was conducive to effective sound propagation downslope (Table 1).

To consider the aggregate contribution of noise emissions from the four combined scenarios, ensonified areas were examined for Scenarios 37 – 40, rather than maximum radii. In the combined scenarios, only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios) (Table 2). The SEL_{24h} areas for Scenario 40, and all effect areas for Scenarios 37, 38 and 39, did not result in merged effect zones and the percentage change in ensonified areas therefore remained low (<5%) (Table 2). The lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities. While the modelled sound fields presented here are specific to the modelled site locations, the effect radii provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

Table 1. Summary of maximum (R_{max}) horizontal distances (in km) from all scenarios considered to the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds (179 and 199 dB re 1 µPa²·s, respectively) based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		R_{max} (km)	R_{max} (km)	R_{max} (km)
1	Area 1, Drillship	5.62	0.78	0.08
2	Area 1, Drillship with OSV	5.87	0.83	0.10
3	Area 1, Pipelay vessel	6.30	0.84	0.05
4	Area 1, Pipelay vessel with resupply vessel	6.56	0.99	0.10
5	Area 1, Pipelay vessel with resupply vessel and support OSV	6.72	1.07	0.12
6	Area 1, IMR vessel	1.99	0.36	0.04
7	Area 1, OCV	15.5	1.71	0.18
8	Area 1, OCV with 3 support vessels	15.7	1.82	0.21
9	Area 2, Drillship	5.60	0.78	0.07
10	Area 2, Drillship with OSV	5.85	0.84	0.11
11	Area 2, Pipelay vessel	6.42	0.85	0.06
12	Area 2, Pipelay vessel with resupply vessel	6.70	0.99	0.09
13	Area 2, Pipelay vessel with resupply vessel and support OSV	6.88	1.08	0.12
14	Area 2, IMR vessel	1.74	0.36	0.04
15	Area 2, OCV	15.1	1.70	0.19
16	Area 2, OCV with 3 support vessels	15.4	1.81	0.21
17	Area 3, Drillship	5.30	0.78	0.08
18	Area 3, Drillship with OSV	12.1	0.84	0.11
19	Area 3, Pipelay vessel	5.78	0.84	0.05
20	Area 3, Pipelay vessel with resupply vessel	12.8	0.99	0.09
21	Area 3, Pipelay vessel with resupply vessel and support OSV	13.0	1.08	0.12
22	Area 3, IMR vessel	2.64	0.36	0.04
23	Area 3, OCV	14.0	1.96	0.19
24	Area 3, OCV with 3 support vessels	14.0	2.10	0.21
25	Area 4, Pipelay vessel	7.87	0.88	0.05
26	Area 4, Pipelay vessel with resupply vessel	9.72	1.20	0.10
27	Area 4, Pipelay vessel with resupply vessel and support OSV	18.3	1.47	0.12
28	Area 4, IMR vessel	2.24	0.37	0.04
29	Area 5, Drillship	10.0	1.56	0.08
30	Area 5, Drillship with OSV	10.4	1.66	0.11
31	Area 5, Pipelay vessel	12.2	1.69	0.06
32	Area 5, Pipelay vessel with resupply vessel	12.8	1.99	0.10
33	Area 5, Pipelay vessel with resupply vessel and support OSV	12.9	2.18	0.12
34	Area 5, IMR vessel	3.76	0.63	0.04
35	Area 5, OCV	17.0	4.39	0.19
36	Area 5, OCV with 3 support vessels	17.3	4.58	0.21

Noise exposure criteria: [a] NOAA (2019) and [b and c] Southall et al. (2019).
A dash indicates the level was not reached within the limits of the modelled resolution (20 m)

Table 2. Summary of percentage change in ensonified area between multiple individual scenarios and combined scenarios based on the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		Percentage change in ensonified area from individual scenarios to combined (%)	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
37	Area 1 pipelay vessel with resupply vessel and support OSV + Area 3 drillship with OSV	+ 0.37	*	*
38	Area 1 OCV with 3 support vessels + Area 2 IMR vessel + Area 3 drillship with OSV	+ 3.21	+ 0.21	*
39	Area 3 drillship with OSV + Area 5 pipelay vessel with resupply vessel and support OSV	+ 4.03	+ 0.18	*
40	Area 5 drillship with OSV + Area 5 pipelay vessel with resupply vessel and support OSV	+ 12.9	+ 2.98	*

Noise exposure criteria: [a] NOAA (2019) and [b and c] Southall et al. (2019).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2)

Acoustic Modelling – Vertical Seismic Profiling

In addition to vessel noise modelling, the modelling study also considers Vertical Seismic Profiling (VSP) at three sites with a maximum of 300 shots over a 24 hour period. The three VSP locations were identified by Chevron to be representative of the range of water depths across the Development area. Site A lies on the Continental Shelf (Area 5) in the shallowest water (142.6 m), Site B is situated in Area 3, above the Continental Slope, with a water depth of 923.7 m, and Site C is situated in the deepest water, 1153 m, in Area 1.

As VSP is an impulsive noise source, the noise effect criteria are different to those in the vessel scenarios.

Of the three modelled sites, Site A generally resulted in the largest maximum horizontal distances to noise effect criteria thresholds.

Marine mammals:

The results for marine mammal injury applied the criteria from Southall et al. (2019), which requires two metrics (PK and SEL_{24h}) to be considered when assessing marine mammal PTS and TTS, with the longest distance associated with either metric being required to be applied. Table 3 summarises the maximum distances for TTS and PTS, along with the relevant metric associated with the maximum distance for the VSP results. The maximum distance where the NOAA (2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) is also presented in Table 3.

Table 3. Summary of maximum (R_{max}) horizontal distances (in km) from any modelled site to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine mammals.

Hearing group	Modelled distance to effect threshold (R_{max} km)		
	Behavioural response [a]	Impairment: TTS [b]	Impairment: PTS [b]
Low-frequency (LF) cetaceans	2.37	3.20[c]	0.48[c]
High-frequency (HF) cetaceans		–	–
Very high-frequency (VHF) cetaceans		0.13[d]	0.06[d]

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019)
[c] Longest distance to threshold from SEL_{24h} results
[d] Longest distance to threshold from PK results
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles:

- The PK sea turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metrics for PTS and TTS (Finneran et al. 2017) of 204 dB re 1 μPa^2s for PTS and 189 dB re 1 μPa^2s for TTS (summarised in Table 4) was 0.03 km for PTS onset and 0.24 km for TTS onset for the 750 in^3 seismic source. As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that sea turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- The maximum distances to the behavioural response criteria for sea turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000) were 1.03 km and 0.27 km, respectively for the 750 in^3 seismic source (summarised in Table 4).

Table 4. Summary of maximum horizontal distances (in km) from any modelled site to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine turtles.

Hearing group	Behavioural response[1]	Behavioural disturbance[1]	Impairment: TTS[2]	Impairment: PTS[2]
Sea Turtles	1.03 (SPL)	0.27 (SPL)	0.24 (SEL_{24h})	0.03 (SEL_{24h})

Noise exposure criteria: [1] McCauley et al. (2000), and [2] Finneran et al. (2017)

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 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, and
- Fish eggs and fish larvae.

Table 5 summarises the maximum distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric for both modelled locations.

Table 5. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for any modelled site, for single impulse and 24 h sound exposure level (SEL_{24h}) modelled scenarios.

Relevant hearing group	Effect criteria	Water column	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	–	–
	TTS	SEL_{24h}	0.57
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	SEL_{24h}	0.05
	TTS	SEL_{24h}	0.57
Fish eggs, and larvae	Injury	SEL_{24h}	0.05

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Benthic invertebrates:

To assist with assessing the potential effects on crustaceans from VSP operations, the following results were determined:

- The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008), which is representative of no effects, was considered for seafloor sound levels; the sound level was reached at 60.8 m from the acoustic centre of the VSP array.
- Sound levels of 209–212dB re 1 µPa PK-PK from Day et al. (2016b) and 213 dB re 1 µPa from Day et al. (2016a), which are related to impairment in crustaceans, was considered; the level was not reached for any VSP modelling site at a depth of 5 cm above the seafloor.

Animal Movement Modelling

A more realistic representation of the potential exposures for migrating pygmy blue whales in the migration BIA was undertaken using animal movement modelling ('animat modelling') for five of the vessel scenarios, with the results presented separately below. While acoustic modelling inherently assumes static animals, the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) combines modelled sound fields with realistic animal movements to predict how animals might be impacted through sound exposure. The exposure ranges account for animats sampling the sound field vertically and horizontally based on species-specific diving and movement parameters. JASMINE provides a framework for understanding and predicting sound exposure for species of interest and for calculating ranges to relevant regulatory thresholds. The distribution of distances to the source of simulated animals ('animats') predicted to be exposed to sound levels above relevant thresholds was used to calculate the horizontal distance that includes 95% of the animat distances that exceeded a given effect threshold ($ER_{95\%}$). Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed the threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which the animats are exposed to the sound field over time, both vertically and horizontally. The probability that an animat within the $ER_{95\%}$ was exposed above threshold was also computed (P_{exp}) to provide additional context. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA.

Animat modelling was undertaken for a total of nine scenarios to provide an overview of the construction activities across the range of bathymetric and geological variation within the Development footprint.

The animat modelling study considered six individual vessel activity scenarios across four Areas:

- Scenario 8 – Construction (with three support vessels) in Area 1.
- Scenario 14 – IMR vessel under DP in Area 2.
- Scenario 18 – Drillship under DP with an offshore support vessel (OSV) (for 8 hours) in Area 3.
- Scenario 21 – Pipelay (with two support vessels) in Area 3.
- Scenario 30 – Drillship under DP with an offshore support vessel (OSV) (for 8 hours) in Area 5.
- Scenario 33 – Pipelay under DP with one resupply vessel and one OSV in Area 5.

Further to the six individual vessel activity scenarios, three combined scenarios have also been modelled, which consist of multiple vessel activities:

- Scenario 38 – Construction (with three support vessels) in Area 1, IMR in Area 2, and drilling (with OSV) in Area 3.
- Scenario 39 – Drilling (with OSV) in Area 3 and pipelay (with two support vessels) in Area 5.
- Scenario 40 – Drilling (with OSV) in Area 5 and pipelay (with two support vessels) in Area 5.

The key results of the animat modelling are outlined below and summarised Table 6.

- In general, exposure ranges from animal movement modelling for PTS and TTS criteria (Southall et al. 2019) are typically shorter than those predicted using acoustic propagation modelling because of the shorter time ('dwell time') to accumulate sound energy of the moving animats. In this study, there were no exposures above PTS threshold for any of the pygmy blue whale scenarios. The maximum $ER_{95\%}$ for TTS of 0.04 km with a corresponding exposure probability for animats travelling within that range of 67%.
- Exposure ranges ($ER_{95\%}$) for single exposure metrics, such as the SPL behavioural response criteria, are generally comparable to the predicted acoustic ranges. In this study, exposure ranges

were slightly lower than the R_{max} acoustic ranges based on the vertical distribution of the sound field.

- Unrestricted animat seeding resulted in exposures above the SPL behavioural response threshold (NOAA (2019)) for all considered scenarios. Of these, the maximum $ER_{95\%}$ to the threshold was 12.4 km. The probability of an animat within the $ER_{95\%}$ being exposed above the threshold was 99%.

Table 6. Summary of animat simulation results for the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} PTS and TTS thresholds for pygmy blue whales with unrestricted and restricted seeding. Maximum exposure ranges show $ER_{95\%}$ (km) first and probability of exposure of animats travelling within the $ER_{95\%}$ (P_{exp} (%)) in parentheses. A dash (-) indicates that no animat was exposed above the threshold.

Scenario Number	Description	Behavioural response (SPL)[2]	LF-cetacean TTS (SEL_{24h})[1]	LF-cetacean PTS (SEL_{24h})[1]
8	Area 1, OCV with 3 support vessels	12.4 (99%)	0.04 (67%)	–
14	Area 2, IMR vessel	0.73 (88%)	0.02 (87%)	–
18	Area 3, Drillship with OSV	3.02 (73%)	0.02 (76%)	–
21	Area 3, Pipelay vessel with resupply and support OSVs	5.03 (73%)	0.02 (91%)	–
30	Area 5, Drillship with OSV	8.03 (>99%)	0.02 (80%)	–
33	Area 5, Pipelay vessel with resupply vessel and support OSV	9.56 (>99%)	0.02 (77%)	–
38	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV	12.3 (50%)	0.03 (61%)	–
39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	9.47 (63%)	0.02 (77%)	–
40	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	9.55 (98%)	0.02 (79%)	–

[1] Southall et al. (2019) criteria for marine fauna.
[2] NOAA (2019) recommended unweighted behavioural criteria for marine mammals.

1. Introduction

JASCO Applied Sciences (JASCO) undertook a modelling study of underwater sound levels associated with vessel activities and vertical seismic profiling (VSP) for the construction of the Chevron Gorgon Gas Development: Backfill Fields, incorporating site-specific environmental parameters that affect the propagation of underwater sound. The modelling study considers 36 individual vessel scenarios (Scenarios 1–36) across five representative areas (Areas 1–5) within the Development footprint (Figure 1), four combined vessel scenarios incorporating multiple individual scenarios (Scenarios 37–40) (Section 1.1.1), and three VSP scenarios (Scenarios A, B and C) (Section 1.1.2). Vessel activities comprise continuous non-impulsive noise sources, while VSP is an impulsive noise source. The vessels considered within the study are nominal vessels representing the type and class of vessel likely to be used for the Development.

The modelling study predicted the distances from construction activities at which underwater sound levels reached noise effect thresholds and criteria for marine mammals, sea turtles and fish. The corresponding marine mammal thresholds include levels associated with behavioural response, permanent threshold shift (PTS) and temporary threshold shift (TTS), and the marine mammal functional hearing groups considered were low, high, and very-high-frequency cetaceans. Estimated underwater acoustic levels associated with vessel scenarios are presented as sound pressure levels (SPL, L_p), and accumulated sound exposure levels (over 24 hours) (SEL_{24h}, $L_{E,24h}$), as appropriate for non-impulsive (continuous) noise sources. Estimated underwater acoustic levels associated with VSP scenarios are presented as SEL_{24h}, for multiple pulses (5, 10, 25, 50, 100, 150, 200, 250, 300) over a 24 hour period, as well as single-impulse (i.e., per-pulse) metrics, including SPL, per-pulse sound exposure levels (SEL, L_E), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK, $L_{pk\text{-}pk}$), as appropriate for impulsive noise sources.

The representative areas within the Development footprint are as follows:

- Area 1 – Exmouth Plateau, furthest offshore
- Area 2 – Between the Exmouth Plateau and the continental slope
- Area 3 – Immediately offshore of the continental slope
- Area 4 – Continental slope
- Area 5 – Continental shelf

The modelled vessel activity sites within each area are shown in Figure 1.

Some activities in Area 1, and all activities within Areas 2, 3, and 4 lie within the pygmy blue whale (*Balaenoptera musculus brevicauda*) migratory Biologically Important Area (BIA). Therefore, the acoustic modelling results for some vessel scenarios were used in conjunction with animal movement modelling ('animat modelling') simulations to predict the distance at which migrating pygmy blue whales are expected to be exposed above threshold criteria for PTS, TTS, and behavioural response. Sound exposure distribution estimates are determined by moving large numbers of simulated animals (animats) through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models. This approach provides the most realistic prediction of the maximum expected SPL and SEL_{24h} for comparison against the relevant thresholds. Animal movement modelling was undertaken for nine vessel scenarios (Section 1.1.3) to provide an overview of the construction activities across the range of bathymetric and geological variation within the Development footprint.

This report is structured as follows: the remainder of Section 1 provides details on the scenarios considered for modelling, Section 2 explains the metrics used to represent underwater acoustic fields and the effect criteria considered. Sections 3.1 to 3.4 detail the methodology for predicting the source levels and modelling the sound propagation, including the specifications of the considered sound sources and the environmental parameters. Section 3.5 details the methodology for animat modelling of pygmy blue whales. Section 4.1 presents the acoustic results as tabulated ranges to thresholds,

Sections 4.2.1 and 0 provide sound level contour maps, and Section 4.3 includes animal movement modelling results. The acoustic and animat modelling results are then discussed in Section 5.

1.1. Details of Modelling Scenarios

1.1.1. Vessel Noise Sources

This acoustic and exposure study considered the sound-producing activities associated with thirty individual vessel scenarios (outlined in Table 7), each describing a unique combination of sound sources.

Table 7. Summary of modelled scenarios

Scenario	Associated Site(s)	Area	Scenario description
1	1	1 – Exmouth Plateau, furthest offshore	Drillship under DP
2	1 + 2		Drillship under DP + Offshore Support Vessel (OSV) under DP 8hr
3	3		Pipelay vessel under DP
4	3 + 4		Pipelay vessel + resupply vessel, both under DP
5	3 + 4 + 5		Pipelay vessel + resupply vessel + OSV, all under DP
6	6		IMR vessel under DP
7	7		Offshore Construction Vessel (OCV) under DP
8	7 + 8 + 9 + 10		OCV + 3 support vessels, all under DP
9	11	2 – Between the Exmouth Plateau and the continental slope	Drillship under DP
10	11 + 12		Drillship under DP + OSV under DP 8hr
11	13		Pipelay vessel under DP
12	13 + 14		Pipelay vessel + resupply vessel, both under DP
13	13 + 14 + 15		Pipelay vessel + resupply vessel + OSV, all under DP
14	16		IMR vessel under DP
15	17		OCV under DP
16	17 + 18 + 19 + 20		OCV + 3 support vessels, all under DP
17	21	3 – Immediately offshore of the continental slope	Drillship under DP
18	21 + 22		Drillship under DP + OSV under DP 8hr
19	23		Pipelay vessel under DP
20	23+24		Pipelay vessel + resupply vessel, both under DP
21	23+24+25		Pipelay vessel + resupply vessel + OSV, all under DP
22	26		IMR vessel under DP
23	27		OCV under DP
24	27+28+29+30		OCV + 3 support vessels, all under DP
25	31	4 – Continental slope	Pipelay vessel under DP
26	31+32		Pipelay vessel + resupply vessel, both under DP
27	31+32+33		Pipelay vessel + resupply vessel + OSV, all under DP
28	34		IMR vessel under DP
29	35	5 – Continental shelf	Drillship under DP
30	35+36		Drillship under DP + OSV under DP 8hr
31	37		Pipelay vessel under DP
32	37+38		Pipelay vessel + resupply vessel, both under DP
33	37+38+39		Pipelay vessel + resupply vessel + OSV, all under DP
34	40		IMR vessel under DP
35	41		OCV under DP
36	41+42+43+44		OCV + 3 support vessels, all under DP

Scenarios 1 and 2, 9 and 10, 17 and 18, and 29 and 30 represent the operation of a drillship (nominally, the *Dhirubhai Deepwater KG2*), with and without the addition of an Offshore Support Vessel (OSV), respectively, across Area 1, 2, 3 and 5. The drillship has been assumed to operate continuously (24 h), under dynamic positioning (DP) in a static location. The OSV has been modelled using a representative generic vessel, the *MMA Leeuwin*, which has been considered on DP attendance alongside the drillship for 8 hours per day.

Scenarios 3–5, 11–13, 19–21, 25–27, and 31–33 represent the operation of a pipelay vessel in each of the five Areas with none, one, or two support vessels, respectively. The *Allseas Solitaire* has been considered as a representative pipelay vessel. Scenarios with one support vessel include a resupply vessel (nominally *Allseas Alegria*) alongside the pipelay vessel, and scenarios with two support vessels include the resupply vessel and a generic OSV (again represented by the *MMA Leeuwin*) alongside the pipelay vessel. All vessels are assumed to operate under DP for 24 h per day, travelling at 0.3 km per day along the supplied track-lines.

Scenarios 6, 14, 22, 28 and 34 represent the activities of an Inspection, Maintenance and Repair (IMR) vessel, which has been represented by the *Skandi Hercules*. This vessel is modelled in each of the five Areas for 24 h per day under static DP.

Scenarios 7, 15, 23 and 35 represent the operation of an Offshore Construction Vessel (OCV) (nominally the *Skandi Africa*) in Areas 1, 2, 3 and 5, respectively. Scenarios 8, 16, 24 and 36 represent the OCV with the addition of three support vessels; a tug (represented by *Mermaid Sound*), and two OSVs (represented by *MMA Chieftain* and *MMA Coral)*. In these scenarios, all vessels are assumed to operate statically under DP for 24 h per day.

Figure 1 displays an overview of the modelling area showing the locations of the modelled sites within their respective Areas, the pygmy blue whale BIA (and the humpback whale migratory BIA for reference), and the regional bathymetry.

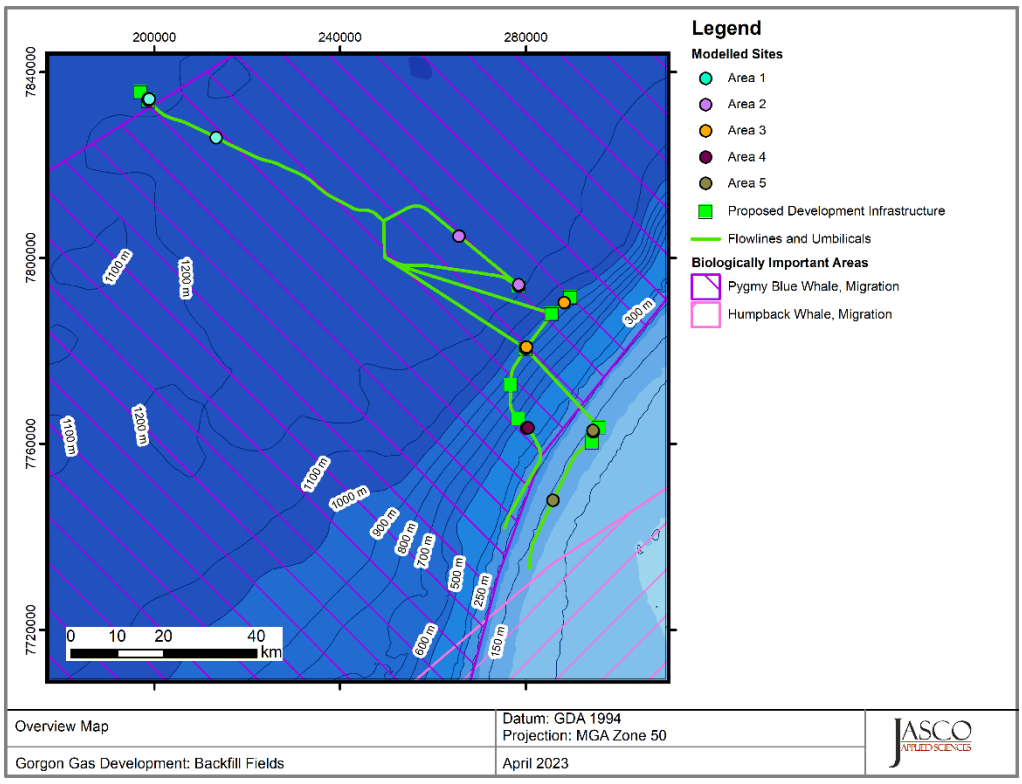


Figure 1. Overview map of the Chevron 'Gorgon Gas Development: Backfill Fields' showing the modelled vessel activity site locations within each representative Development area.

The 36 scenarios outlined in Table 7 comprise a total of 44 acoustic modelling sites that were selected to represent the extent of the construction activities, and these are listed in Table 8. Detailed maps illustrating the site locations within each of the five Areas are included as Figures 2 to 6.

Table 8. Location details for the vessel acoustic modelling sites

Site	Area	Vessel Type	Latitude (S)	Longitude (E)	MGA[1] Zone 50		Water Depth (m)
					X (m)	Y (m)	
1	1	Drillship	19° 34' 00.82"	114° 07' 42.61"	198715	7833915	1153
2		Drillship OSV	19° 34' 00.86"	114° 07' 45.01"	198785	7833915	1153
3		Pipelay	19° 38' 30.23"	114° 15' 58.64"	213313	7825864	1292
4		Pipelay OSV 1 (resupply)	19° 38' 29.23"	114° 15' 59.22"	213330	7825895	1291
5		Pipelay OSV 2 (support)	19° 38' 31.23"	114° 15' 58.04"	213296	7825833	1292
6		IMR vessel	19° 33' 51.07"	114° 07' 42.79"	198715	7834215	1149
7		OCV	19° 33' 51.07"	114° 07' 42.79"	198715	7834215	1149
8		Support tug	19° 33' 51.06"	114° 07' 41.94"	198690	7834215	1149
9		OCV OSV 1	19° 33' 51.09"	114° 07' 43.78"	198744	7834215	1149
10		OCV OSV 2	19° 33' 52.46"	114° 07' 47.90"	198865	7834175	1149
11	2	Drillship	19° 56' 18.05"	114° 52' 59.29"	278440	7793945	1210
12		Drillship OSV	19° 56' 18.08"	114° 53' 01.70"	278510	7793945	1209
13		Pipelay	19° 50' 22.41"	114° 45' 43.14"	265609	7804719	1328
14		Pipelay OSV 1 (resupply)	19° 50' 21.55"	114° 45' 43.94"	265632	7804746	1328
15		Pipelay OSV 2 (support)	19° 50' 23.28"	114° 45' 42.34"	265586	7804692	1328
16		IMR vessel	19° 56' 08.30"	114° 52' 59.42"	278440	7794245	1211
17		OCV	19° 56' 18.05"	114° 52' 59.29"	278440	7793945	1210
18		Support tug	19° 56' 18.04"	114° 52' 58.43"	278415	7793945	1210
19		OCV OSV 1	19° 56' 18.06"	114° 53' 00.29"	278469	7793945	1210
20		OCV OSV 2	19° 56' 19.41"	114° 53' 04.43"	278590	7793905	1208
21	3	Drillship	20° 03' 33.49"	114° 53' 45.53"	279953	7780570	923
22		Drillship OSV	20° 03' 33.52"	114° 53' 47.94"	280023	7780570	921
23		Pipelay	19° 58' 17.92"	114° 58' 34.84"	288243	7790379	972
24		Pipelay OSV 1 (resupply)	19° 58' 18.80"	114° 58' 35.62"	288266	7790352	971
25		Pipelay OSV 2 (support)	19° 58' 17.06"	114° 58' 34.05"	288220	7790405	974
26		IMR vessel	20° 03' 23.74"	114° 53' 45.66"	279953	7780870	932
27		OCV	20° 03' 33.49"	114° 53' 45.53"	279953	7780570	923
28		Support tug	20° 03' 33.48"	114° 53' 44.67"	279928	7780570	924
29		OCV OSV 1	20° 03' 33.50"	114° 53' 46.53"	279982	7780570	922
30		OCV OSV 2	20° 03' 34.85"	114° 53' 50.67"	280103	7780530	918
31	4	Pipelay	20° 12' 49.63"	114° 53' 44.27"	280133	7763465	400
32		Pipelay OSV 1 (resupply)	20° 12' 48.89"	114° 53' 45.19"	280159	7763488	399
33		Pipelay OSV 2 (support)	20° 12' 50.38"	114° 53' 43.35"	280106	7763442	400
34		IMR vessel	20° 12' 49.75"	114° 53' 54.60"	280433	7763465	389
35	5	Drillship	20° 13' 22.18"	115° 01' 56.74"	294442	7762640	142
36		Drillship OSV	20° 13' 22.20"	115° 01' 59.16"	294512	7762640	142
37		Pipelay	20° 21' 18.61"	114° 56' 53.00"	285807	7747880	141
38		Pipelay OSV 1 (resupply)	20° 21' 19.13"	114° 56' 54.09"	285838	7747865	141
39		Pipelay OSV 2 (support)	20° 21' 18.11"	114° 56' 51.91"	285775	7747895	141
40		IMR vessel	20° 13' 12.42"	115° 01' 56.87"	294442	7762940	145
41		OCV	20° 13' 22.18"	115° 01' 56.74"	294442	7762640	142
42		Support tug	20° 13' 22.17"	115° 01' 55.88"	294417	7762640	142
43		OCV OSV 1	20° 13' 22.19"	115° 01' 57.74"	294471	7762640	142
44		OCV OSV 2	20° 13' 23.53"	115° 02' 01.89"	294592	7762600	141

[1] Map Grid of Australia (MGA)

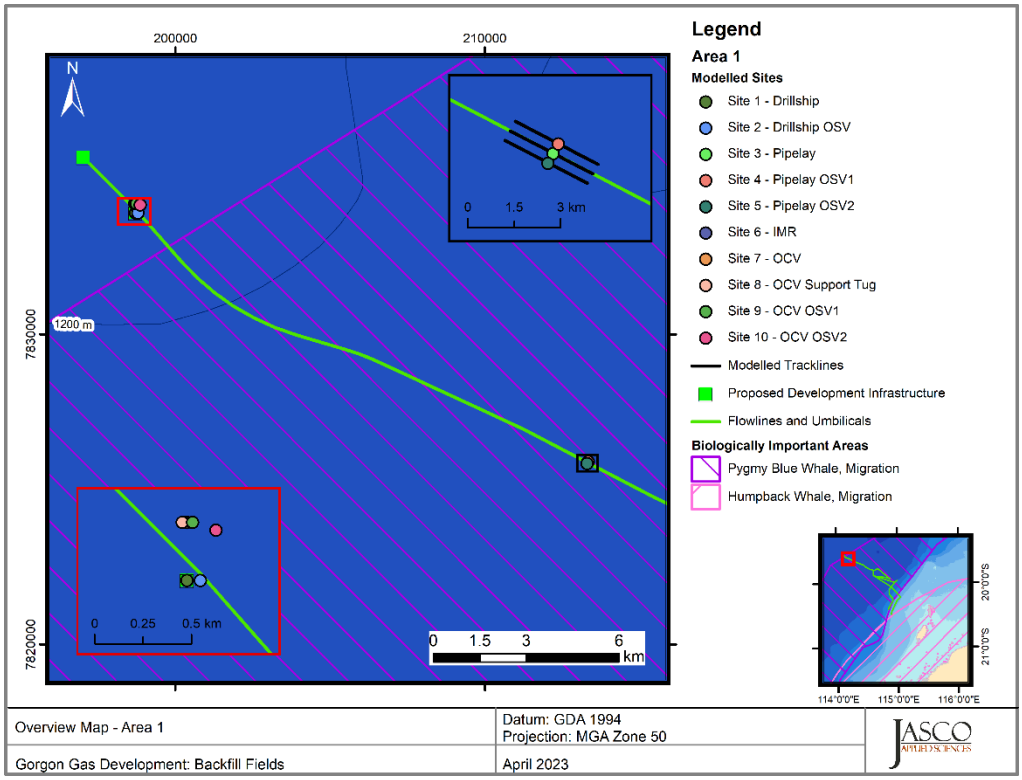


Figure 2. Overview map of Area 1 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top right).

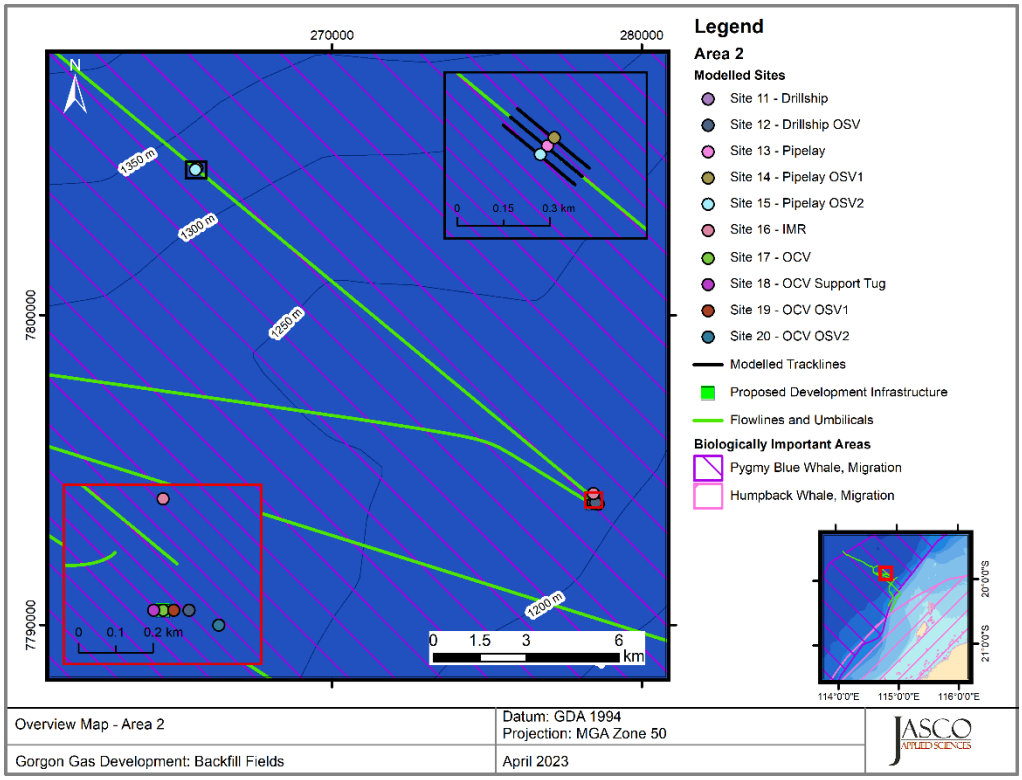


Figure 3. Overview map of Area 2 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top right).

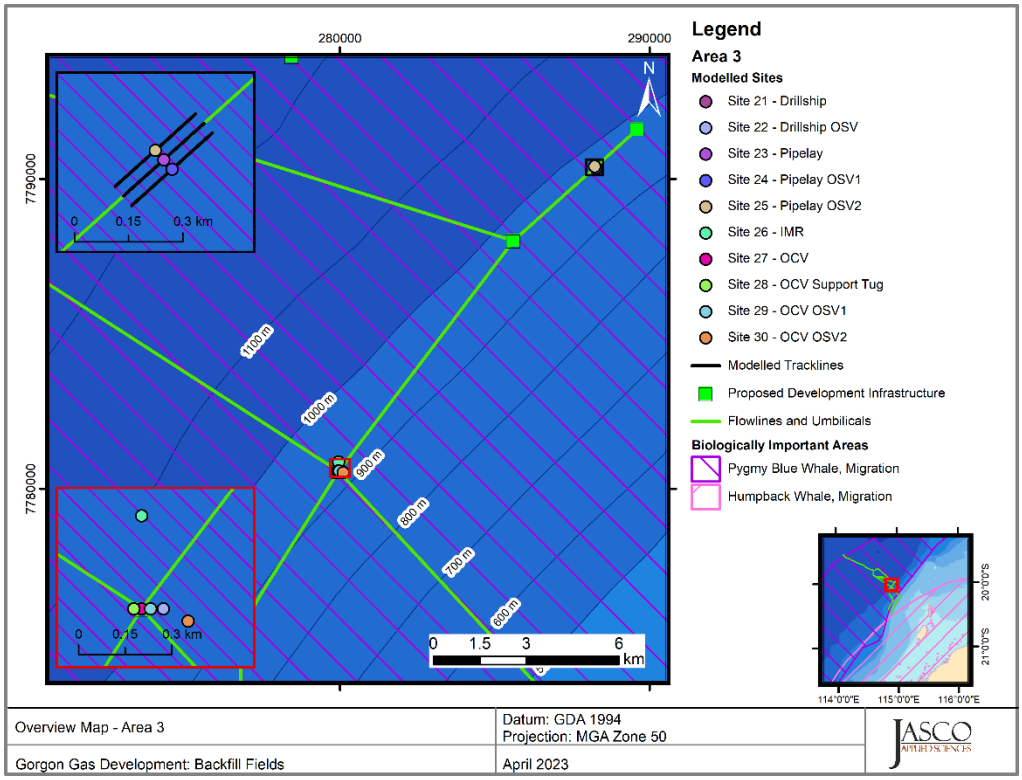


Figure 4. Overview map of Area 3 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top left).

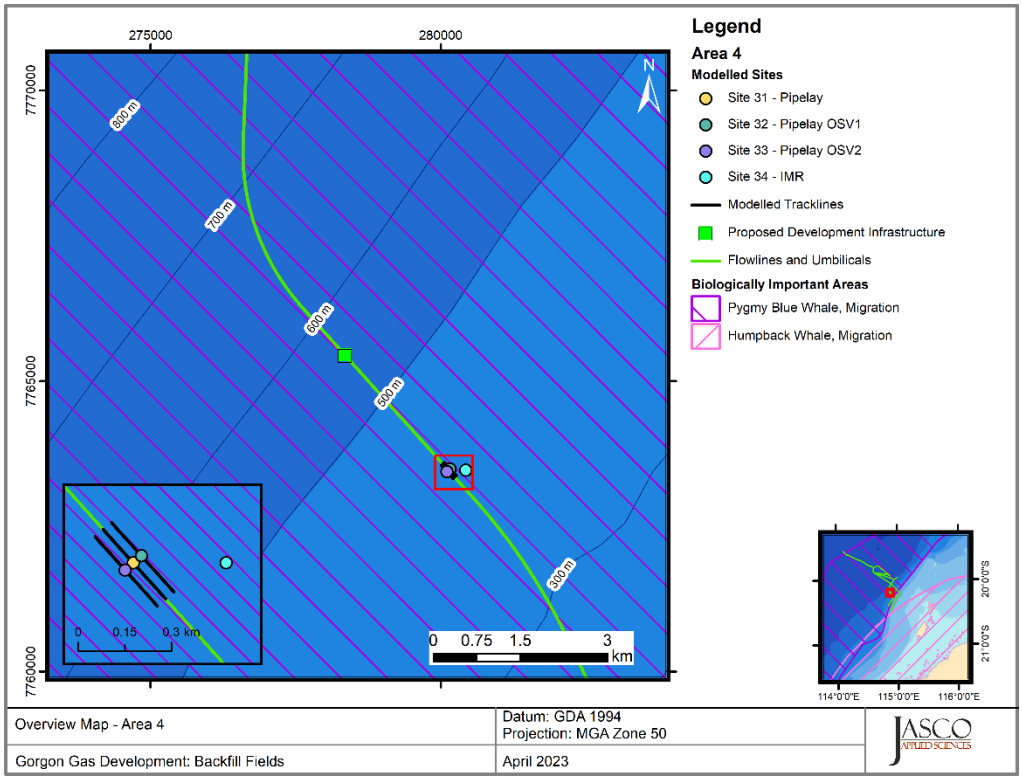


Figure 5. Overview map of Area 4 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios.

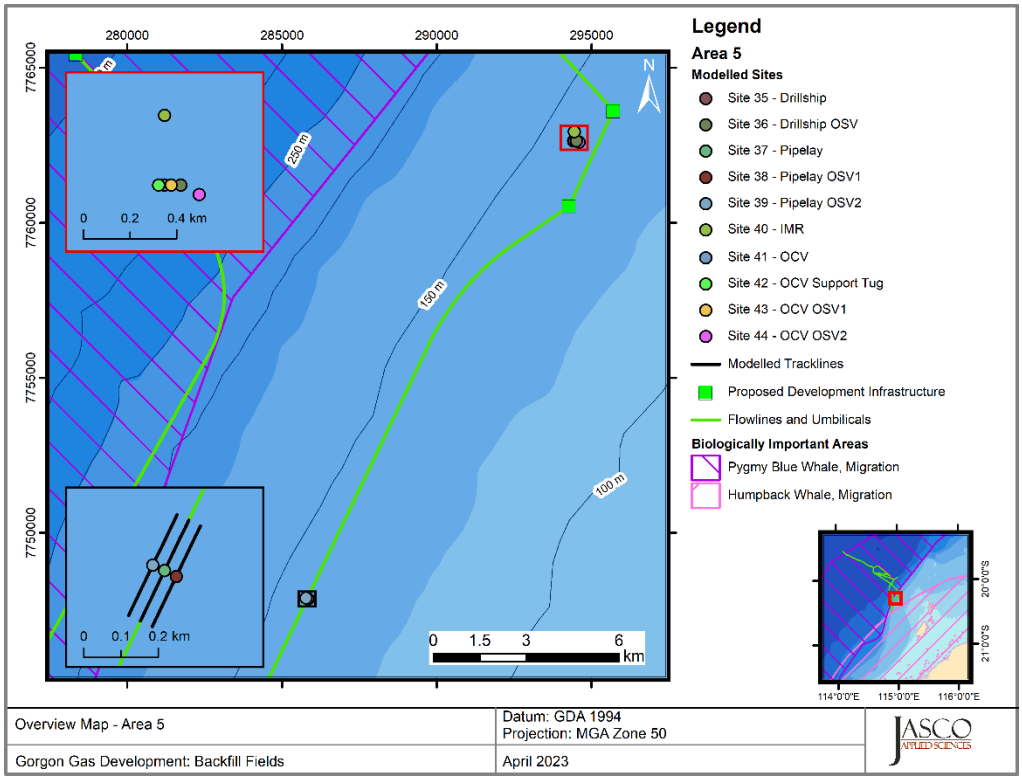


Figure 6. Overview map of Area 5 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, top left) and the modelled pipelay tracklines (black, bottom left).

In addition to the 36 individual vessel scenarios, four combined scenarios have also been modelled, which consider the aggregate contribution of noise emissions from concurrent works. The four combined scenarios are summarised in Table 9.

Table 9. Summary of modelled combined scenarios.

Combined scenario	Associated individual scenarios	Associated sites	Scenario description
37	5, 18	3, 4, 5, 21, 22	Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV
38	8, 14, 18	7, 8, 9, 10, 16, 21, 22	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV
39	18, 33	21, 22, 37, 38, 39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels
40	30, 33	35, 36, 37, 38, 39	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels

1.1.2. Vertical Seismic Profiling Acoustic Source

The modelling study considers three VSP scenarios occurring at three sites as shown in Figure 7 and detailed in Table 10. The three VSP locations were identified by Chevron to be representative of the range of water depths across the Development area. Site A lies on the Continental Shelf (Area 5) in the shallowest water (142.6 m), Site B is situated in Area 3, above the Continental Slope, with a water depth of 923.7 m, and Site C is situated in the deepest water, 1153 m, in Area 1.

Table 10. Location details for VSP acoustic modelling sites

Site	Area	Latitude (S)	Longitude (E)	MGA[1] Zone 50		Water depth (m)
				X (m)	Y (m)	
A	5	20° 13' 20.9892" S	115° 1' 56.172" E	294424.9	7762676	142.6
B	3	20° 3' 33.3684" S	114° 53' 45.3372" E	279947.4	7780574	923.7
C	1	19° 34' 0.822" S	114° 7' 42.5784" E	198714	7833915	1153

[1] Map Grid of Australia (MGA)

The proposed VSP array has a total volume of 750 in^3 in a delta cluster configuration. A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250, and 300 shots over 24 hours to realistically represent a range of potential operations.

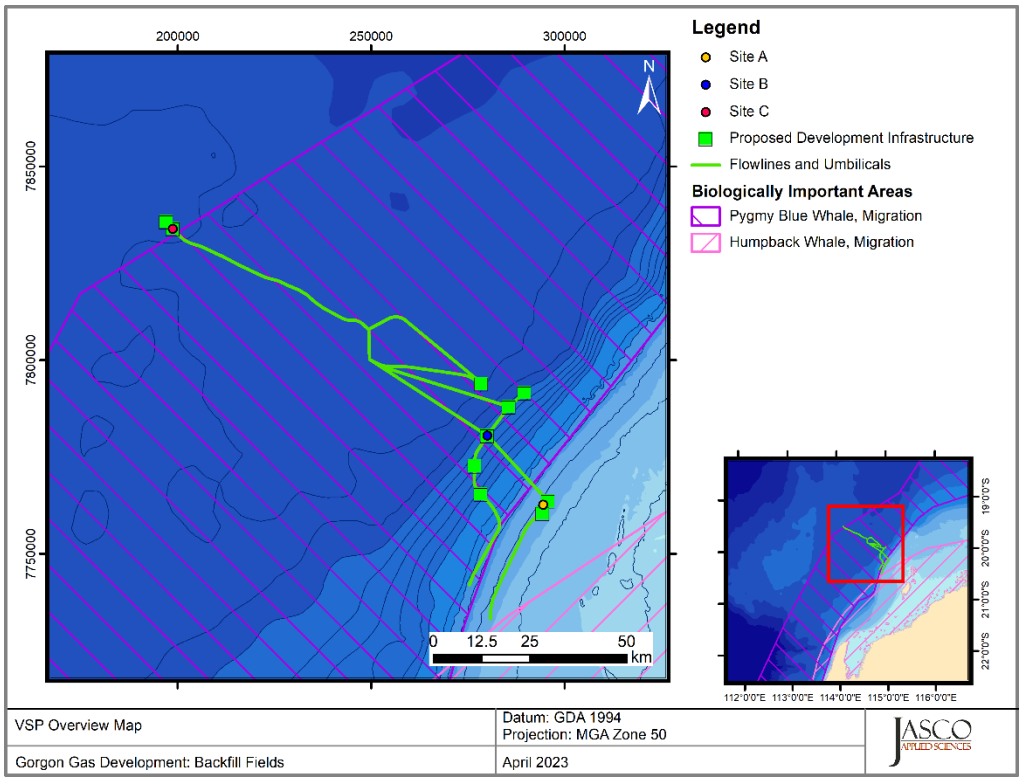


Figure 7. VSP Overview Map.

1.1.3. Animal Movement Modelling

Animal movement modelling simulations were run for migrating pygmy blue whales for vessel Scenarios 8, 14, 18, 21, 30, 33, 38, 39 and 40, as summarised in Table 7 and Table 9. Each of the animat simulations were run for a representative 24 h duration. The simulation area was selected to encompass a buffer of approximately 30 km from either modelled site, in any direction, based on the maximum acoustic range. Figure 8 shows an overview of the animat modelling simulation extents, along with the scenario locations and the pygmy blue whale BIA.

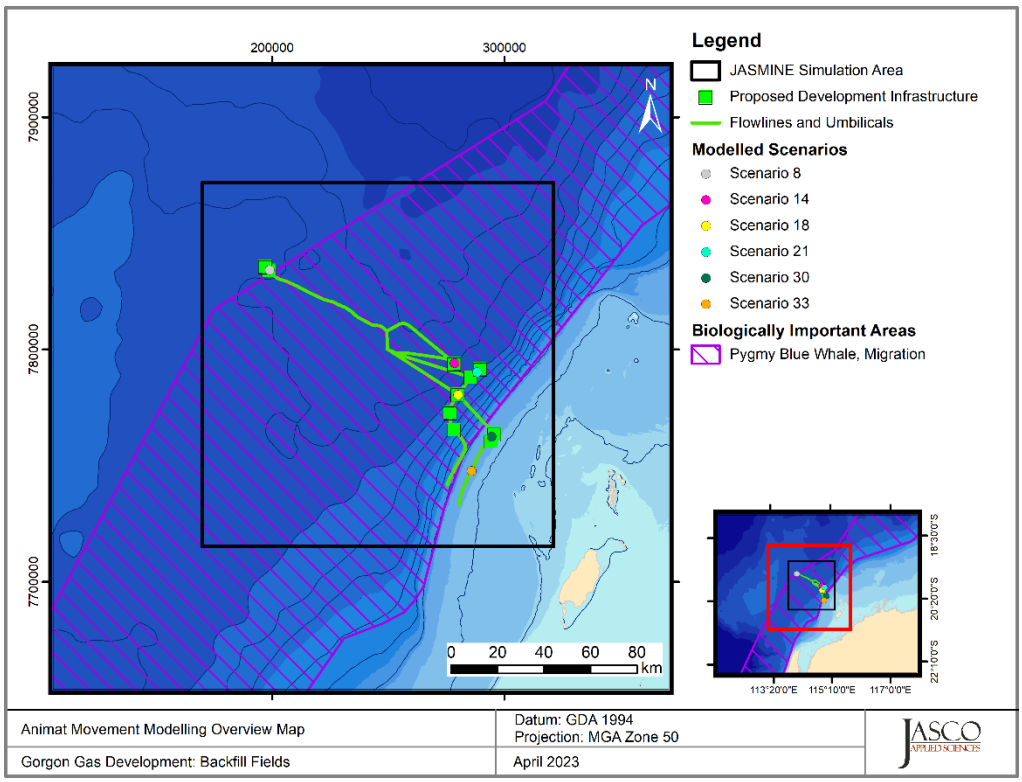


Figure 8. Overview map of the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios, showing the animat movement modelling simulation extents along with the scenario locations and the pygmy blue whale BIAs.

2. Noise Effect Criteria

To assess the potential effects of a sound-producing activity, it is necessary to first establish exposure criteria and associated thresholds for which sound levels may be expected to have an adverse effect on animals. Whether acoustic 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.

Two sound level metrics, SPL and SEL, are commonly used to evaluate non-impulsive noise and its effects on marine life. In this report, the duration of the SEL accumulation is defined as integrated over a 24-hour period. The acoustic metrics in this report reflect the ANSI and ISO standards for acoustic terminology, ANSI S1.1 (S1.1-2013) and ISO 18405:2017 (2017).

The following thresholds and guidelines for this study were chosen because they represent the best available science:

1. Marine mammals:
    a. 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 for non–impulsive and impulsive sources.
    b. Marine mammal behavioural thresholds based on the current interim U.S. National Oceanic and Atmospheric Administration (NOAA) (2019) unweighted criterion for marine mammals of 120 dB re 1 µPa (SPL; L_p) and 160 dB re 1 µPa (SPL; L_p) for non–impulsive and impulsive sound sources.
2. Fish, fish eggs, and larvae:
    a. Sound exposure guidelines for fish, fish eggs, and larvae (Popper et al. 2014).
3. Sea turtles:
    a. Frequency–weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of PTS and TTS in turtles for non–impulsive and impulsive sound sources.
    b. Sea turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_p) for impulsive noise, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000).
4. Invertebrates:
    a. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration (ms^{-2}) at the seafloor to help assess effects of noise on crustaceans through comparing to results in Day et al. (2016a), Day et al. (2019), Day et al. (2016b), Day et al. (2017) and Payne et al. (2008).

Section 2.1, along with Appendix A.3 and A.4, expand on the thresholds, guidelines, and sound levels for marine mammals.

2.1. Marine Mammals

Cetaceans represent a potentially sensitive receptor group of marine mammals and were the focus of this assessment. The criteria applied in this study to assess possible effects of non-impulsive noise sources on marine mammals are summarised in Table 11, with impulsive noise criteria summarised in Table 12.

2.1.1. Injury and Hearing Sensitivity Changes

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 assist in assessing the potential for effect on marine mammals, this report applies the criteria recommended by Southall et al. (2019), considering both PTS and TTS (see Table 11). Appendix A.3 provides more information about the Southall et al. (2019) criteria, with frequency weighting explained in detail in Appendix A.4.

2.1.2. Behavioural Response

The NMFS noise criterion was selected for this assessment because it represents the most commonly applied behavioural response criterion by regulators. Whilst the newly published Southall et al. (2021) provides recommendations and discusses the nuances of assessing behavioural response, the authors of the study do not present new numerical thresholds for onset of behavioural responses for marine mammals, so the previously established guidelines from the US National Oceanic and Atmospheric Administration (NOAA) (2019) have been used. Accordingly, behavioural responses were assumed to occur in areas ensonified above an unweighted SPL of 120 dB re 1 µPa for continuous noise sources (Table 11), and 160 dB re 1 µPa for impulsive noise sources (Table 12) (NOAA 2019). Appendix A.3 provides more information about the development of this criteria.

Table 11. Criteria for effects of non-impulsive noise exposure, including vessel noise, for 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 (Lp; dB re 1 µPa)	Weighted SEL24h (LE,24h; dB re 1 µPa2·s)	Weighted SEL24h (LE,24h; dB re 1 µPa2·s)
Low-frequency (LF) cetaceans	120	199	179
High-frequency (HF) cetaceans		198	178
Very High-frequency (VHF) 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 $\mu Pa^2 \cdot s$.

Table 12. Criteria for effects of impulsive noise exposure for marine mammals: Unweighted sound pressure level (SPL), 24 h sound exposure level (SEL_{24h}), and peak (PK) thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS onset thresholds [a] (received level)		TTS onset thresholds [a] (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 (LF) cetaceans	160	183	219	168	213
High-frequency (HF) cetaceans		185	230	170	224
Very high-frequency (VHF) cetaceans		155	202	140	196
Otariid seals		183	232	168	226

[a] 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.

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 Section 2.2.1 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. The criteria for fish, fish eggs, fish larvae and sea turtles are presented below.

2.2.1. Fish, Eggs, and Larvae

Table 13 lists the relevant effects thresholds from Popper et al. (2014) for non-impulsive 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.

Table 13. Criteria for non-impulsive (vessel and drilling) noise exposure for fish and sea turtles, 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).

Impulsive noise from airguns (i.e., from VSP) was assessed in this study based on the relevant effects thresholds from Popper et al. (2014) listed in Table 14. 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 VSP operations have been applied over the total number of impulses per day.

Table 14. Criteria for impulsive 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).

2.2.2. 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) (Table 13). Finneran et al. (2017) presented revised thresholds for turtle injury, considering frequency weighted SEL, which have been applied in this study for vessels (Table 15). 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).

Table 15. Acoustic effects of non-impulsive noise on sea turtles, weighted SEL_{24h}, Finneran et al. (2017).

PTS onset thresholds* (received level)	TTS onset thresholds* (received level)
220	200

[a] L_E, cumulative sound exposure over a 24 h period, with a reference value of 1 µPa^2·s.

McCauley et al. (2000) 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 Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re 1 µPa SPL reported (McCauley et al. 2000) as the level that may result in a behavioural response to marine turtles. The 175 dB re 1 µPa level from McCauley et al. (2000) is recommended as a criterion for behavioural disturbance. These thresholds are shown in Table 16.

Table 16. Acoustic effects of impulsive noise on sea turtles: Unweighted sound pressure level (SPL), 24 h sound exposure level (SEL_{24h}), and peak pressure (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	McCauley et al. (2000)	166	NA	
Behavioural disturbance		175		
PTS onset thresholds [a] (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds [a] (received level)			189	226

[a] 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.

2.3. Invertebrates

Research is ongoing into the relationship between sound and its effects on crustaceans, including the relevant metrics for both effect and impact. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing. Water depth and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves. Information is only available to define levels for assessment for impulsive sources.

At the seafloor interface, crustaceans and bivalves 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 of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds so there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day et al. (2016b), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, we cannot propose authoritative thresholds to inform the impact assessment. However, levels can be determined for pressure metrics presented in literature to assist the assessment.

The pressure and acceleration examples provided in Day et al. (2016a)) indicate that the acceleration and pressure signals occurred simultaneously, which was interpreted as an indication that the waterborne sounds were responsible for the accelerations measured by the geophones. For clarity, it is important to distinguish that the acceleration from waterborne sound energy is not ground roll,

which Day et al. (2016a) correctly define as the sound that propagates along the interface at a speed lower than the shear wave speed of the sediment. However, the report subsequently uses ground roll for all further discussions of particle acceleration. While Day et al. (2016a) discuss that they chose the simplest measure of ground roll, it should have been referred to as “the acceleration from waterborne sound energy”, or ‘waterborne acceleration’ for short.

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no effect, and it was therefore applied in this assessment. Additionally for context related to different levels of potential impairment, the PK-PK sound levels determined for crustaceans in Day et al. (2016b), 209–212 dB re 1 µPa and 213 dB re 1 µPa from Day et al. (2019), are also included.

3. Methods

The modelled sites have been split into five representative Areas to capture the variability of the marine environment across the Development footprint (refer to Figure 1 and the wide regional bathymetry in Appendix B.1.1). Area 1 is furthest from shore and the modelled sites are located in water depths of 1,149 m to 1,292 m. The modelled drilling, IMR and construction activities in Area 1 (Scenarios 1, 2, 6, 7 and 8) lie outside of the pygmy blue whale BIA. The modelled pipelaying activities in Area 1 (Scenarios 3, 4 and 5) lie within the pygmy blue whale BIA.

All activities in Areas 2 to 4 lie within the pygmy blue whale BIA. The water depths of modelled sites in Area 2 range from 1208 m to 1328 m. Area 3 is located over the foot of the continental slope; the water depths of modelled sites in Area 3 range from 918 m to 974 m. Area 4 considers modelled sites directly above the continental shelf, in 400 m of water. The water depth of the modelled sites for Area 4 was chosen based on a sensitivity analysis of seven slope locations of varying water depth; the chosen location resulted in the largest ranges to considered isopleth criteria.

Finally, Area 5 represents vessel activities on the continental shelf, in water depths of 141m to 145 m. Area 5 activities are located outside of the pygmy blue whale BIA.

To allow for operational flexibility, the sound speed profile implemented within the modelling was selected through a sensitivity analysis considering all months of the year. The month of August was found to be the most favourable for sound propagation, resulting in the largest ranges to considered isopleths criteria. As such, August was selected as the conservative choice for modelling. Additional detail can be found in Appendix B.1.2.

Geoacoustics information for Areas 1, 2, 3 and 4 were taken from Duncan and Erbe (2019) as provided by the client. For Area 1, the seabed geoacoustic model was characterised by 5 m of silt overlaying a 200 m thick package of silt and sand sediments underlain by a sedimentary rock half space. Areas 2 and 3 were modelled with a geoacoustic profile characterised by ~300m thick package of silt and sand sediments underlain by a sedimentary rock half space. Area 4 utilised a ‘Slope’ geoacoustic profile characterised by 50 m of silt overlaying a 150 m thick package of silt and sand sediments underlain by a sedimentary rock half space. Area 5, on the continental shelf, was adjacent to drill core site obtained during IODP Cruise 356 (Gallagher et al. 2017). The geoacoustic profile from the sampled core was therefore utilised during modelling of sites in Area 5; a 450 m thick package of unconsolidated sediments underlain by a sedimentary rock half space. Further details on the associated geoacoustic properties used in this modelling study are provided in Appendix B.1.3.

The following sections provide a high-level description of the inputs used for this underwater noise modelling study. The sections are divided into subsections detailing the source inputs for the different vessels (Section 3.1) and VSP activities (Section 3.2), with Sections 3.3 and 3.4 providing details on the applied modelling techniques and model configuration information. Section 3.5 provides details on the animal movement modelling methodology.

3.1. Vessel Noise Sources

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of noise 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 (e.g., conventional propellers vs. Voith Schneider propulsion), and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband noise emissions 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 (Spence et al. 2007).

For the modelled vessels, Figures 9 to 11 present summary plots of considered source spectra for comparison purposes; additional detail on the sources is provided in Sections 3.1.1 to 3.1.4.

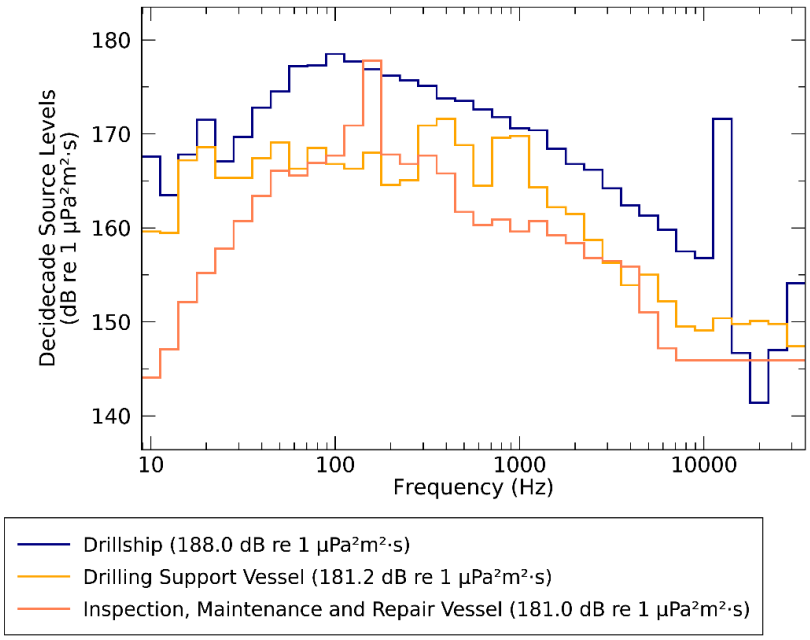


Figure 9. Energy source level (ESL) spectra (in decidecade frequency-band) for the three sound sources associated with Scenarios 1, 2, 6, 9, 10, 14, 17, 18, 22, 28, 29, 30, and 34: the drillship; the drillship support vessel (drillship OSV); and Inspection, Maintenance and Repair (IMR) vessel. All vessels are modelled under dynamic positioning.

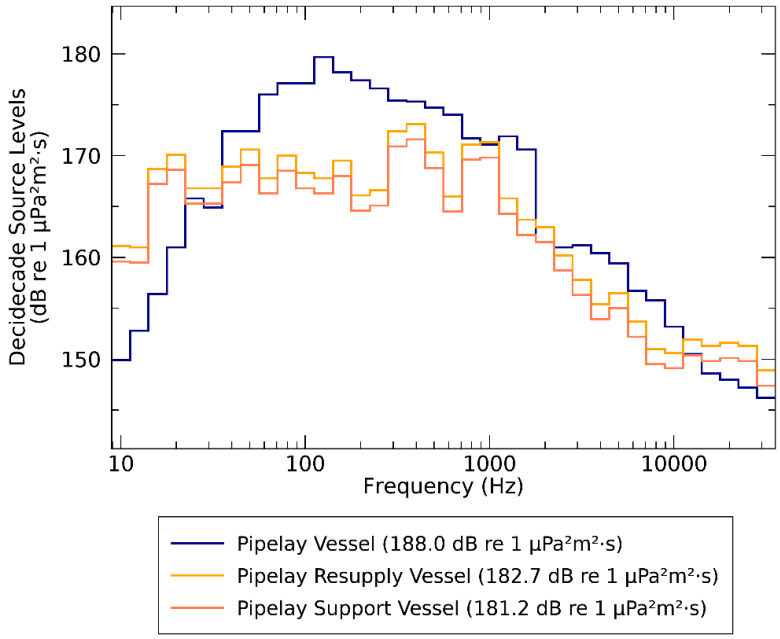


Figure 10. Energy source level (ESL) spectra (in decidecade frequency-band) for the three sound sources associated with Scenarios 3-5, 11-13, 19-21, 25-27, and 31-33: the pipelay vessel; the pipelay resupply vessel (pipelay OSV 1); and the pipelay support vessel (pipelay OSV 2). All vessels are modelled under dynamic positioning.

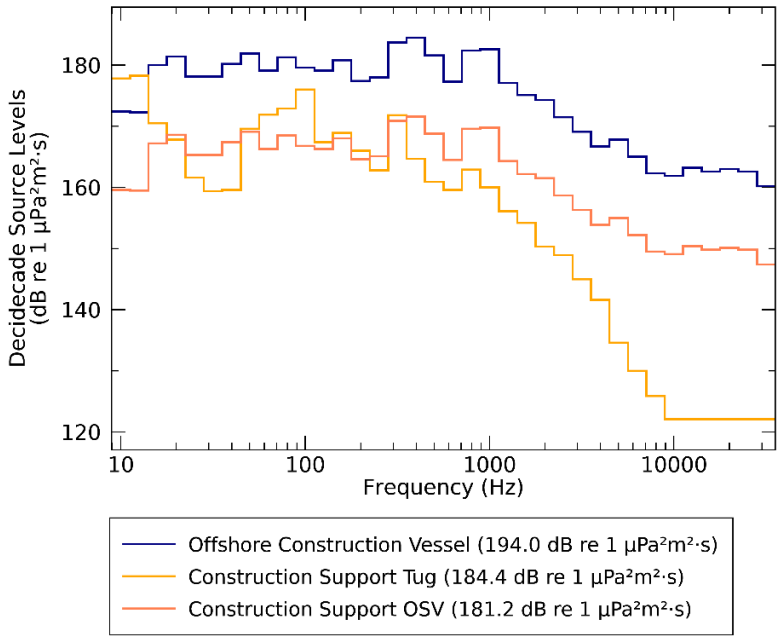


Figure 11. Energy source level (ESL) spectra (in decidecade frequency-band) for the sound sources associated with Scenarios 7, 8, 15, 16, 23, 24, 35, and 36 the offshore construction vessel (OCV), OCV support tug, and OCV support vessels (OSV), of which there are two. All vessels are modelled under dynamic positioning.

Each vessel considered here was modelled as a single source, with source levels detailed in the legends of Figures 9 to 11. Apart from the drillship and pipelay vessels, which have been modelled with source depths equal to their drafts (per the location of their thrusters), all source depths were based on the approximate location of noise emissions using a depth of 0.7 × ship draft, which aligns with current international standards, ISO 17208-1 (2016).

The following sections (Sections 3.1.1 to 3.1.4) detail the example vessels identified by Chevron as suitable representative vessels for the type/class of vessels that would be required to undertake the operations.

3.1.1. Drilling

3.1.1.1. Drillship

The vessel nominated as a representative drillship for this modelling study is the *Dhirubhai Deepwater KG2* (Figure 12). This vessel has an overall length, beam and draft of 228 m, 42 m, and 11.9 m, respectively. The thrusters of this vessel are located at the extent of its draft, and this vessel has been modelled with a source depth of 11.9 m.



Figure 12. *Dhirubhai Deepwater KG2*, the representative drillship.

As there are currently no publicly available underwater sound measurements of the *Dhirubhai Deepwater KG2*, measurements obtained for a similar vessel, the *Stena IceMAX*, have been used as a proxy. The *Stena IceMAX* is an identical size to the *Dhirubhai Deepwater KG2*. Underwater noise measurements of the *Stena IceMAX* were obtained from MacDonnell (2017). The broadband (10 Hz to 31 kHz) source level of this vessel has been modelled as 188.0 dB re 1 $\mu Pa^2m^2 \cdot s$, with the spectral shape for this vessel also available from MacDonnell (2017) (Figure 9).

3.1.1.2. Drilling Offshore Support Vessel (OSV)

In some drilling scenarios, the drillship has been modelled with an offshore support vessel (OSV) alongside under DP for 8 hours. We have considered the *MMA Leeuwin* as a generic OSV in this capacity. The average broadband (10 Hz to 31 kHz) source level of the *MMA Leeuwin* undertaking DP exercises has been measured as 181.2 dB re 1 $\mu Pa^2m^2 \cdot s$ (Esso and ExxonMobil 2021). A publicly available spectral shape of another generic OSV, the *Siem Sapphire* (McPherson et al. 2021), has been scaled to the *MMA Leeuwin* broadband source level (Figure 9). The source depth of the *MMA Leeuwin* has been modelled as 70% of the vessel draft (draft of 6.5 m, resulting in a source depth of 4.6 m), per ISO 17208-1 (2016).

3.1.2. Inspection, Maintenance and Repair (IMR)

The multi-purpose vessel, *Skandi Hercules*, has been nominated as a representative IMR vessel for this Development. This vessel has a length of 110 m, beam of 24 m, and draft of 7.8 m (source depth of 5.5 m). This vessel has been modelled using sound measurements from the similarly sized construction vessel, *Deep Orient*, which has a publicly available broadband source level and source spectra (Quijano and McPherson 2021). The broadband (10 Hz to 31 kHz) source level has been modelled as 181.0 dB re 1 $\mu Pa^2m^2 \cdot s$ (Figure 9).

3.1.3. Pipelay

3.1.3.1. Pipelay Vessel

The *Allseas Solitaire* (Figure 13) has been considered as a representative pipelay vessel in each of the five modelling Areas. This vessel has a length of 368 m (including stinger), beam of 41 m, and draft of 14.5 m (source depth of 14.5 m as thrusters are located at extent of draft).



Figure 13. *Allseas Solitaire*, the representative pipelay vessel

Underwater noise levels related to the *Allseas Solitaire* are publicly available from Tougaard and Griffiths (2020).

The broadband (10 Hz to 31 kHz) source level of the *Allseas Solitaire* is reported in Table 3.1 by Tougaard and Griffiths (2020) for several measurement occasions. This study considers a broadband source level of 188.0 dB re 1 $\mu Pa^2m^2 \cdot s$, which is the median level of those supplied in the referenced table. The source spectra for the *Allseas Solitaire* was also obtained from Tougaard and Griffiths (2020) (Figure 10).

3.1.3.2. Pipelay Resupply Offshore Support Vessel (OSV)

A pipelay resupply OSV has been modelled alongside the pipelay vessel in Scenarios 4, 5, 12, 13, 20, 21, 26, 27, 32 and 33. The resupply vessel has been represented by the *Allseas Alegria*, an OSV, which has an overall length of 83 m, beam of 19 m and draft of 6.3 m (source depth of 4.4m).

As there are no publicly available measurements of the source level of the *Allseas Alegria*, the source level of the OSV *MMA Leeuwin* (Esso and ExxonMobil 2021) was scaled up to correspond with a suitable source level for the *Allseas Alegria*. The overall power of the *MMA Leeuwin* is 4,960 kw, while the *Allseas Alegria* has an overall power of 7000 kW, hence the need to scale up the publicly available source level. The broadband (10 Hz to 31 kHz) source level of the *Allseas Alegria* has been modelled as 182.7 dB re 1 $\mu Pa^2m^2 \cdot s$. As per the drilling OSV (Section 3.1.1.2), the spectra for this vessel has been represented *via* scaling the spectra of the *Siem Sapphire* (McPherson et al. 2021) (Figure 10).

3.1.3.3. Pipelay Offshore Support Vessel (OSV)

In addition to the pipelay resupply OSV, a second concurrent support OSV has been considered alongside the pipelay vessel in Scenarios 5, 13, 21, 27 and 33. This vessel was specified as a generic OSV and is identical to the drilling OSV specified in Section 3.1.1.2.

3.1.4. Construction

3.1.4.1. Offshore Construction Vessel (OCV)

An offshore construction vessel (OCV) is considered in Scenarios 7, 8, 15, 16, 23, 24, 35 and 36. A representative vessel of this vessel class has been considered as the *Skandi Africa.* This vessel has an overall length of 161 m, a beam of 32 m, and a draft of 9.3 m (resulting in a source depth of 6.5 m) (Figure 14). In this modelling study, the *Skandi Africa* has been represented by the OSV *Siem Sapphire*, which is a similarly sized (91m long, 22m beam, 8.0m draft) vessel, with similar installed power (21,100 kW for the *Skandi Africa*, 22,840 kW for the *Siem Sapphire*). The publicly available source level and spectra of the *Siem Sapphire* (McPherson et al. 2021) have been scaled down slightly (based on installed power) to represent the *Skandi Africa*, resulting in a broadband (10 Hz to 31 kHz) source level of 194.0 dB re 1 $\mu Pa^2m^2 \cdot s$ (Figure 11).

3.1.4.2. Construction Support Tug

In Scenarios 8, 16, 24 and 36, the OCV has been considered with support from three other vessels in close proximity. The first of these is a support tug, which has been represented by the *Mermaid Sound*. The *Mermaid Sound* has a length of 50 m, a beam of 13.4 m, and a draft of 4.9 m (resulting in a source depth of 3.4 m). As there are no publicly available measurements of the sound produced by the *Mermaid Sound*, this vessel has been directly represented by another Tug, the *Katun*. The source level and spectra of the *Katun* has been measured by JASCO Applied Sciences (Hannay et al. 2004). The broadband (10 Hz to 31 kHz) source level has been modelled as 184.4 dB re 1 $\mu Pa^2m^2 \cdot s$ (Figure 11).

3.1.4.3. Construction Offshore Support Vessels (OSV 1 and OSV 2)

In addition to the Support Tug, Scenarios 8, 16, 24 and 36 also include two construction support OSVs modelled alongside the OCV. The two OSVs have been represented by the *MMA Chieftain* and the *MMA Coral*. Both OSVs are 70 m long, with drafts of 6.1 m (source depths modelled as 4.3 m). The beam of the *MMA Chieftain* is 16 m, and the beam of the *MMA Coral* is 17 m.

For modelling purposes, both OSVs have been represented with the source level associated with the *MMA Leeuwin*, a similarly sized OSV, which was measured while undertaking comparable activities (Esso and ExxonMobil 2021). The broadband (10 Hz to 31 kHz) source level of each OSV has therefore been modelled as 181.2 dB re 1 $\mu Pa^2m^2 \cdot s$. As per the other OSVs considered in this modelling study, the spectra for these two vessels has been represented *via* scaling the spectra of the *Siem Sapphire* (McPherson et al. 2021) (Figure 11).



Figure 14. *Skandi Africa*, the representative Offshore Construction Vessel.

3.2. Vertical Seismic Profiling Acoustic Source

The pressure signature of the individual airguns and the composite decidecade band point-source equivalent directional levels (i.e., source levels) of the 750 in^3 Vertical Seismic Profiling (VSP) source suspended at a depth of 5 m were modelled with JASCO's Airgun Array Source Model (AASM; Appendix C). A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250 and 300 shots over 24 hours to realistically represent a range of potential operations.

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; and
- Interactions between different airguns in the array.

3.3. Geometry and Modelled Regions

JASCO's Marine Operations Noise Model (MONM-BELLHOP; see Appendix B.2.2) was used to predict the acoustic field at frequencies of 10 Hz to 25 kHz for all vessels. To supplement the MONM results, high-frequency results for propagation loss were modelled using Bellhop (Porter and Liu 1994) for frequencies from 1.26 to 25 kHz . The MONM and BELLHOP results were combined to produce results for the full frequency range of interest. The sound field modelling calculated propagation losses up to 100 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 3250 m, with step sizes that increased with depth.

To produce the maps of received sound level isopleths, and to calculate distances to specified sound level thresholds, the maximum-over-depth level was calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth levels were then resampled (by linear triangulation) to produce a regular Cartesian grid. The contours and threshold ranges were calculated from these grids of the modelled acoustic fields.

3.4. Accumulated SEL

In this study, the sound sources were considered to be continuously operating with new sound energy constantly being introduced to the environment. The reported source levels are usually in terms of sound pressure levels (SPL), representing the average instantaneous acoustic level of a considered source. The evaluation of the cumulative sound field (i.e., in terms of SEL_{24h}) depends on the number of seconds of operation during the accumulation period.

For all stationary sources, the SPL modelling results were converted to SEL by the duration of the measurement, which is appropriate for a non-impulsive noise source. As SEL was assessed over 24 h and for a stationary vessel over a day, the conversion from SPL was obtained by increasing the levels by $10*\log_{10}(T)$, where T is 86400 (the number of seconds in 24 h). For scenarios where a vessel was transiting along a track a similar adjustment to the SPL was applied, however the time factor was determined based on the step size along the track and the vessel's speed, see Appendix B.4 for details.

3.5. Animal Movement and Exposure Modelling

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats to sound arising from the vessel activity scenarios (Tables 7 and 9). JASMINE integrates the predicted sound field with biologically meaningful movement rules for each marine mammal species (pygmy blue whales for the current analysis) that results in an exposure history for each animat in the model. An overview of the exposure modelling process using JASMINE is shown in Figure 15.

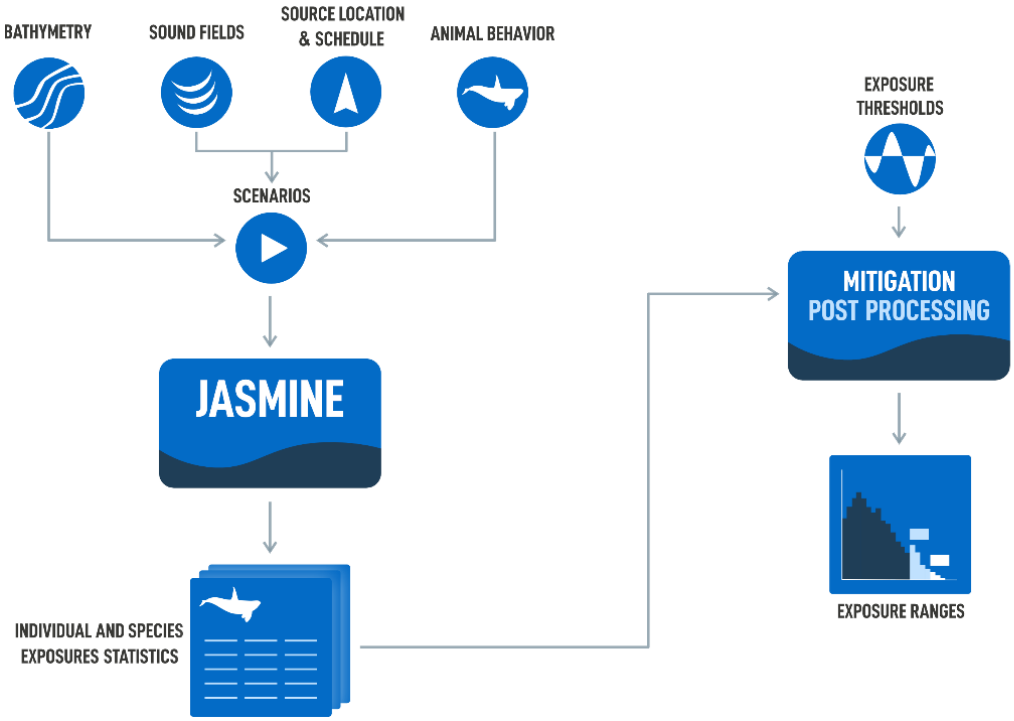


Figure 15. Exposure modelling process overview.

In JASMINE, the sound received by the animats is determined by the proposed vessel activities. As illustrated in Figure 16, animats are programmed to behave like the marine animals that may be present in an area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species. For cumulative metrics, an individual animat's sound exposure levels are summed over a 24 h duration to determine its total received energy, and then compared to the relevant threshold criteria. For single-exposure metrics, the maximum exposure is evaluated against threshold criteria for each 24 h period. For additional information on JASMINE, see Appendix D.

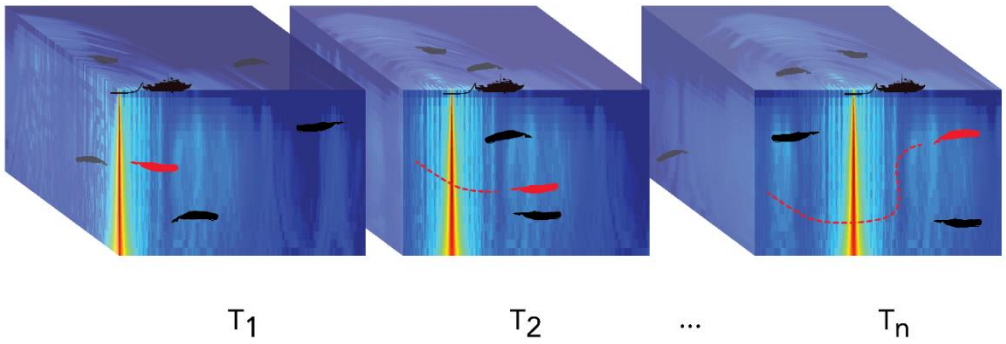


Figure 16. Depiction of animats in a moving sound field. Example animat (red) shown moving with each time step (T_n). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

The exposure criteria for non-impulsive sounds (described in Section 2) were used to determine the number of animats that exceeded thresholds. To generate statistically reliable probability density functions, model simulations were run with animat sampling densities of 4 animats/km^2. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA. To evaluate PTS, TTS and behavioural response, exposure results were obtained using detailed behavioural information for migrating pygmy blue whales (described in Section 3.5.2). The simulation was run for a representative period of 24 h to coincide with the acoustic modelling effort. A subset of acoustic modelling scenarios was considered for animal movement modelling. Animat scenarios included acoustic modelling Scenarios 8, 19, 32, 33 and 34 (see Tables 7 and 9). Due to their locations within or close to the migratory pygmy blue whale BIA, all considered scenarios were run for migrating pygmy blue whales restricted to the BIA as well as unrestricted.

Despite the Development's proximity to the humpback whale BIA, animal movement modelling was not considered for humpback whales as the acoustic footprints of the corresponding vessel activities did not reach the BIA.

Figure 17 shows an example animat track (generated for information purposes only and not related to the results presented in this report) with associated received levels from a stationary point source. The top panel displays the animat track relative to the point source, and the bottom panel displays the accumulation of SEL_{24h} for TTS and PTS criteria. At approximately 50 seconds, the animat is exposed so that the TTS threshold is exceeded, and at approximately 700 seconds the animat is exposed so that the PTS threshold is exceeded.

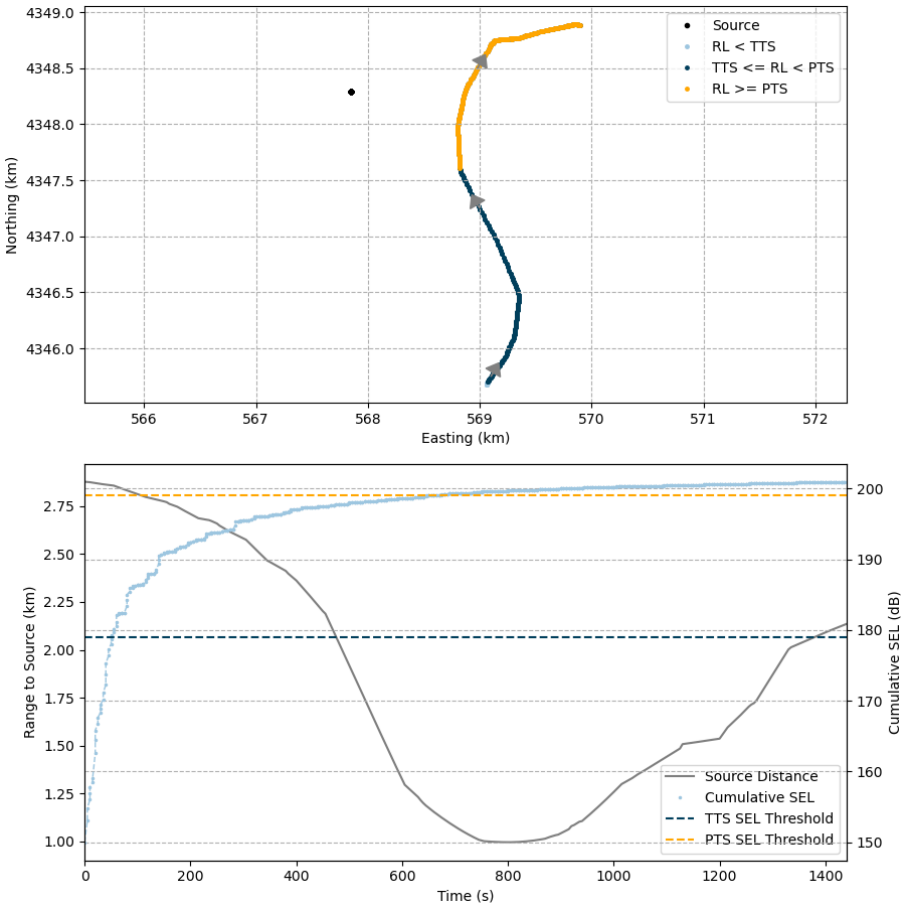


Figure 17. Animat track from an example simulation showing northward movement over a 1400 s duration. The upper panel shows a plan view of both a stationary point source and a foraging animat. Animat steps are coloured to indicate whether the accumulated sound energy at that point has exceeded either TTS or PTS threshold criteria. The lower panel shows horizontal distance in kilometres to the source (grey line; left y-axis) and cumulative 24-h SEL ($L_{E,24h}$, dB re 1 µPa²·s; right y-axis) as a function of time. Note that this example does not use data from the current study.

3.5.1. Exposure-based Radial Distance Estimation

The results from the animal movement and exposure modelling provided a way to estimate radial distances to effect thresholds. The distance to the closest point of approach (CPA) for each of the animats was recorded. The $ER_{95\%}$ (95% Exposure Range) is the horizontal distance that includes 95% of the animat CPAs that exceeded a given effect threshold (Figure 18). Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which animats sample the sound field over time, both vertically and horizontally. The sound field varies as a function of range, depth, and azimuth based on a variety of factors such as bathymetry, sound speed profile, and geoacoustic parameters. The way the animats sample the sound field depends upon species-typical swimming and diving characteristics (e.g., swim speed, dive depth, surface intervals, and reversals). Furthermore, even within a particular species definition, these characteristics vary with behavioral state (e.g., feeding, migrating). As this results in some animats not exceeding threshold criteria even within the $ER_{95\%}$, the probability that an animat within that distance was exposed above threshold within the $ER_{95\%}$ was also computed (P_{exp}) to provide additional context.

Acoustic ranges are reported for both $R_{95\%}$ and R_{max}, however, exposure ranges are reported for $ER_{95\%}$ only since, statistically, ER_{max} is not defined. JASMINE is a Monte Carlo simulation, and the results are probabilistic in nature. This is in contrast with acoustic modelling, where there is a specific maximum isopleth range for a given source/environment setup.

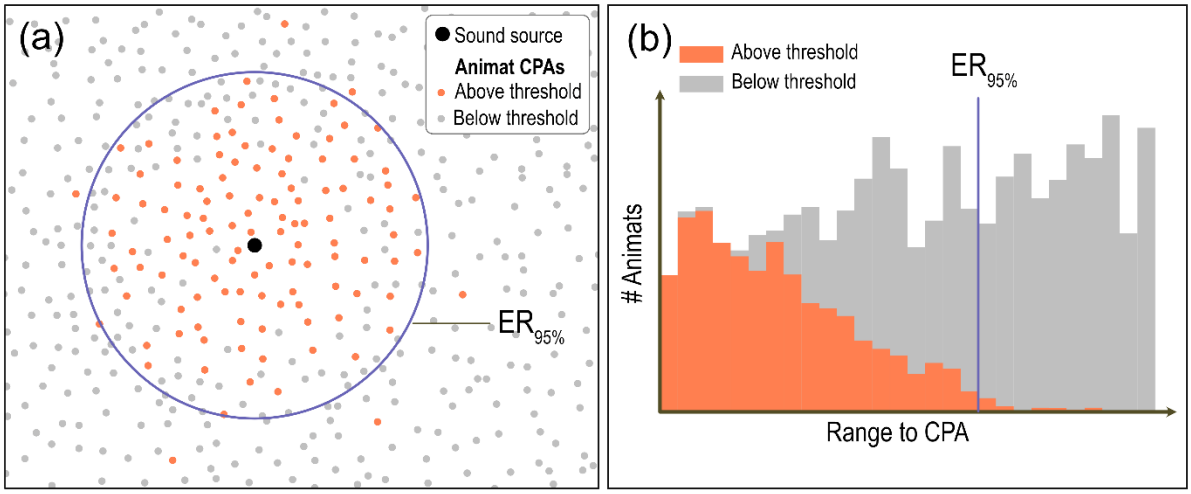


Figure 18. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of distances to animat CPAs. The 95% exposure range ($ER_{95\%}$) is indicated in both panels.

3.5.2. Pygmy Blue Whale Behaviour

Animal movement modelling scenarios are located within or adjacent to the migration BIA for pygmy blue whales, therefore migration was the only behavioural profile considered. The north-bound migration was selected for modelling because previous work (McPherson 2022) showed that this behavioural profile resulted in more conservative PTS and TTS exposure range estimates. Detailed information on pygmy blue whales was derived from a range of sources that used multi-sensor tags to record fine-scale dive and movement behaviour (Owen et al. 2016, AIMS unpublished data 2021), as well as satellite tags to record travel speed (Thums and Ferreira 2021).

Multi-sensor tags typically record the depth of an animal along with various movement parameters such as swim speed and their body's orientation. Owen et al. (2016) equipped a sub-adult pygmy blue whale with a multi-sensor tag off Western Australia. They identified dives for the tagged animal as migratory, feeding, or exploratory (i.e., no lunges recorded which would indicate feeding). Pygmy blue whales in the simulation area are presumed to be migrating, and so feeding was not included in the model. Exploratory dives were considered to be part of migratory behaviour, and so the two dive types were modelled together such that the animats were migrating 95% of the time and engaged in exploratory dives 5% of the time (Owen et al. 2016).

Using data from Owen et al. (2016), the approximate length of a bout of exploratory dives could be determined, as well as the average (± SD) depth of this dive type. The speed of travel for both dive behaviours was calculated from data presented in Thums and Ferreira (2021), who analysed data from satellite tags deployed on pygmy blue whales in the Northwest Marine Region. All remaining parameters were calculated from two multi-sensor tags deployed on pygmy blue whales off Western Australia (AIMS unpublished data 2021).

The behaviour of migrating pygmy blue whales was modelled to reflect animats transiting through the modelling area on a 45° track for the northward migration. This represents the animals migrating along the west coast of Australia to their breeding grounds in Indonesia (Double et al. 2014, Thums and Ferreira 2021).

4. Results

4.1. Vessel Activities – Acoustic Modelling Tabulated Results

Tables 17 to 21 present the maximum and 95% distances (defined in Appendix B.3) to SPL levels for each of the five Areas.

To consider the aggregate contribution of noise emissions from the four combined scenarios, ensonified areas were examined for Scenarios 37 – 40, rather than maximum radii. Tables 22 and 23 present the ensonified areas for the four combined scenarios and compare the total ensonified area to the summed areas of the corresponding individual scenarios. The changes in ensonified areas are presented as km^2 and as percentage change.

Tables 24 to 28 present the maximum distances to frequency-weighted SEL_{24h} thresholds, as well as total ensonified areas. Tables 29 and 30 present the changes in ensonified areas for the combined scenarios compared to their corresponding individual scenarios.

For the results below, the distances to isopleths/thresholds were reported from either the centroid of several sources, from the most dominant single source, or from a track. When an isopleth completely envelopes multiple sources the centroid was used, and when several closed isopleths exist the most dominant source was used. Maps are provided in Section 4.2 to assist with contextualising tabulated distances.

Table 17. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 1. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 1 – Drillship		Scenario 2 – Drillship with OSV		Scenario 3 – Pipelay vessel		Scenario 4 – Pipelay vessel with resupply vessel		Scenario 5 – Pipelay vessel with resupply vessel and support vessel		Scenario 6 – IMR vessel		Scenario 7 – OCV		Scenario 8 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.04	0.04	0.05	0.05	–	–	–	–	0.04	0.04
160	0.04	0.04	0.06	0.06	0.04	0.04	0.05	0.04	0.05	0.05	–	–	0.06	0.06	0.07	0.07
158[b]	0.05	0.05	0.08	0.08	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.11	0.11	0.15	0.14	0.12	0.12	0.13	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.13	1.29	1.23	1.35	1.30	0.53	0.51	2.51	2.43	2.66	2.57
120[c]	5.62	5.38	5.87	5.61	6.30	6.00	6.56	6.24	6.72	6.39	1.99	1.91	15.5	13.7	15.7	13.9
110	20.6	17.4	28.7	17.9	22.1	17.8	28.6	18.8	29.6	20.3	5.80	5.60	36.6	31.1	42.6	31.6

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 18. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 2. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 9 – Drillship		Scenario 10 – Drillship with OSV		Scenario 11 – Pipelay vessel		Scenario 12 – Pipelay vessel with resupply vessel		Scenario 13 – Pipelay vessel with resupply vessel and support vessel		Scenario 14 – IMR vessel		Scenario 15 – OCV		Scenario 16 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	0.03	0.03	–	–	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.03	0.03	0.03	0.03	–	–	–	–	0.04	0.04
160	0.04	0.04	0.07	0.07	0.03	0.03	0.05	0.04	0.05	0.05	–	–	0.06	0.06	0.07	0.07
158[b]	0.04	0.04	0.07	0.07	0.05	0.05	0.06	0.06	0.07	0.06	0.02	0.02	0.08	0.08	0.09	0.09
150	0.11	0.11	0.15	0.14	0.12	0.11	0.14	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.12	1.29	1.23	1.34	1.30	0.53	0.52	2.06	1.98	2.60	2.49
120[c]	5.60	5.34	5.85	5.56	6.42	6.06	6.70	6.31	6.88	6.46	1.74	1.68	15.1	11.0	15.4	11.5
110	18.7	17.1	19.6	17.7	26.2	19.5	33.7	21.9	34.9	23.9	7.50	6.60	35.9	31.2	36.6	31.7

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 19. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 3. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 17 – Drillship		Scenario 18 – Drillship with OSV		Scenario 19 – Pipelay vessel		Scenario 20 – Pipelay vessel with resupply vessel		Scenario 21 – Pipelay vessel with resupply vessel and support vessel		Scenario 22 – IMR vessel		Scenario 23 – OCV		Scenario 24 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	–	–	0.04	0.04	–	–	–	–	0.02	0.02
170[a]	–	–	–	–	–	–	0.03	0.03	0.04	0.04	–	–	–	–	0.04	0.04
160	0.04	0.04	0.06	0.06	0.04	0.04	0.05	0.05	0.06	0.05	–	–	0.06	0.06	0.07	0.06
158[b]	0.05	0.05	0.08	0.08	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.12	0.11	0.15	0.14	0.12	0.12	0.14	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.13	1.28	1.23	1.36	1.30	0.53	0.52	3.05	2.62	3.39	3.16
120[c]	5.30	4.94	12.1	5.23	5.78	5.41	12.8	5.78	13.0	6.12	2.64	2.46	14.0	12.8	14.0	12.9
110	26.9	24.5	27.1	24.9	28.3	26.1	28.5	26.4	28.6	26.5	8.38	7.53	41.5	36.4	41.7	37.8

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 20. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 4. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 25 – Pipelay vessel		Scenario 26 – Pipelay vessel with resupply vessel		Scenario 27 – Pipelay vessel with resupply vessel and support vessel		Scenario 28 – IMR vessel	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	0.03	0.03	–	–
170[a]	–	–	0.03	0.03	0.05	0.05	–	–
160	0.04	0.04	0.05	0.04	0.07	0.07	–	–
158[b]	0.05	0.05	0.06	0.06	0.09	0.08	0.02	0.02
150	0.12	0.12	0.14	0.14	0.20	0.19	0.05	0.05
140	0.39	0.38	0.44	0.41	0.64	0.61	0.17	0.17
130	1.94	1.80	2.10	1.95	2.92	2.69	0.55	0.52
120[c]	7.87	7.19	9.72	7.37	18.3	16.6	2.24	2.04
110	39.5	29.7	40.2	32.3	58.0	47.0	9.85	9.24

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 21. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 5. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 29 – Drillship		Scenario 30 – Drillship with OSV		Scenario 31 – Pipelay vessel		Scenario 32 – Pipelay vessel with resupply vessel		Scenario 33 – Pipelay vessel with resupply vessel and support vessel		Scenario 34 – IMR vessel		Scenario 35 – OCV		Scenario 36 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	0.03	0.03	0.03	0.03	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.04	0.04	0.05	0.05	–	–	–	–	0.03	0.03
160	0.04	0.04	0.07	0.07	0.04	0.04	0.05	0.05	0.05	0.05	–	–	0.07	0.06	0.07	0.07
158[b]	0.05	0.05	0.07	0.07	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.12	0.11	0.15	0.14	0.12	0.12	0.15	0.14	0.15	0.14	0.06	0.05	0.21	0.20	0.23	0.22
140	0.64	0.61	0.69	0.66	0.67	0.64	0.73	0.69	0.75	0.72	0.18	0.17	1.14	1.07	1.23	1.15
130	2.96	2.64	3.26	2.75	3.18	2.75	3.33	3.09	3.55	3.24	0.91	0.83	4.85	4.48	5.18	4.73
120[c]	10.0	8.63	10.4	9.10	12.2	10.1	12.8	10.5	12.9	10.9	3.76	3.43	17.0	13.8	17.3	14.5
110	32.4	25.3	32.7	27.2	35.8	28.3	36.6	29.9	38.4	31.0	13.2	9.94	56.8	46.1	69.1	49.8

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 22. SPL: Total ensonified area (km²) above sound pressure levels (SPLs) for combined scenarios 37 and 38. The ensonified areas for the corresponding individual scenarios are provided, as well as the percentage difference in area. Scenario descriptions are given in Table 9.

SPL (L_p; dB re 1 µPa)	Scenario 37 – Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV				Scenario 38 – Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV			
	Ensonified area, combined scenario (km²)	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Ensonified area, combined scenario (km²)*	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
180	0.001	0.001	/	*	0.003	0.003	/	*
170[a]	0.01	0.01	/	*	0.01	0.01	/	*
160	0.01	0.01	/	*	0.02	0.02	/	*
158[b]	0.02	0.02	/	*	0.04	0.04	/	*
150	0.11	0.11	/	*	0.22	0.22	/	*
140	1.08	1.08	/	*	1.95	1.95	-0.002	- 0.09
130	9.97	9.97	- 0.006	- 0.06	27.1	27.1	0.03	+ 0.11
120[c]	218.4	217.6	+ 0.80	+ 0.37	668.3	647.5	20.8	+ 3.21
110	2387.8	2218.8	+ 168.9	+ 7.62	4563.5	4370.4	193.1	+ 4.42

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).
/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km²).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²).

Table 23. SPL: Total ensonified area (km²) above sound pressure levels (SPLs) for combined scenarios 39 and 40. The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

SPL (L_p; dB re 1 µPa)	Scenario 39 - Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels				Scenario 40 - Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels			
	Ensonified area, combined scenario (km²)	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Ensonified area, combined scenario (km²)*	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
180	0.002	0.002	/	*	0.002	0.002	/	*
170[a]	0.01	0.01	/	*	0.01	0.01	/	*
160	0.01	0.01	/	*	0.01	0.01	/	*
158[b]	0.02	0.02	/	*	0.02	0.02	/	*
150	0.12	0.12	/	*	0.12	0.12	/	*
140	2.20	2.20	/	*	3.15	3.14	+ 0.01	+ 0.33
130	38.6	38.6	+ 0.05	+ 0.13	60.4	58.6	+ 1.76	+ 3.01
120[c]	466.3	448.2	+ 18.1	+ 4.03	707.1	626.2	+ 80.9	+ 12.9
110	4377.7	3800.8	+ 576.9	+ 15.2	4847.5	4723.1	+ 124.4	+ 2.63

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).
/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km²).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²).

Table 24. Area 1, *Weighted SEL_{24h}:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 1 - Drillship		Scenario 2 – Drillship with OSV		Scenario 3 – Pipelay vessel		Scenario 4 – Pipelay vessel with resupply vessel		Scenario 5 – Pipelay vessel with resupply vessel and support vessel		Scenario 6 – IMR vessel		Scenario 7 – OCV		Scenario 8 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.10	0.02	0.05	0.03	0.10	0.05	0.12	0.06	0.04	0.01	0.18	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.002	0.04	0.002	–	/	0.04	0.002	0.04	0.002	–	/	0.02	0.002	0.15	0.003
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.01	0.06	0.03	0.11	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	0.02	/	0.02	0.002	–	/	0.05	0.01	0.04	0.01	–	/	0.02	0.00	0.04	0.003
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.88	0.83	2.05	0.84	2.32	0.99	2.97	1.07	3.46	0.36	0.41	1.71	9.03	1.82	10.2
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.06	0.03	0.01	0.06	0.02	0.09	0.04	0.02	0.002	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.27	29.1	3.31	29.3	0.62	1.16	0.76	1.90	1.02	3.09	0.27	0.24	2.46	19.0	2.61	21.3
Sea Turtles	200	0.09	0.02	0.12	0.03	0.06	0.04	0.10	0.05	0.11	0.05	0.05	0.01	0.13	0.06	0.18	0.07

Table 25. Area 2, *Weighted SEL_{24h}:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 9 - Drillship		Scenario 10 – Drillship with OSV		Scenario 11 – Pipelay vessel		Scenario 12 – Pipelay vessel with resupply vessel		Scenario 13 – Pipelay vessel with resupply vessel and support vessel		Scenario 14 – IMR vessel		Scenario 15 – OCV		Scenario 16 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.07	0.02	0.11	0.02	0.06	0.04	0.09	0.05	0.12	0.06	0.04	0.01	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	–	/	0.05	0.001	–	/	–	/	–	/	–	/	–	/	0.04	0.002
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.02	0.01	0.06	0.03	0.11	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	–	/	–	/	–	/	0.04	0.01	0.05	0.01	–	/	–	/	0.04	0.002
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.88	0.84	2.05	0.85	2.33	0.99	2.97	1.08	3.46	0.36	0.41	1.70	8.99	1.81	10.2
High-frequency (HF) cetaceans	178	0.13	0.05	0.17	0.06	0.02	0.01	0.05	0.03	0.09	0.04	–	/	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.27	29.1	3.31	29.3	0.62	1.15	0.76	1.91	1.02	3.09	0.27	0.24	2.46	19.0	2.61	21.3
Sea Turtles	200	0.09	0.02	0.11	0.03	0.07	0.04	0.10	0.05	0.12	0.05	0.05	0.01	0.13	0.05	0.17	0.07

Table 26. Area 3, *Weighted SEL_{24h}:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa^2·s)	Scenario 17 - Drillship		Scenario 18 – Drillship with OSV		Scenario 19 – Pipelay vessel		Scenario 20 – Pipelay vessel with resupply vessel		Scenario 21 – Pipelay vessel with resupply vessel and support vessel		Scenario 22 – IMR vessel		Scenario 23 – OCV		Scenario 24 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.11	0.02	0.05	0.04	0.09	0.05	0.12	0.06	0.04	0.004	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.001	0.04	0.002	–	/	–	/	–	/	–	/	0.01	0.001	0.16	0.004
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.02	0.06	0.03	0.10	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	0.02	0.001	0.02	0.001	0.02	0.01	0.04	0.01	0.04	0.01	0.02	0.001	0.01	0.001	0.14	0.004
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.89	0.84	2.06	0.84	2.34	0.99	3.00	1.08	3.50	0.36	0.41	1.96	10.3	2.10	12.3
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.05	0.03	0.02	0.06	0.03	0.09	0.04	0.02	0.001	0.14	0.06	0.18	0.07
Very High-frequency (VHF) cetaceans	153	3.28	29.1	3.31	29.3	0.62	1.16	0.80	1.93	1.02	3.13	0.27	0.23	2.46	18.9	2.62	21.4
Sea Turtles	200	0.09	0.03	0.12	0.03	0.06	0.04	0.10	0.05	0.12	0.05	0.05	0.01	0.13	0.05	0.18	0.07

Table 27. Area 4, *Weighted SEL_{24h}:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 25 – Pipelay vessel		Scenario 26 – Pipelay vessel with resupply vessel		Scenario 27 – Pipelay vessel with resupply vessel and support vessel		Scenario 28 – IMR vessel	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)
PTS									
Low-Frequency (LF) cetaceans	199	0.05	0.04	0.10	0.05	0.12	0.06	0.04	0.004
High-frequency (HF) cetaceans	198	–	/	0.03	/	0.04	/	–	/
Very High-frequency (VHF) cetaceans	173	0.02	0.01	0.06	0.03	0.10	0.04	0.03	0.004
Sea Turtles	220	–	/	0.05	0.01	0.04	0.01	0.02	0.001
TTS									
Low-Frequency (LF) cetaceans	179	0.88	2.52	1.20	4.08	1.47	6.13	0.37	0.41
High-frequency (HF) cetaceans	178	0.02	0.01	0.05	0.02	0.09	0.04	0.02	0.002
Very High-frequency (VHF) cetaceans	153	0.63	1.19	0.83	2.03	1.06	3.39	0.27	0.24
Sea Turtles	200	0.07	0.04	0.10	0.05	0.12	0.05	0.05	0.01

Table 28. Area 5, *Weighted SEL_{24h}:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 29 - Drillship		Scenario 30 – Drillship with OSV		Scenario 31 – Pipelay vessel		Scenario 32 – Pipelay vessel with resupply vessel		Scenario 33 – Pipelay vessel with resupply vessel and support vessel		Scenario 34 – IMR vessel		Scenario 35 – OCV		Scenario 36 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.11	0.02	0.06	0.04	0.10	0.05	0.12	0.06	0.04	0.01	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.002	0.05	0.002	-	/	0.03	0.002	0.05	0.002	–	/	–	/	–	/
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.01	0.06	0.05	0.12	0.04	0.03	0.003	0.18	0.11	0.21	0.12
Sea Turtles	220	0.02	0.001	0.02	0.001	–	/	0.04	0.01	0.05	0.01	0.02	0.001	–	/	0.03	0.002
TTS																	
Low-Frequency (LF) cetaceans	179	1.56	6.43	1.66	7.16	1.69	7.73	1.99	11.2	2.18	14.2	0.63	1.21	4.39	51.5	4.58	59.1
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.06	0.03	0.01	0.06	0.03	0.09	0.04	0.02	0.002	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.30	31.4	3.33	32.7	0.63	1.20	0.83	2.12	1.12	3.67	0.28	0.24	2.66	22.1	2.80	23.3
Sea Turtles	200	0.09	0.02	0.12	0.03	0.06	0.04	0.11	0.05	0.12	0.06	0.05	0.01	0.13	0.06	0.17	0.07

Table 29. Combined scenarios 37 and 38, *Weighted SEL_{24h}:* Total ensonified area (km^2) above frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017). The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 37 - Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV				Scenario 38 - Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV			
		Ensonified area, combined scenario (km^2)	Sum of ensonified areas of individual scenarios (km^2)	Change in ensonified area from individual scenarios to combined (km^2)	Percentage change in ensonified area from individual scenarios to combined (%)	Ensonified area, combined scenario (km^2)	Sum of ensonified areas of individual scenarios (km^2)	Change in ensonified area from individual scenarios to combined (km^2)	Percentage change in ensonified area from individual scenarios to combined (%)
PTS									
Low-Frequency (LF) cetaceans	199	0.08	0.08	/	*	0.15	0.15	/	*
High-frequency (HF) cetaceans	198	0.003	0.004	/	*	0.01	0.01	/	*
Very High-frequency (VHF) cetaceans	173	0.14	0.14	/	*	0.22	0.22	+ 0.002	+ 0.91
Sea Turtles	220	0.01	0.01	/	*	0.01	0.01	/	*
TTS									
Low-Frequency (LF) cetaceans	179	5.52	5.53	/	*	12.7	12.7	+ 0.03	+ 0.21
High-frequency (HF) cetaceans	178	0.09	0.09	/	*	0.13	0.13	/	*
Very High-frequency (VHF) cetaceans	153	32.4	32.4	- 0.002	- 0.006	50.9	50.9	+ 0.004	+ 0.008
Sea Turtles	200	0.08	0.08	/	*	0.10	0.10	/	*

/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2).

Table 30. Combined 39 and 40, *Weighted SEL_{24h}*: Total ensonified area (km^2) above frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017). The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Scenario 39 - Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels				Scenario 40 - Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels			
		Ensonified area, combined scenario (km^2)	Sum of ensonified areas of individual scenarios (km^2)	Change in ensonified area from individual scenarios to combined (km^2)	Percentage change in ensonified area from individual scenarios to combined (%)	Ensonified area, combined scenario (km^2)	Sum of ensonified areas of individual scenarios (km^2)	Change in ensonified area from individual scenarios to combined (km^2)	Percentage change in ensonified area from individual scenarios to combined (%)
PTS									
Low-Frequency (LF) cetaceans	199	0.08	0.08	/	*	0.08	0.08	/	*
High-frequency (HF) cetaceans	198	0	0	/	*	0	0	/	*
Very High-frequency (VHF) cetaceans	173	0.14	0.14	/	*	0.14	0.14	/	*
Sea Turtles	220	0.01	0.01	/	*	0.01	0.01	/	*
TTS									
Low-Frequency (LF) cetaceans	179	16.3	16.3	+ 0.03	+ 0.18	22.0	21.4	+ 0.64	+ 2.98
High-frequency (HF) cetaceans	178	0.09	0.09	/	*	0.09	0.09	/	*
Very High-frequency (VHF) cetaceans	153	33.0	33.0	+ 0.009	+ 0.03	36.6	36.4	+ 0.14	+ 0.38
Sea Turtles	200	0.08	0.08	/	*	0.08	0.08	/	*

/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2).

4.2. Vessel Activities - Sound Field Maps and Graphs

Maps of the estimated sound fields, threshold contours, and isopleths of interest for SPL and SEL_{24h} sound fields are presented for the vessel activity scenarios. The SPL results for individual and combined scenarios are presented in Figures 19 to Figure 58 (Section 4.2.1), whilst the SEL_{24h} results for individual scenarios are presented in Figures 59 to 92 (Section 4.2.2). SEL_{24h} results for combined scenarios are not illustrated as these effect zones remain identical to their corresponding individual scenarios.

4.2.1. Instantaneous SPL Sound Level Contour Maps

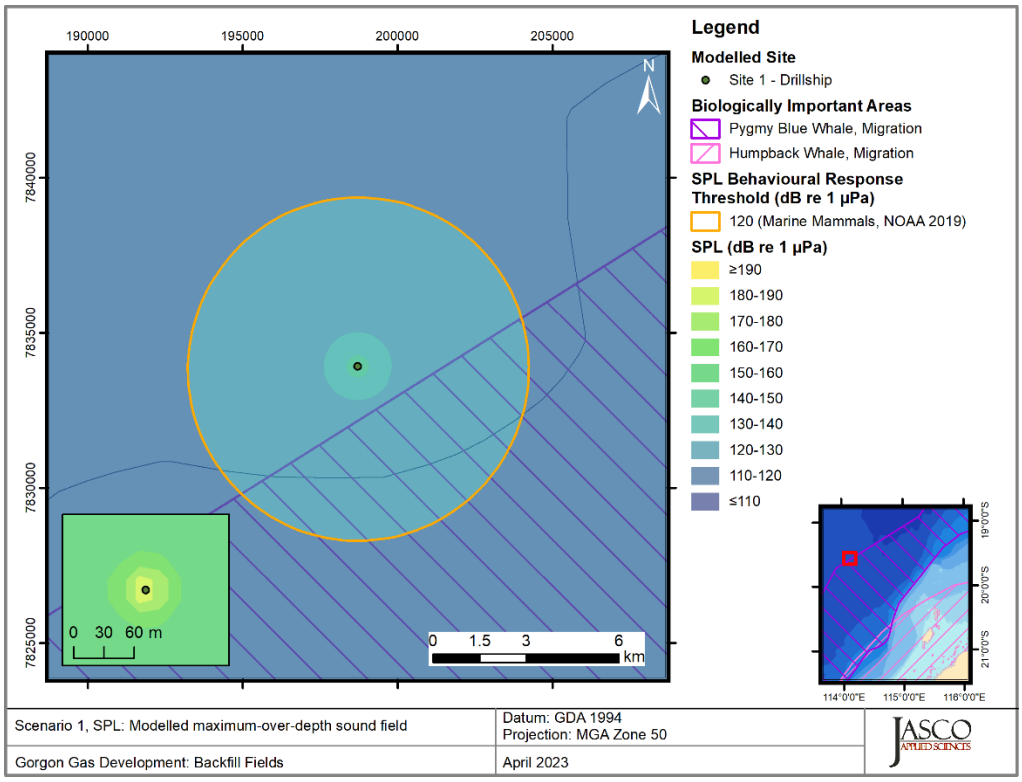


Figure 19. *Scenario 1, Area 1 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

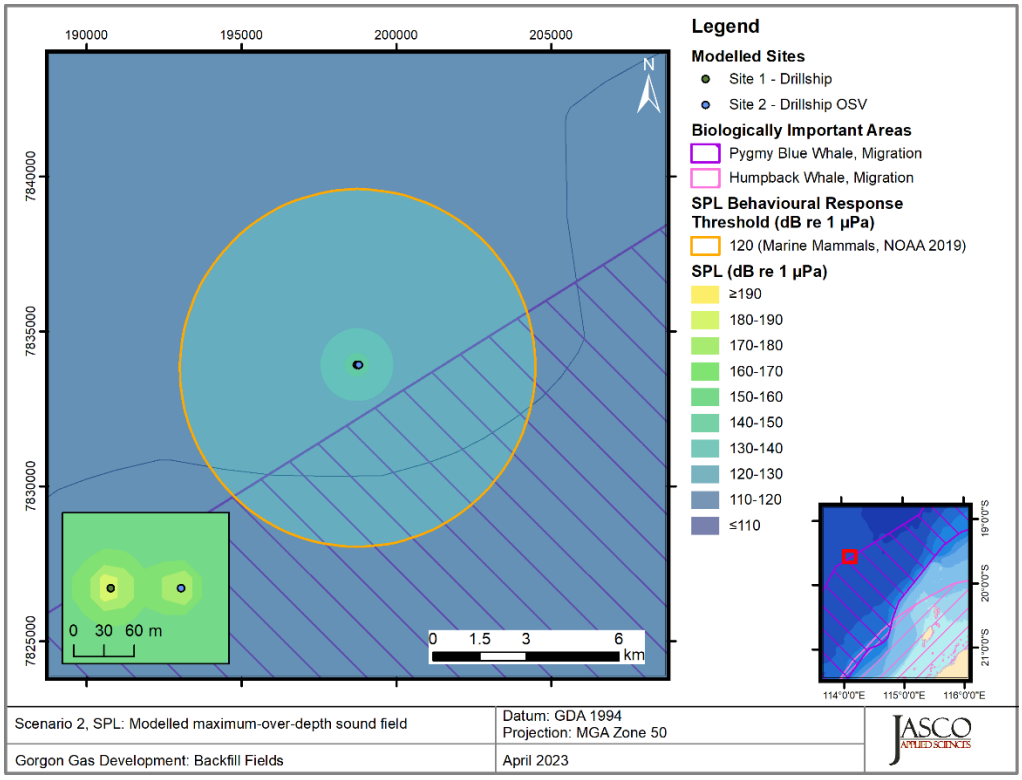


Figure 20. *Scenario 2, Area 1 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

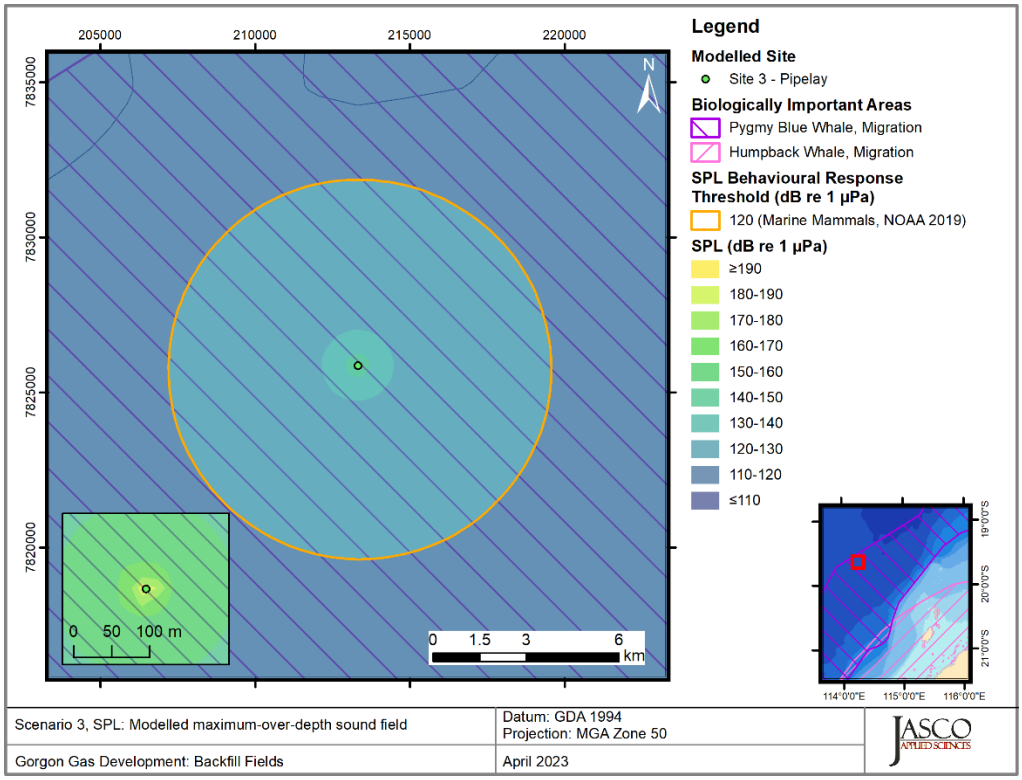


Figure 21. *Scenario 3, Area 1 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

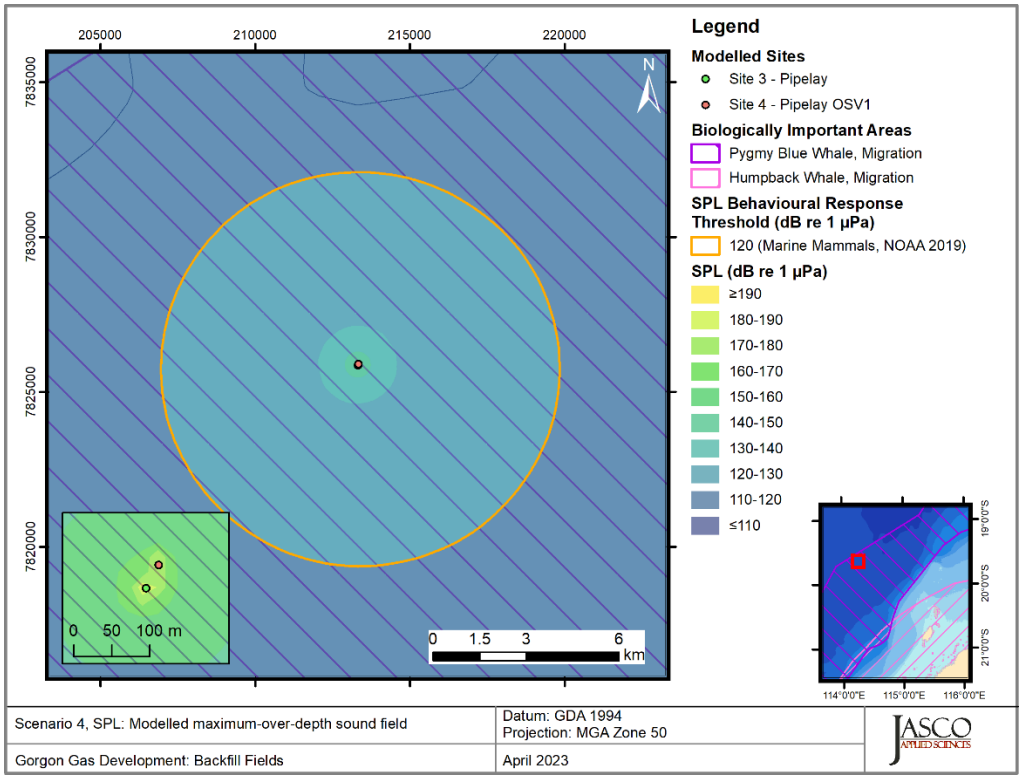


Figure 22. *Scenario 4, Area 1 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

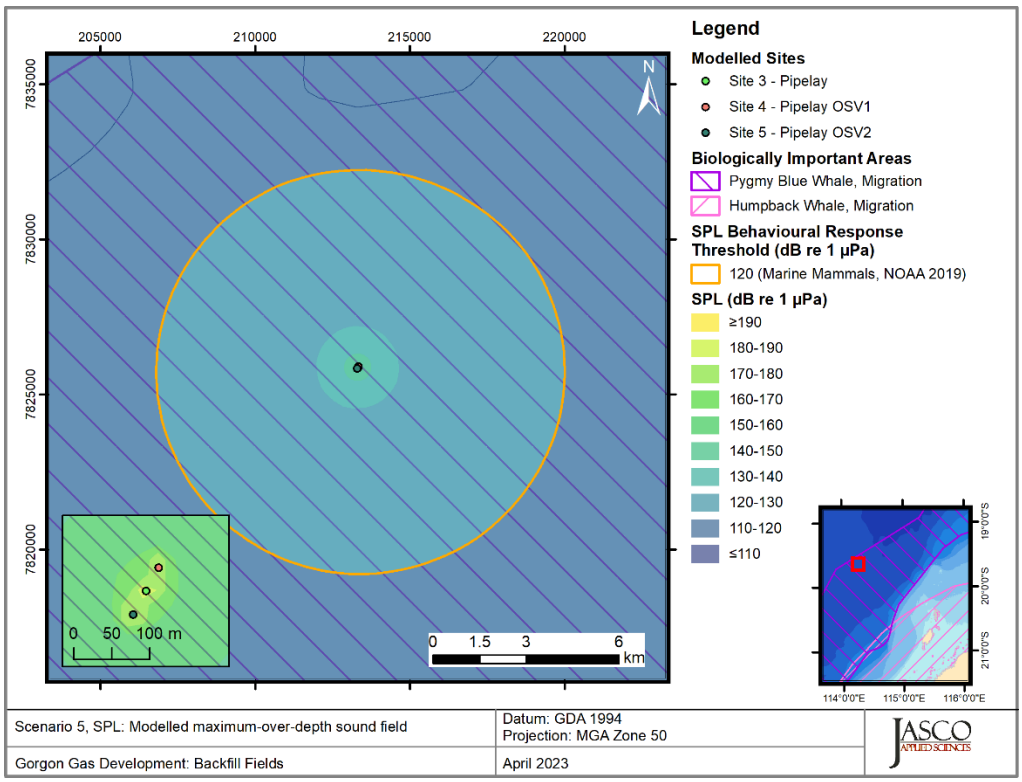


Figure 23. *Scenario 5, Area 1 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

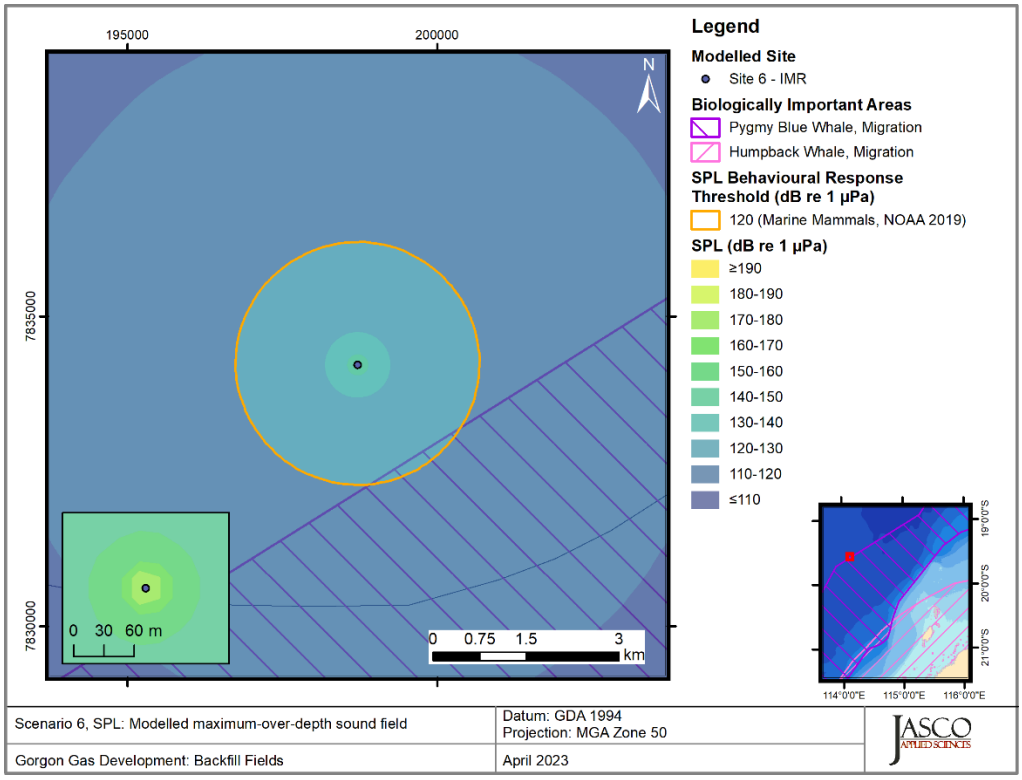


Figure 24. *Scenario 6, Area 1 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

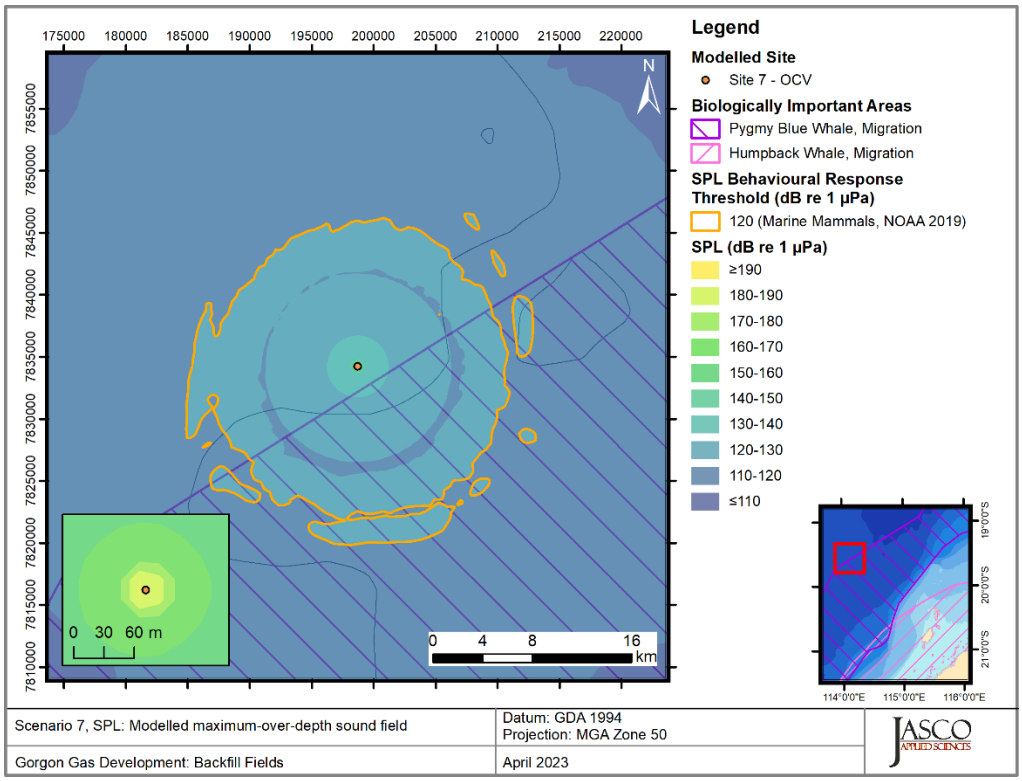


Figure 25. *Scenario 7, Area 1 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

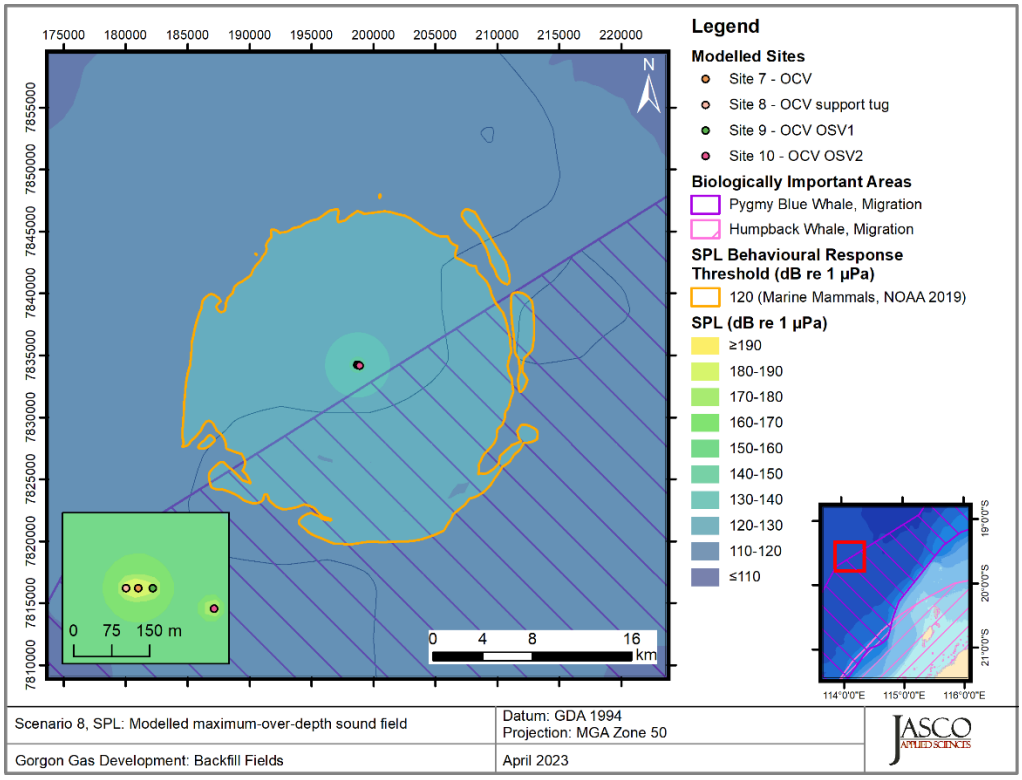


Figure 26. *Scenario 8, Area 1 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

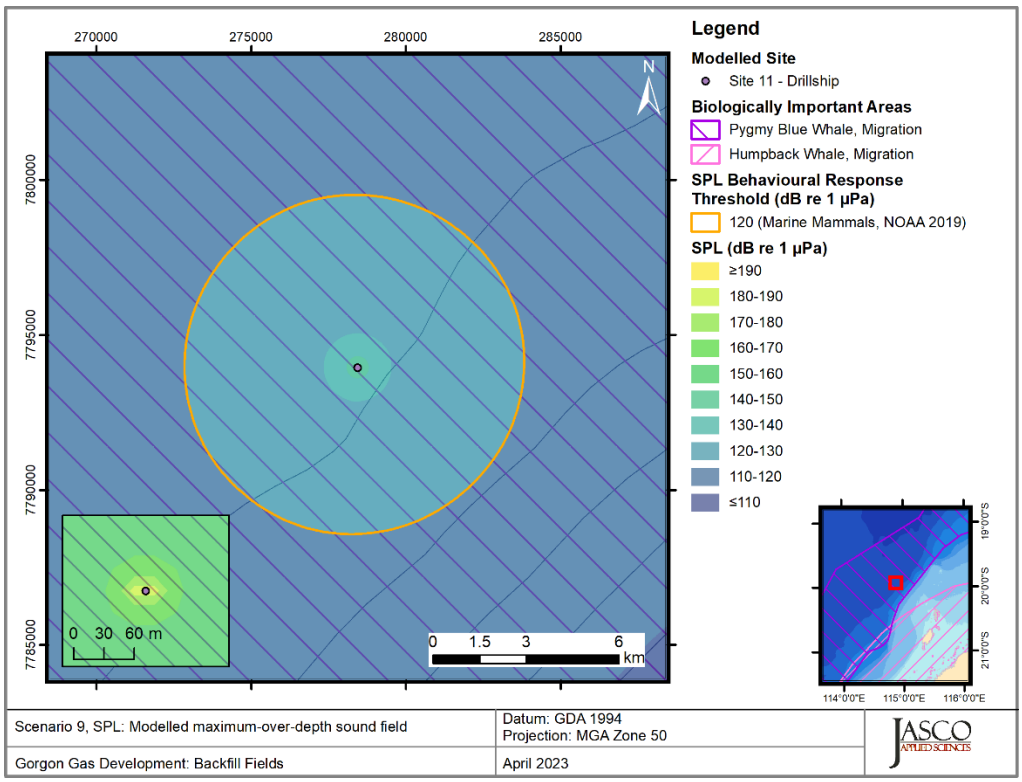


Figure 27. *Scenario 9, Area 2 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

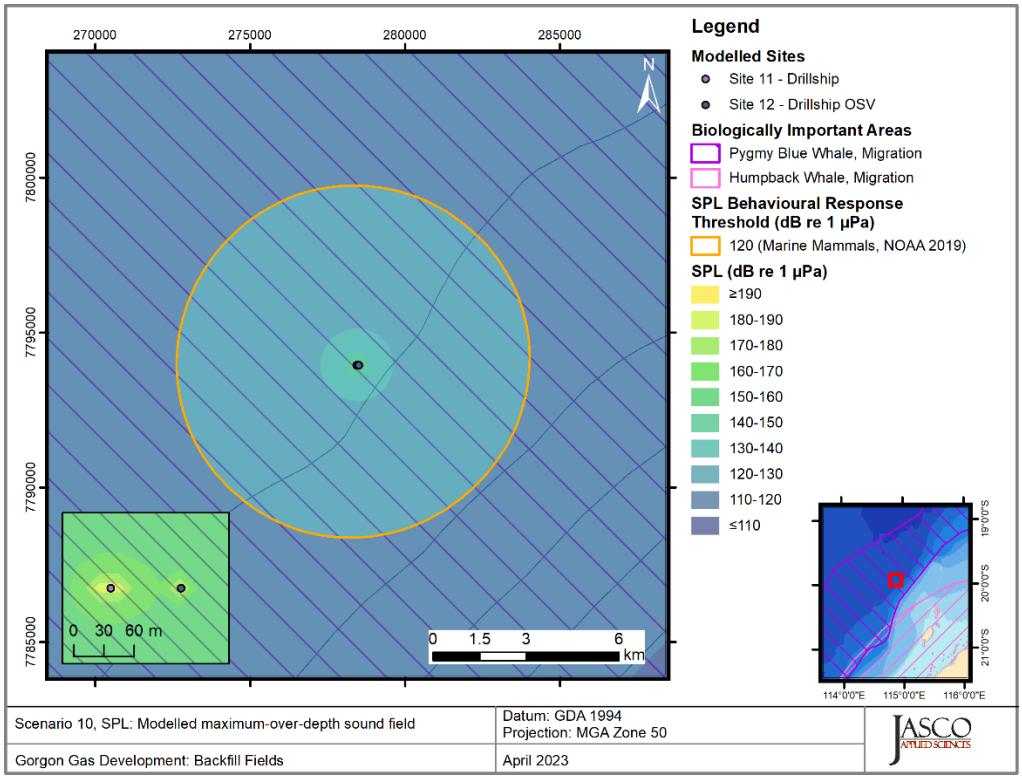


Figure 28. *Scenario 10, Area 2 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

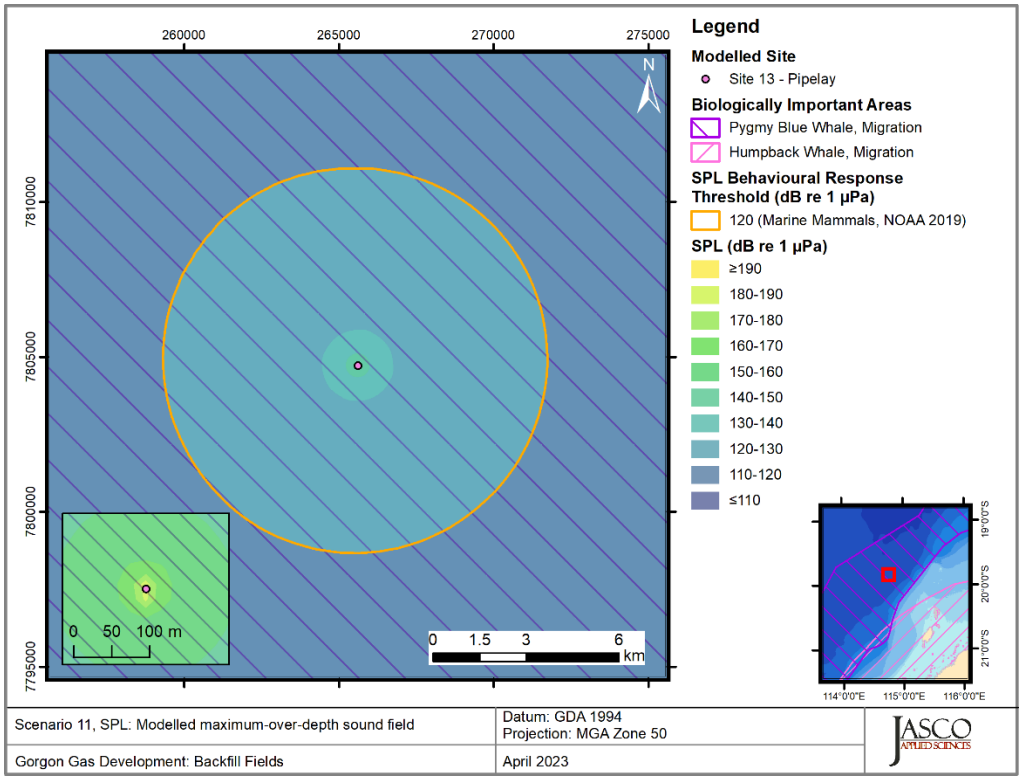


Figure 29. *Scenario 11, Area 2 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

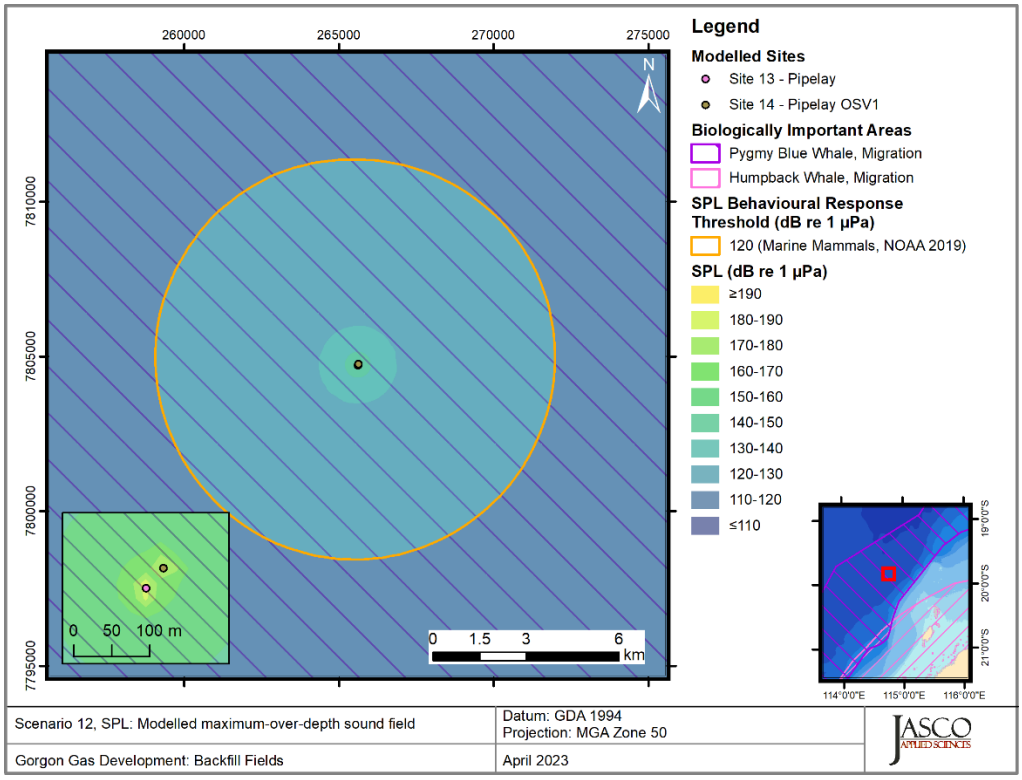


Figure 30. *Scenario 12, Area 2 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

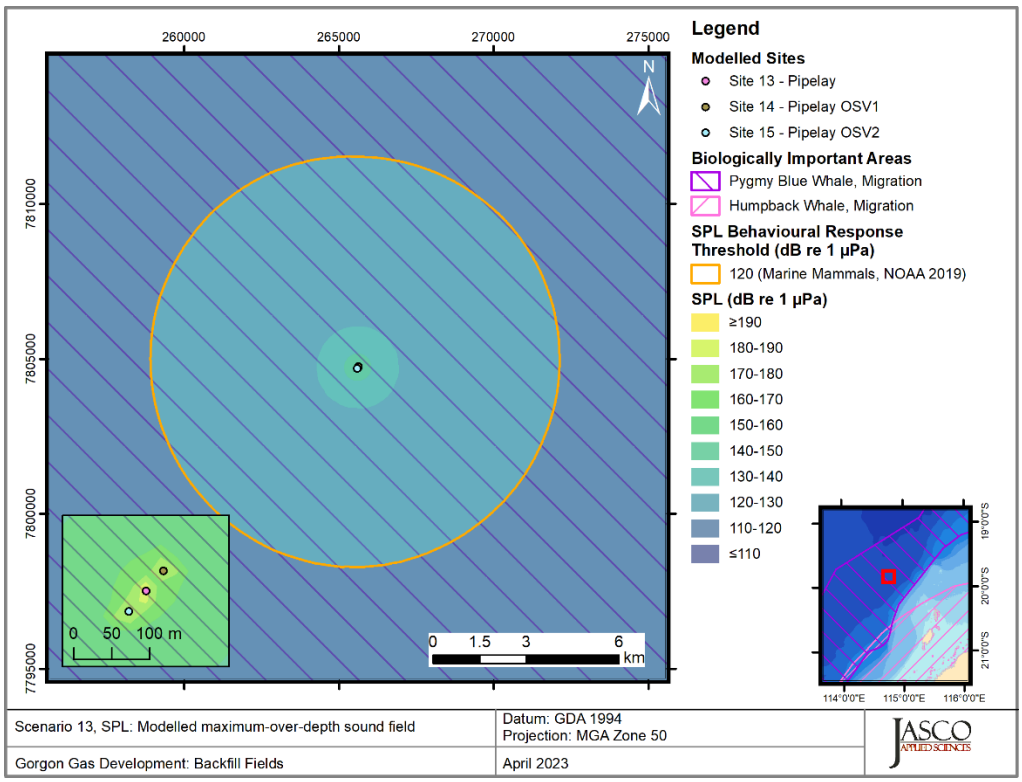


Figure 31. *Scenario 13, Area 2 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

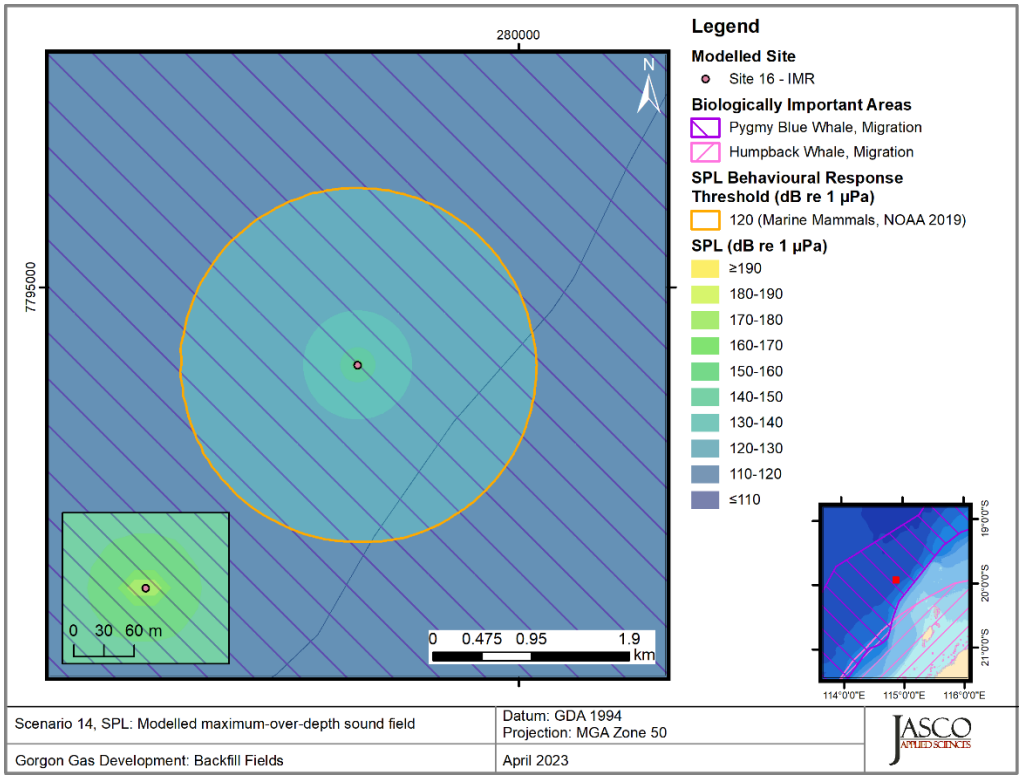


Figure 32. *Scenario 14, Area 2 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

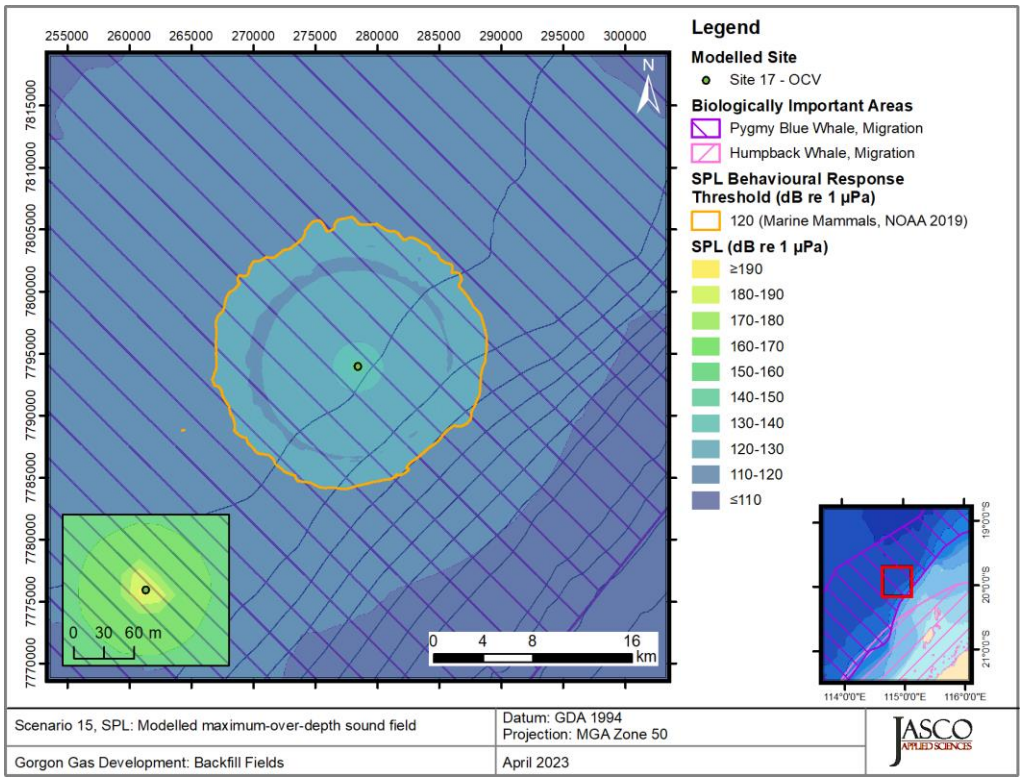


Figure 33. *Scenario 15, Area 2 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

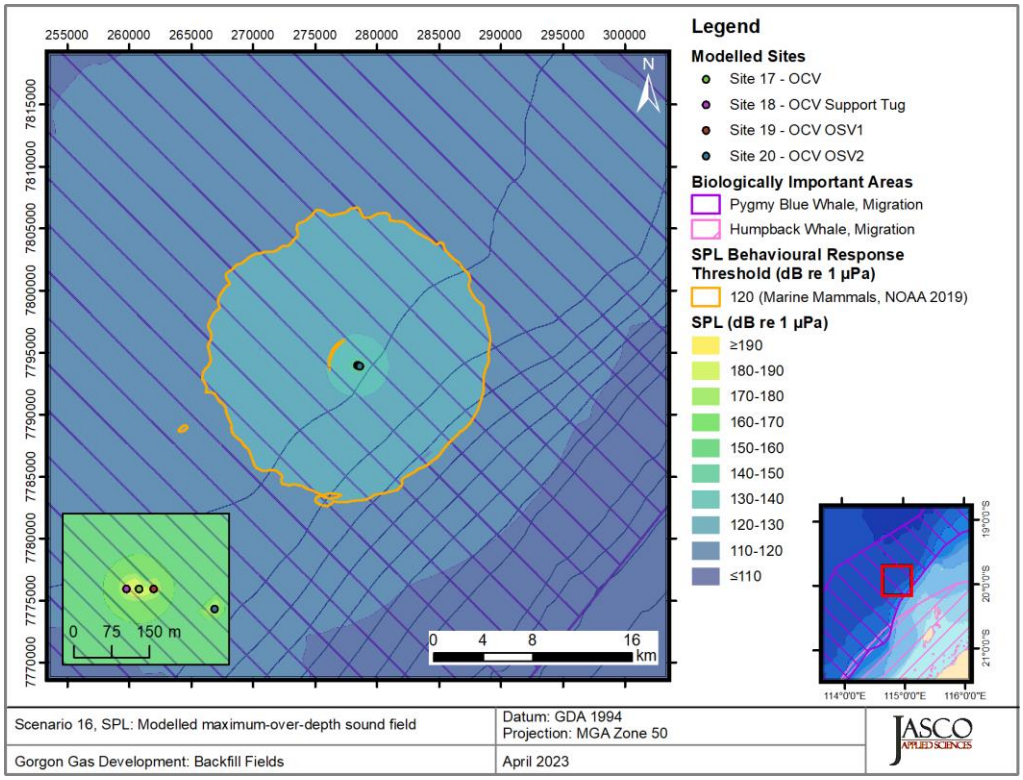


Figure 34. *Scenario 16, Area 2 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

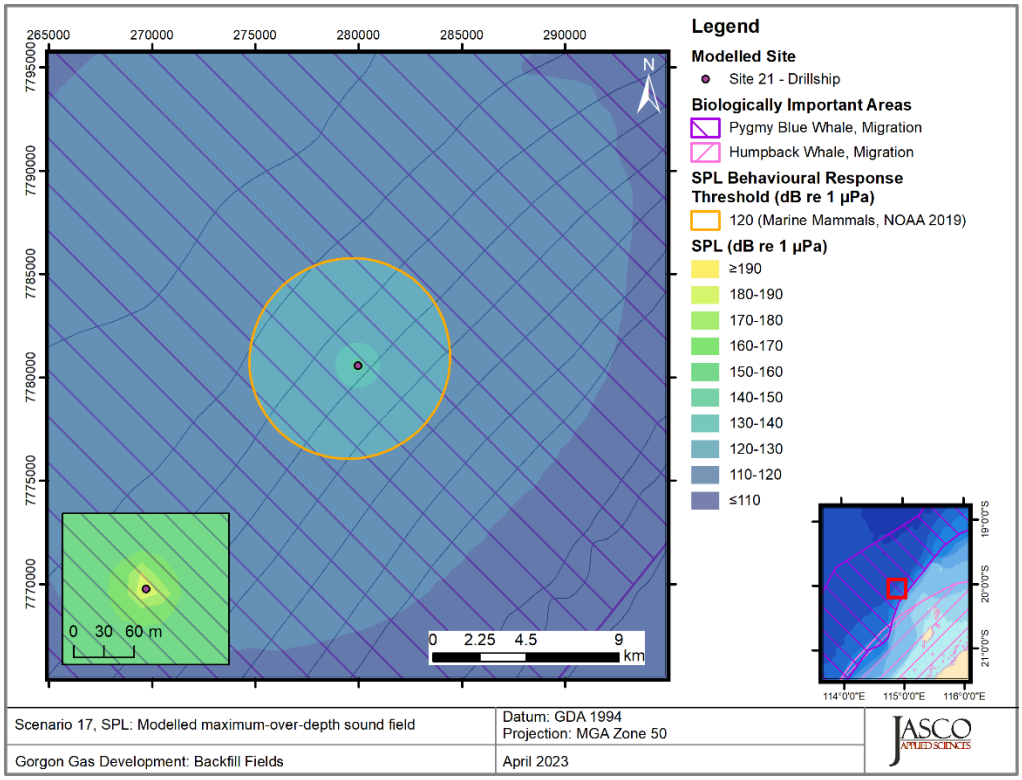


Figure 35. *Scenario 17, Area 3 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

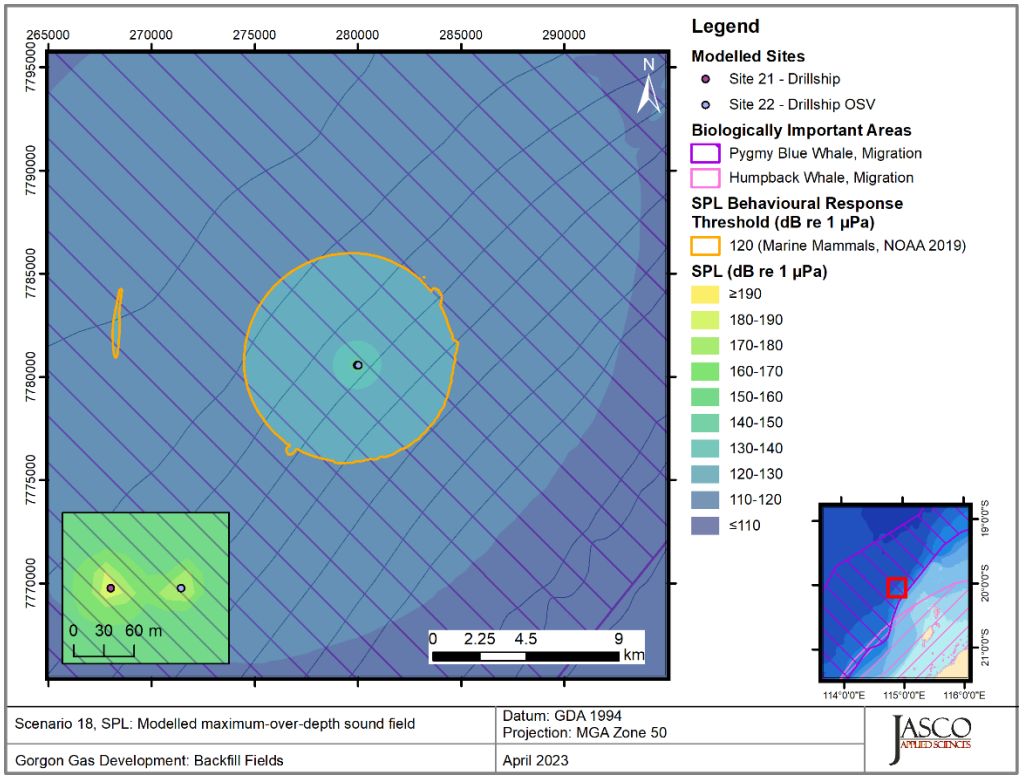


Figure 36. *Scenario 18, Area 3 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

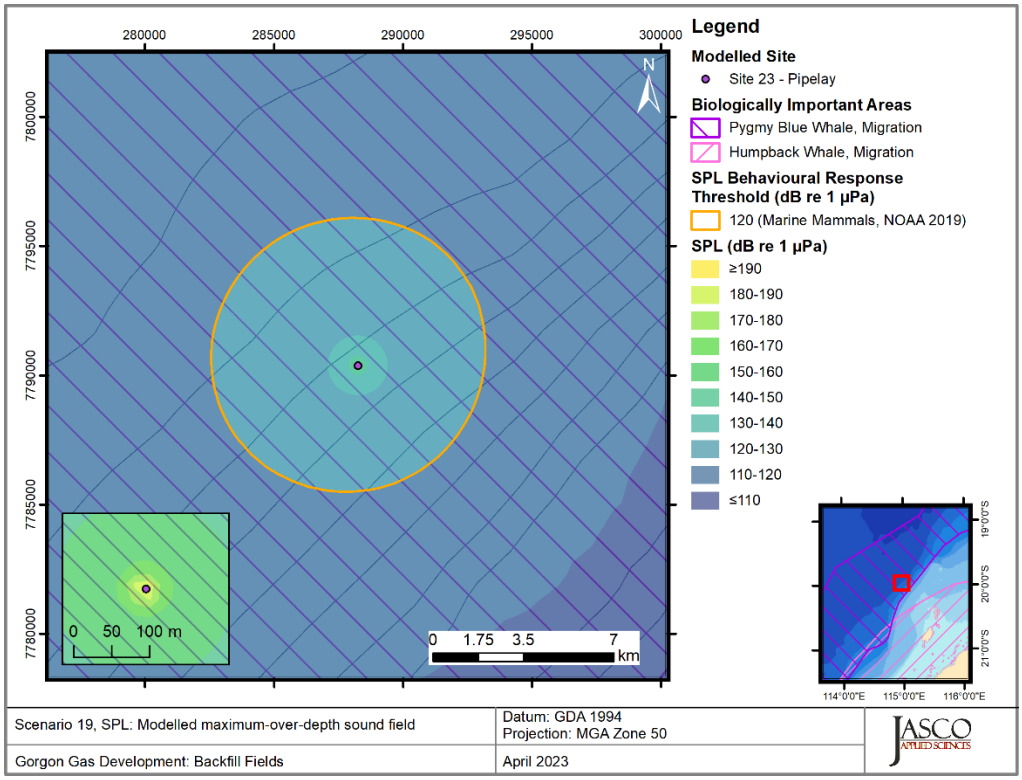


Figure 37. *Scenario 19, Area 3 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

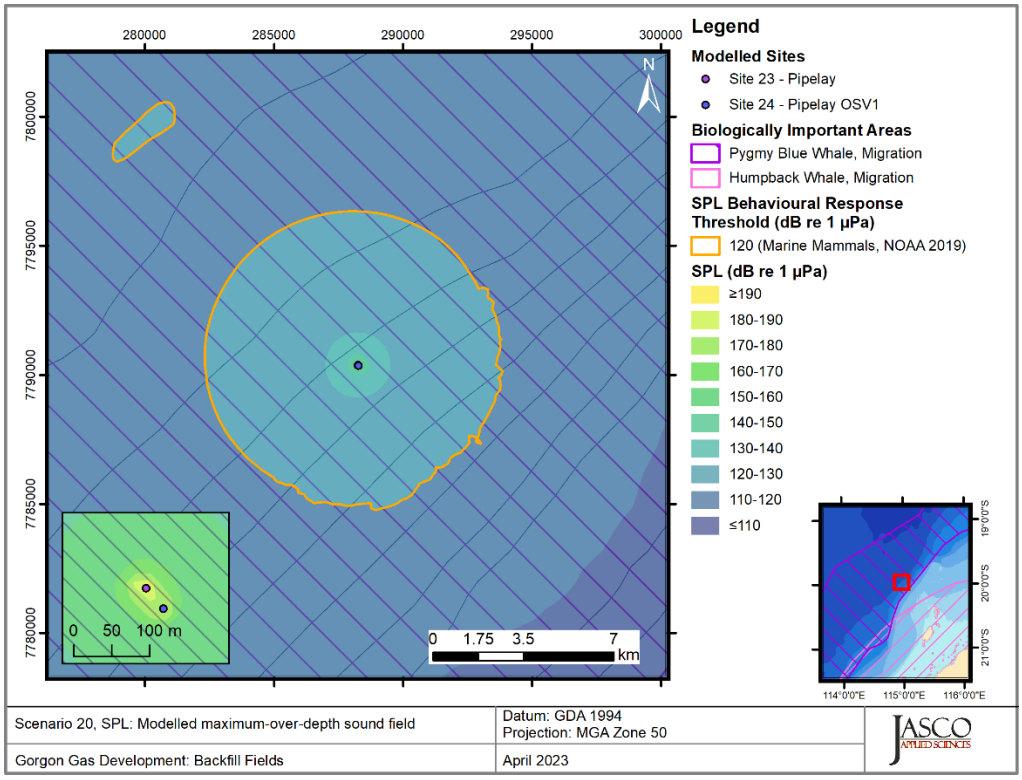


Figure 38. *Scenario 20, Area 3 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

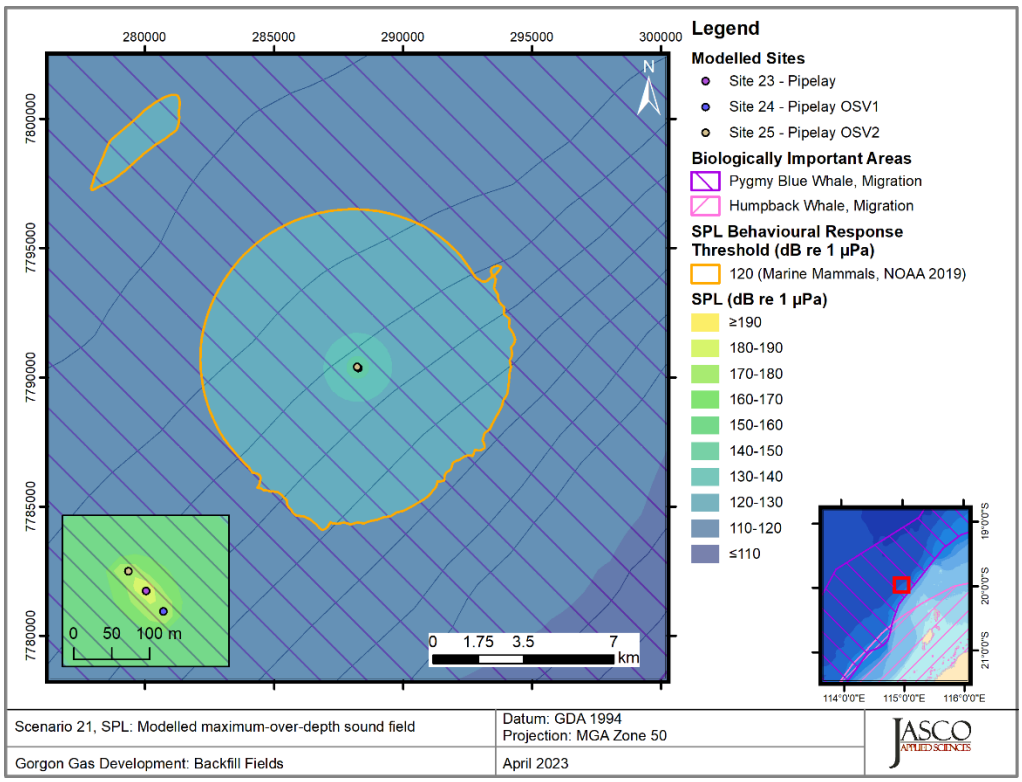


Figure 39. *Scenario 21, Area 3 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

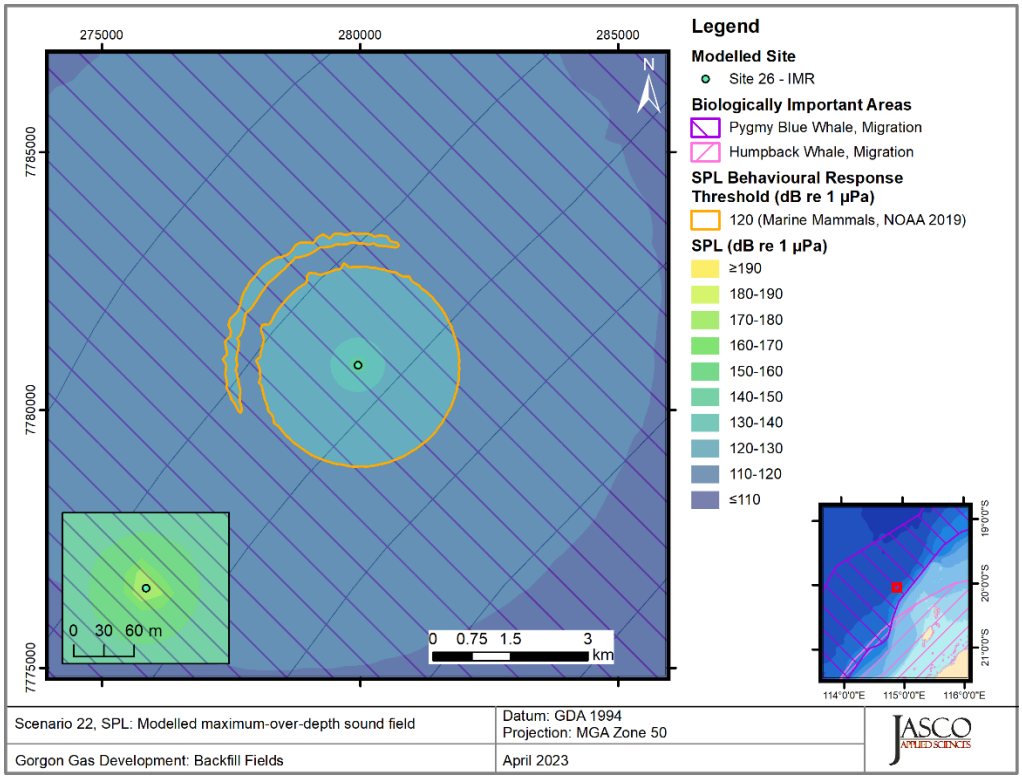


Figure 40. *Scenario 22, Area 3 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

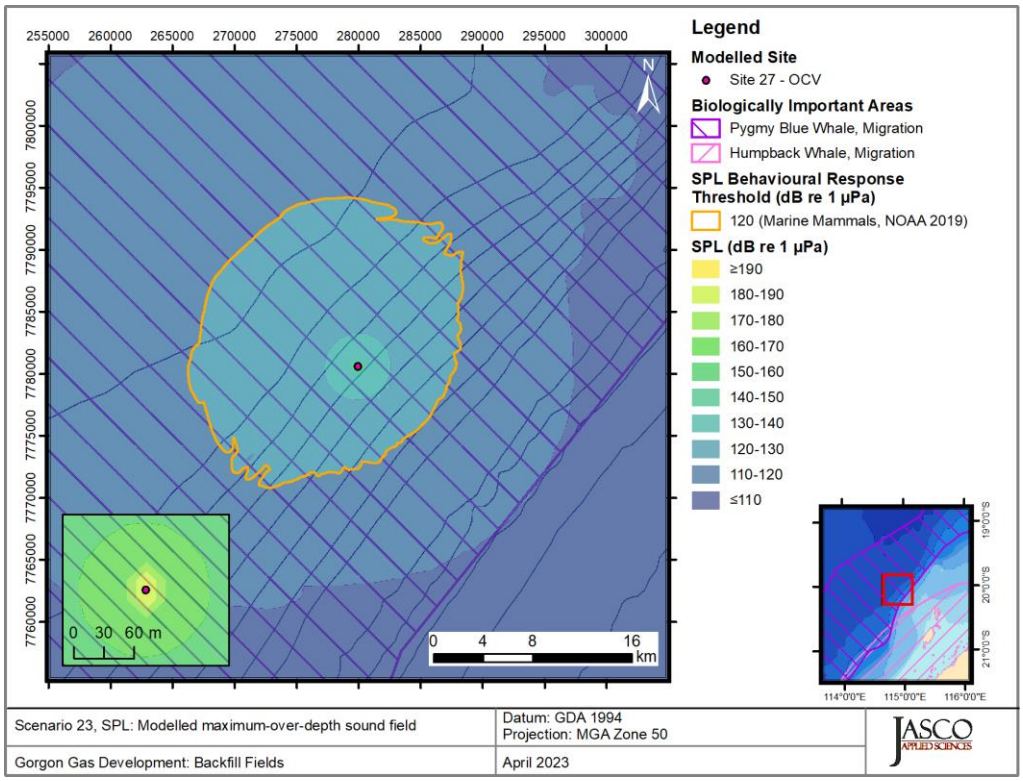


Figure 41. *Scenario 23, Area 3 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

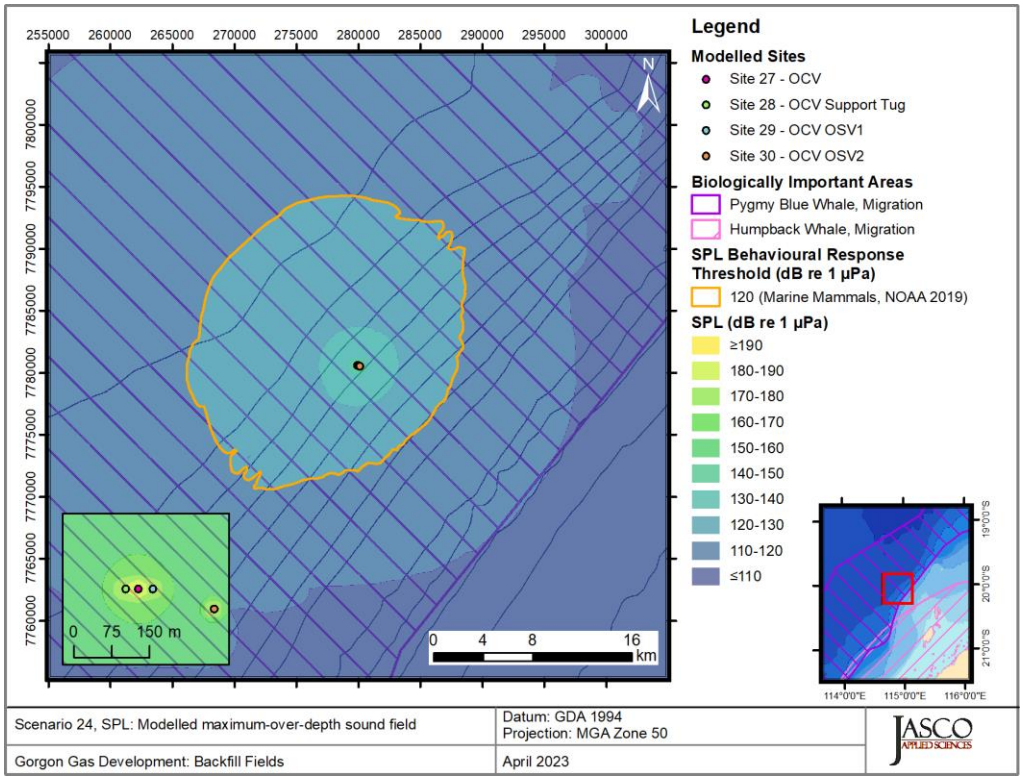


Figure 42. *Scenario 24, Area 3 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

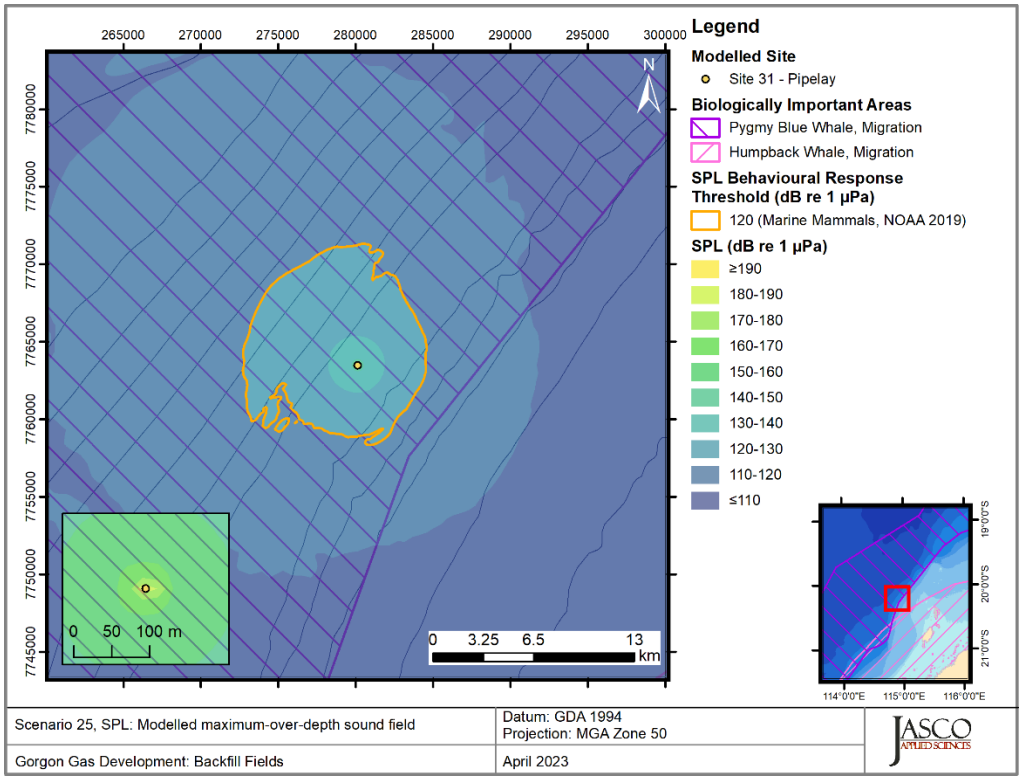


Figure 43. *Scenario 25, Area 4 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

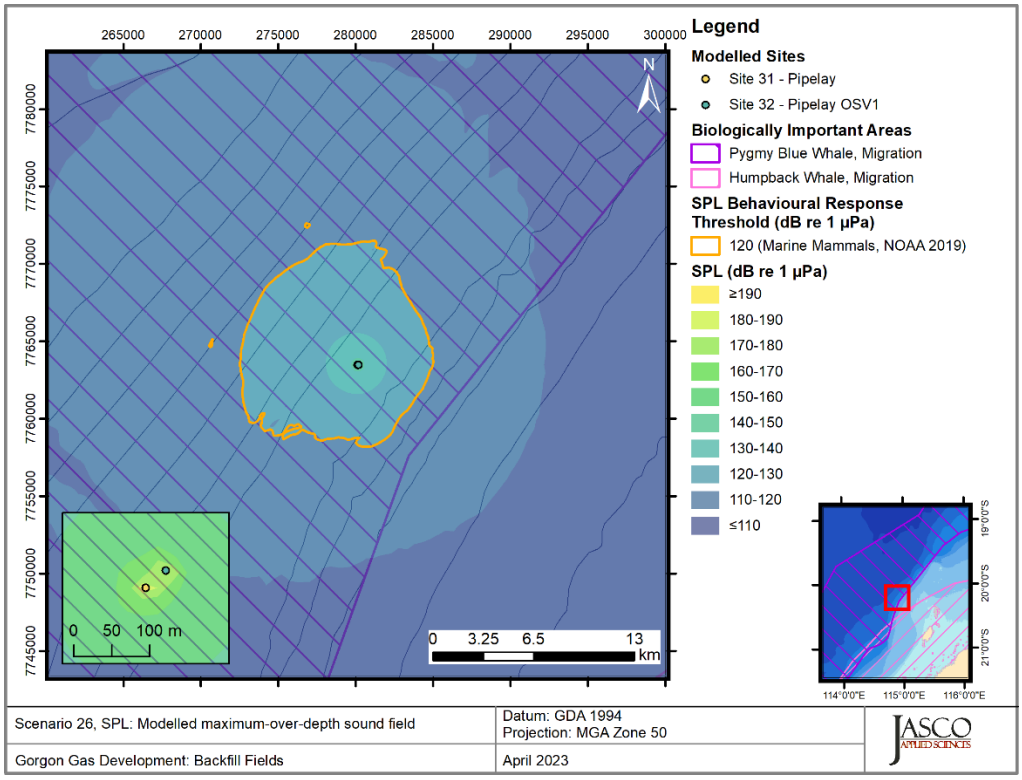


Figure 44. *Scenario 26, Area 4 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

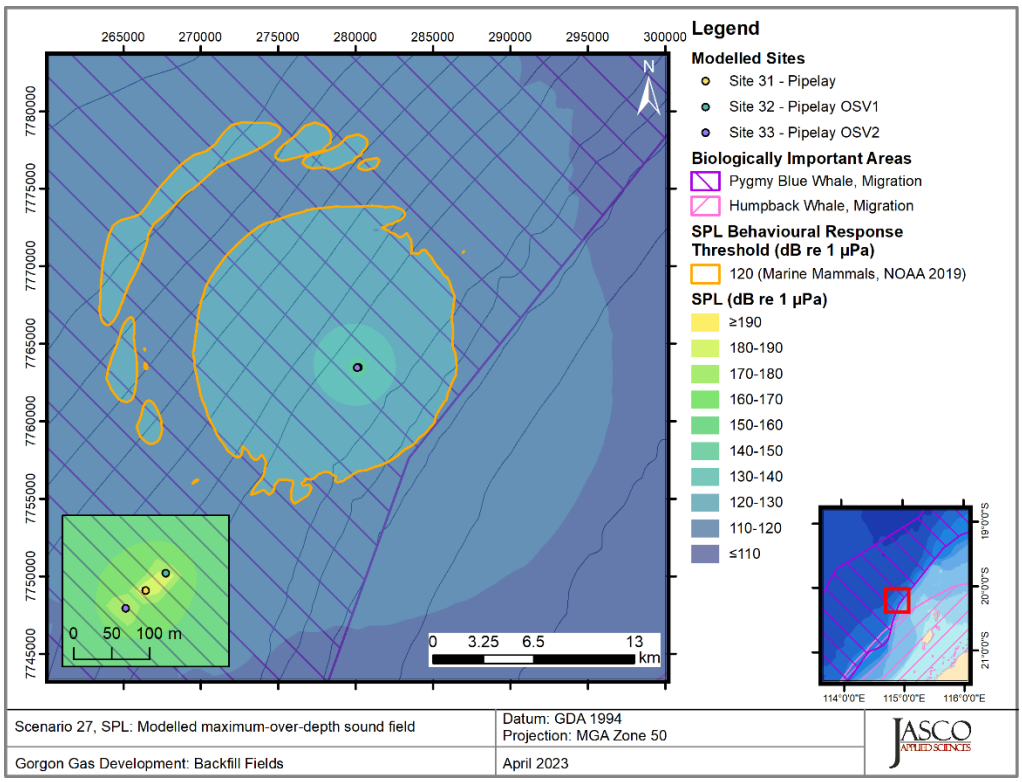


Figure 45. *Scenario 27, Area 4 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

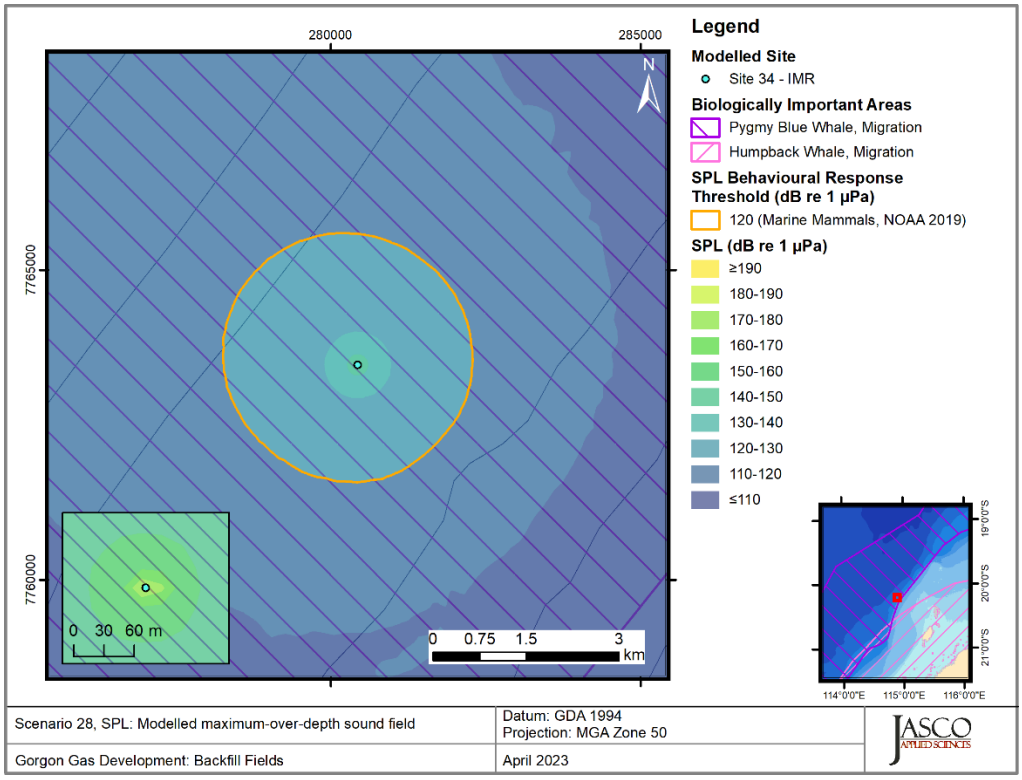


Figure 46. *Scenario 28, Area 4 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

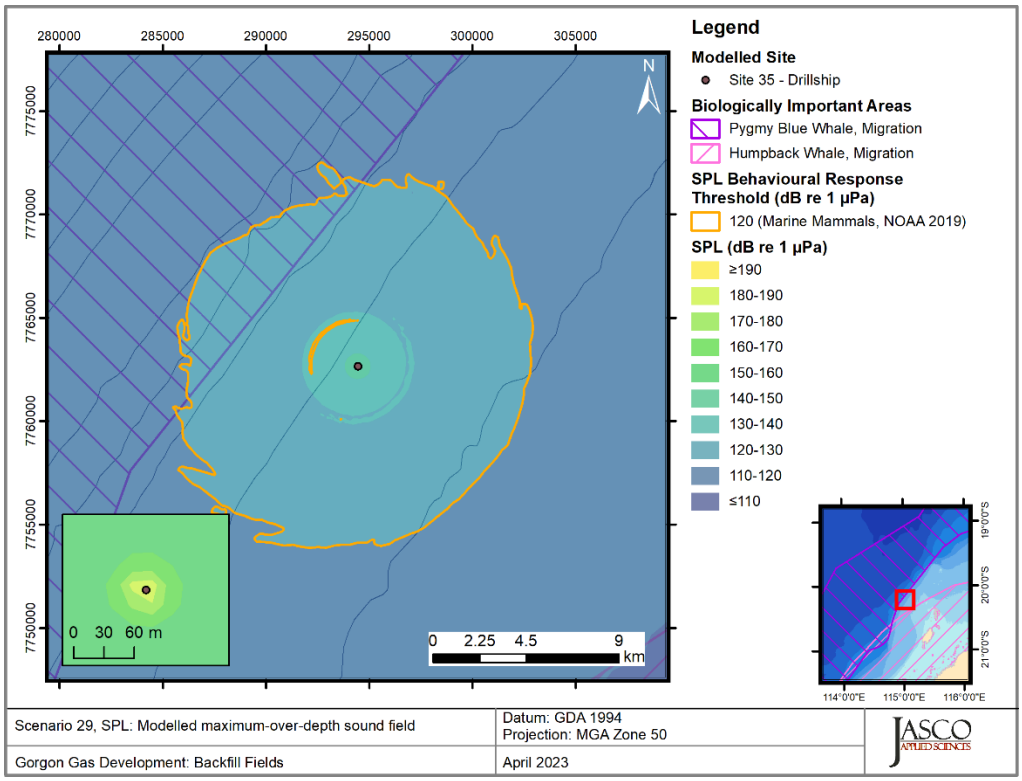


Figure 47. *Scenario 29, Area 5 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

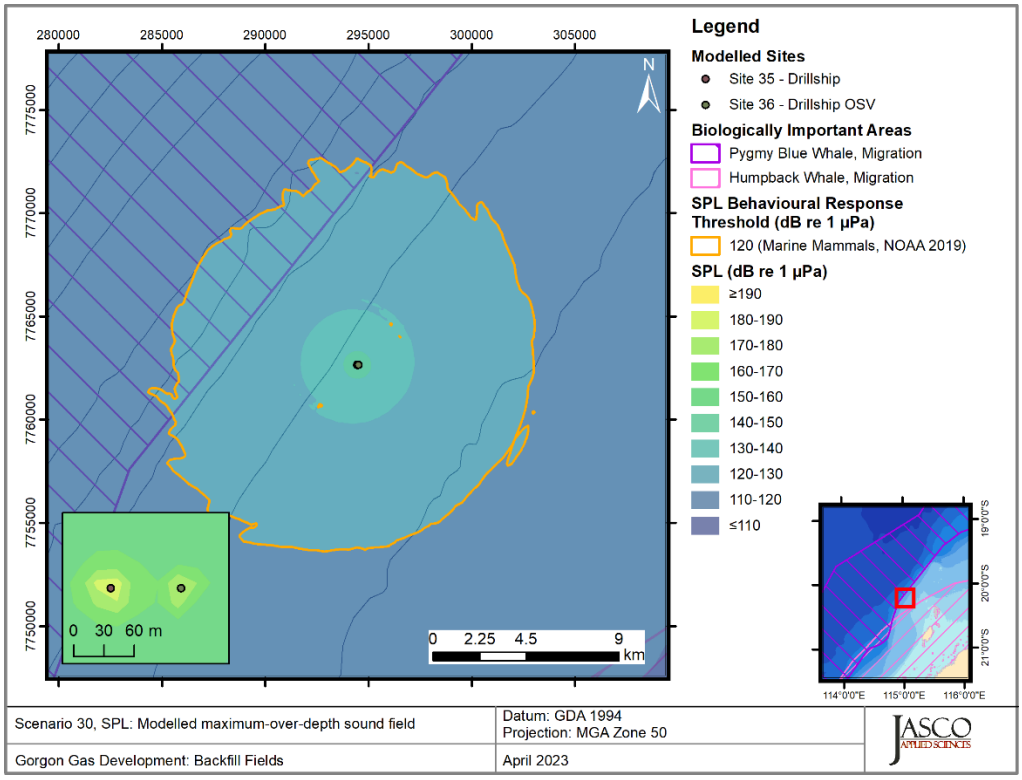


Figure 48. *Scenario 30, Area 5 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

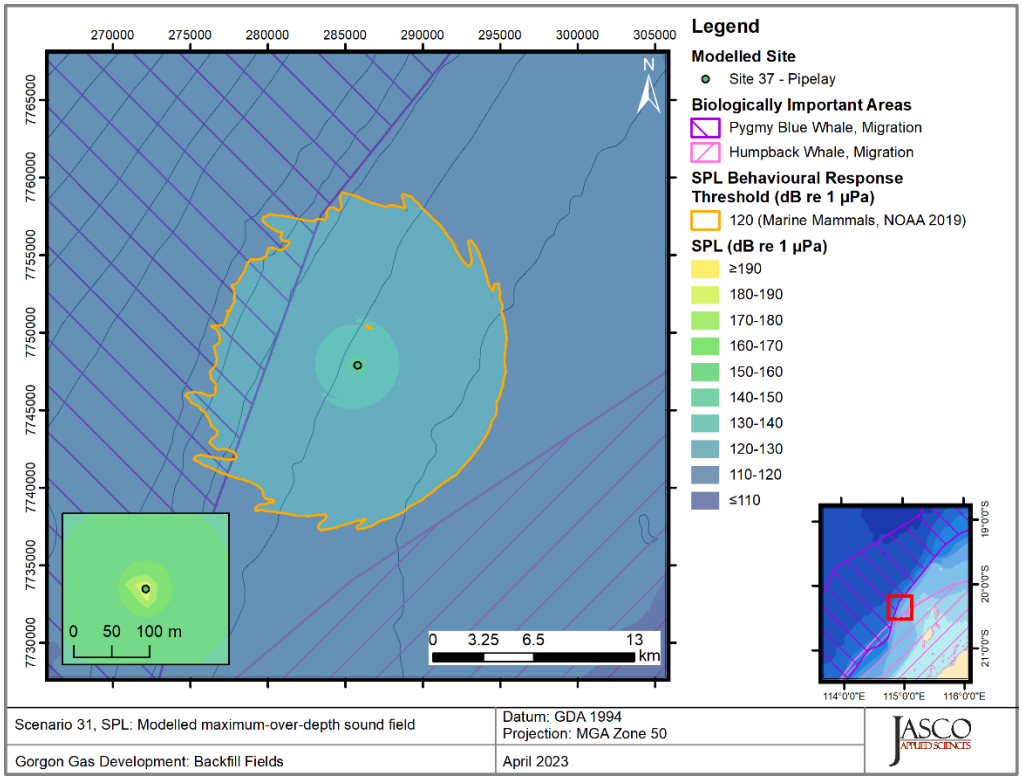


Figure 49. *Scenario 31, Area 5 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

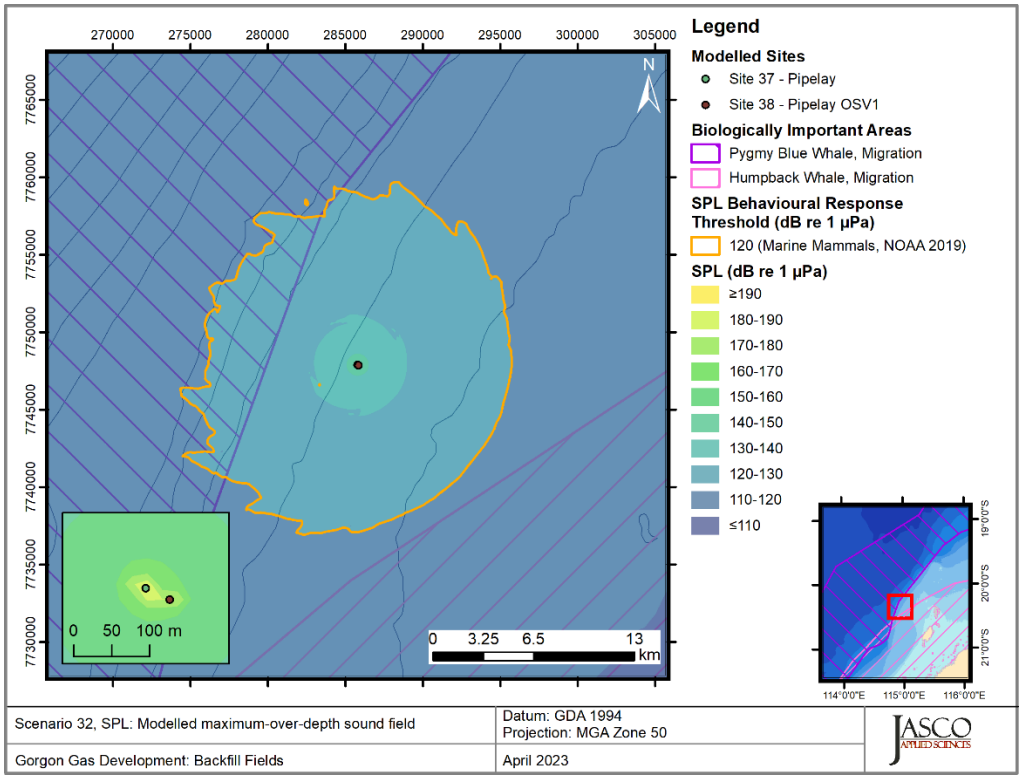


Figure 50. *Scenario 32, Area 5 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

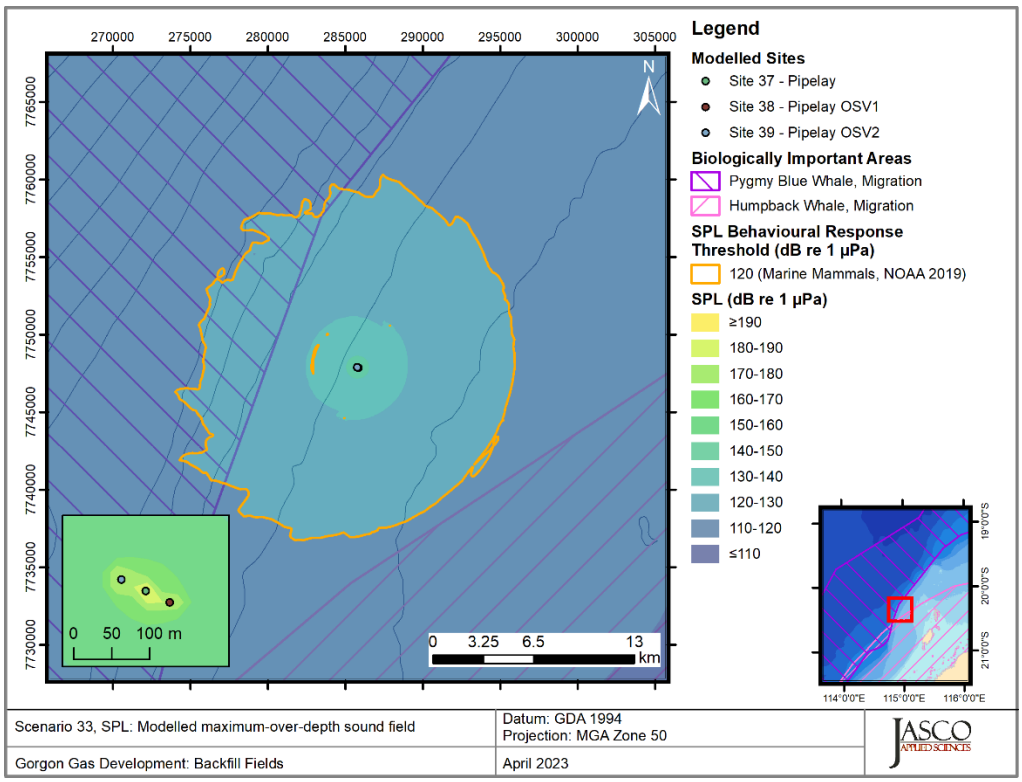


Figure 51. *Scenario 33, Area 5 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

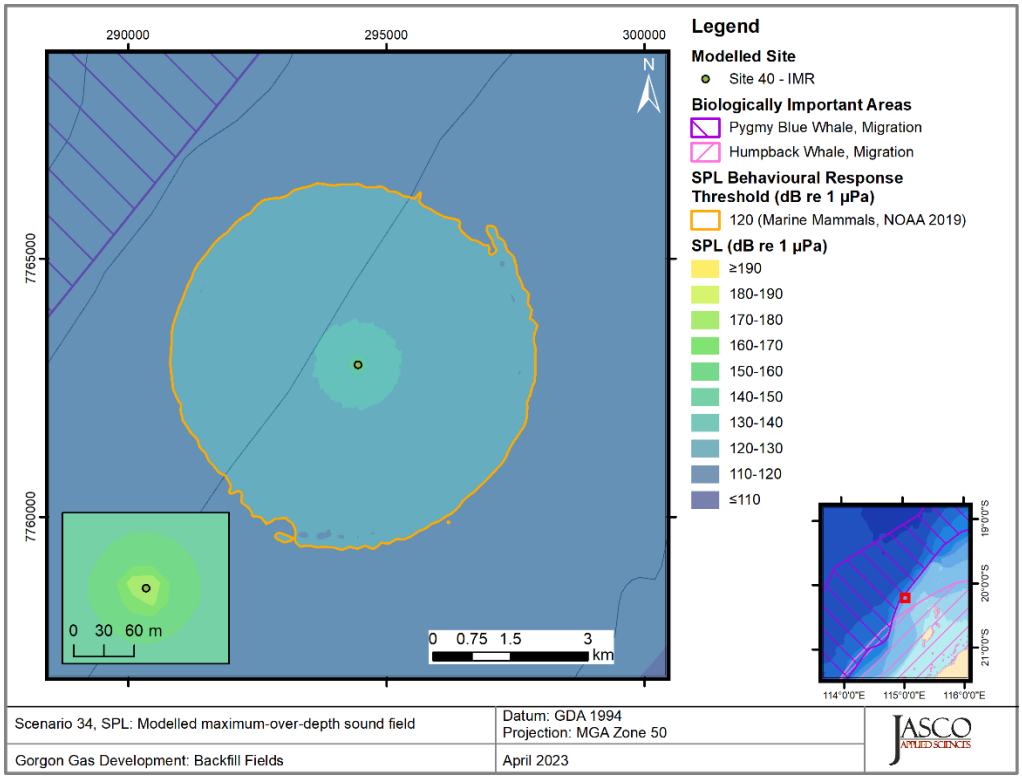


Figure 52. *Scenario 34, Area 5 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

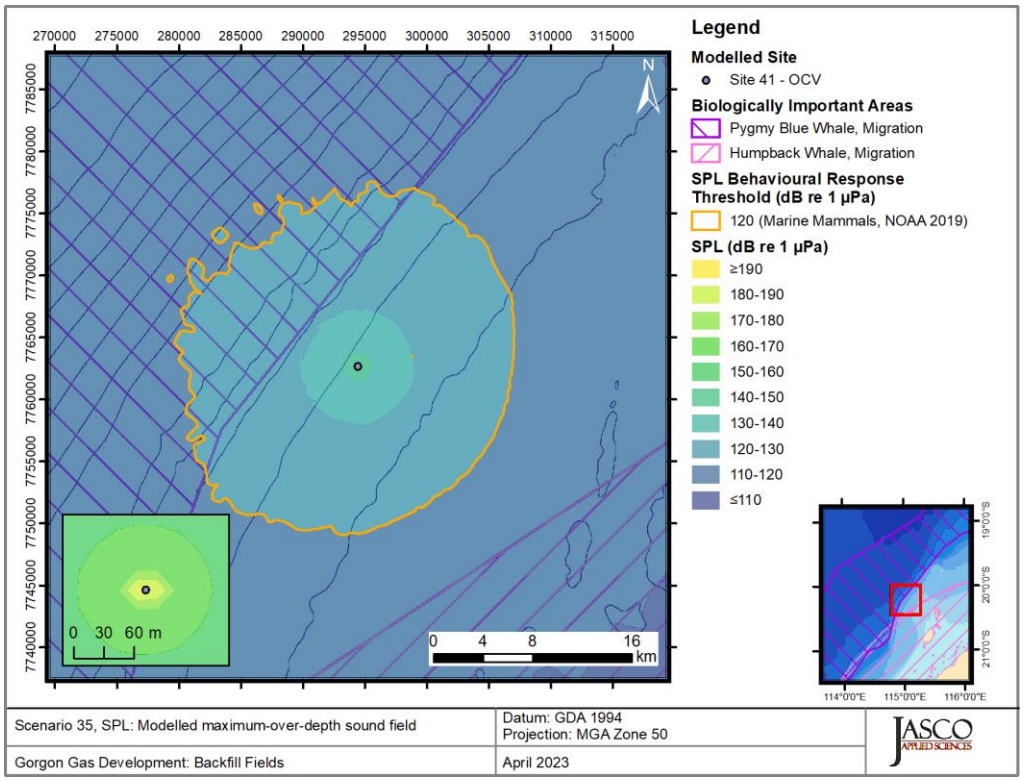


Figure 53. *Scenario 35, Area 5 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

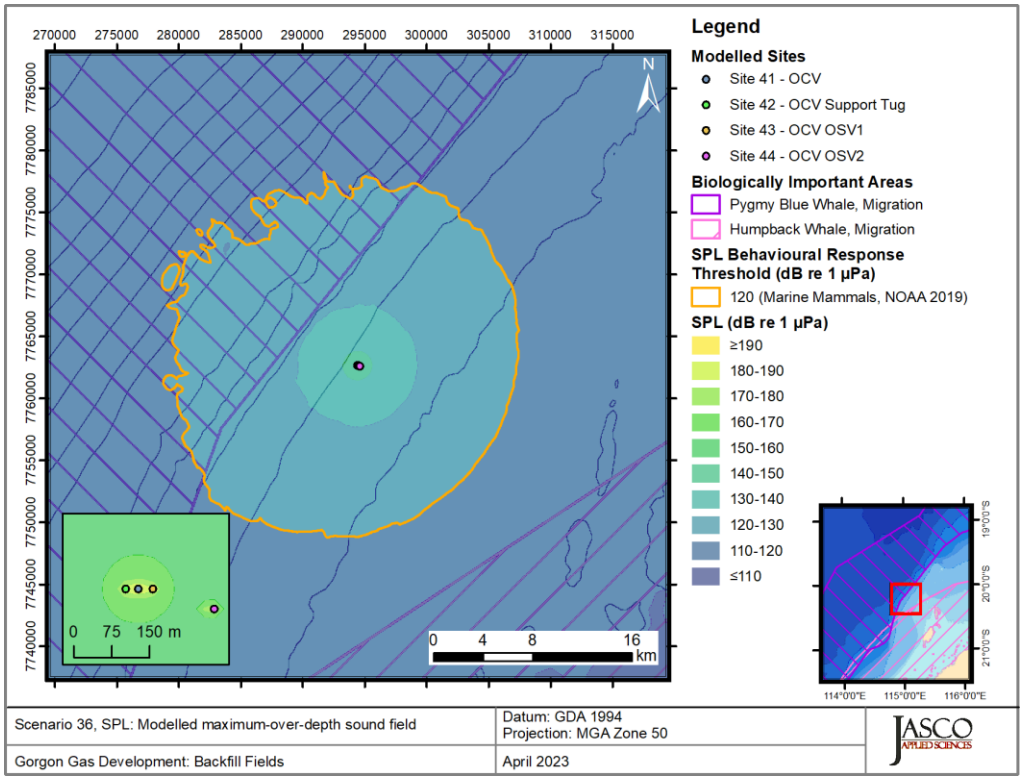


Figure 54. *Scenario 36, Area 5 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

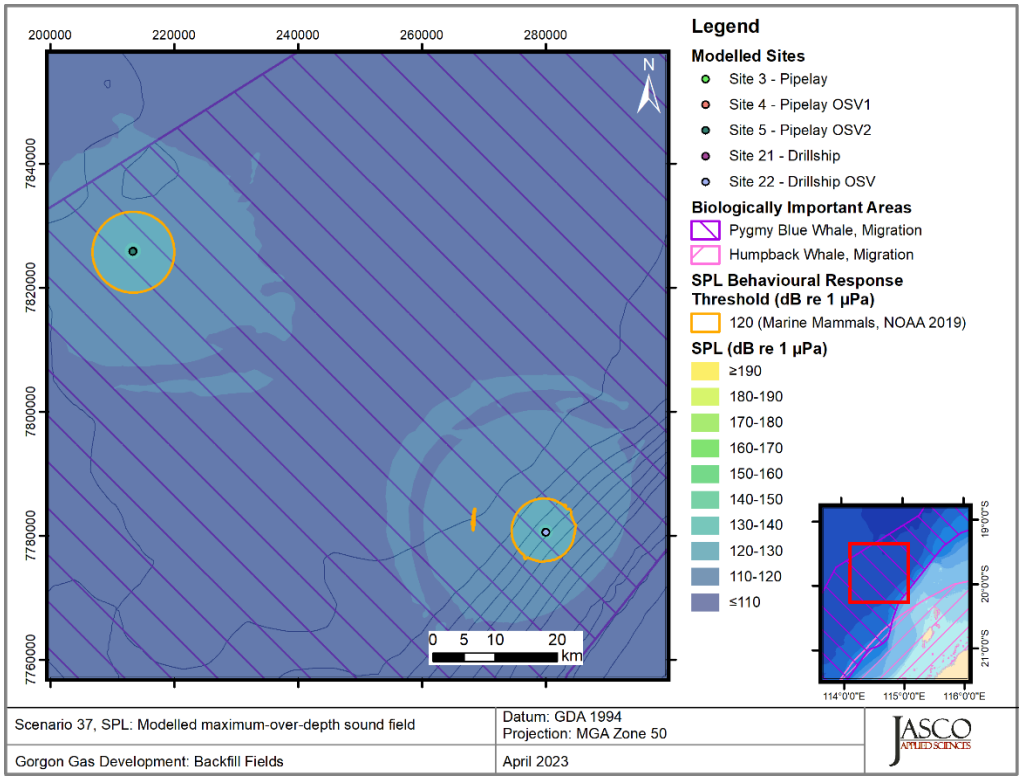


Figure 55. *Scenario 37, Combined scenario: Area 1 pipelay with OSVs and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

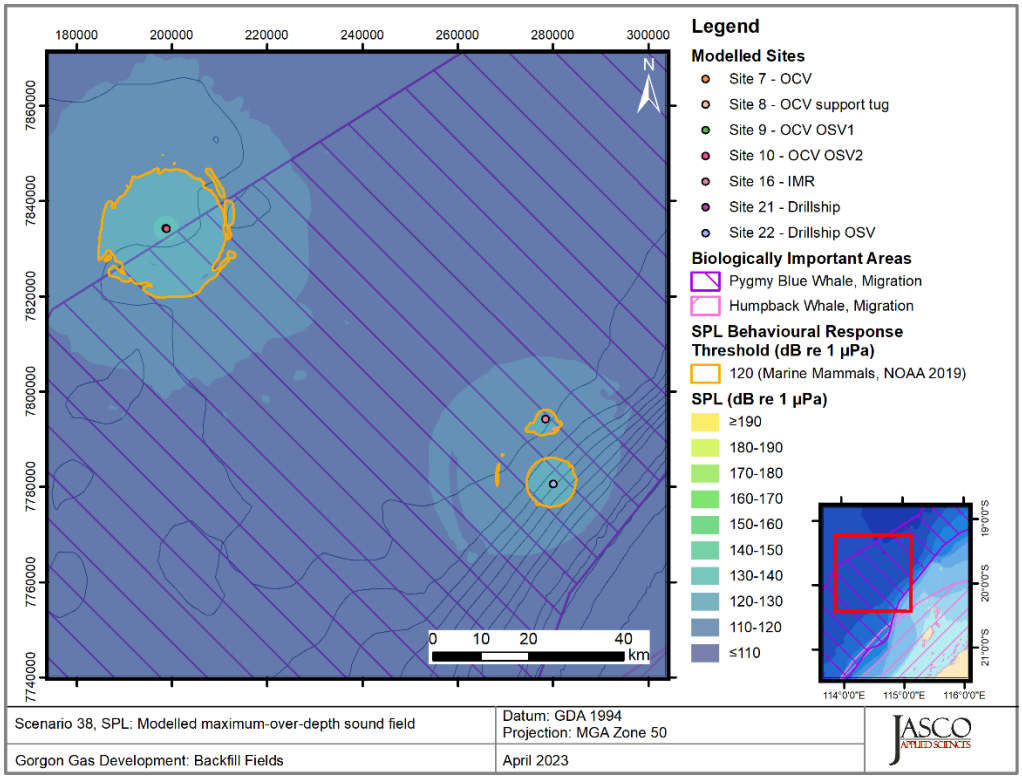


Figure 56. *Scenario 38 Combined scenario: Area 1 Construction with support vessels, Area 2 IMR vessel, and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

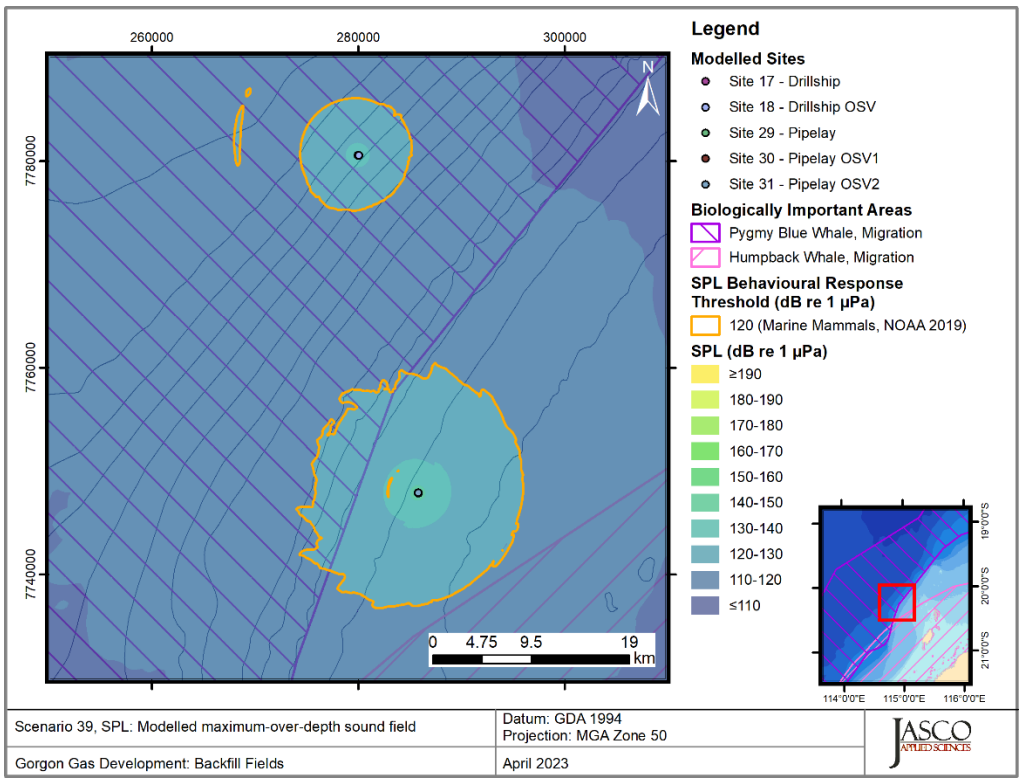


Figure 57. *Scenario 39, Combined scenario: Area 5 pipelay with OSVs and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

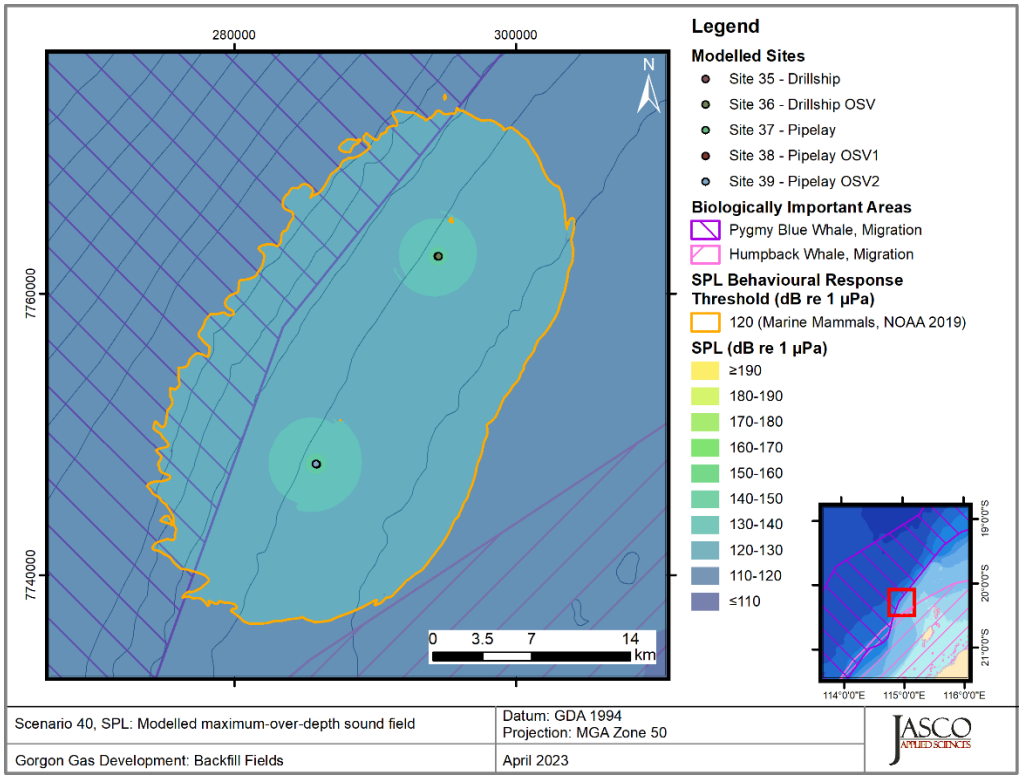


Figure 58. *Scenario 40, Combined scenario: Area 5 pipelay with OSVs and Area 5 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

4.2.2. Accumulated SEL_{24h} Sound Level Contour Maps

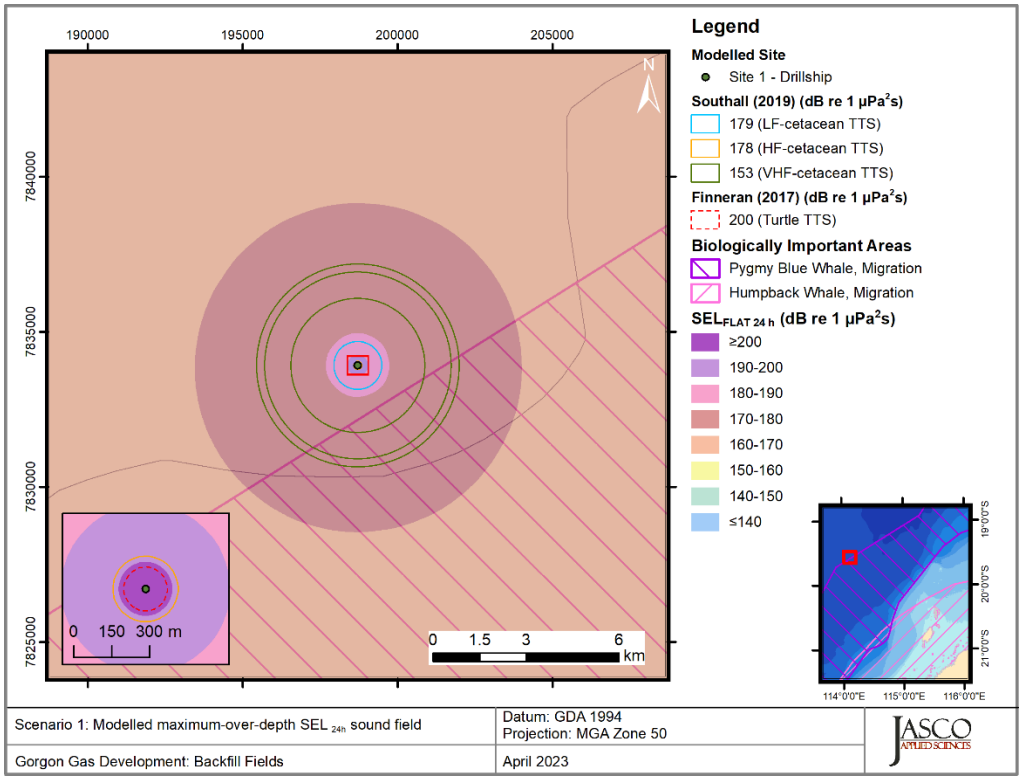


Figure 59. *Scenario 1, Area 1 Drillship*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

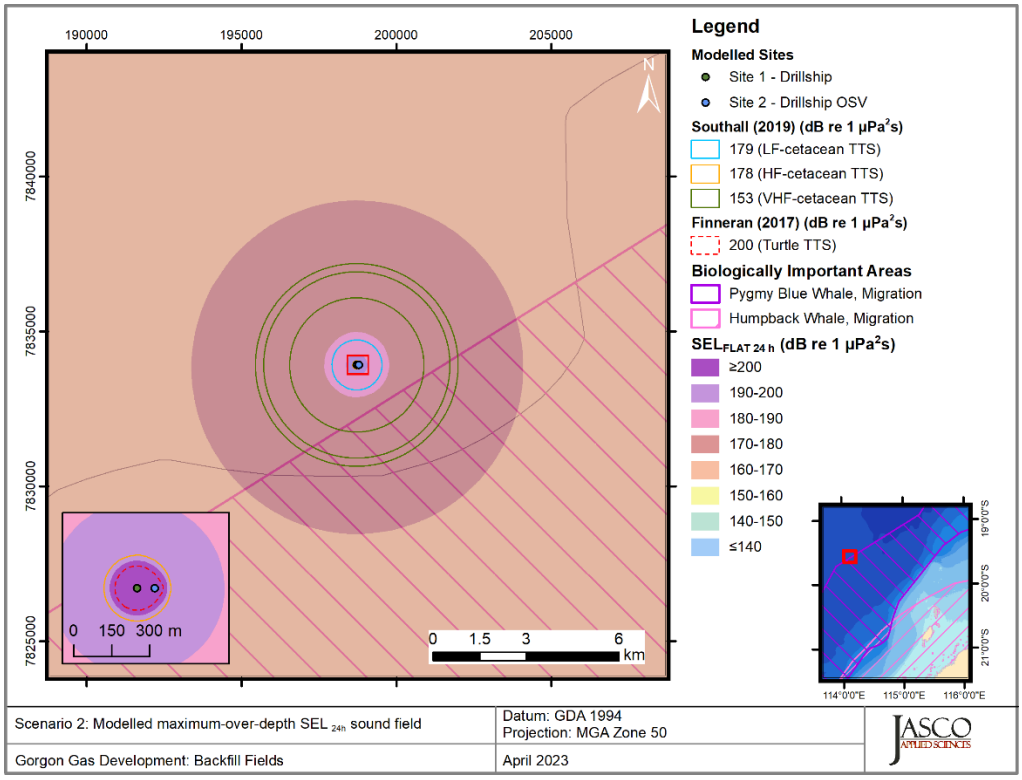


Figure 60. *Scenario 2, Area 1 Drillship with OSV*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

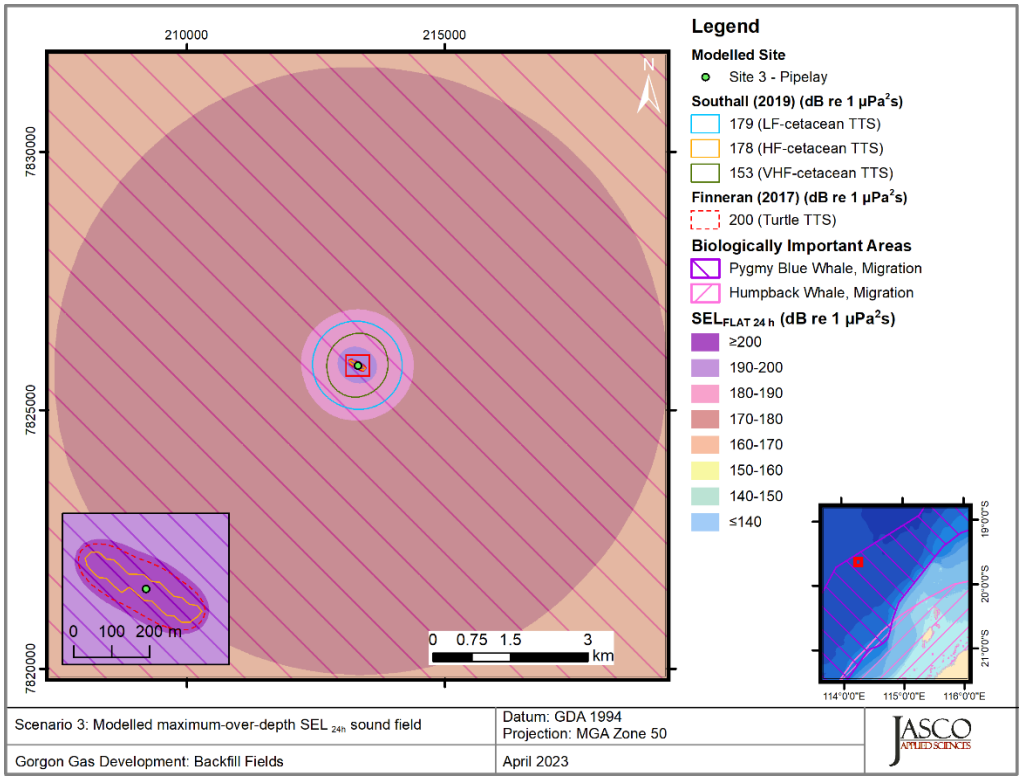


Figure 61. *Scenario 3, Area 1 Pipelay vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

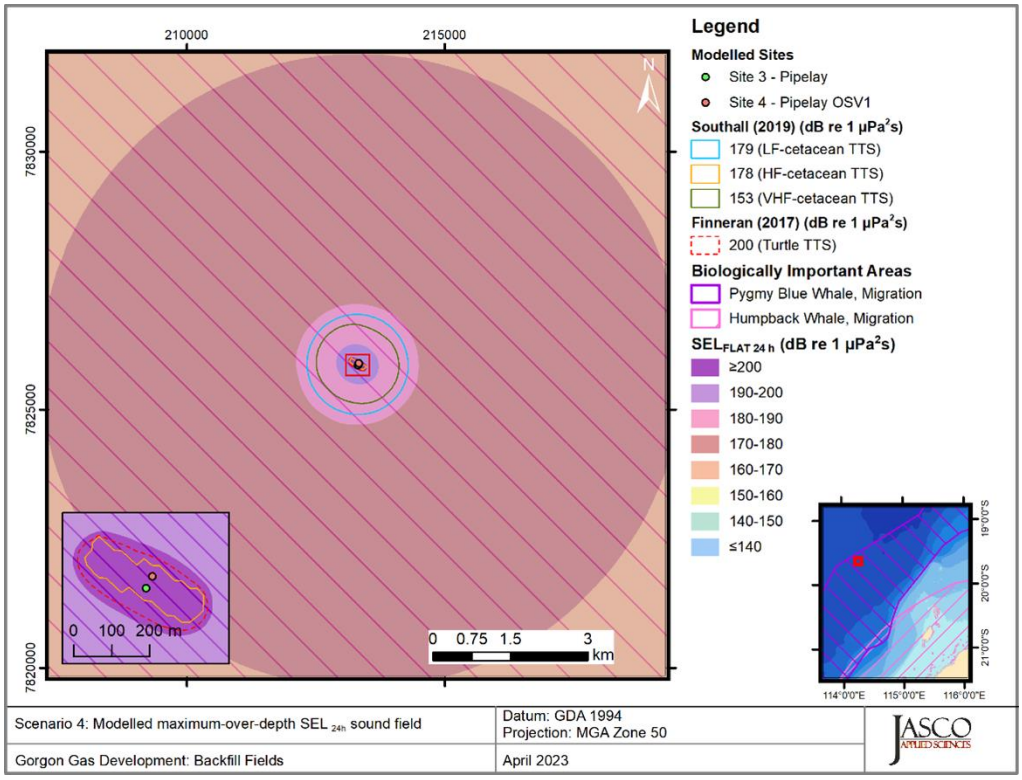


Figure 62. *Scenario 4, Area 1 Pipelay vessel with resupply OSV, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

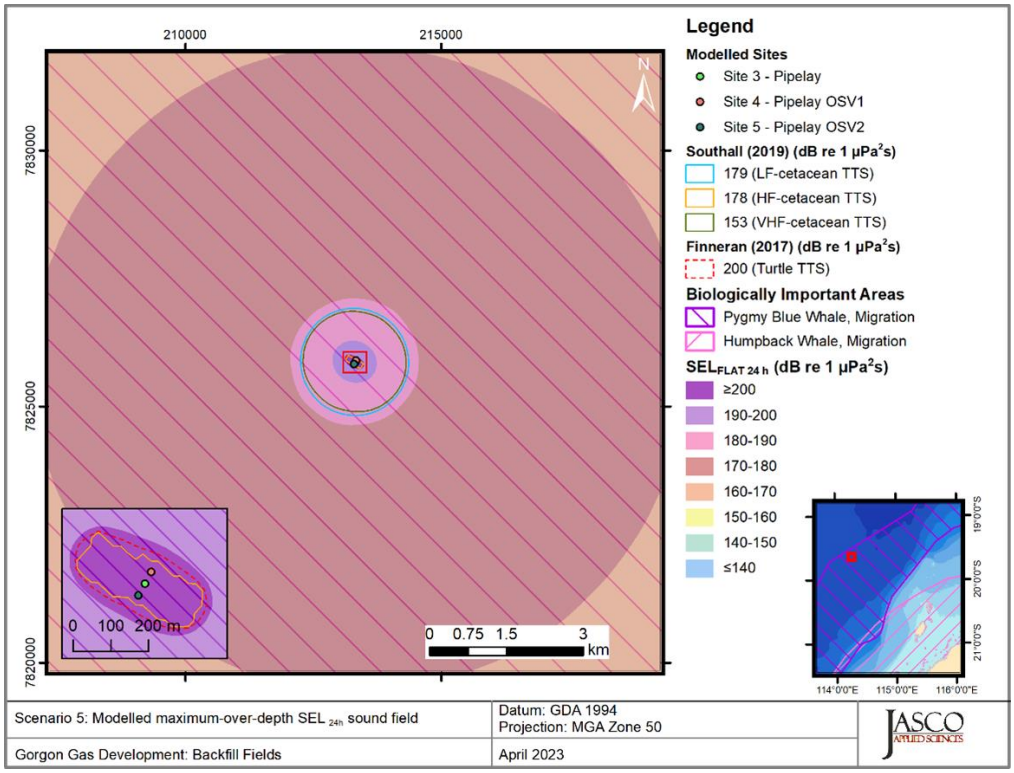


Figure 63. *Scenario 5, Area 1 Pipelay vessel with resupply OSV and support OSV, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

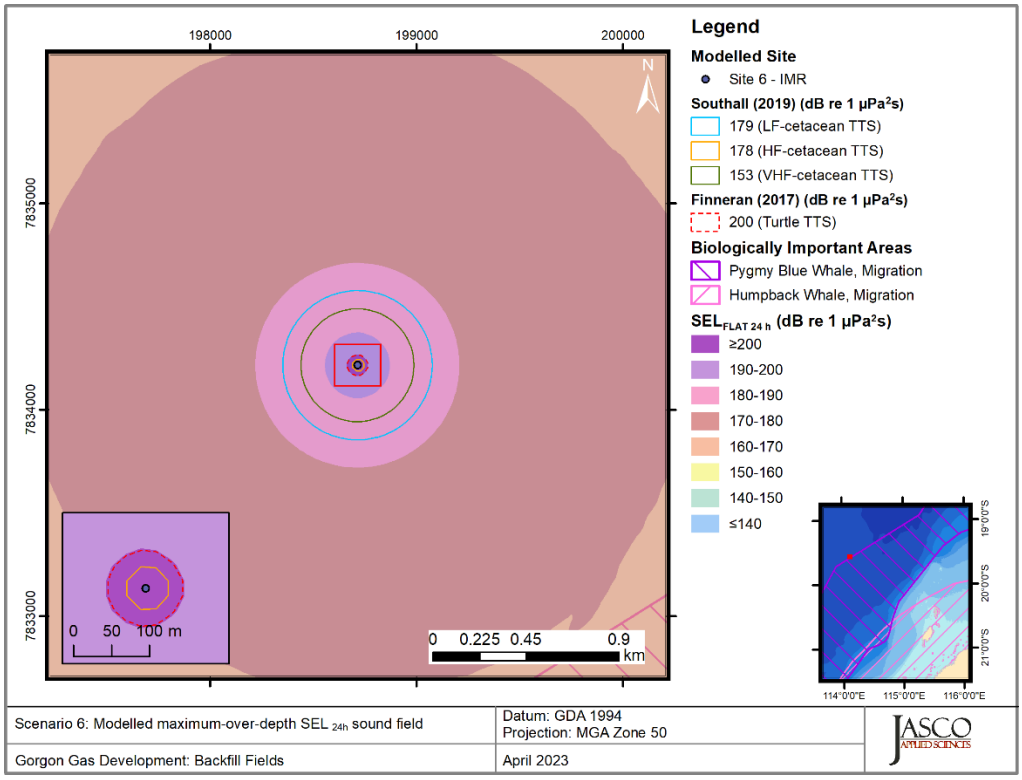


Figure 64. *Scenario 6, Area 1 IMR vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

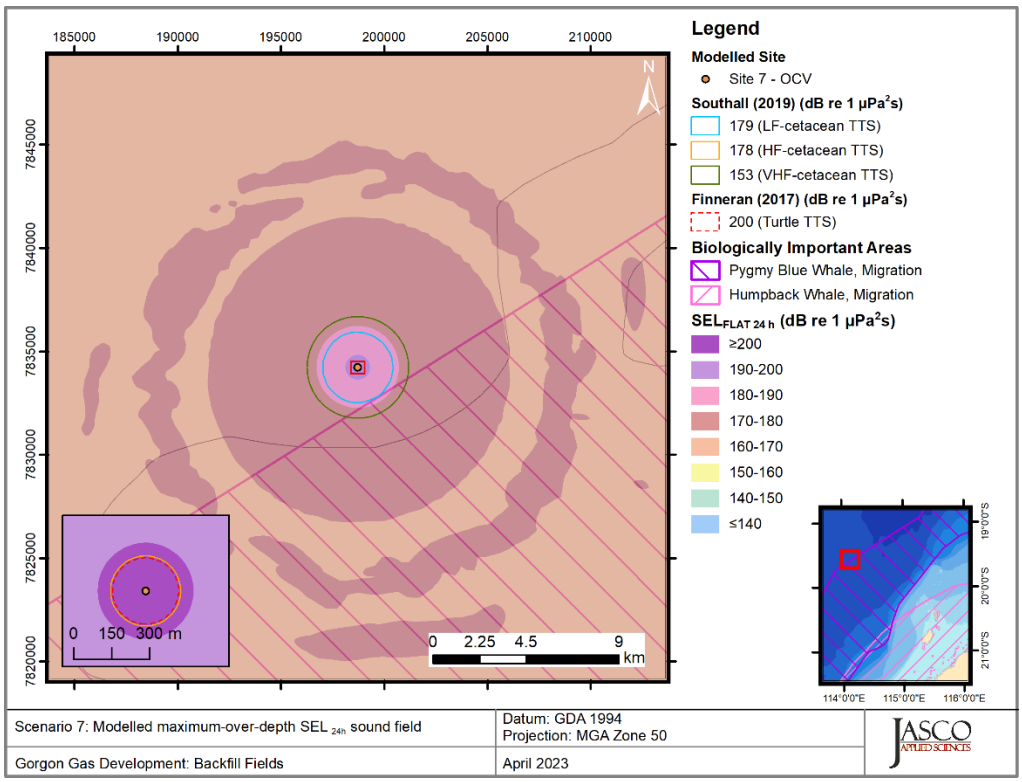


Figure 65. *Scenario 7, Area 1 OCV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

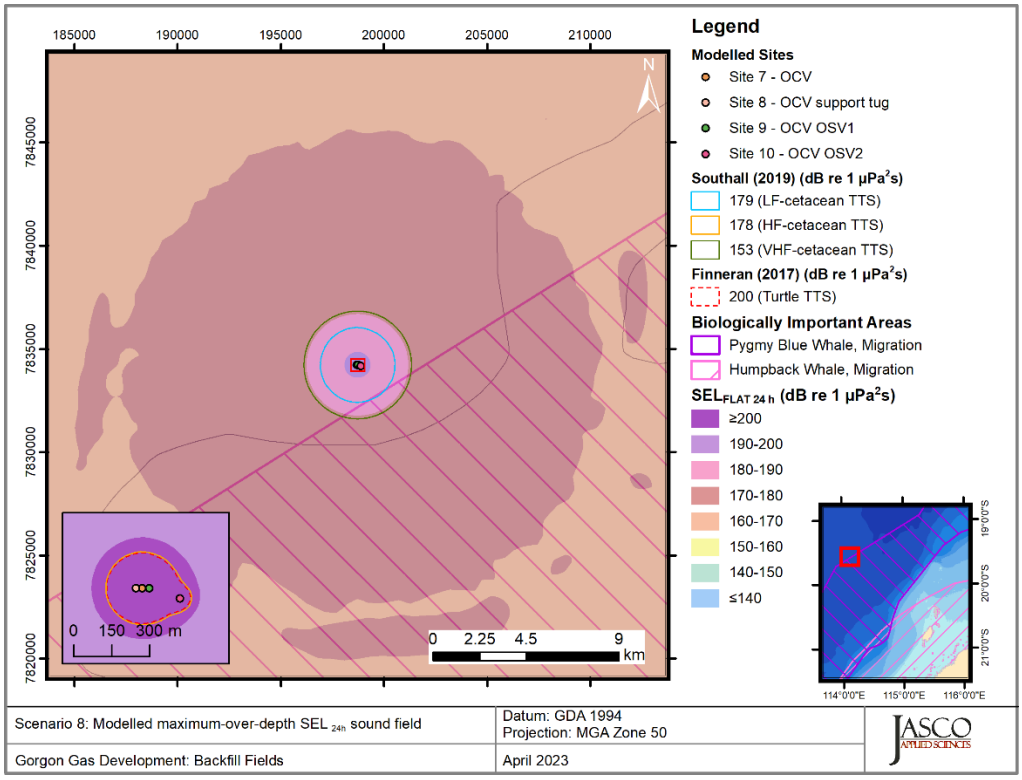


Figure 66. *Scenario 8, Area 1 OCV with three support vessels*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

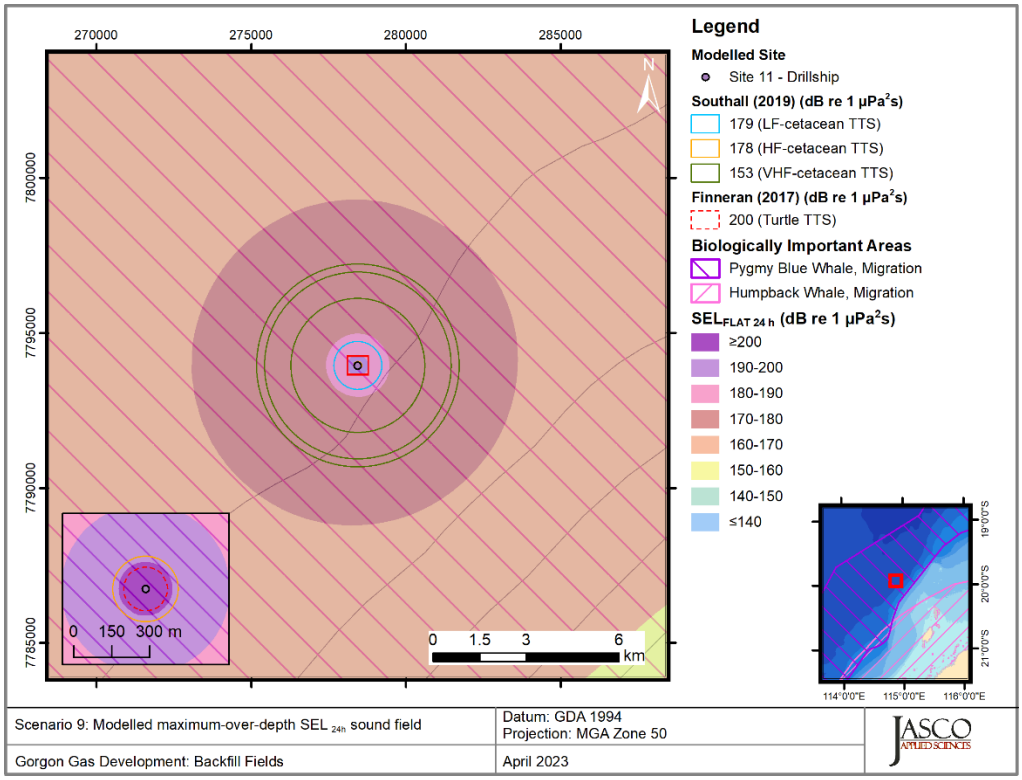


Figure 67. *Scenario 9, Area 2 Drillship*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

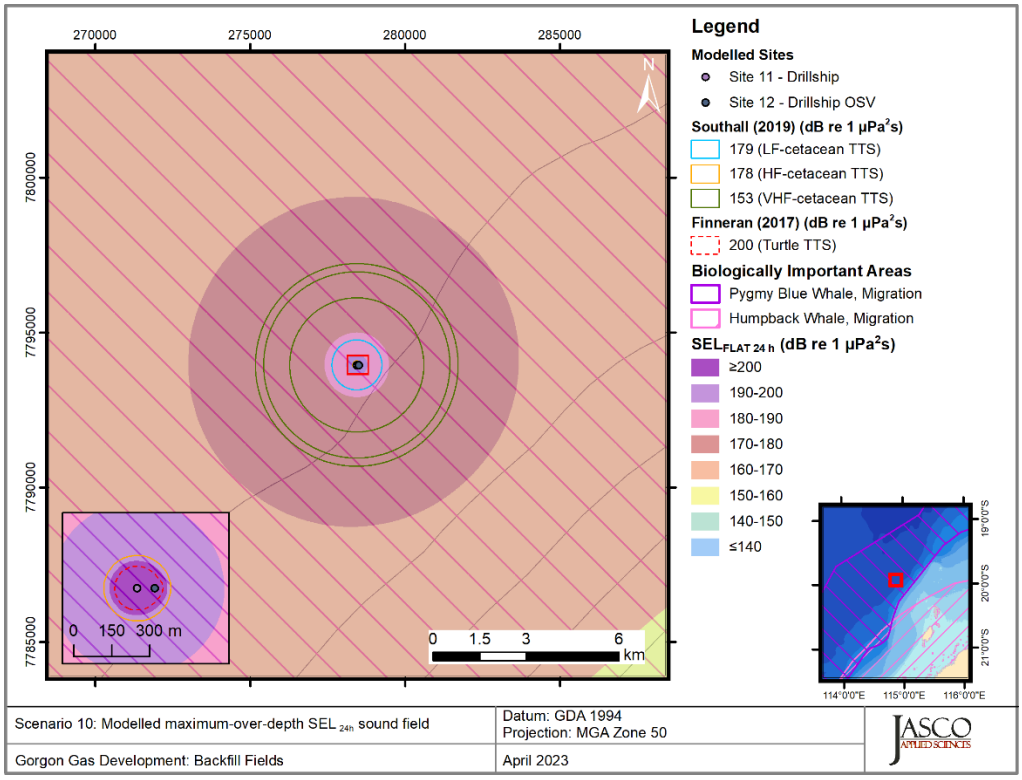


Figure 68. *Scenario 10, Area 2 Drillship with OSV*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

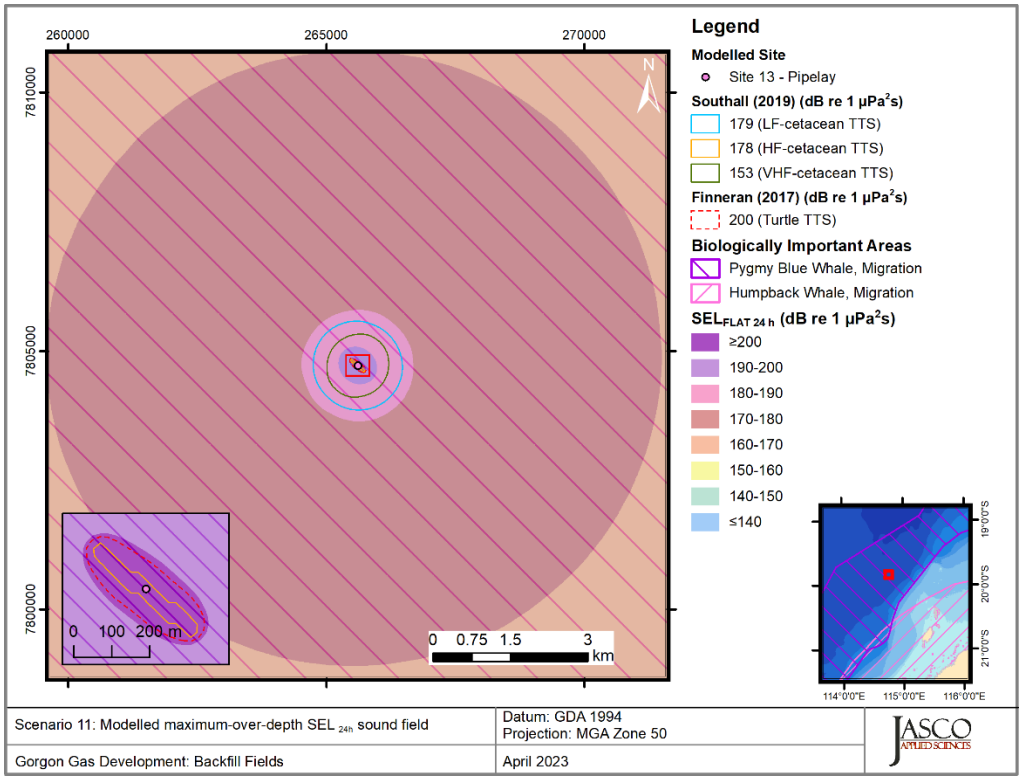


Figure 69. *Scenario 11, Area 2 Pipelay vessel*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

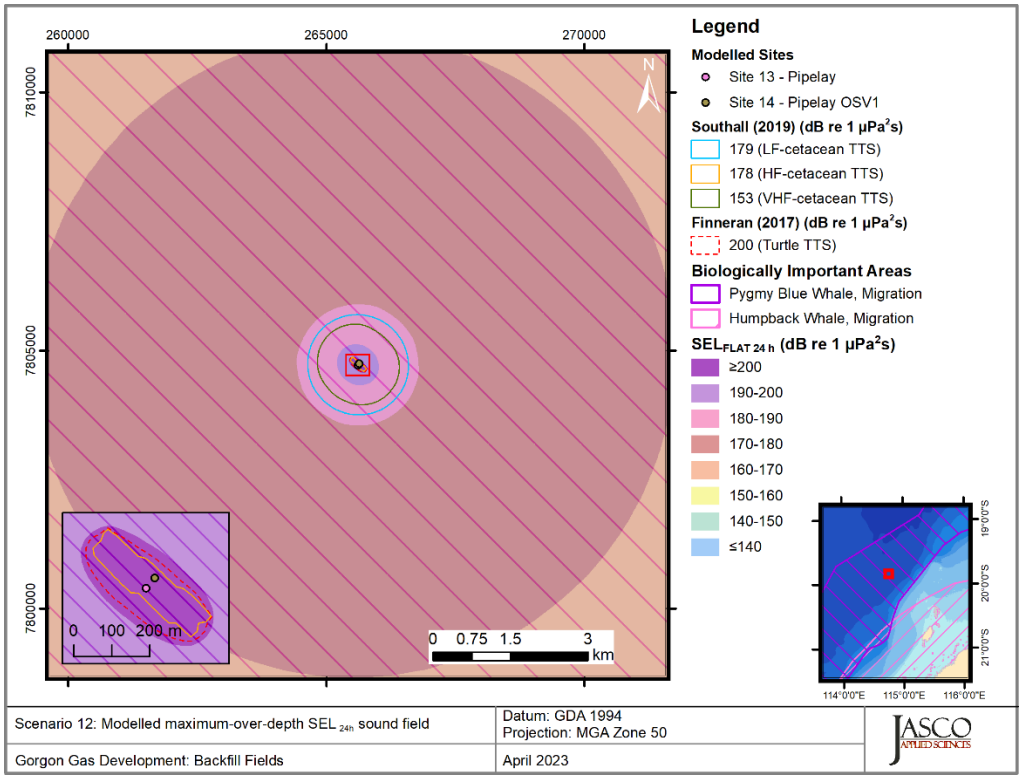


Figure 70. *Scenario 12, Area 2 Pipelay vessel with resupply OSV*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

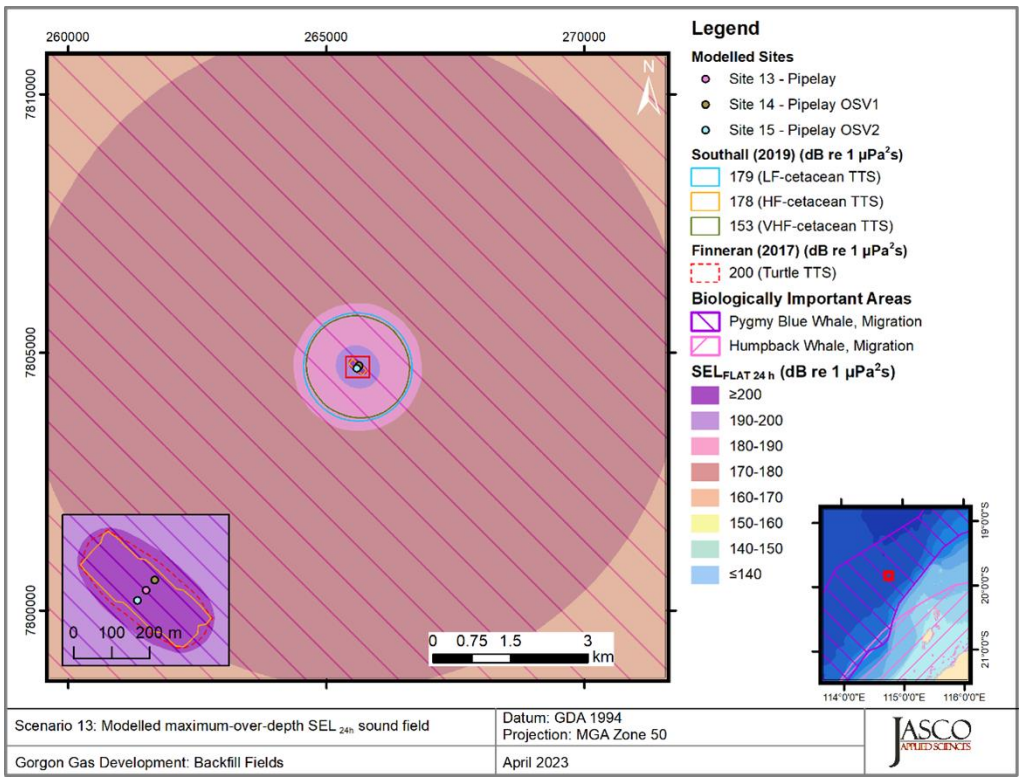


Figure 71. Scenario 13, Area 2 Pipelay vessel with resupply OSV and support OSV, SEL$_{24h}$: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

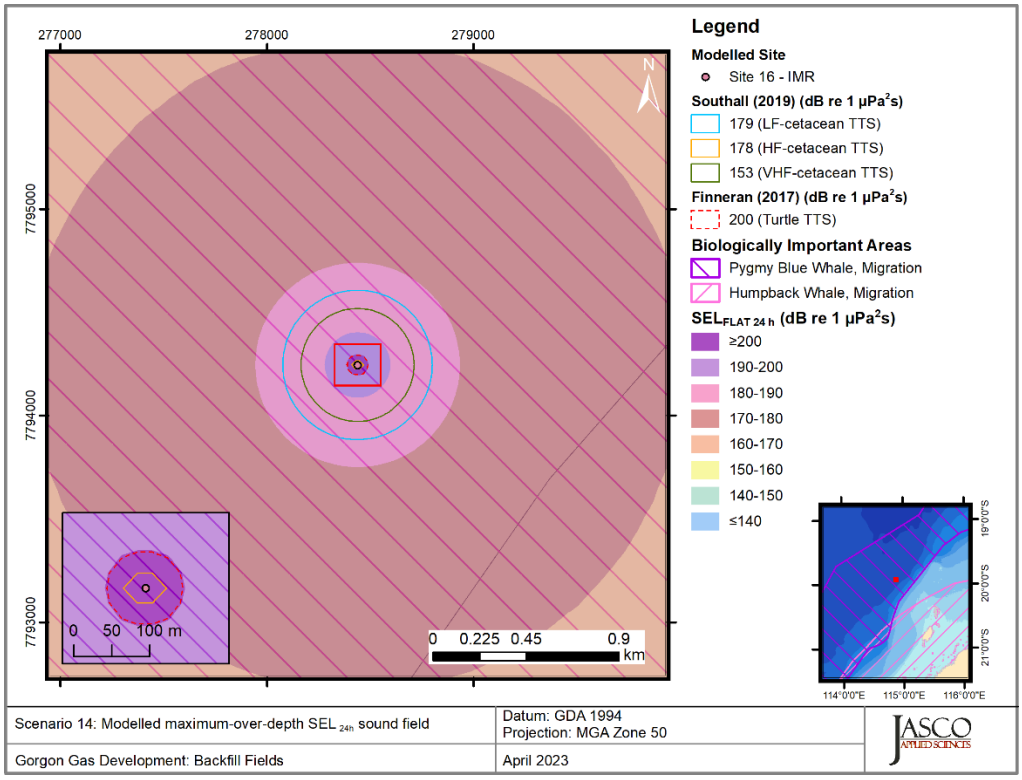


Figure 72. *Scenario 14, Area 2 IMR vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

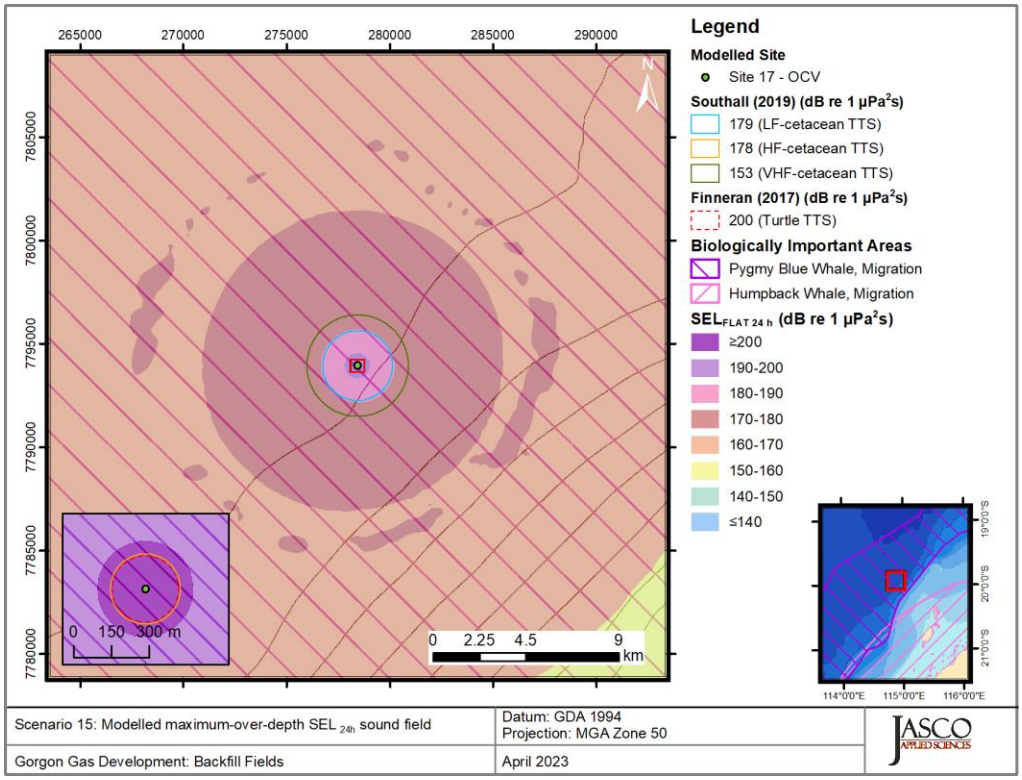


Figure 73. *Scenario 15, Area 2 OCV, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

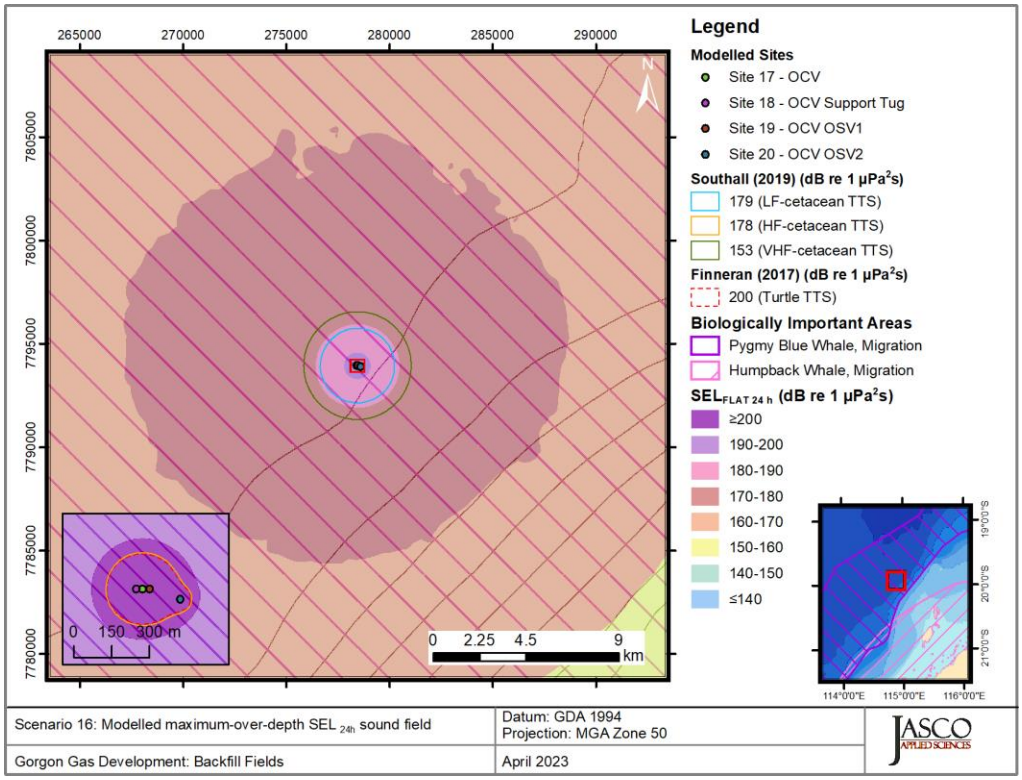


Figure 74. *Scenario 16, Area 2 OCV with three support vessels*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

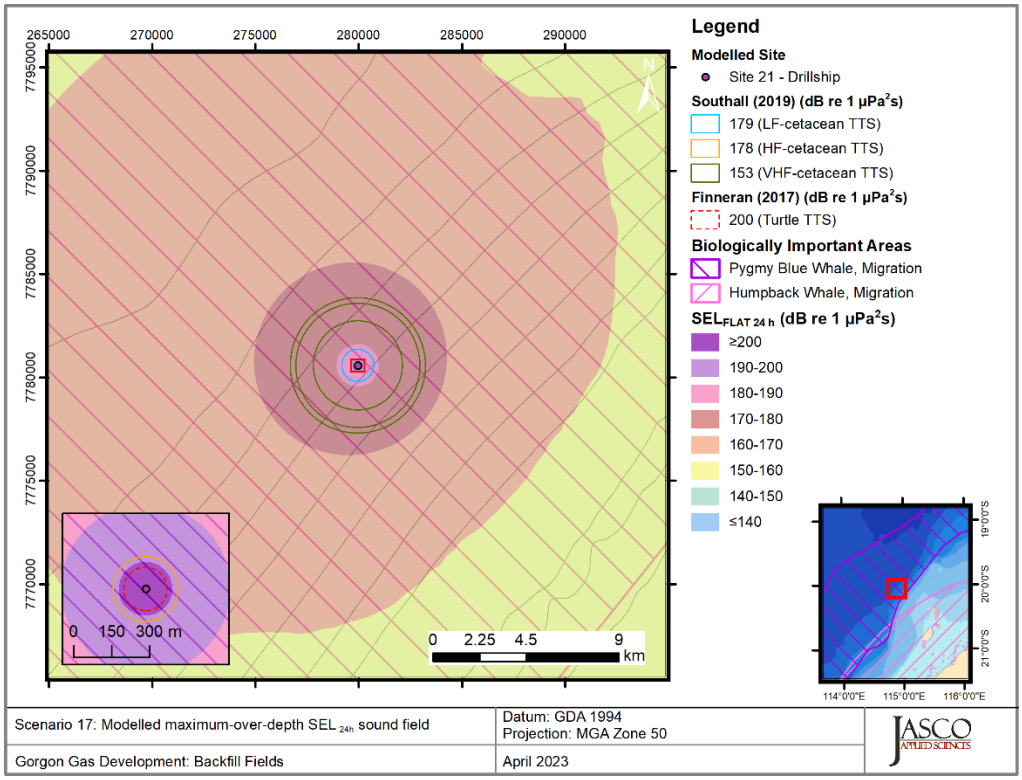


Figure 75. *Scenario 17, Area 3 Drillship*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

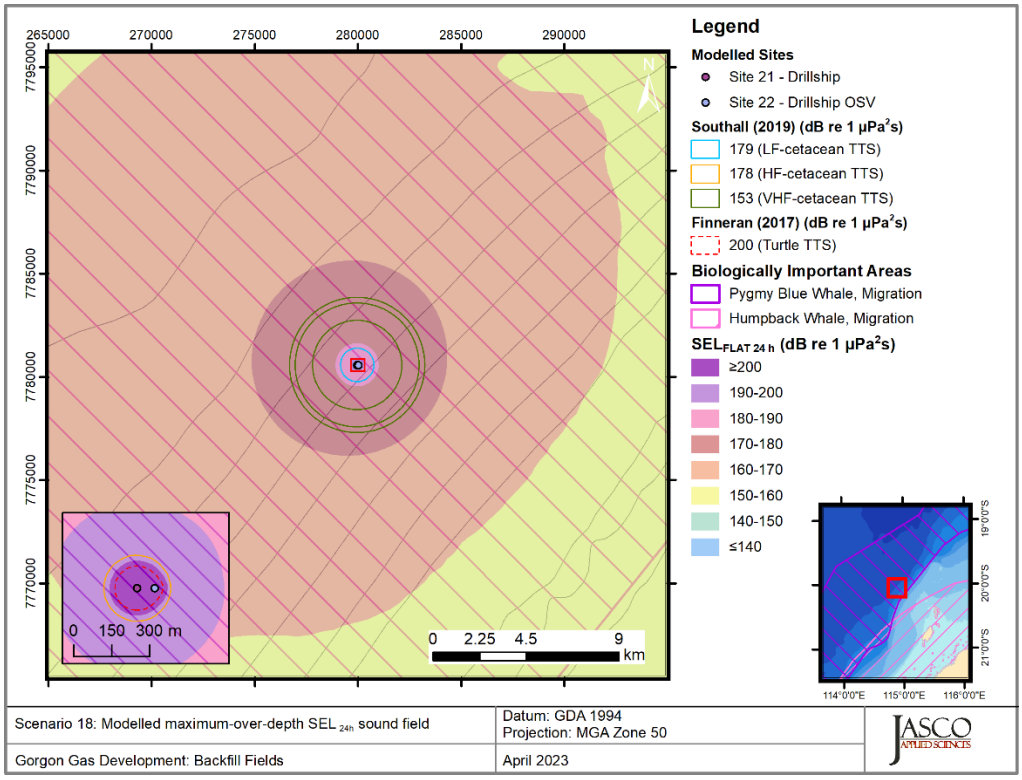


Figure 76. Scenario 18, Area 3 Drillship with OSV, SEL24h: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

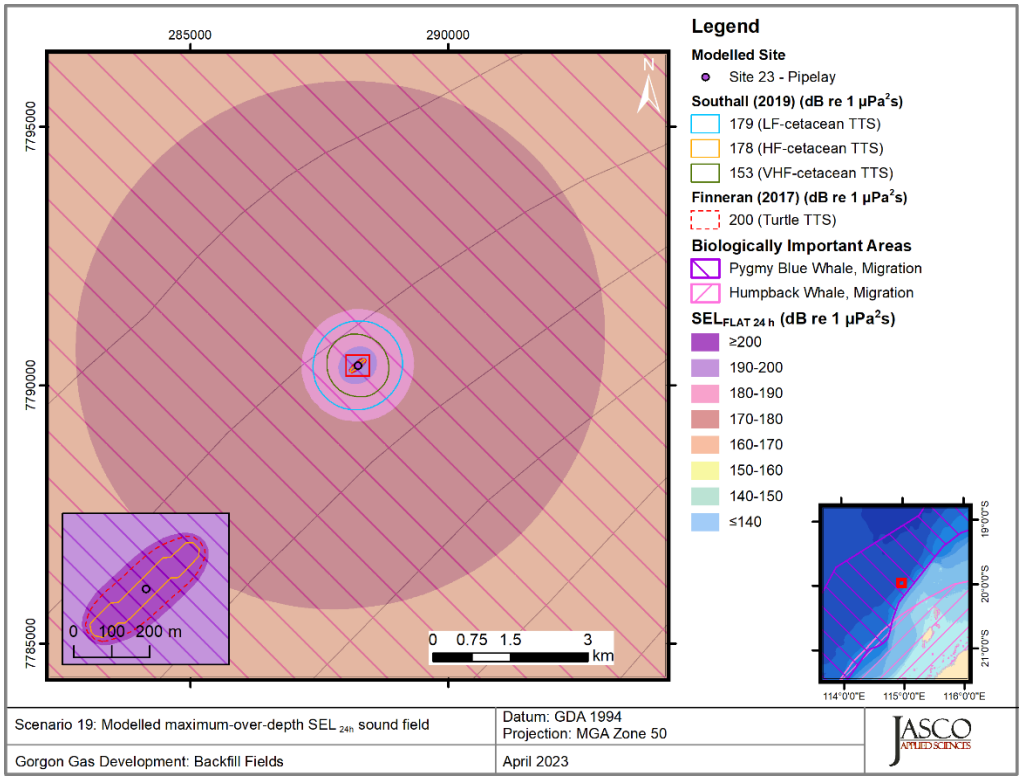


Figure 77. *Scenario 19, Area 3 Pipelay vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

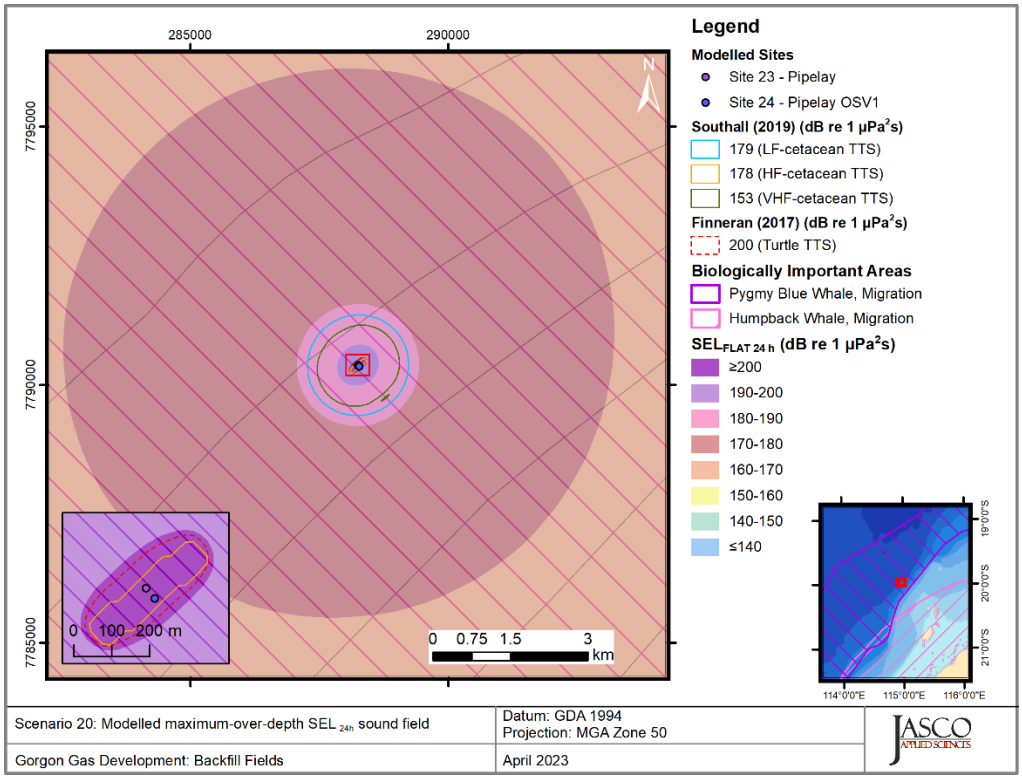


Figure 78. *Scenario 20, Area 3 Pipelay vessel with resupply OSV*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

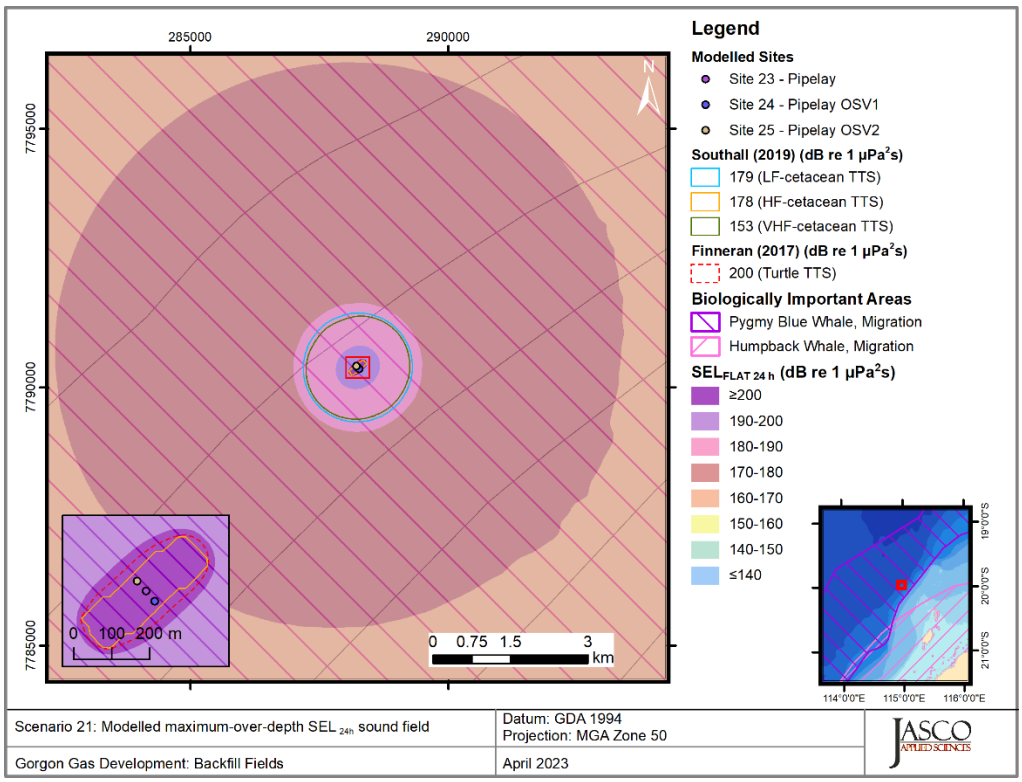


Figure 79. Scenario 21, Area 3 Pipelay vessel with resupply OSV and support OSV, SEL$_{24h}$: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

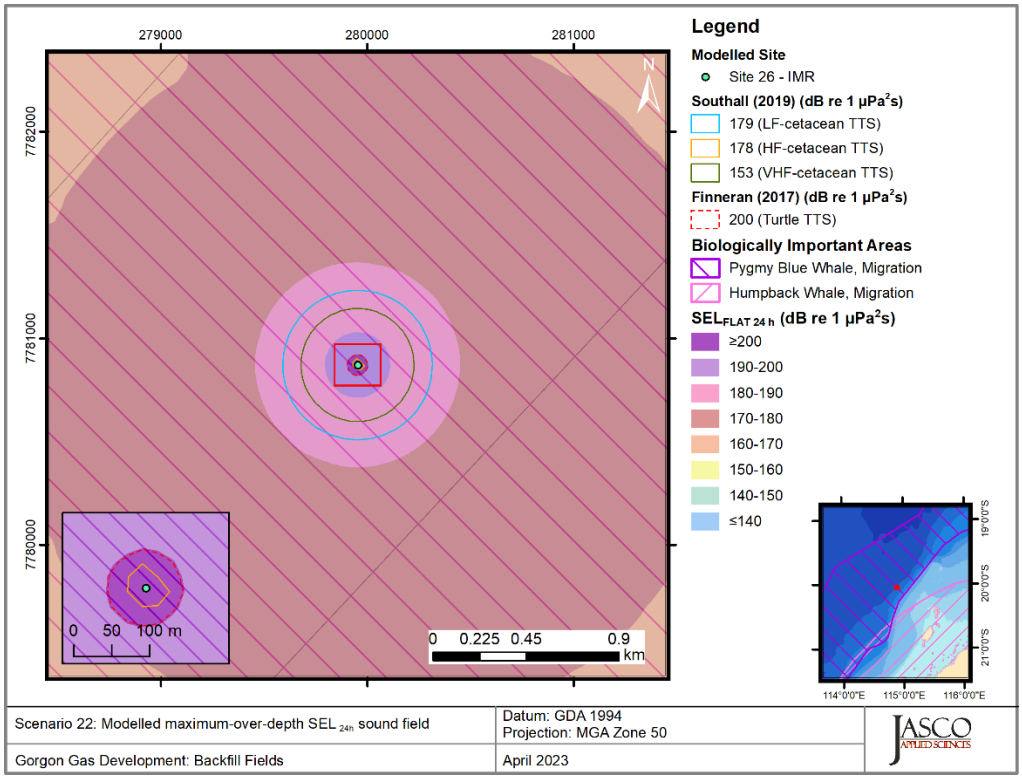


Figure 80. *Scenario 22, Area 3 IMR vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

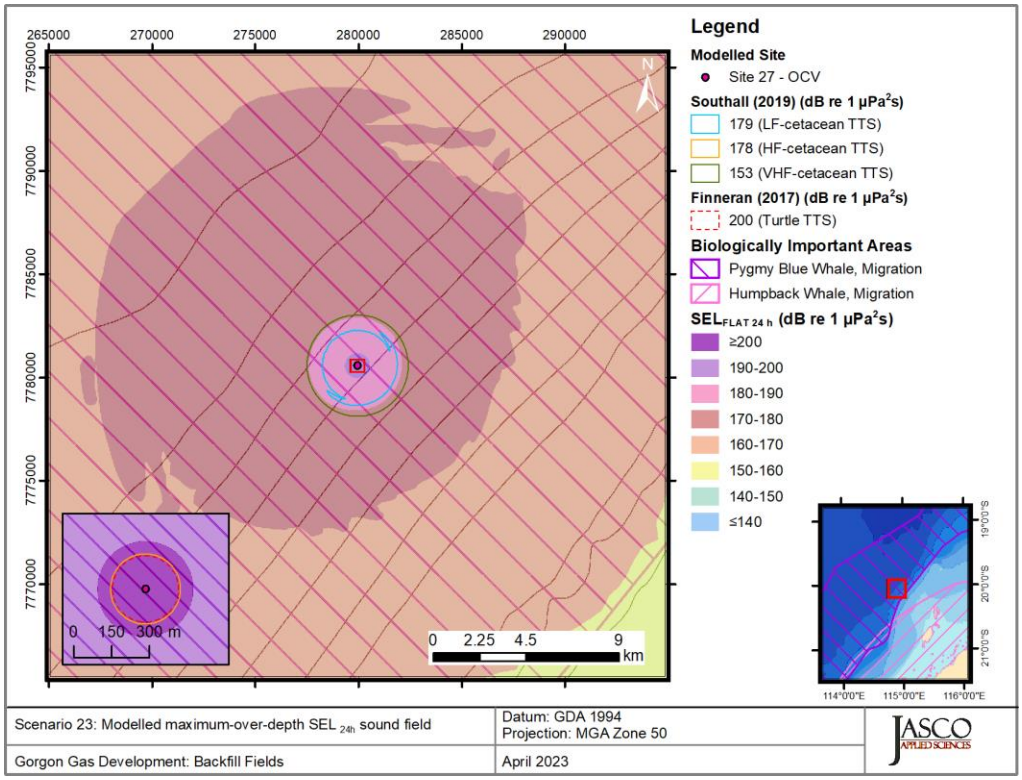


Figure 81. *Scenario 23, Area 3 OCV, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

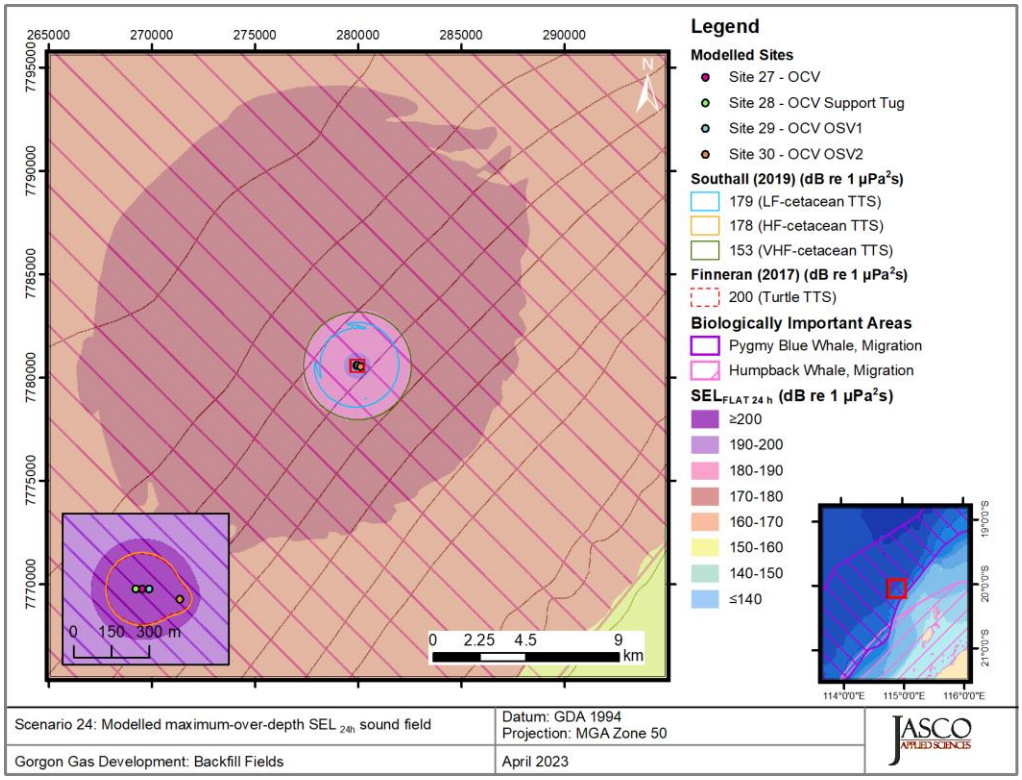


Figure 82. *Scenario 24, Area 3 OCV with three support vessels*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

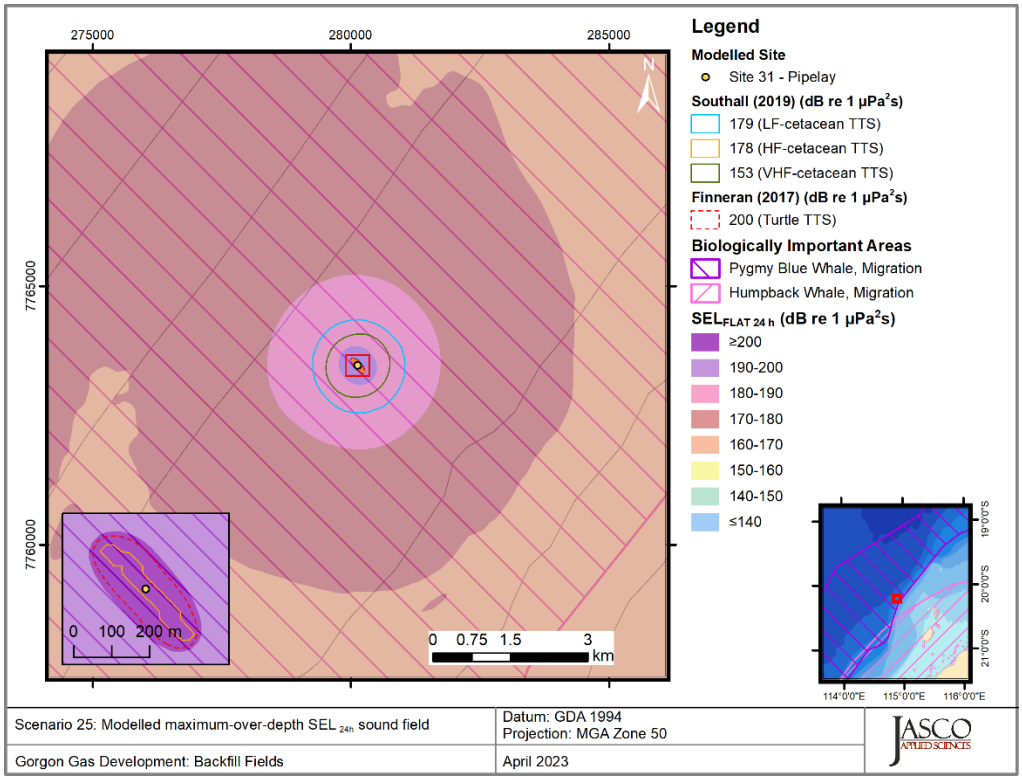


Figure 83. *Scenario 25, Area 4 Pipelay vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

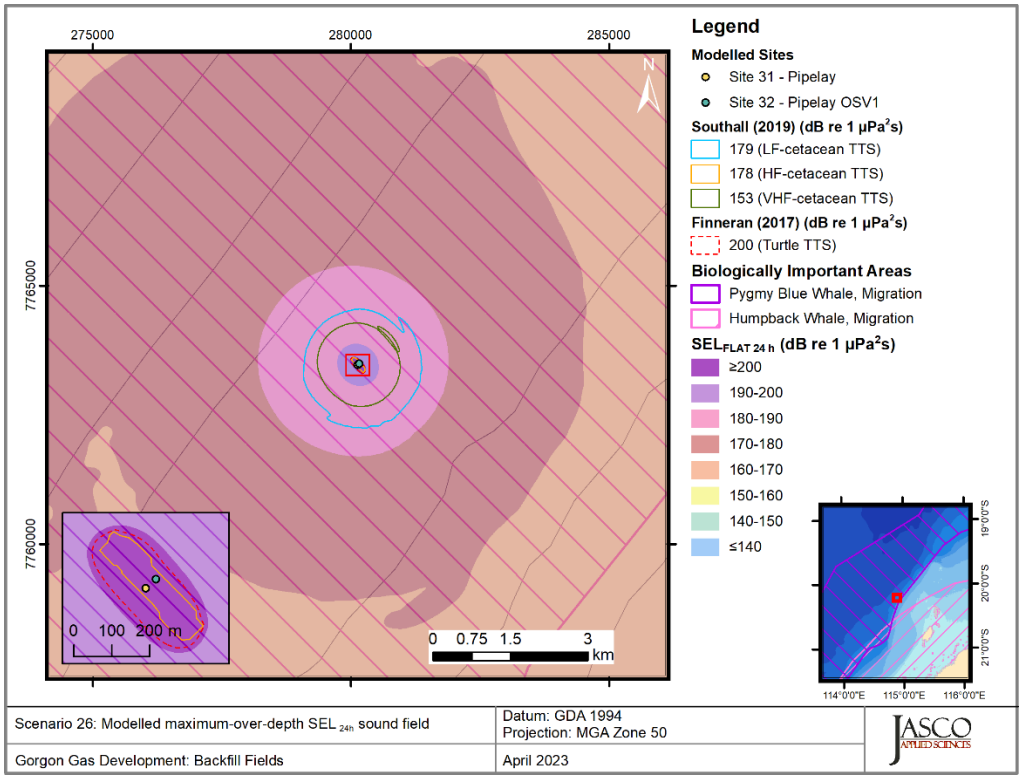


Figure 84. *Scenario 26, Area 4 Pipelay vessel with resupply OSV*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

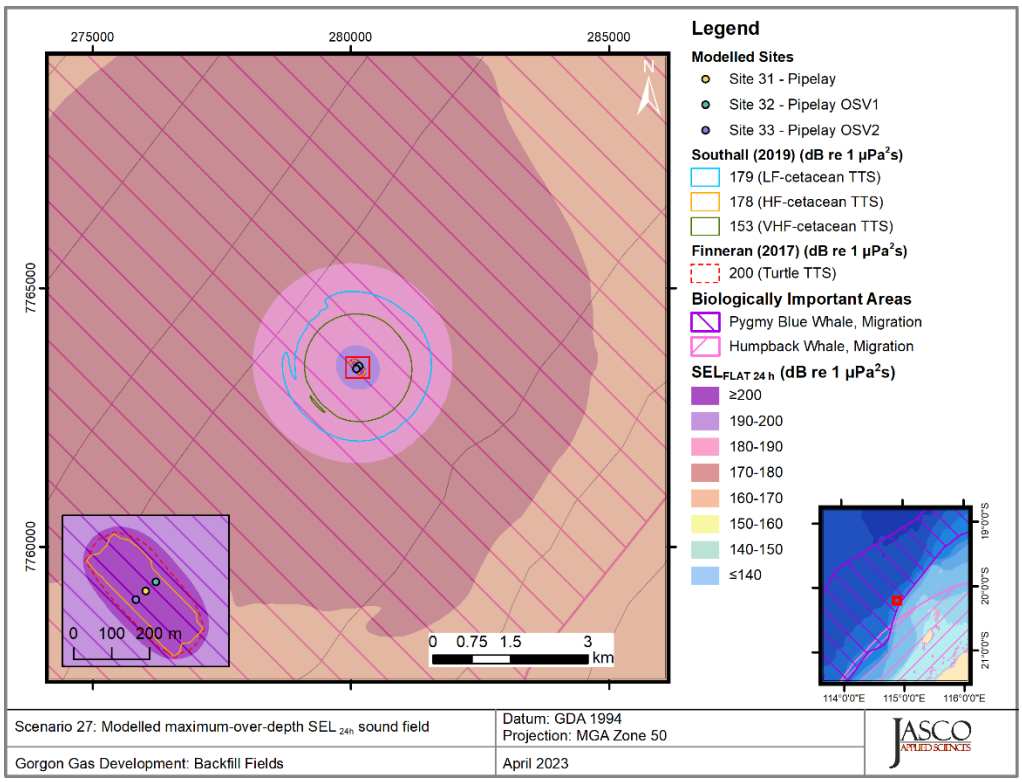


Figure 85. Scenario 27, Area 4 Pipelay vessel with resupply OSV and support OSV, SEL$_{24h}$: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

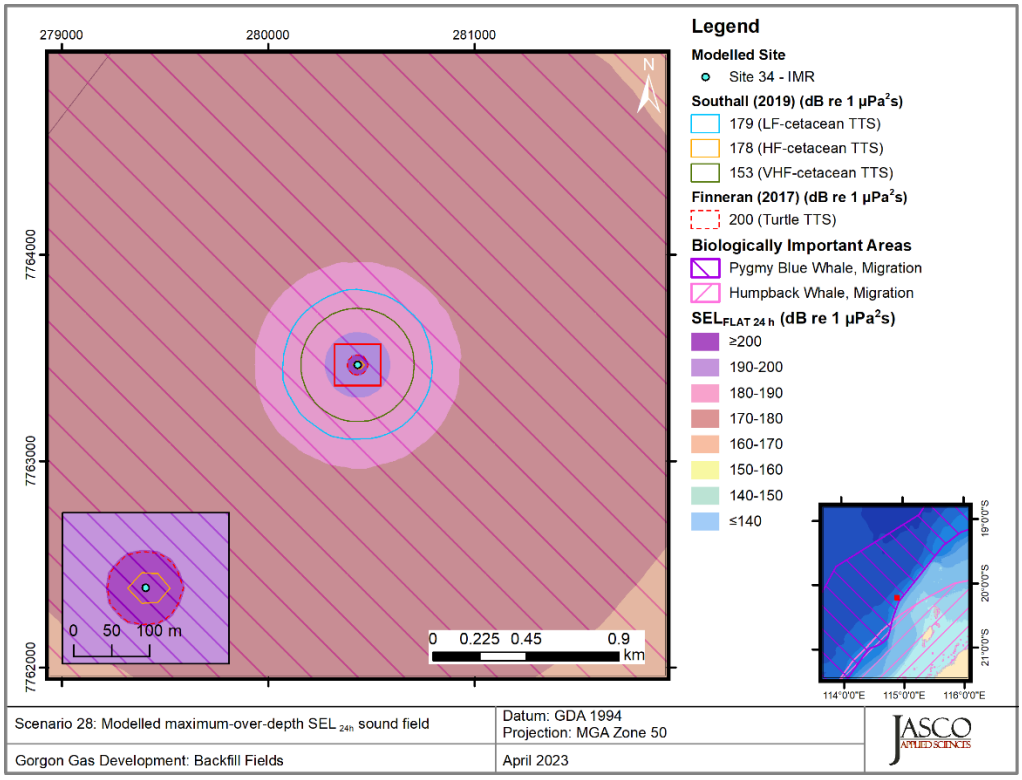


Figure 86. *Scenario 28, Area 4 IMR vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

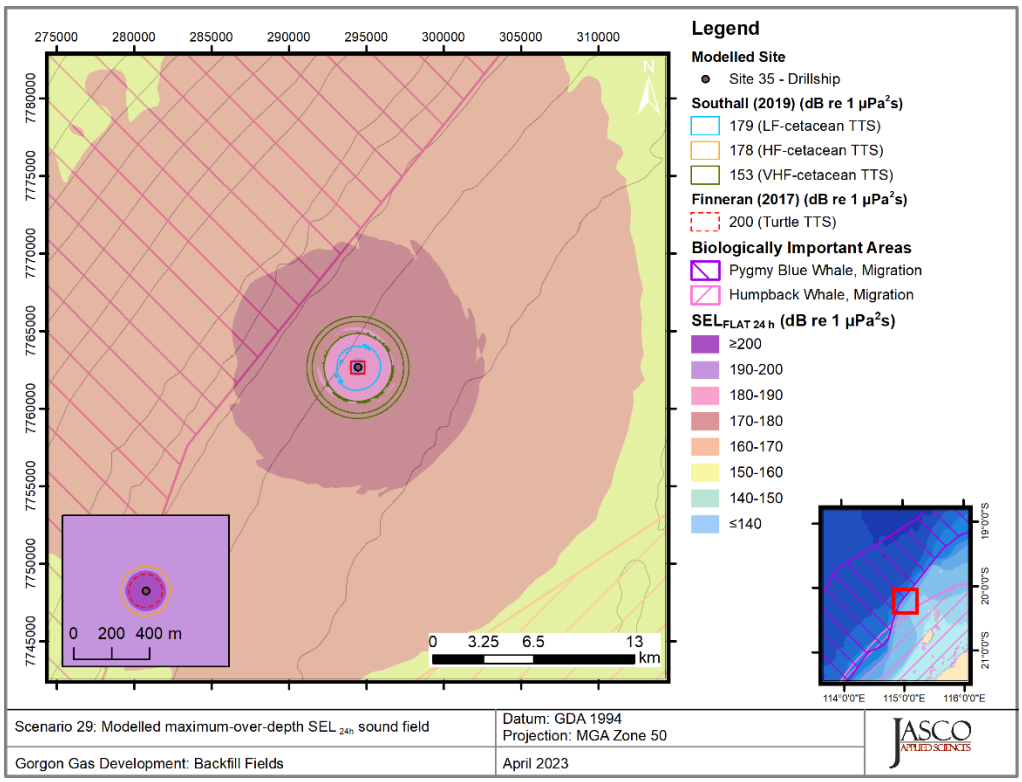


Figure 87. *Scenario 29, Area 5 Drillship*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

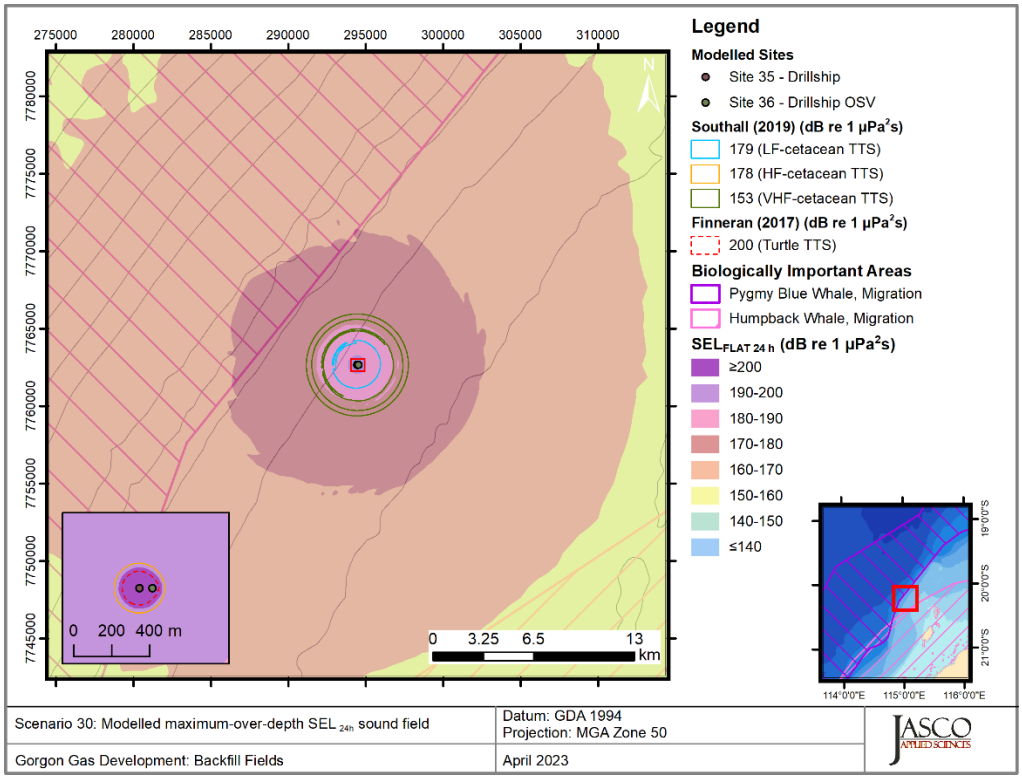


Figure 88. *Scenario 30, Area 5 Drillship with OSV*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

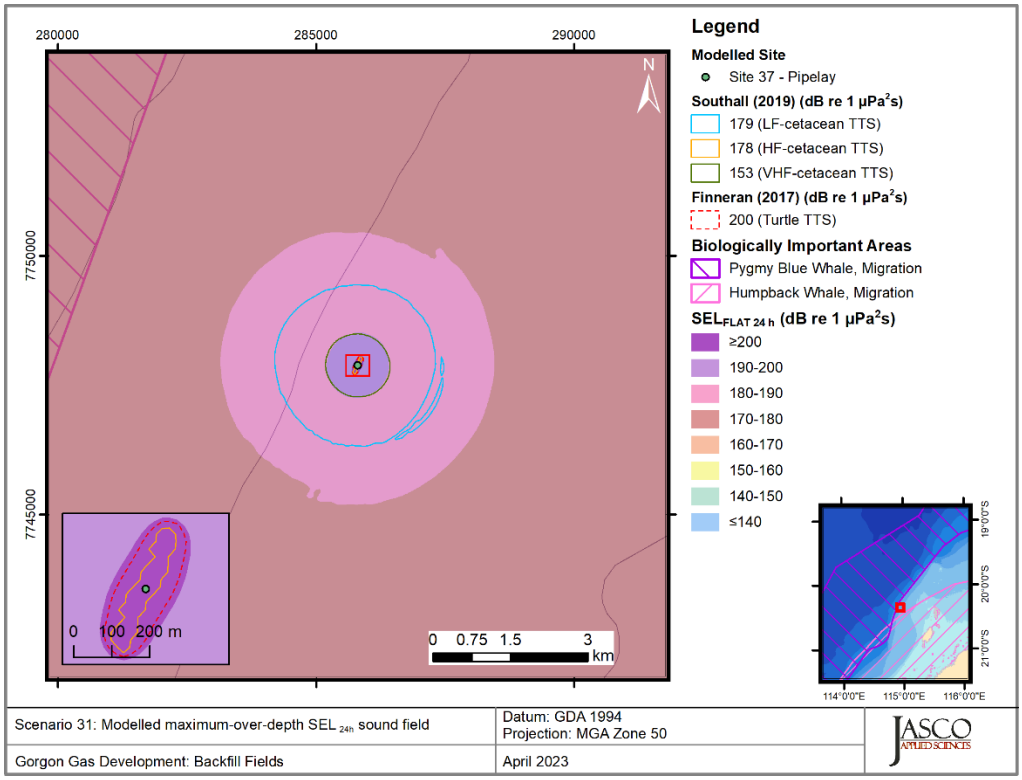


Figure 89. *Scenario 31, Area 5 Pipelay vessel*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

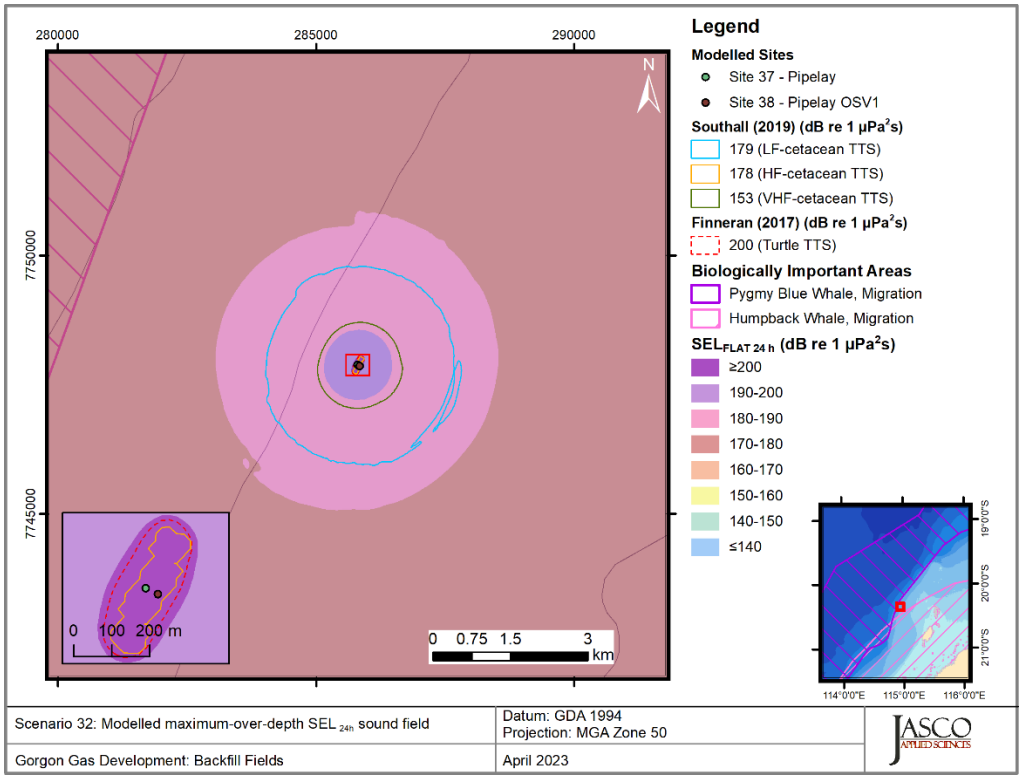


Figure 90. *Scenario 32, Area 5 Pipelay vessel with resupply OSV, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

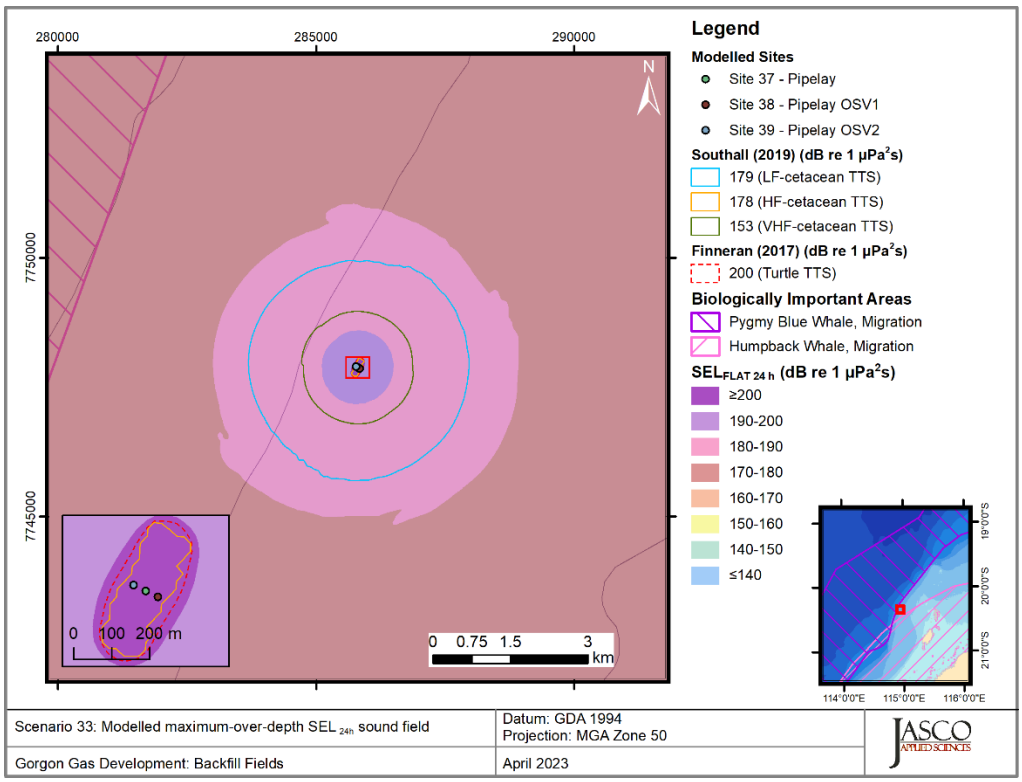


Figure 91. Scenario 33, Area 5 Pipelay vessel with resupply OSV and support OSV, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

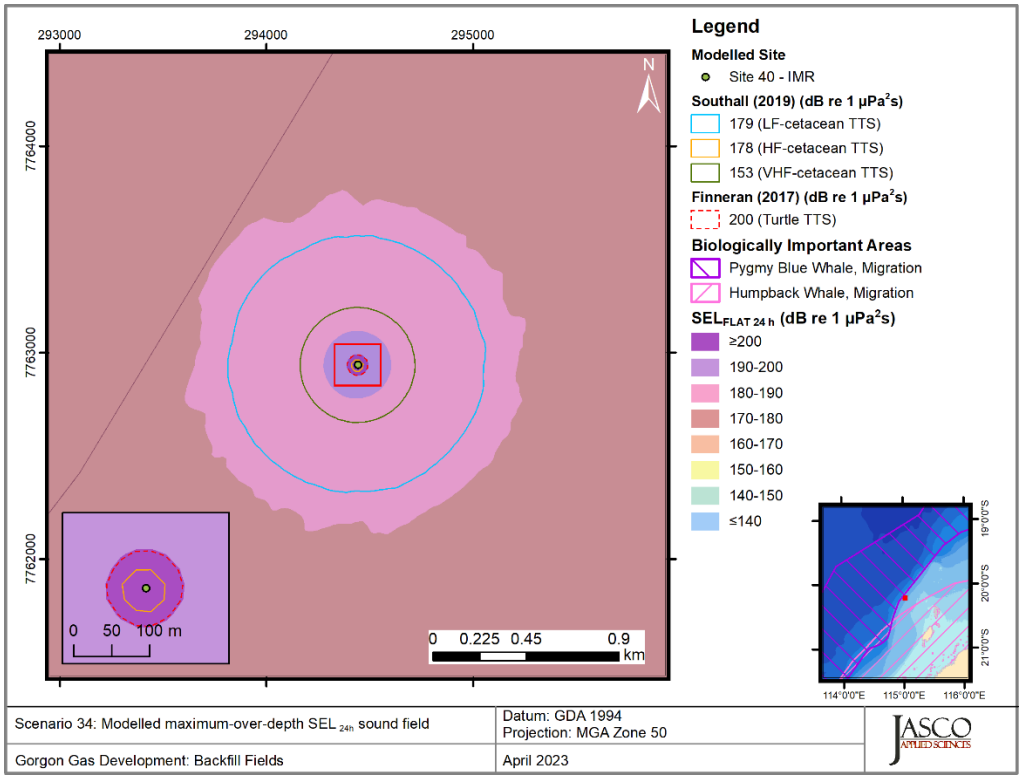


Figure 92. *Scenario 34, Area 5 IMR vessel*, *SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

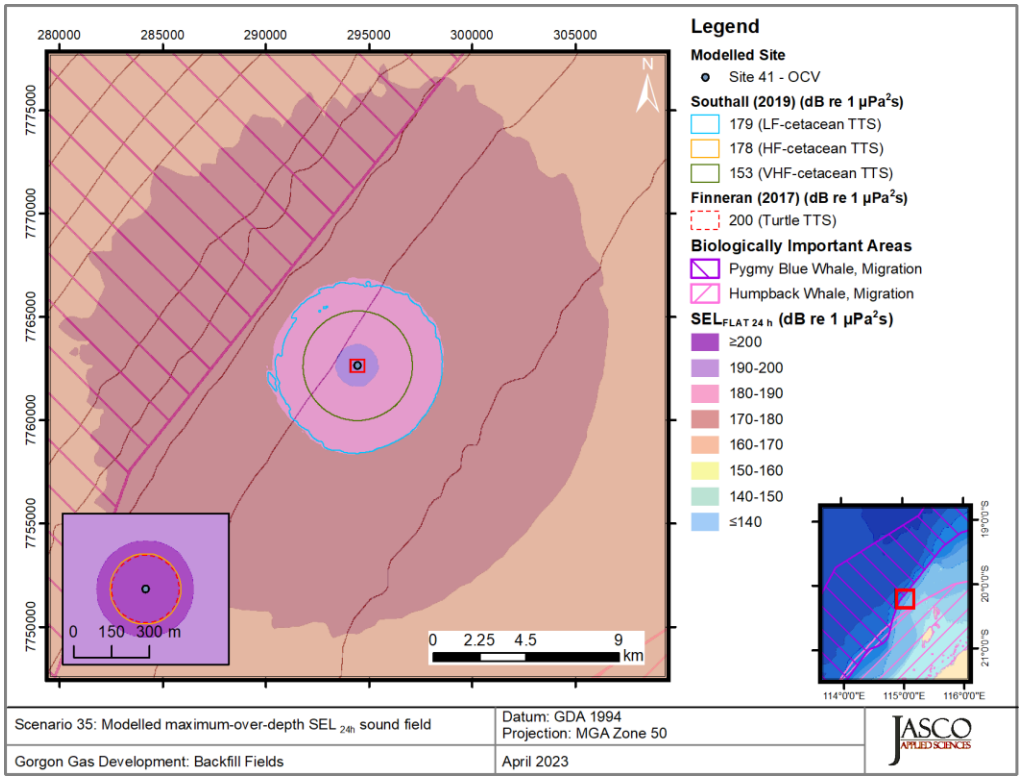


Figure 93. *Scenario 35, Area 5 OCV, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

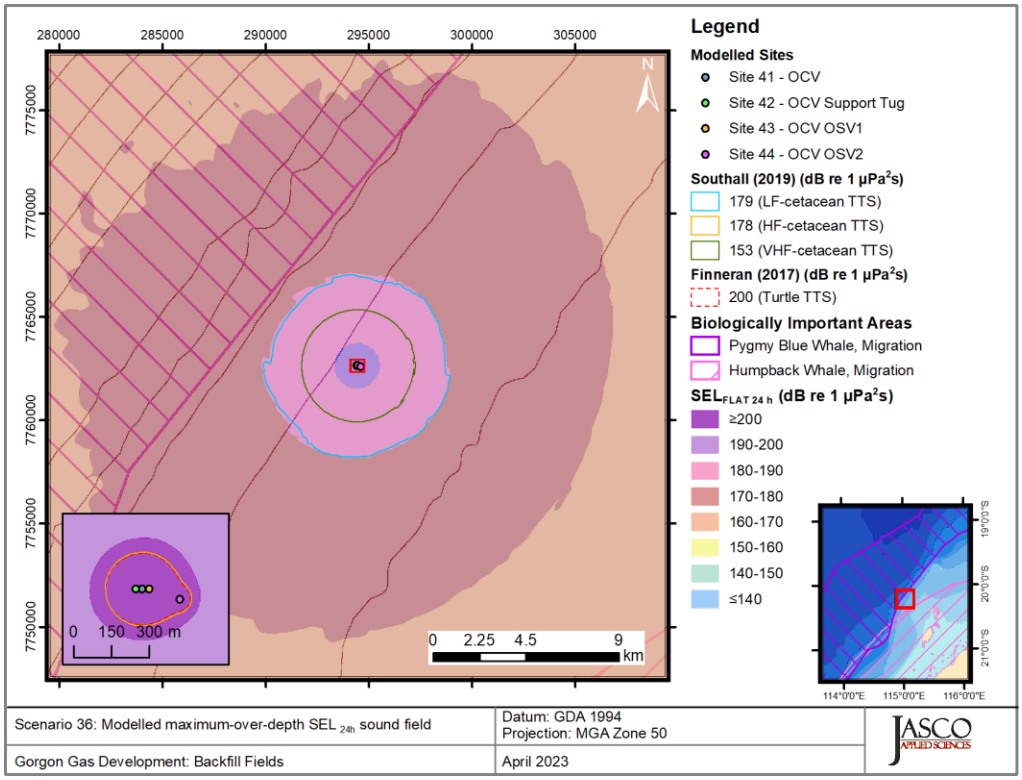


Figure 94. *Scenario 36, Area 5 OCV with three support vessels*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

4.3. Vertical Slice Plots

Vertical slice plots (Figures 95 to 99) are provided to illustrate the underwater propagation of the most significant noise source in each of the five Areas. In Areas 1, 2, 3 and 5, the most significant noise is the OCV; as the OCV was not modelled in Area 4, the pipelay vessel is illustrated.

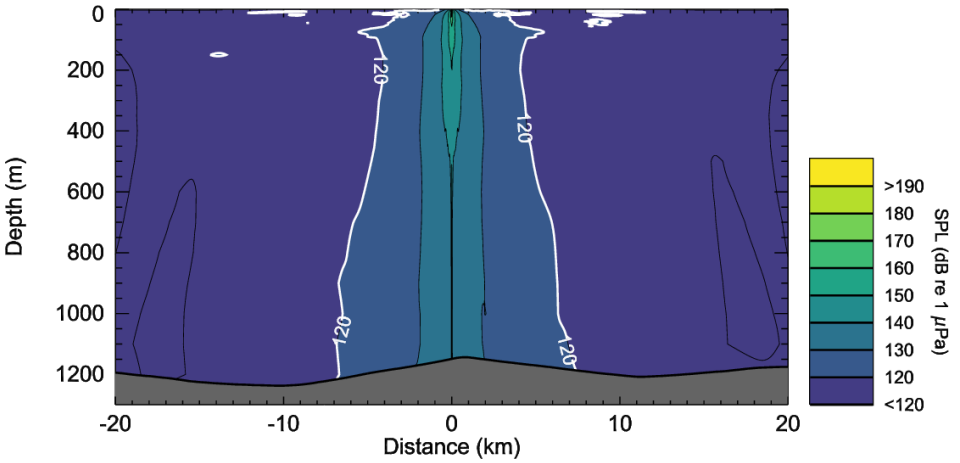


Figure 95. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 1 (Site 7).

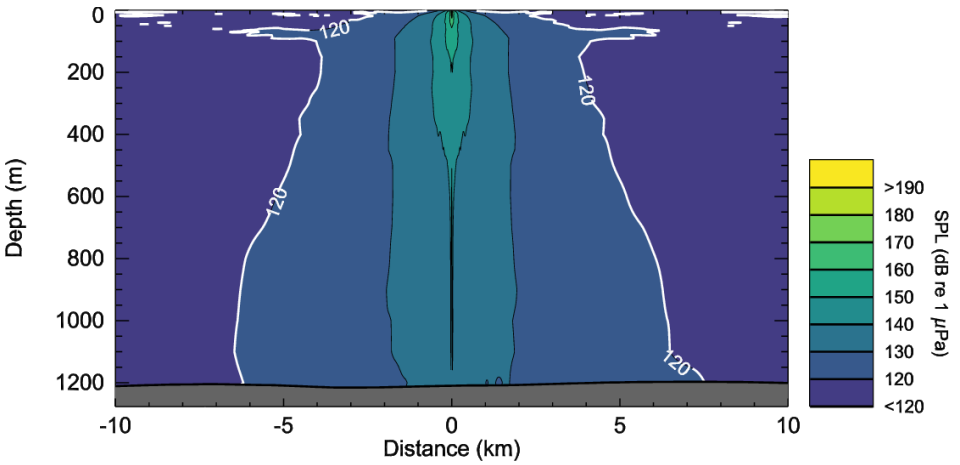


Figure 96. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 2 (Site 17).

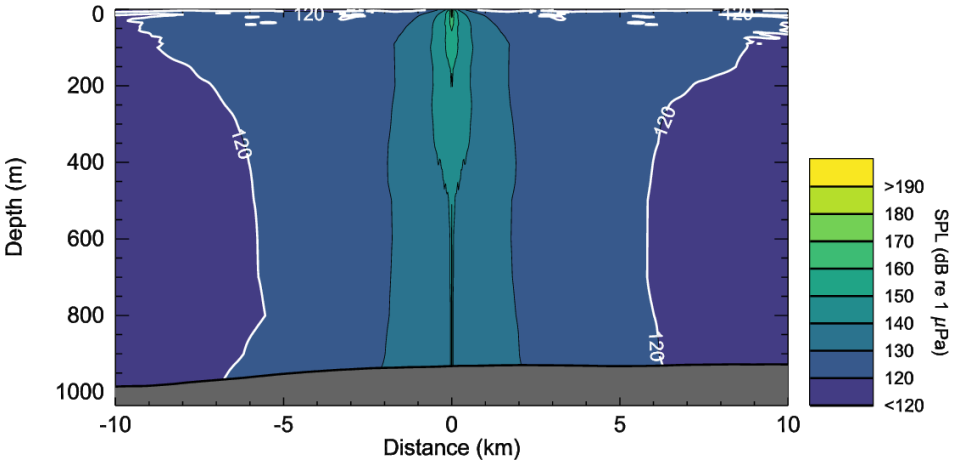


Figure 97. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 3 (Site 27).

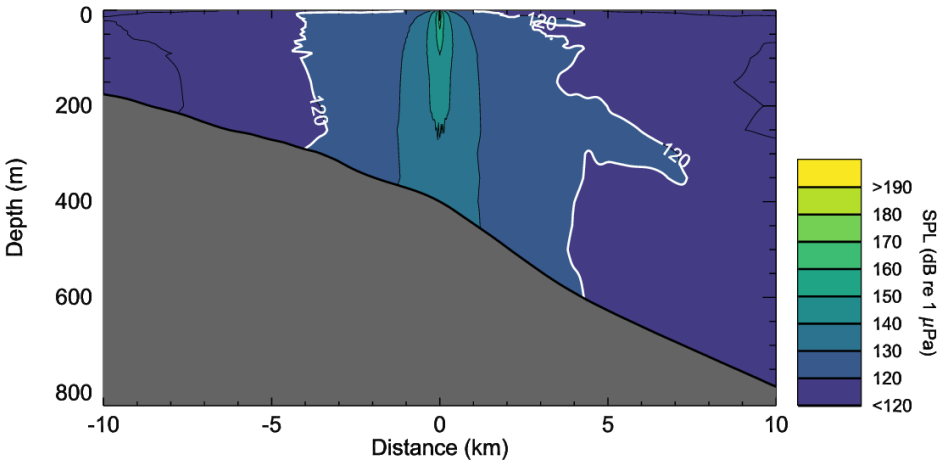


Figure 98. Vertical slice plot of Sound Pressure Levels (SPLs) for the pipelay vessel in Area 4 (Site 31).

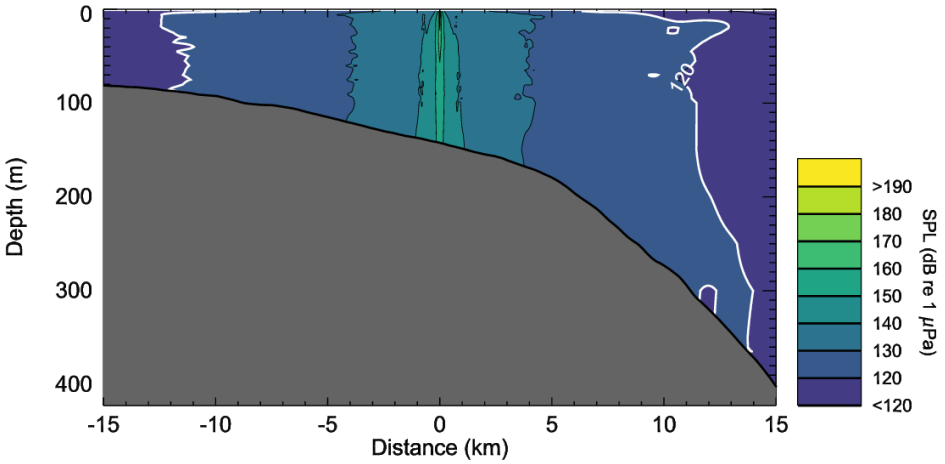


Figure 99. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 5 (Site 41).

4.4. VSP Tabulated Results and Maps

4.4.1. 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 at the well centre, with results provided in Appendix C along with the horizontal directivity plots.

Table 31 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the sagittal plane of the array), endfire (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.

Appendix C.3 shows the broadside, endfire, and vertical overpressure signature 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 31. Far-field source level specifications for the 750 in^3 Vertical Seismic Profiling (VSP) array, 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
Broadside	239.2	214.5	168.8
Endfire	239.4	214.5	165.8
Vertical	239.2	214.5	173.6
Vertical (surface affected source level)	239.3	216.1	176.6

4.4.2. 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:

- Per-pulse SEL sound fields (Table 32) are used as inputs into the 24 h SEL scenario and to provide context for the range to 160 dB re 1 µPa²·s, relevant for the EPBC Act Policy Statement 2.1 (DEWHA 2008).
- SPL sound fields (Table 33) were used to determine the distances to marine mammal and turtle behavioural thresholds (see Sections 2.1 and 2.2).
- PK metrics within the water column (Table 34) are relevant to thresholds and guidelines for marine mammals, sea turtles, fish, fish eggs and larvae (as well as plankton; see Sections 2.1 and 2.2).
- PK metrics at the seafloor (Table 35) are relevant to guidelines for fish, fish eggs and larvae (Section 2.2).
- PK-PK metrics at the seafloor (Table 36) are relevant to sound levels used in assessing effect on benthic invertebrates (see Section 2.3).

The SPL sound fields, and distances to relevant isopleths can be visualised on the contour maps presented in Section 4.4.4.1.

Table 32. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth unweighted per-pulse sound exposure level (SEL) isopleths.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site A		Site B		Site C	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	0.04	0.04	0.04	0.04	0.04	0.04
170	0.14	0.14	0.13	0.13	0.13	0.13
160[a]	0.61	0.58	0.42	0.41	0.42	0.41
150	2.76	2.50	1.56	1.51	1.63	1.56
140	7.99	7.04	4.49	4.16	4.85	4.61
130	22.5	20.0	18.7	17.6	14.4	12.1
120	>100	/	50.1	41.9	36.2	29.8
110	>100	/	96.2	84.8	70.0	60.2

[a] Low power zone assessment criteria DEWHA (2008).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ is not reported when the R_{max} was greater than the maximum modelling extent.

Table 33. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth unweighted per-pulse sound pressure level (SPL) isopleths.

SPL (L_p; dB re 1 µPa)	Site A		Site B		Site C	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.03	0.03	0.03	0.03	0.03	0.03
180	0.12	0.12	0.12	0.12	0.12	0.12
175[a]	0.27	0.25	0.21	0.20	0.21	0.20
170	0.58	0.55	0.374	0.362	0.372	0.36
166[b]	1.03	0.79	0.59	0.57	0.59	0.57
160[c]	2.37	2.09	1.33	1.28	1.35	1.30
150	6.20	5.50	4.23	3.90	4.48	4.26
140	20.2	16.2	13.5	12.5	11.0	10.0
130	98.1	83.0	44.5	39.7	31.3	27.1
120	>100	/	90.6	80.7	61.0	51.5

[a] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000).
[b] Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000).
[c] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ is not reported when the R_{max} was greater than the maximum modelling extent.

Table 34. *VSP, PTS, and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth peak pressure level (PK) PTS and TTS thresholds for marine mammals (Southall et al. 2019), fish (Popper et al. 2014), and sea turtles (Finneran et al. 2017).

Hearing group		PK threshold (L_{pk}; dB re 1 µPa)	Site A	Site B	Site C
			Distance R_{max} (km)	Distance R_{max} (km)	Distance R_{max} (km)
LF cetaceans	PTS	219	–	–	–
	TTS	213	–	–	–
HF cetaceans	PTS	230	–	–	–
	TTS	224	–	–	–
VHF cetaceans	PTS	202	0.06	0.06	0.06
	TTS	196	0.13	0.13	0.13
Sea turtles	PTS	232	–	–	–
	TTS	226	–	–	–
Fish: No swim bladder (also applied to sharks)		213	–	–	–
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae		207	–	–	–

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 35. *VSP, seafloor PK*: Maximum (R_{max}) horizontal distances (in m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled seafloor peak pressure level thresholds (Popper et al. 2014) (PK).

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Site A	Site B	Site C
		Distance R_{max} (m)	Distance R_{max} (m)	Distance R_{max} (m)
Fish: No swim bladder (also applied to sharks)	213	*	*	*
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Sea turtles, fish eggs, and larvae	207	*	*	*

An asterisk indicates that the sound level was not reached.

Table 36. Maximum (R_{max}) horizontal distances (in m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled seafloor peak-peak pressure levels (PK-PK).

PK-PK (L_{pk-pk}; dB re 1 µPa)	Site A	Site B	Site C
	Distance R_{max} (m)	Distance R_{max} (m)	Distance R_{max} (m)
213[a,b,c]	*	*	*
212[b,c]	*	*	*
210[a,b]	*	*	*
209[a,b]	*	*	*
202[d]	60.8	*	*

[a] Day et al. (2019), lobster
[b] Day et al. (2016a), lobster and scallops
[c] Day et al. (2017), scallops.
[d] Payne et al. (2008), lobster
An asterisk indicates that the sound level was not reached.

4.4.3. Multiple Pulse Sound Fields

This section presents the sound fields in terms of SEL accumulated over 24 h of activity, for the modelled scenarios (Table 10). A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250 and 300 shots over 24 hours to realistically represent a range of potential operations Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum and 95% distances (R_{max} and $R_{95\%}$; calculated as detailed in B.3) to marine mammals and turtle PTS and TTS thresholds (listed in Table 37), and to estimate maximum distance and the area to injury and TTS guidelines for fish (Table 14). (Southall et al. 2019)

Table 37. *VSP, multiple-pulse SEL, Site A*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals (Southall et al. 2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.11	0.15	0.19	0.23	0.45	0.48
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.20	0.49	0.67	1.03	1.68	2.13	2.62	2.91	3.20
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.16	0.18	0.21	0.24

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 38. *VSP, multiple-pulse SEL, Site B*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals Southall et al. (2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.10	0.15	0.18	0.21	0.23	0.26
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.19	0.27	0.42	0.60	0.84	1.02	1.20	1.46	1.68
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.15	0.17	0.19	0.21

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 39. *VSP, multiple-pulse SEL, Site C*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals (Southall et al. 2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.10	0.15	0.18	0.21	0.23	0.26
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.19	0.27	0.42	0.59	0.83	1.03	1.19	1.34	1.47
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.15	0.17	0.19	0.21

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 40. *VSP, multiple-pulse SEL, Site A:* Maximum-over-depth distances 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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
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	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.11	0.16	0.27	0.43	0.50	0.54	0.57

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).

Table 41. *VSP, multiple-pulse SEL, Site B:* Maximum-over-depth distances 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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
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	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.10	0.15	0.22	0.27	0.31	0.34	0.37

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).

Table 42. *VSP, multiple-pulse SEL, Site C:* Maximum-over-depth distances 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)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
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	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.10	0.15	0.22	0.27	0.31	0.34	0.37

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).

4.4.4. Sound Field Maps

Maps of the estimated sound fields, threshold contours, and isopleths of interest for the VSP operations are presented for Sites A-C. The per-pulse SPL sound fields are presented as contour maps in Figures 100–102. The SEL_{24h} sound fields are presented as contour maps in Figures 103–105 for 300 impulses per day. This figure presents the unweighted SEL_{24h} in 10 dB steps, as well as the isopleths corresponding to thresholds or guidelines for which R_{max} is greater than 20 m, the modelling resolution.

4.4.4.1. Maximum-over-depth Per-Pulse Sound Fields

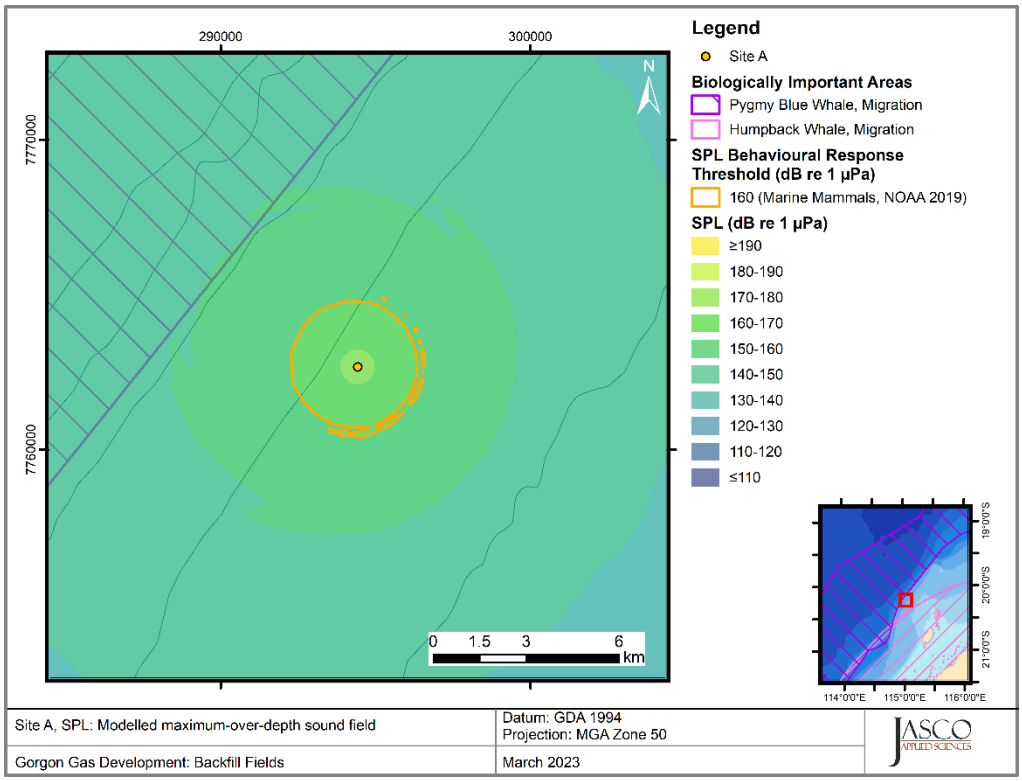


Figure 100. *VSP, Site A, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

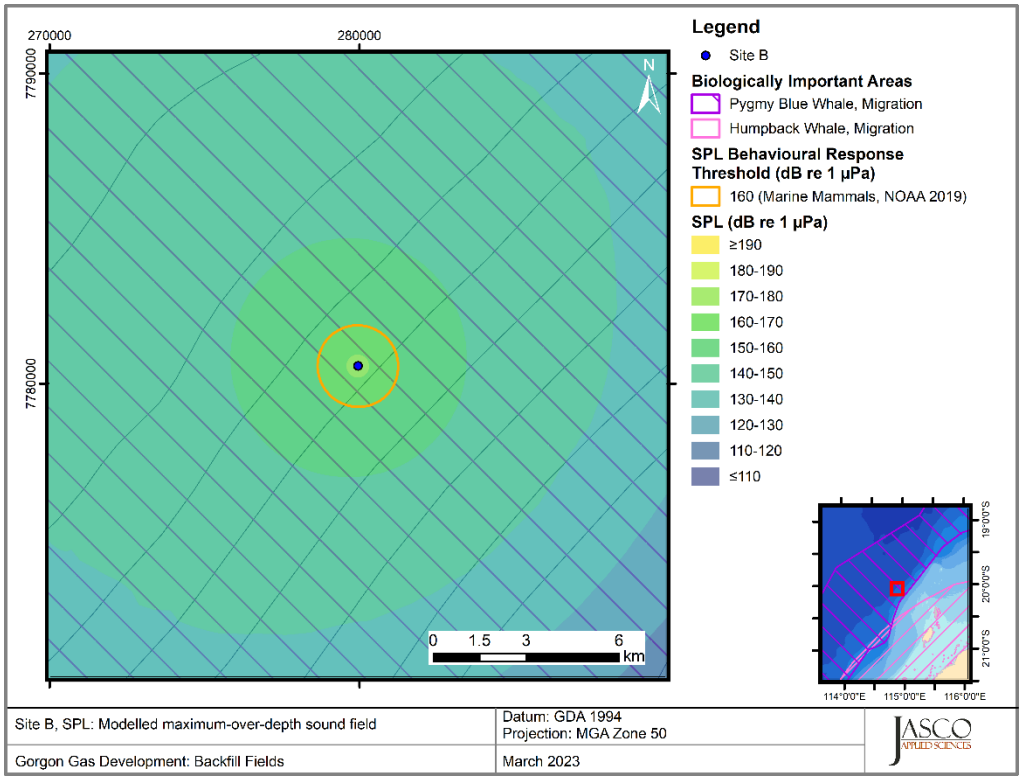


Figure 101. *VSP, Site B, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

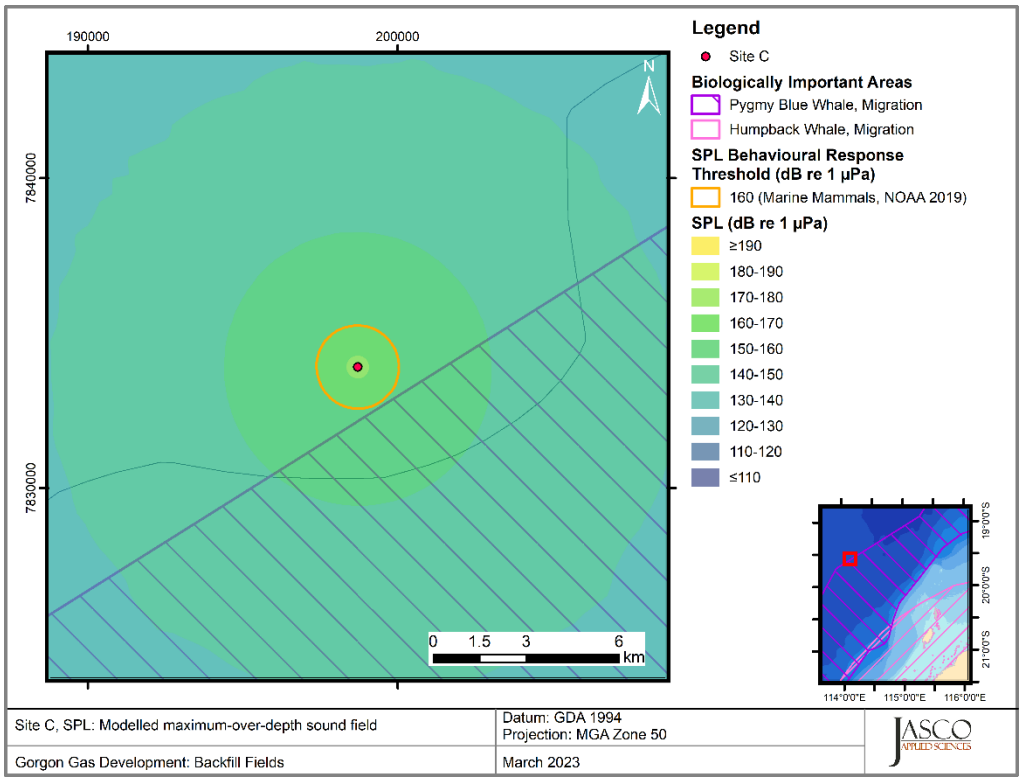


Figure 102. *VSP, Site C, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

4.4.4.2. Accumulated Multi-Pulse Sound Fields

Thresholds for permanent threshold shift (PTS) and some thresholds for TTS were either not reached or were small enough such that they could not be displayed on a map. Refer to the radii tables in Section 4.4.3 for distances.

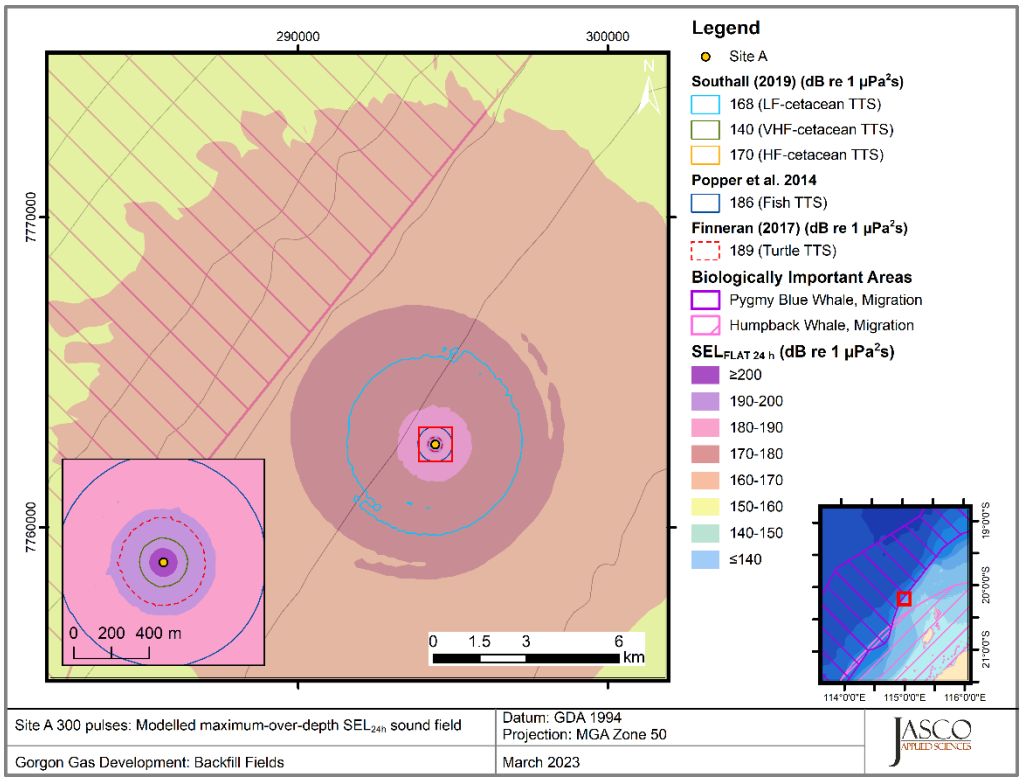


Figure 103. *VSP, Site A, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

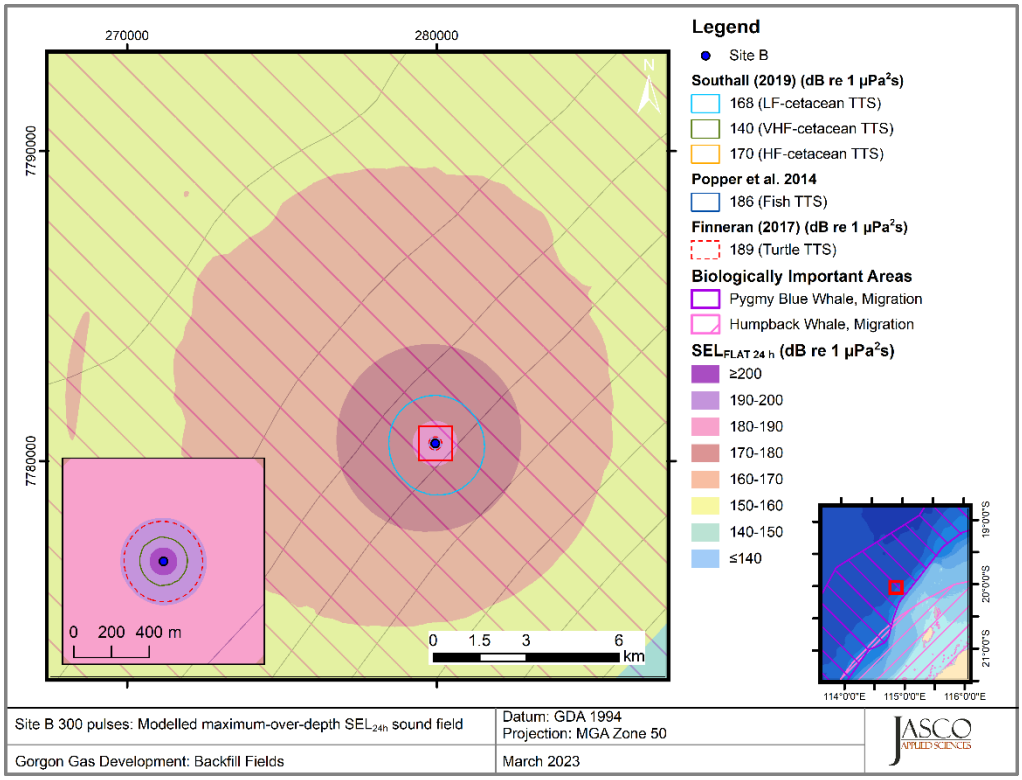


Figure 104. *VSP, Site B, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

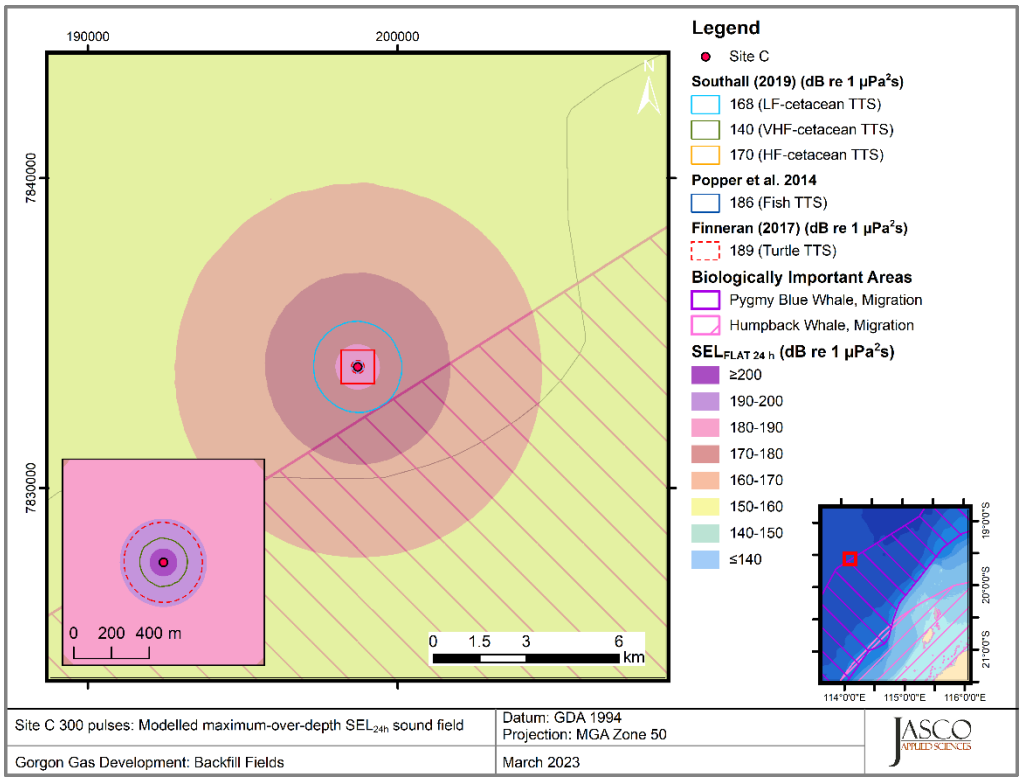


Figure 105. *VSP, Site C, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

4.5. Animal Movement Exposure Ranges

Table 45 shows results for scenarios with unrestricted animat seeding. Results include $ER_{95\%}$ exposure ranges calculated for the 120 dB behavioural response threshold and SEL_{24h} thresholds for both TTS and PTS, and the probability of an animat being exposed above the threshold within the $ER_{95\%}$.

Section 4.5.1 includes histograms of CPA ranges to SEL_{24h} TTS, and the behavioural response threshold for pygmy blue whales with BIA-restricted and unrestricted animat seeding where exposures above threshold occurred. Note that no pygmy blue whale animats were exposed above threshold for PTS for any of the scenarios. Additionally, no pygmy blue whale animats were exposed above threshold for TTS for Scenarios 8, 30, 33 and 40 with BIA-restricted animat seeding. Due to the lack of exposures in these scenarios, no histograms of CPA ranges are presented for these cases.

Table 43. Summary of animat simulation results for north-bound migrating pygmy blue whales with animats restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, restricted											
	Scenario 8		Scenario 14		Scenario 18		Scenario 21		Scenario 30		Scenario 33	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–	–	–	–	–	–	–
TTS (SEL_{24h})[2]	–	–	0.02	87	0.02	53	0.02	85	–	–	–	–
Behavioural response (SPL)[3]	12.3	99	0.70	89	3.02	73	4.99	73	8.02	>99	9.34	>99

[1] LF-weighted SEL_{24h} (199 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

Table 44. Summary of animat simulation results for combined scenarios for north-bound migrating pygmy blue whales with animats restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, restricted					
	Scenario 38		Scenario 39		Scenario 40	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.02	77	0.02	53	–	–
Behavioural response (SPL)[3]	12.1	40	9.16	60	8.89	>99

[1] LF-weighted SEL_{24h} (199 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

Table 45. Summary of animat simulation results for north-bound migrating pygmy blue whales with animats not restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, unrestricted											
	Scenario 8		Scenario 14		Scenario 18		Scenario 21		Scenario 30		Scenario 33	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.04	67	0.02	87	0.02	76	0.02	91	0.02	80	0.02	77
Behavioural response (SPL)[3]	12.4	99	0.73	88	2.76	77	5.03	73	8.03	>99	9.56	>99

[1] LF-weighted SEL_{24h} (199 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

Table 46. Summary of animat simulation results for combined scenarios for north-bound migrating pygmy blue whales with animats not restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, unrestricted					
	Scenario 38		Scenario 39		Scenario 40	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.03	61	0.02	77	0.02	79
Behavioural response (SPL)[3]	12.3	50	9.47	63	9.55	98

[1] LF-weighted SEL_{24h} (199 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 $\mu Pa^2 \cdot s$) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

4.5.1. Exposure Range Histograms

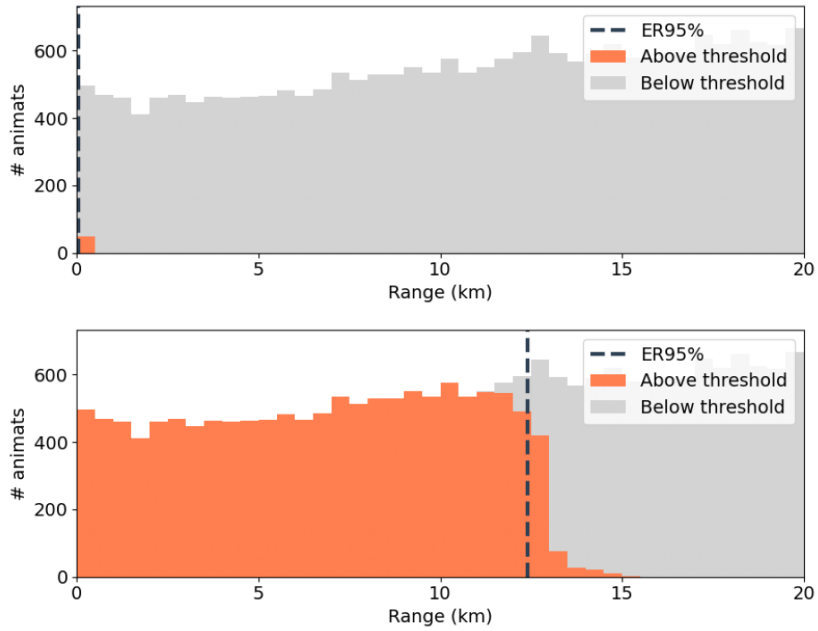


Figure 106. *Scenario 8, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

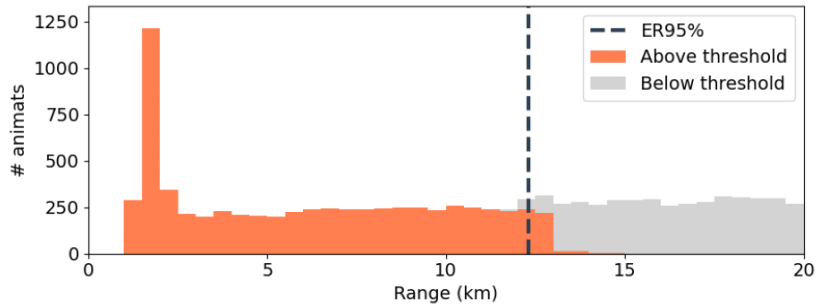


Figure 107. *Scenario 8, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SPL behavioural threshold. Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

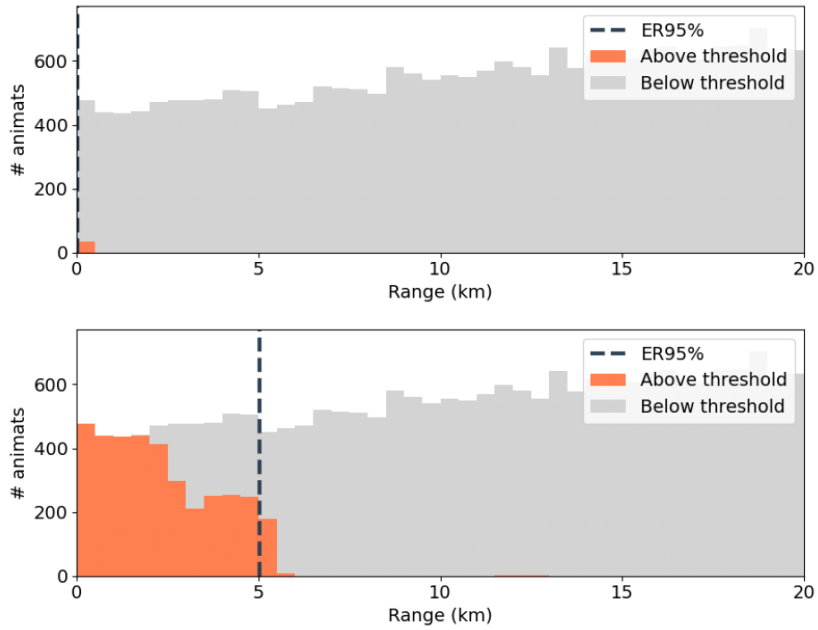


Figure 108. *Scenario 21, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

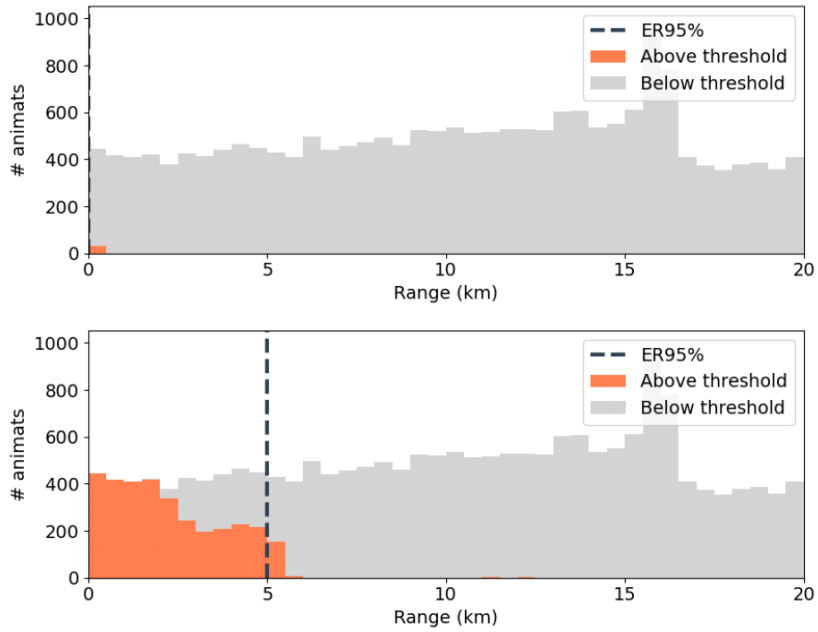


Figure 109. *Scenario 21, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

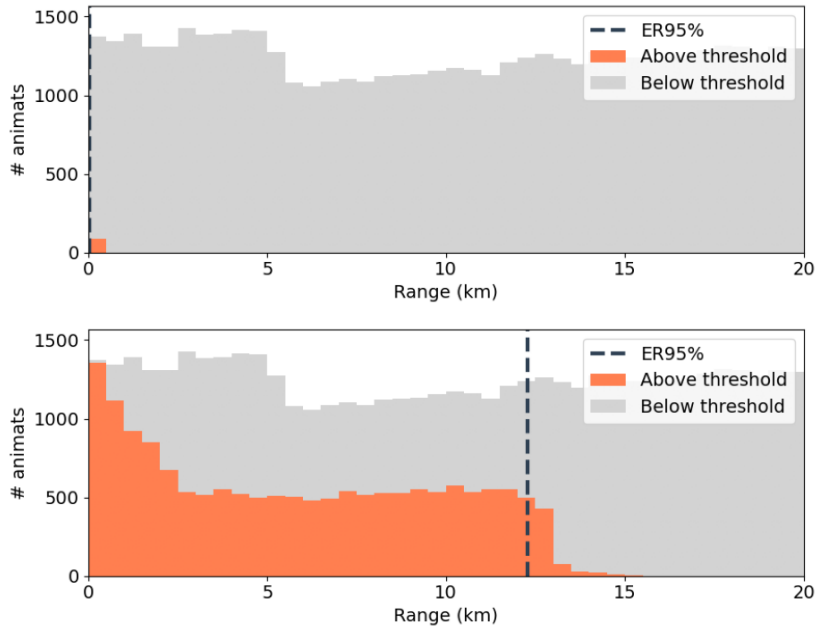


Figure 110. *Scenario 38, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

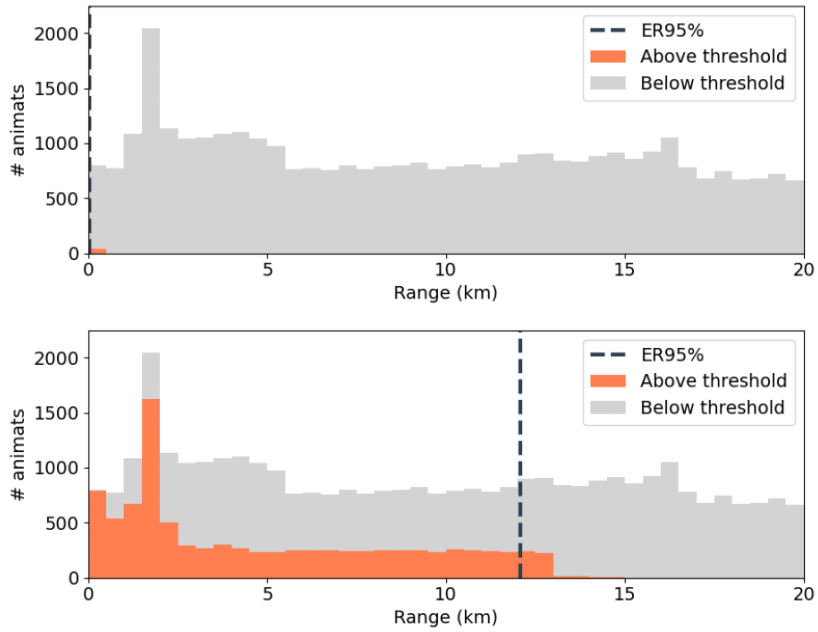


Figure 111. *Scenario 38, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

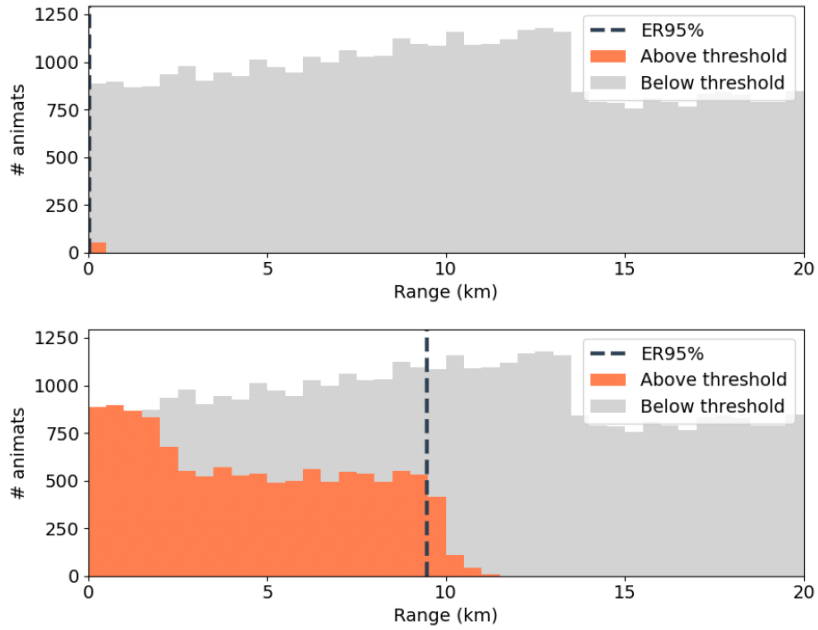


Figure 112. *Scenario 39, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

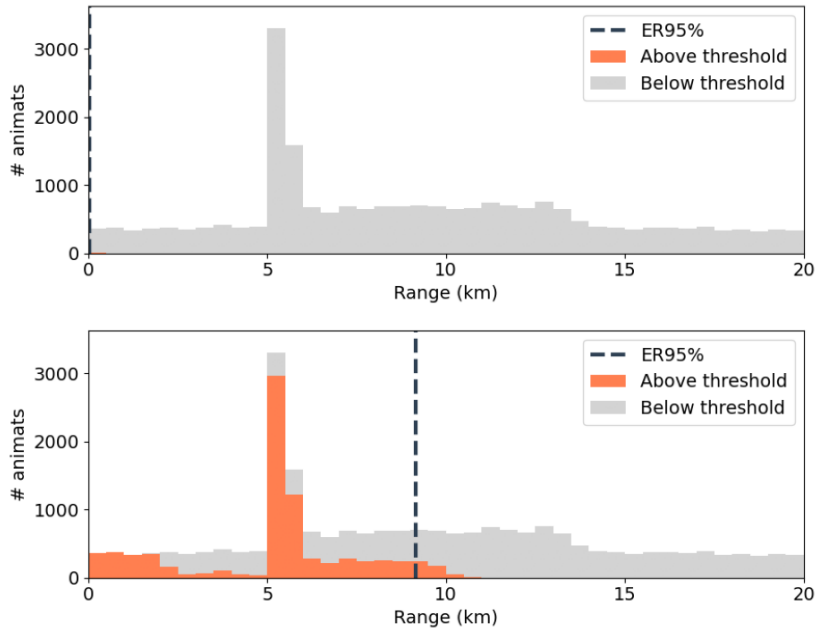


Figure 113. *Scenario 39, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

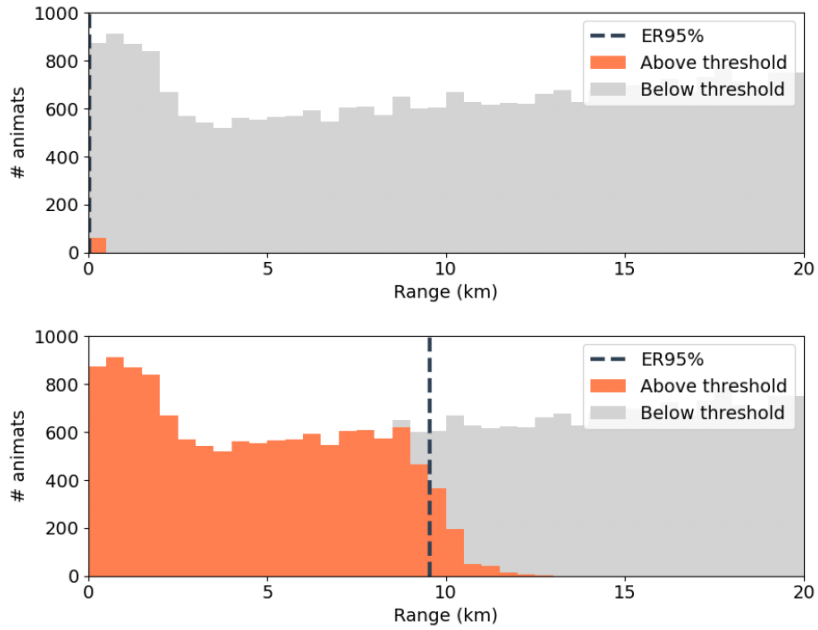


Figure 114. *Scenario 40, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

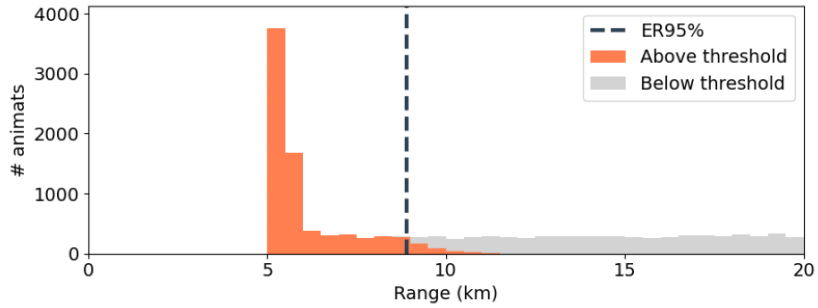


Figure 115. *Scenario 40, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SPL behavioural threshold. Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

5. Discussion and Conclusion

This modelling study predicted underwater sound levels associated with the construction of the Chevron Gorgon Gas Development: Backfill Fields. The modelled sound-emitting activities were vessel activities and vertical seismic profiling (VSP). The modelling study considered 36 individual vessel activity scenarios (Scenarios 1–36) across five Areas, four combined scenarios incorporating multiple individual vessel scenarios (Scenarios 37–40), and three VSP scenarios (Scenarios A, B, and C). Maximum, 95th percentile ranges (R_{max} and $R_{95\%}$) and ensonified area were computed to PTS, TTS, and behavioural response thresholds. The animal movement and exposure analysis combined species-typical movements for migrating pygmy blue whales with modelled sound fields to estimate both exposure range ($ER_{95\%}$) along with the probability of exposure within the calculated exposure ranges for five vessel activity scenarios.

5.1. Acoustic Modelling – Vessel Scenarios

Table 47 summarises the maximum horizontal distances to behavioural (unweighted SPL) and physiological effects (LF cetacean weighted TTS and PTS) thresholds across all 36 modelled individual vessel activity scenarios. LF cetaceans are summarised due to the proximity of the pygmy blue whale BIA; maximum horizontal distances to physiological effects thresholds for other hearing groups (HF and VHF cetaceans and turtles) are included in Section 4.1.

Table 47. Summary of maximum (R_{max}) horizontal distances (in km) from all scenarios considered to the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds (179 and 199 dB re 1 µPa²·s, respectively) based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		R_{max} (km)	R_{max} (km)	R_{max} (km)
1	Area 1, Drillship	5.62	0.78	0.08
2	Area 1, Drillship with OSV	5.87	0.83	0.10
3	Area 1, Pipelay vessel	6.30	0.84	0.05
4	Area 1, Pipelay vessel with resupply OSV	6.56	0.99	0.10
5	Area 1, Pipelay vessel with resupply and support OSVs	6.72	1.07	0.12
6	Area 1, IMR vessel	1.99	0.36	0.04
7	Area 1, OCV	15.5	1.71	0.18
8	Area 1, OCV with 3 support vessels	15.7	1.82	0.21
9	Area 2, Drillship	5.60	0.78	0.07
10	Area 2, Drillship with OSV	5.85	0.84	0.11
11	Area 2, Pipelay vessel	6.42	0.85	0.06
12	Area 2, Pipelay vessel with resupply OSV	6.70	0.99	0.09
13	Area 2, Pipelay vessel with resupply and support OSVs	6.88	1.08	0.12
14	Area 2, IMR vessel	1.74	0.36	0.04
15	Area 2, OCV	15.1	1.70	0.19
16	Area 2, OCV with 3 support vessels	15.4	1.81	0.21
17	Area 3, Drillship	5.30	0.78	0.08
18	Area 3, Drillship with OSV	12.1	0.84	0.11
19	Area 3, Pipelay vessel	5.78	0.84	0.05
20	Area 3, Pipelay vessel with resupply OSV	12.8	0.99	0.09
21	Area 3, Pipelay vessel with resupply and support OSVs	13.0	1.08	0.12
22	Area 3, IMR vessel	2.64	0.36	0.04
23	Area 3, OCV	14.0	1.96	0.19
24	Area 3, OCV with 3 support vessels	14.0	2.10	0.21
25	Area 4, Pipelay vessel	7.87	0.88	0.05
26	Area 4, Pipelay vessel with resupply OSV	9.72	1.20	0.10
27	Area 4, Pipelay vessel with resupply and support OSVs	18.3	1.47	0.12
28	Area 4, IMR vessel	2.24	0.37	0.04
29	Area 5, Drillship	10.0	1.56	0.08
30	Area 5, Drillship with OSV	10.4	1.66	0.11
31	Area 5, Pipelay vessel	12.2	1.69	0.06
32	Area 5, Pipelay vessel with resupply OSV	12.8	1.99	0.10
33	Area 5, Pipelay vessel with resupply and support OSVs	12.9	2.18	0.12
34	Area 5, IMR vessel	3.76	0.63	0.04
35	Area 5, OCV	17.0	4.39	0.19
36	Area 5, OCV with 3 support vessels	17.3	4.58	0.21

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019).
A dash indicates the level was not reached within the limits of the modelled resolution (20 m)

The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel; the largest behavioural response zone for the IMR vessel was 3.76 km and the largest low-frequency (LF) cetacean TTS zone was 0.63 km (both in Area 5) (Table 47).

For the results tables presented in Section 4.1, 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 calculation grids of the modelled sound fields, distances to these levels could not be estimated for practicable computational purposes. It is likely that SPL isopleths could be reached at distances between the source and the modelled horizontal resolution (20 m); however, distances to injurious accumulated SEL thresholds may not be reached at any range due the species-specific frequency weighing functions. Additionally, if close-to-source radii are comparable to the dimensions of the modelled vessel then they may only be reached within close proximity to a vessel, if at all.

The modelled individual vessel activity scenarios aimed to demonstrate the iterative effect of adding additional support vessels to each vessel activity (i.e. drilling, pipelaying and construction). In every modelled Area, and for each activity, additional support vessels generated larger distances to effect thresholds (Table 47).

In Areas 1, 2, 3 and 5, the OCV with construction support vessels resulted in the longest distances to effect thresholds (Table 1). The 120 dB SPL marine mammal behavioural effect zone from construction activities with support vessels featured a radius of 15.7 km in Area 1, 15.4 km in Area 2, 14 km in Area 3, and 17.3km in Area 5. Construction activities were not modelled in Area 4, and in this Area the pipelay vessel with two support vessels resulted in the longest distances to effect thresholds (120 dB marine mammal behavioural effect radii of 18.3 km).

It should be noted that in Scenarios 18, 20, 21 and 27 (drilling and pipelay in Areas 3 and 4), successive reflections between the seabed and the sea-surface result in convergence zones, which when combined with a high vessel source level, is evident as ‘sound islands’ for low level isopleths like the marine mammal behavioural threshold of 120 dB re 1 µPa (SPL) for non-impulsive sound sources. These are apparent in Figures 36, 38, 39, and 45. Modelled sites that resulted in sound ‘islands’ can be distinguished in Tables 19 and 20 by comparing the R_{max} effect distance with the $R_{95\%}$ effect distance, with the latter being notably smaller.

Furthermore, the successive reflections resulting from the underwater propagation environment caused some SEL_{24h} thresholds to be exceeded more than once. The very-high frequency (VHF) cetacean TTS threshold (153 dB, weighted) was exceeded more than once in Scenarios 1, 2, 9, 10, 17, 18, 20, 27, 29 and 30 (Figures 59, 60, 67, 68, 75, 76, 78, 85, 87, and 88), and the LF cetacean TTS threshold was exceeded more than once in Scenarios 31 and 32 (Figures 89 and 90). The reported effect radii for these scenarios relate to the longest exceedance distance.

Offshore activities over deep water in Areas 1 and 2 generally featured smaller effect zones than equivalent activities in Areas 3, 4 and 5 where the continental shelf environment was more conducive to effective sound propagation. For sources located above the continental slope, significant amounts of energy can be reflected from the seabed in such a way that this energy can propagate downslope and be trapped in the deep sound channel where it can propagate for larger distances (for example, see Figure 98). Effect zones in Areas 3 and 4 clearly demonstrated more favourable propagation conditions in an offshore direction, with less acoustic energy propagating onto the continental shelf (refer to Figures 39 and 45).

In addition to the 36 individual modelled scenarios, four combined scenarios were also modelled, which incorporated concurrent combinations of individual vessel activity scenarios across the five Areas. Table 48 summarises the percentage change in area ensonified above threshold levels between the corresponding individual vessel activity scenarios and the combined scenarios where the individual vessel activities occur concurrently.

Table 48. Summary of percentage change in ensonified area between corresponding individual scenarios and combined scenarios based on the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS thresholds based on Southall et al. (2019).

Scenario number	Description	Marine Mammal behavioural response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		Percentage change in ensonified area (km^2) from individual to combined scenarios (%)	Percentage change in ensonified area (km^2) from individual to combined scenarios (%)	Percentage change in ensonified area from individual scenarios to combined (%)
37	Area 1, pipelay vessel with 2 OSVs + Area 3, drillship with OSV	+0.37	-0.18	*
38	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV	+3.21	0	*
39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	+4.04	0	*
40	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	+12.9	+2.80	*

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2)

Only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios. The SEL_{24h} areas for Scenario 40, and all areas for Scenarios 37, 38 and 39, did not result in merged effect zones and the percentage change in ensonified areas therefore remained low (<5%) (Figures 55, 56, and 57). The lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities.

The pipelaying activities modelled here were located in the centre of flowlines in order to provide a nominal location along the track. At either end of the flowlines, the pipelay vessel and its support vessels will be closer to activities being conducted at specific infrastructure, such as construction or drilling. While the modelled sound fields presented here are specific to the modelled site locations, the effect radii summarised in Section 4.1 provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

The sound speed profile (Appendix B.1.2) was derived from data from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). The profile was defined by considering the Development location and was generally consistent with an open ocean deep water profile and it was applied to all modelled sites. This type of sound speed profile is characterised by decreasing sound speed due to decreases in temperature below the sea surface, however at some water depths, sound speeds increase as density increases due to hydrostatic overburden (Jensen et al. 2011). The profile had a minimum sound speed at approximately 800–1000 m water depth, which defines the sound channel axis and is the approximate centre of the deep sound channel. For energy trapped within the deep sound channel or duct, upward travelling energy would be refracted downward and downward travelling energy would be refracted upwards. When acoustic energy becomes trapped in the deep sound channel, it propagates very large distances with little loss within the ocean interior.

5.2. Acoustic Modelling - VSP Scenarios

The VSP produces generally symmetric sound fields across all three sites, as observed in Figures 100–105. Tables 32–42 show that modelling at Site A generally resulted in the largest ranges to considered effect criteria. Site A is the shallowest site and is located above a more reflective seabed than the other considered sites, fine sand sediments compared to silty sediments. These two factors likely contributed to the larger radii at Site A compared to Sites B and C. Sites B and C have very similar distances to thresholds despite the differing seabed characteristics. Whilst the water depths at these sites do differ by about 230 m, they are both located in water approximately 1000 m deep and the radii to effects criteria are therefore likely characterised by similar propagation mechanisms.

Marine mammals:

Marine mammal injury criteria, from Southall et al. (2019), requires two metrics (PK and SEL_{24h}) to be considered for impulsive noise when assessing marine mammal PTS and TTS with the longest distance associated with either metric required to be applied. In this study, the longest horizontal distances to the low-frequency cetacean PTS and TTS thresholds were associated with the SEL_{24h} metric (0.48 km and 3.20 km, respectively), while the longest horizontal distances to the very-high-frequency cetacean PTS and TTS thresholds were associated with the PK metric (0.06 km and 0.13 km, respectively).

The maximum distance to the NOAA (2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) was 2.37 km, which was associated with Site A. The corresponding distances at Sites B and C were 1.33 km and 1.35 km, respectively.

Sea turtles:

For sea turtles, the maximum distance to the SEL_{24h} metrics of 204 dB re 1 μPa^2s for PTS and 189 dB re 1 μPa^2s for TTS was 0.03 km for PTS onset and 0.24 km for TTS onset for the 750 in^3 seismic source (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that sea turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.

The PK sea turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.

The maximum distances to the behavioural response criteria for sea turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance were 1.03 km and 0.27 km, respectively for the 750 in^3 seismic source (McCauley et al. 2000).

Fish, fish eggs, and fish larvae:

The effects of sound exposure on fish were considered in relation to both PK and SEL_{24h} metrics associated with mortality, potential mortal injury and impairment, based on quantitative criteria from Popper et al. (2014) for 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.

Table 49 summarises the maximum distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric across all three modelled locations. The mortality and recoverable injury distances were comparable across the three sites, but the distance to the TTS threshold was longest at Site A.

Table 49. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for any modelled site, for single impulse and 24 h sound exposure level (SEL_{24h}) modelled scenarios.

Relevant hearing group	Effect criteria	Water column	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	–	–
	TTS	SEL_{24h}	0.57
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	SEL_{24h}	0.05
	TTS	SEL_{24h}	0.57
Fish eggs, and larvae	Injury	SEL_{24h}	0.05

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Benthic invertebrates:

The maximum radius of ensonified areas where sound levels exceeded 202 dB re 1 µPa PK-PK (Payne et al. 2008) was 60.8 m from Site A; in this area crustaceans may be negatively affected by sound. This threshold was not exceeded at Sites B or C. Sound levels of 209 to 213 dB re 1 µPa PK-PK (Day et al. (2016a); Day et al (2016b)), which are related to crustacean impairment, were also considered in this study; these levels were not reached for any VSP modelling site at a depth of 5 cm above the seafloor.

5.3. Animal Movement Modelling

The estimated sound fields produced by source and propagation models for the planned construction of the Chevron Gorgon Gas Development were incorporated into an animat sound exposure model for migrating pygmy blue whales to estimate the radial distance within which 95% of the exposure exceedances occur ($ER_{95\%}$), along with the probability that an animat with the closest point of approach within that distance would be exposed above the relevant threshold (P_{exp}).

For the exposure analysis, a subset of acoustic modelling scenarios (see Table 7) were run with BIA-restricted and unrestricted animat seeding. Scenarios 8 and Scenarios 30, 33 and 40 are located approximately 1.6 and 5.5 km outside of the migratory BIA for pygmy blue whales, respectively, whereas Scenarios 14, 18 and 21 fully, and Scenarios 38 and 39 partially overlap with the BIA (Figure 8).

Sections 5.3.1 and 5.3.2 summarise the PTS, TTS and behavioural exposure range results, with Table 50 summarising the maximum exposure range results for pygmy blue whales not restricted to their corresponding BIAs.

Table 50. Summary of animat simulation results for PTS, TTS, and SPL behavioural response criteria for pygmy blue whales with unrestricted seeding Exposure ranges show $ER_{95\%}$ (km) first and probability of exposure of animats travelling within the $ER_{95\%}$ (P_{exp} (%)) in parentheses. A dash (-) indicates that no animat was exposed above the threshold.

Scenario Number	Species	Behavioural response (SPL)[4]	TTS (SEL_{24h})[3]	PTS (SEL_{24h})[3]
		120[2]	179[1]	199[1]
8	Pygmy blue whale	12.4 (99%)	0.04 (67%)	–
14		0.73 (88%)	0.02 (87%)	–
18		2.76 (77%)	0.02 (76%)	–
21		5.03 (73%)	0.02 (91%)	–
30		8.03 (>99%)	0.02 (80%)	–
33		9.56 (>99%)	0.02 (77%)	–
38		12.3 (50%)	0.03 (61%)	–
39		9.47 (63%)	0.02 (77%)	–
40		9.55 (98%)	0.02 (79%)	–

[1] LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)
[2] SPL (L_p; dB re 1 µPa)
[3] Southall et al. (2019) criteria for marine fauna.
[4] NOAA (2019) recommended unweighted behavioural threshold for marine mammals.

5.3.1. Behavioural Effects

Exposure ranges for single exposure metrics, such as the SPL behavioural response criteria, are typically comparable to the predicted acoustic ranges. Acoustic ranges are conservatively calculated using the maximum-over-depth sound fields while exposure ranges account for animats sampling the sound field vertically based on species-specific diving parameters, so exposure ranges are often slightly lower than acoustic ranges.

For all considered scenarios with unrestricted animat seeding, the $ER_{95\%}$ to behavioural threshold ranged from 0.73–12.4 km for pygmy blue whales, with P_{exp} varying between 50 and >99%. Overall, ranges were longest for Scenarios 8 and 38.

The different site locations within the scenarios and their impact on exposure ranges are also visible in the histograms showing the CPA ranges to the behavioural response threshold for BIA-restricted pygmy blue whale animats (see Section 4.5.1).

Scenario 21 is located within the migratory BIA for pygmy blue whales and therefore, shows no significant difference between the BIA-restricted and the unrestricted animat seeding simulations (see Figures 108 and 109).
Scenario 39 includes Sites 21 and 22, which are both located within the migratory BIA for pygmy blue whales, and Sites 37 to 39, which are located approximately 5.5 km outside of the BIA. Figure 111 shows CPA ranges to the behavioural response threshold with a high frequency of exposure ranges within the 5 – 6 km bins, which is the closest any animats can come to Sites 37 to 39 of Scenario 39. Any exposure ranges below that are associated with exposures to Sites 21 and 22 as these ones are located within the BIA.
A similar argument can be applied to the CPA ranges for BIA-restricted animats for Scenario 38 (Figure 111).Furthermore, the closest distance between the modelled sites from Scenario 8, Sites 7 to 10, and the BIA is approximately 1.6 km, which explains why minimum CPA ranges for BIA-restricted animats are within the 1.5 to 2 km bin (see Figure 107). A similar argument applies to the CPA ranges for BIA-restricted animats for Scenario 40 (see Figure 115), where the BIA is located approximately 5.5 km from the associated modelled sites.

Due to the main lobe of acoustic energy extending to larger ranges as depth increases, the animat determined exposure ranges were slightly lower than the static acoustic ranges for all considered scenarios, as expected based on the vertical distribution of the sound field. Migrating pygmy blue whales are expected to spend most of their time in a behavioural mode where most dives reach less than 60 m in depth. Figure 116 shows a vertical slice beginning at the source location and extending towards deeper water at an azimuth of 315°. This plot shows how migrating pygmy blue whales sample the upper portion of the water column, which is quieter, and results in exposure ranges that are shorter than acoustic ranges at this location.

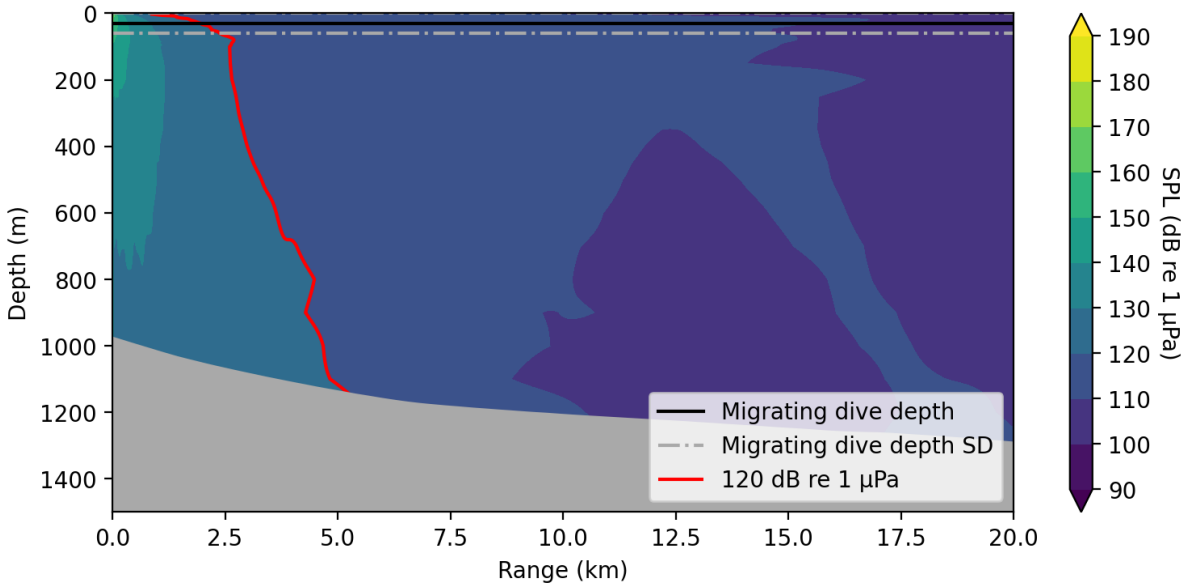


Figure 116. *Scenario 21, Site 23:* Example SPL vertical from the pipelay vessel at an azimuth of 315°. The 120 dB behavioural response threshold is highlighted in red, and the migrating pygmy blue whale dive depth (mean and one standard deviation) is indicated by horizontal lines.

5.3.2. PTS and TTS

Exposure ranges from animal movement modelling for PTS and TTS criteria are typically shorter than those predicted using acoustic propagation modelling because of the generally shorter time (‘dwell time’) to accumulate sound energy of the moving animats. In this analysis, there were no PTS exposures predicted for any of the pygmy blue whale simulations. Unrestricted seeding of animats resulted in a maximum $ER_{95\%}$ for TTS of 0.04 km with a corresponding exposure probability for animats travelling within that range of 67%.

Exposure ranges are, in general, slightly longer for TTS and PTS for unrestricted vs BIA-restricted scenarios because unrestricted animats have more opportunities to be exposed to sound fields closer to the source and for a longer time, which effectively lengthens their dwell time. This is the case for this study. Restricting animats to the migratory BIA for pygmy blue whales resulted in no exposures above TTS for Scenarios 8, 30, 33 and 40. The maximum $ER_{95\%}$ for TTS was 0.02 km with a corresponding exposure probability for animats travelling within the range of 87%.

5.4. Conclusion

This modelling study considered underwater sound levels associated with vessel activities and VSP for the construction of the Chevron Gorgon Gas Development: Backfill Fields. The modelling study considered 30 individual vessel activity scenarios across five representative Areas of the Development, four combined vessel scenarios, and scenarios at three VSP sites. The modelling study predicted the distances from operations at which underwater sound levels reached noise effect thresholds and criteria for marine mammals, sea turtles and fish.

The greatest horizontal distances were associated with the OCV with construction support vessels in Areas 1, 2, 3 and 5, which resulted in a 120 dB SPL marine mammal behavioural effect radius of up to 17.3 km. In Area 4, where construction was not modelled, the pipelay vessel with two support vessels resulted in the longest distances to effect thresholds (120 dB SPL marine mammal behavioural effect radii 18.3 km in Area 4). The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel.

In the combined vessel scenarios, the lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities. Only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities in Area 5 combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios). While the modelled sound fields presented here are specific to the modelled site locations, the effect radii summarised in Section 4.1 provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

The VSP results demonstrated that the greatest distances to noise-effect thresholds were generally associated with Site A, the shallowest site, rather than Sites B and C. It is likely that the shallow water depth at Site A resulted in sound reflecting from the seabed. The longest horizontal distances to the low-frequency cetacean PTS and TTS thresholds were 0.48 km and 3.20 km, respectively. The maximum distance to the 160 dB re 1 µPa (SPL) marine mammal behavioural response criterion was 2.37 km, which was associated with Site A. The corresponding distances at Sites B and C were 1.33 km and 1.35 km, respectively. For sea turtles, behavioural disturbance could occur up to 1.03 km from the VSP acoustic centre, with PTS and TTS maximum distances of 0.03 km and 0.24 km, respectively. All effect zones for fish were less than 0.6 km. Crustaceans may be affected within 60.8 m of Site A, but levels were not predicted to exceed effect thresholds at Sites B or C.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict sound exposure for migrating pygmy blue whales in their migration BIA. The exposure ranges predicted using animat modelling are significantly more realistic than the acoustic modelling outlined above, due to the incorporation of species-specific realistic movements. In this study, there were no exposures above PTS threshold for any of the pygmy blue whale scenarios. The maximum $ER_{95\%}$ to TTS threshold was 0.04 km. 67% of pygmy blue whale animats that travelled within this distance were exposed above the TTS threshold. All scenarios resulted in the exposure of pygmy blue whale animats above the SPL behavioural response threshold NOAA (2019). Of these, the maximum $ER_{95\%}$ to the threshold was 12.4 km pygmy blue whales (Scenario 8 – OCV under DP with three support vessels). The probability of exposure for animats that travelled within this range was 99%.

Glossary

1/3-octave

One third of an octave. *Note*: A 1/3-octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec).

absorption

The conversion of sound energy to heat energy. Specifically, the reduction of sound pressure amplitude due to particle motion energy converting to heat in the propagation medium.

acoustic noise

Sound that interferes with an acoustic process.

acoustic self-noise

Sound at a receiver caused by the deployment, operation, or recovery of a specified receiver, and its associated platform (ISO 18405:2017).

agent-based modelling

A computer simulation of autonomous agents (sometimes called animats) acting in an environment, used to assess the agents' experience of the environment and/or their effect on the environment. See also animal movement modelling.

ambient sound

Sound that would be present in the absence of a specified activity (ISO 18405:2017). It is usually a composite of sound from many sources near and far, e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

animal movement modelling

Simulation of animal movement based on behavioural rules for the purpose of predicting an animal's experience of an environment. A type of agent-based modelling.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium. Attenuation depends on frequency—higher frequency sounds are attenuated faster than lower frequency sounds.

audiogram

A graph or table of hearing threshold as a function of frequency that describes the hearing sensitivity of an animal over its hearing range.

auditory frequency weighting

The process of applying an auditory frequency-weighting function. An example for marine mammals are the auditory frequency-weighting functions published by Southall et al. (2007).

auditory frequency-weighting function

Frequency-weighting function describing a compensatory approach accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.

background noise

Combination of ambient sound, acoustic self-noise, and, where applicable, sonar reverberation (ISO 18405:2017) that is detected, measured, or recorded with a signal.

bandwidth

A range within a continuous band of frequencies. Unit: hertz (Hz).

broadband level

The total level measured over a specified frequency range. If the frequency range is unspecified, the term refers to the entire measured frequency range.

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

Member of the order Cetacea. Cetaceans are aquatic 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 a longitudinal wave. In seismology/geophysics, it's called a primary wave or P-wave. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

conductivity-temperature-depth (CTD)

Measurement data of the ocean's conductivity, temperature, and depth; used to compute sound speed profiles and salinity.

continuous sound

A sound whose sound pressure level remains above the background noise during the observation period and may gradually vary in intensity with time, e.g., sound from a marine vessel.

critical band

The auditory bandwidth within which background noise strongly contributes to masking of a single tone. Unit: hertz (Hz).

critical ratio level

The difference between the sound pressure level of a masked tone, which is barely audible, and the spectral density level of the background noise at similar frequencies, referenced to 1 Hz. Unit: decibel (dB).

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006). For example, one decade up from 1000 Hz is 10,000 Hz, and one decade down is 100 Hz.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Especially suited to quantify variables with a large dynamic range.

decidecade

One tenth of a decade. Approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct), and for this reason sometimes referred to as a 1/3-octave.

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing centre frequency.

delphinid

Member of the family of oceanic dolphins (Delphinidae), composed of approximately 35 extant species, including dolphins, porpoises, and killer whales.

energy source level

A property of a sound source equal to the sound exposure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 $\mu Pa^2\,m^2\,s$.

ensonified

Exposed to sound.

equal-loudness-level contour

Curve that shows, as a function of frequency, the sound pressure level required to produce a given loudness for a listener having normal hearing, listening to a specified kind of sound in a specified manner (ANSI S1.1-2013).

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.

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.

frequency weighting

The process of applying a frequency-weighting function.

frequency-weighting function

The squared magnitude of the sound pressure transfer function (ISO 18405:2017). For sound of a given frequency, the frequency-weighting function is the ratio of output power to input power of a specified filter, sometimes expressed in decibels. Examples include the following:

- *Auditory frequency-weighting function*: compensatory frequency-weighting function accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.
- *System frequency-weighting function*: frequency-weighting function describing the sensitivity of an acoustic recording system, which typically consists of a hydrophone, one or more amplifiers, and an analog-to-digital converter.

functional hearing group

Category of animal species when classified according to their hearing sensitivity, hearing anatomy, and susceptibility to sound. For marine mammals, initial groupings were proposed by Southall et al. (2007), and revised groupings are developed as new research/data becomes available. Revised groupings proposed by Southall et al. (2019) include low-frequency cetaceans, high-frequency cetaceans, very high-frequency cetaceans, phocid carnivores in water, other carnivores in water, and sirenians. See auditory frequency-weighting functions, which are often applied to these groups. Example hearing groups for fish include species for which the swim bladder is involved in hearing, species for which the swim bladder is not involved in hearing, and species without a swim bladder (Popper et al. 2014).

geoacoustic

Relating to the acoustic properties of the seabed.

harmonic

A sinusoidal sound component that has a frequency that is an integer multiple of the frequency of a sound to which it is related. For a sound with a fundamental frequency of f, the harmonics have frequencies of $2f$, $3f$, $4f$, etc.

hearing threshold

For a given species or functional hearing group, the sound level for a given signal that is barely audible (i.e., that would be barely audible for a given individual in the presence of specified background noise during a specific percentage of experimental trials).

hertz (Hz)

Unit of frequency defined as one cycle per second. Often expressed in multiples such as kilohertz (1 kHz = 1000 Hz).

high-frequency (HF) cetaceans

See functional hearing group. *Note*: The mid- and high-frequency cetaceans groups proposed by Southall et al. (2007) were renamed high- and very-high-frequency cetaceans, respectively, by Southall et al. (2019).

hydrophone

An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

hydrostatic pressure

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).

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 s), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Sources of impulsive sound include, among others, explosives, seismic airguns, and impact pile drivers.

isopleth

A line drawn on a map through all points having the same value of some specified quantity (e.g., sound pressure level isopleth).

knot (kn)

Unit of vessel speed equal to 1 nautical mile per hour.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. For example, a value of sound pressure level with reference to 1 μPa^2 can be written in the form *x* dB re 1 μPa^2.

low-frequency (LF) cetaceans

See functional hearing group.

masking

Obscuring of sounds of interest by other sounds at similar frequencies.

median

The 50th percentile of a statistical distribution.

mid-frequency (MF) cetaceans

See functional hearing group. *Note*: The mid-frequency cetaceans group proposed by Southall et al. (2007) was renamed high-frequency cetaceans by Southall et al. (2019).

monopole source level (MSL)

A source level that has been calculated using an acoustic model that accounts for the effect of the sea-surface and seabed on sound propagation, assuming a point source (monopole). Often used to quantify source levels of vessels or industrial operations from measurements. See also radiated noise level.

Monte Carlo simulation

A method of investigating the distribution of a non-linear multi-variate function by random sampling of its input variable distributions.

multiple linear regression

A statistical method that seeks to explain the response of a dependent variable using multiple explanatory variables.

M-weighting

A set of auditory frequency-weighting functions proposed by Southall et al. (2007).

mysticete

Member of the Mysticeti, a suborder of cetaceans. Also known as baleen whales, mysticetes have baleen plates (rather than teeth) that they use to filter food from water (or from sediment as for grey whales). This group includes rorquals (Balaenopteridae, such as blue, fin, humpback, and minke whales), right and bowhead whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

***N* percent exceedance level**

The sound level exceeded *N* % of the time during a specified time interval. See also percentile level.

non-impulsive sound

Sound that is not an impulsive sound. Not necessarily a continuous sound.

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

Member of Odontoceti, a suborder of cetaceans. These whales, dolphins, and porpoises have teeth (rather than baleen plates). Their skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid

Member of the family Otariidae, one of the three groupings of pinnipeds (along with phocids and walrus). These eared seals, commonly called fur seals and sea lions, are adapted to semi-aquatic life; they use their large fore flippers for propulsion underwater and can walk on all four limbs on land.

otariid pinnipeds underwater (OW)

See functional hearing group.

other marine carnivores in water (OCW)

See functional hearing group.

parabolic equation method

A computationally efficient solution to the acoustic wave equation that is used to model propagation loss. The parabolic equation approximation omits effects of backscattered sound (which are negligible for most ocean-acoustic propagation problems), simplifying the computation of propagation loss.

particle acceleration, particle displacement, particle motion, particle velocity

See sound particle acceleration, sound particle displacement, sound particle motion, sound particle velocity.

peak sound pressure level (PK), zero-to-peak sound pressure level

The level (L_{pk}) of the squared maximum magnitude of the sound pressure (p_{pk}^2) in a stated frequency band and time window. Defined as $L_{\mathrm{pk}} = 10log_{10}(p_{\mathrm{pk}}^2/p_0^2) = 20log_{10}(p_{pk}/p_0)$. Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 μPa^2.

peak-to-peak sound pressure

The difference between the maximum and minimum sound pressure over a specified frequency band and time window. Unit: pascal (Pa).

percentile level

The sound level not exceeded *N* % of the time during a specified time interval. The *N*th percentile level is equal to the (100−*N*) % exceedance level. See also N percent exceedance level.

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. Considered auditory injury. Compare with temporary threshold shift.

phocid

Member of the family Phocidae, one of the three groupings of pinnipeds (along with otariids and walrus). 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 underwater.

phocid pinnipeds underwater (PW), phocid carnivores in water (PCW)

See functional hearing group.

pinniped

Member of the superfamily Pinnipedia, which is composed of 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.

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, $\mathrm{PL}(x) = \mathrm{SL} - L(x)$. Unit: decibel (dB). See also transmission loss.

radiated noise level (RNL)

A source level that has been calculated assuming sound pressure decays geometrically with distance from the source, with no influence of the sea-surface or seabed. Often used to quantify source levels of vessels or industrial operations from measurements. See also monopole source level.

received level

The level of a given field variable measured (or that would be measured) at a given location.

reference value

Standard value of a quantity used for calculating underwater sound level. The reference value depends on the quantity for which the level is being calculated:

Quantity	Reference value
Sound pressure	p_0^2 = 1 µPa^2 or p_0 = 1 µPa
Sound exposure	E_0 = 1 µPa^2 s
Sound particle displacement	δ_0^2 = 1 pm^2
Sound particle velocity	u_0^2 = 1 nm^2/s^2
Sound particle acceleration	a_0^2 = 1 µm^2/s^4

sensation level

Difference between the sound pressure level and hearing threshold at a specified frequency. Unit: decibel (dB).

shear wave

A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called a secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sirenians (SI)

Members of the order Sirenia, which includes several manatee species and the dugong. See also functional hearing group.

sound

A time-varying disturbance in the pressure, stress, or material displacement of a medium propagated by local compression and expansion of the medium. In common meaning, a form of energy that propagates through media (e.g., water, air, ground) as pressure waves.

sound exposure

Time integral of squared sound pressure over a stated time interval in a stated frequency band. The time interval can be a specified time duration (e.g., 24 h) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: pascal squared second (Pa^2 s). Symbol: E.

sound exposure level (SEL)

The level (L_E) of the sound exposure (E) in a stated frequency band and time window: $L_E = 10\log_{10}(E/E_0)$ (ISO 18405:2017). Unit: decibel (dB). Reference value (E_0) for sound in water: 1 μPa^2 s.

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 (ISO 18405:2017). Unit: pascal squared second per hertz (Pa^2 s/Hz).

sound field

Region containing sound waves.

sound intensity

Product of the sound pressure and the sound particle velocity (ISO 18405:2017). The magnitude of the sound intensity is the sound energy flowing through a unit area perpendicular to the direction of propagation per unit time. Unit: watt per metre squared (W/m^2). Symbol: I.

sound particle acceleration

The rate of change of sound particle velocity. Unit: metre per second squared (m/s^2). Symbol: a.

sound particle motion

Movement caused by the action of sound of the smallest volume of a medium that represents its mean physical properties. Important for determining effects of underwater noise on fishes and invertebrates because their hearing organs sense particle motion rather than sound pressure.

sound particle displacement

Displacement of a material element caused by the action of sound, where a material element is the smallest element of the medium that represents the medium's mean density (ISO 18405:2017). Unit: metre (m). Symbol: δ.

sound particle velocity

The velocity of a particle in a material moving back and forth in the direction of the pressure wave. Unit: metre per second (m/s). Symbol: u.

sound pressure

The contribution to total pressure caused by the action of sound (ISO 18405:2017). Unit: pascal (Pa). Symbol: p.

sound pressure level (SPL), rms sound pressure level

The level (L_p) of the time-mean-square sound pressure (p_{rms}^2) in a stated frequency band and time window: $L_p = 10\log_{10}(p_{\mathrm{rms}}^2/p_0^2) = 20\log_{10}(p_{rms}/p_0)$, where rms is the abbreviation for root-mean-square. Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 µPa^2. SPL can also be expressed in terms of the root-mean-square (rms) with a reference value of p_0 = 1 µPa. The two definitions are equivalent.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

soundscape

The characterization of the ambient sound in terms of its spatial, temporal, and frequency attributes, and the types of sources contributing to the sound field (ISO 18405:2017).

source level (SL)

A property of a sound source equal to the sound pressure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 µPa^2 m^2.

spectrogram

A visual representation of acoustic amplitude over time and frequency. A spectrogram's resolution in the time and frequency domains should generally be stated as it determines the information content of the representation.

spectrum

Distribution of acoustic signal content over frequency, where the signal's content is represented by its power, energy, mean-square sound pressure, or sound exposure.

surface duct

The upper portion of a water column within which the gradient of the sound speed profile causes sound to refract upward and therefore reflect repeatedly off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)

Reversible loss of hearing sensitivity caused by noise exposure. Compare with permanent threshold shift.

thermocline

A depth interval near the ocean surface that experiences larger temperature gradients than the layers above and below it due to warming or cooling by heat conduction from the atmosphere and by warming from the sun.

transmission loss (TL)

The difference between a specified level at one location and that at a different location: $\mathrm{TL}(x_1,x_2) = L(x_1) - L(x_2)$ (ISO 18405:2017). Unit: decibel (dB). See also propagation loss.

unweighted

Term indicating that no frequency-weighting function is applied.

very high-frequency (VHF) cetaceans

See functional hearing group.

wavelength

Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

This section describes in detail the acoustic metrics, impact criteria, and frequency weighting relevant to the modelling study.

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 International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI S1.1-2013).

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:

$$L_p = 10 \log_{10} \left(\frac{1}{T} \int_T g(t)\, p^2(t)\, dt \Big/ p_0^2 \right) \text{ dB} \qquad \text{(A-1)}$$

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.

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):

$$L_E = 10 \log_{10} \left(\int_T p^2(t)\, dt \Big/ T_0 p_0^2 \right) \text{ dB} \qquad \text{(A-2)}$$

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:

$$L_{E,N} = 10 \log_{10} \left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \right) \text{ dB}\,. \qquad \text{(A-3)}$$

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.4). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

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. A decidecade is sometimes referred to as a "1/3 octave" because one tenth of a decade is approximately equal to one third of an octave. Each decade represents a factor 10 in sound frequency. Each octave represents a factor 2 in sound frequency. The centre frequency of the ith band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}} \text{ kHz} \tag{A-4}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i) \tag{A-5}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modelling spans from band 10 (f_c (10) = 10 Hz) to band 44 ($f_c(44)$ = 25 kHz).

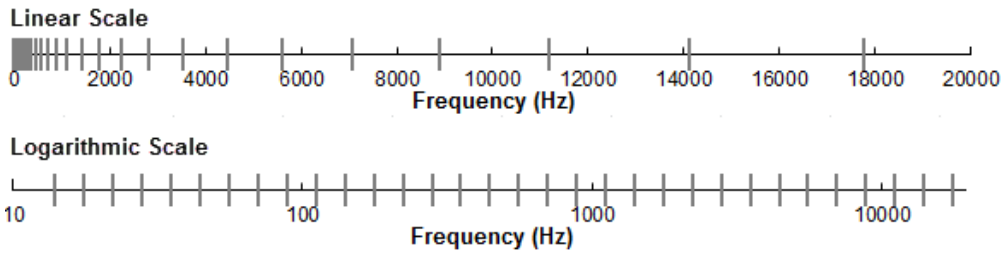


Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{lo,i}$ and $f_{hi,i}$:

$$L_{p,i} = 10\, log_{10} \int_{f_{lo,i}}^{f_{hi,i}} S(f)\, df \text{ dB} \tag{A-6}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}} \text{ dB} \tag{A-7}$$

Figure A-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient sound signal. Because the decidecade bands are wider than 1 Hz, 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.

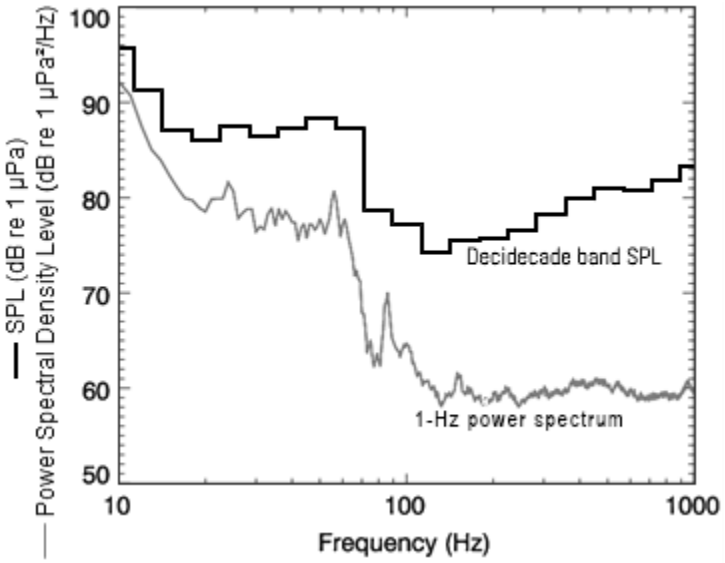


Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the power spectrum.

A.3. Marine Mammal Noise Effect Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggest 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 auditory injury, impairment, and disturbance. The following sections summarise the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury and Hearing Sensitivity Changes

In recognition of shortcomings of the SPL-only based auditory injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual auditory injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for humans; see Appendix A.4). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

As of present, a definitive approach is still not apparent. There is consensus in the research community that an SEL-based method is preferable, either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes auditory injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018 (NMFS 2018). Southall et al. (2019) revisited the interim criteria published in 2007. All noise exposure criteria in NMFS (2018) and Southall et al. (2019) are identical (for impulsive and non-impulsive sounds); however, the 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 in Southall et al. (2019).

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, Southall et al. 2021).

A.3.2.1. Non-Impulsive Noise

NMFS currently uses step function (all-or-none) threshold of 120 dB re 1 µPa SPL (unweighted) for non-impulsive sounds to assess and regulate noise-induced behavioural impacts on 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, 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).

A.3.2.2. Impulsive Noise

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)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 US 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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^{2}\right]^{a}\left[1+(f/f_{hi})^{2}\right]^{b}}\right)\right] \quad \text{(A-8)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), 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 acoustic impacts on marine mammals (NMFS 2018), and in the latest guidance by Southall (2019). The updates did not affect the content related to either the definitions of frequency-weighting functions or the threshold values. Table A-1 lists the frequency-weighting parameters for each hearing group relevant to this assessment, and Figure A-3 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	flo (Hz)	fhi (kHz)	*K* (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
High-frequency cetaceans (most dolphins, plus sperm, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
Very-high-frequency cetaceans (true porpoises, *Kogia*, river dolphins, *Cephalorhynchus* spp., *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

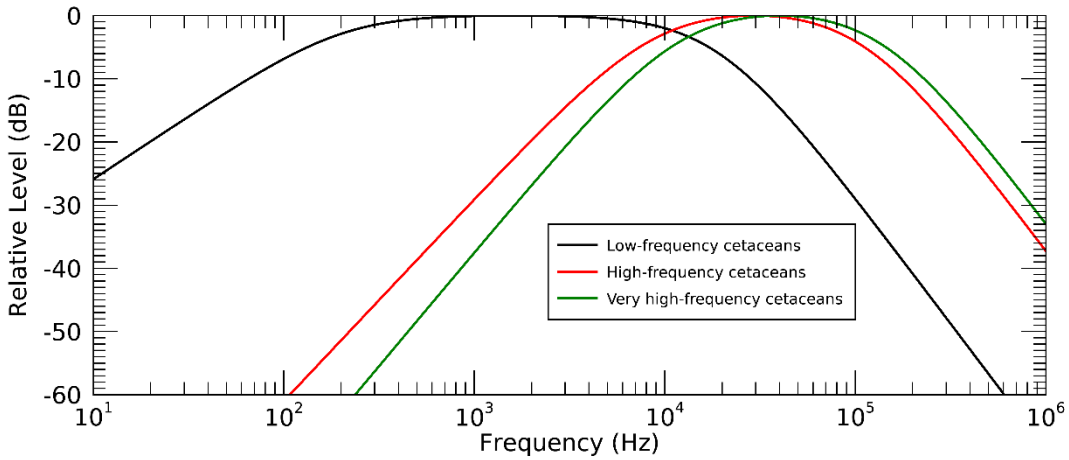


Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019).

Appendix B. Methods and Parameters

B.1. Environmental Parameters

B.1.1. Bathymetry

Bathymetry throughout the modelled area was extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009). Bathymetry data were re-gridded and combined onto a Map Grid of Australia (MGA) coordinate projection (Zone 50) with a regular grid spacing of 200 × 200 m (Figure B-1).

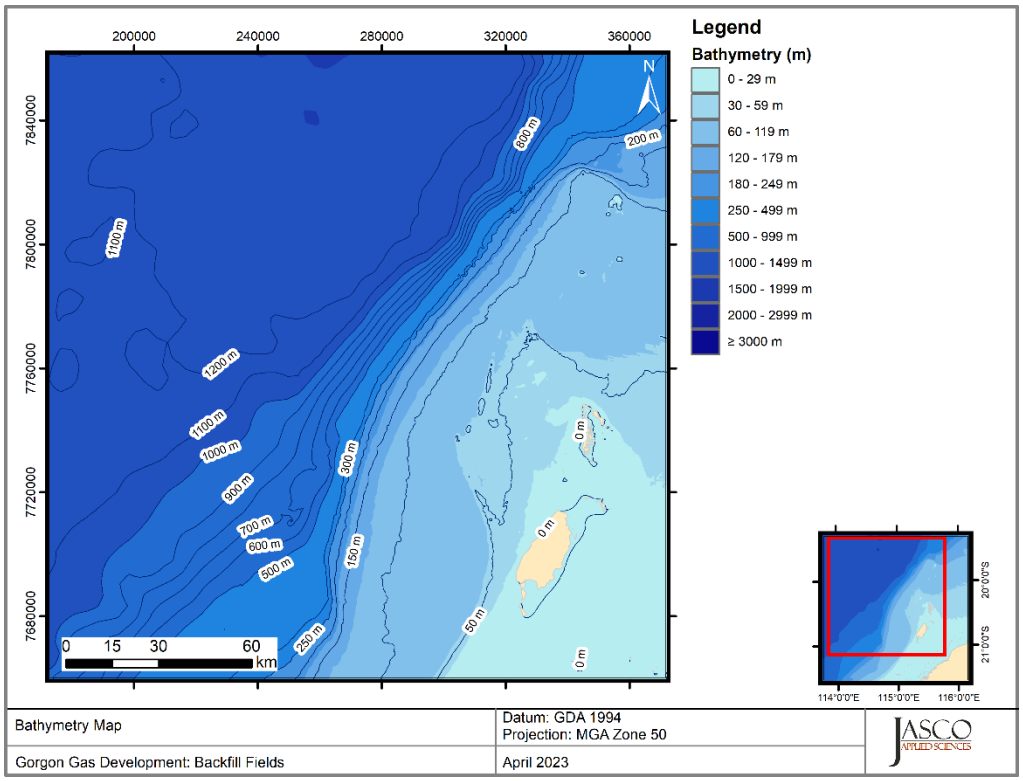


Figure B-1. Bathymetry in the modelled area.

B.1.2. Sound Speed Profile

The sound speed profile in the area was derived from temperature and salinity profiles from the US 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 US 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 at distances less than 100 km around a representative modelled site. To allow for operational flexibility, the sound speed profiles considered for modelling of operations were selected through a sensitivity analysis considering all months, as shown in Figure B-2. The month of August was found to be the most favourable for sound propagation and this profile was considered in the modelling.

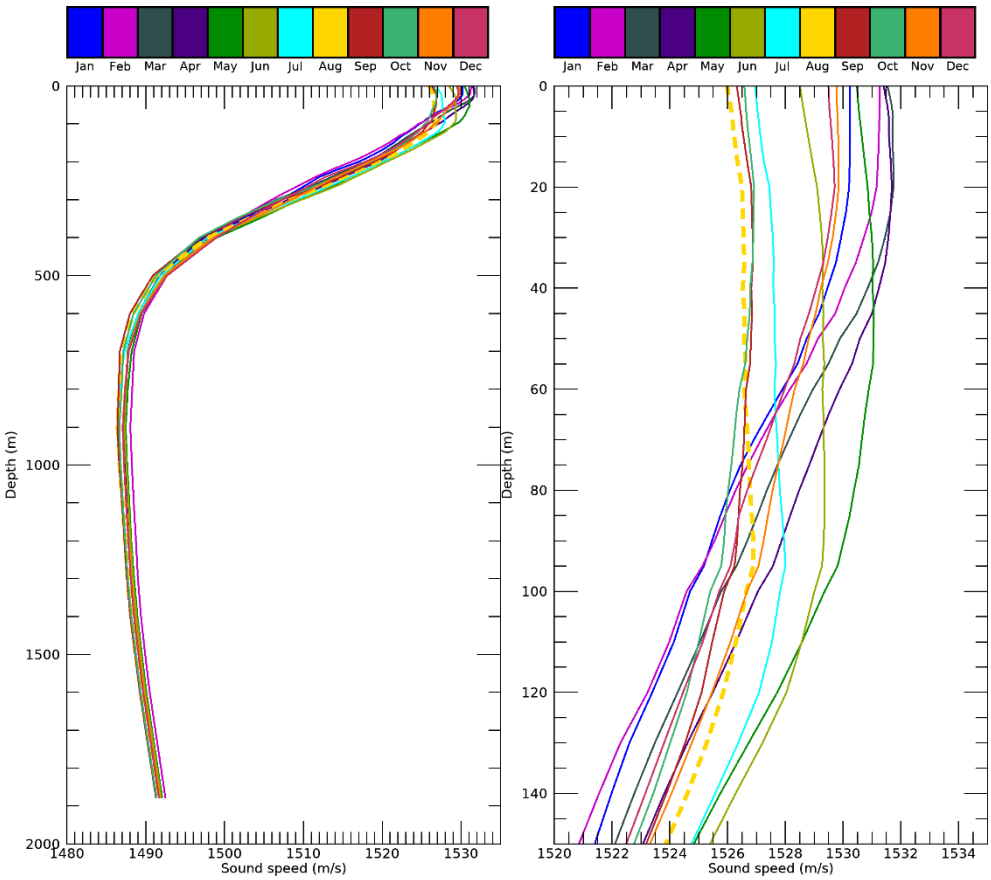


Figure B-2. Sound speed profiles per month for the modelled area: (Left) full profile and (right) top 150 m. The dashed profile indicates the profile considered in the modelling (August).

B.1.3. Geoacoustics

The propagation model used in this study considers five geoacoustic areas, which determine how sound is reflected from the seabed, as well as how it is transmitted, reflected, and absorbed into the sediment layers.

For Areas 1 to 4, information on seabed geology was provided by the client in the form of a geohazards assessment report (Duncan and Erbe 2019). Based on the information provided in that report, the seabed in the study area was divided into four geoacoustic regions.

1. Kangaroo Syncline – The region in water depths greater than 1200 m, close enough to the continental shelf to have potentially been affected by debris flows, as described by Duncan and Erbe (2019).
2. Exmouth Plateau and surrounding area – The Exmouth plateau and the region in water depths greater than 1200 m, considered unlikely to be impacted by debris flow events.
3. Continental Slope – The top of the continental slops was taken as the 200 m bathymetry contour. The bottom of the slope was taken as the 1200 m bathymetry contour, except in the vicinity of the saddle leading to the Exmouth plateau where the 1000 m contour was used.
4. Continental Shelf – Water depths less than 200 m.
5. For the purposes of this modelling study, Area 1 was situated in the Exmouth Plateau, Areas 2 and 3 were situated in the Kangaroo Syncline Area, and Area 4 was situated in the Continental Slope region. The composition of the seabed in each of these regions is summarised in Tables B-1 to B-3.

Table B-1. Geoacoustic profile for the Exmouth Plateau sites (Area 1). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Carbonate silt	1.70	1561-1566	1.0	130	2.5
5-205	Sedimentary transition layer	1.96	1580-1766	1.0		
>205	Sedimentary rock halfspace	2.40	3400	0.1		

Table B-2. Geoacoustic profile for the Kangaroo Syncline sites (Areas 2 and 3). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Carbonate silt	1.70	1561-1566	1.0	270	2.5
5-15	45 ky bp debris flow	1.90	1636-1645	1.0		
15-20	Post MTC1 transitional	1.92	1650-1700	1.0		
20-120	Mass transport complex	1.95	1710-1803	0.8		
120-320	Sedimentary transition layer	1.96	1790-1980	1.0		
>320	Sedimentary rock halfspace	2.40	3400	0.1		

Table B-3. Geoacoustic profile for the Continental Slope sites (Area 4). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50	Carbonate silt	1.70	1565-1611	1.0	259	2.5
50-200	Sedimentary transition layer	1.96	1620-1759	1.0		
>200	Sedimentary rock halfspace	2.40	3400	0.1		

Area 5, on the Continental Shelf, was located in close proximity to a coring location sampled during IODP Cruise 356 Gallagher et al. (2017). The core information was used to estimate the thickness of the un-lithified sediment and the average sediment lithology. The geoacoustic properties were then calculated using the grain-shearing sediment model of Buckingham (2005) based on the information from Gallagher et al. (2017). The core information indicated a loose sediment layer approximately 450 m thick overlaying the bedrock estimated as cemented calcarenite (Table B-4) (the parameters for calcarenite were taken from Duncan et al. (2013)).

Table B-4. Geoacoustic profile for Continental Shelf sites (Area 5). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

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)
0-3	Silty Sand	1.66-1.67	1539-1650	0.24-0.68	200.0	3.65
3-10		1.67-1.69	1650-1740	0.68-0.96		
10-50	Increasingly consolidated sand-silt-clay	1.75-1.78	1704-1872	0.80-1.26		
50-100		1.78	1872-1979	1.26-1.51		
100-450		1.78-1.96	1979-2382	1.51-2.04		
>450	Well-cemented sand/calcarenite	2.20	2600	0.12		

B.2. Sound Propagation Models

B.2.1. Propagation Loss

The propagation of sound through the environment was modelled by predicting the acoustic propagation 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 propagation loss occurs. Propagation 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. Propagation loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic energy source level (ESL), expressed in dB re 1 $\mu Pa^2 \cdot s\ m^2$, and propagation loss (PL), 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 $\mu Pa^2 \cdot s$ by:

$$RL = SL - PL. \tag{B-1}$$

B.2.2. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). While other models may be more accurate for steep-angle propagation in high-shear environment, MONM is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1 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 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 propagation 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 B-3).

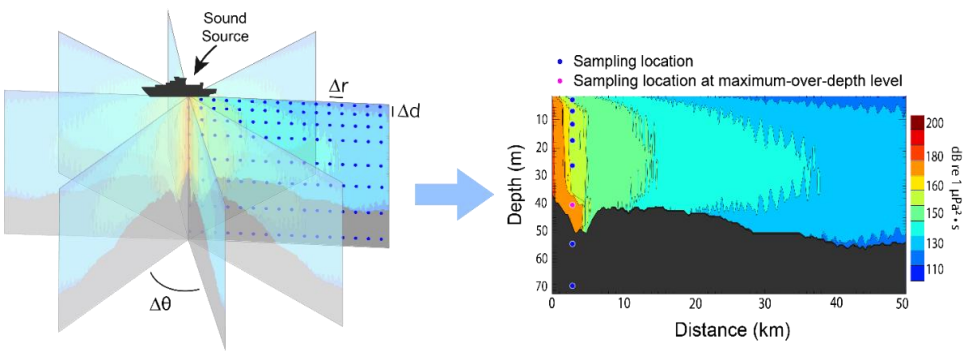


Figure B-3. The N×2-D and maximum-over-depth modelling approach used by MONM.

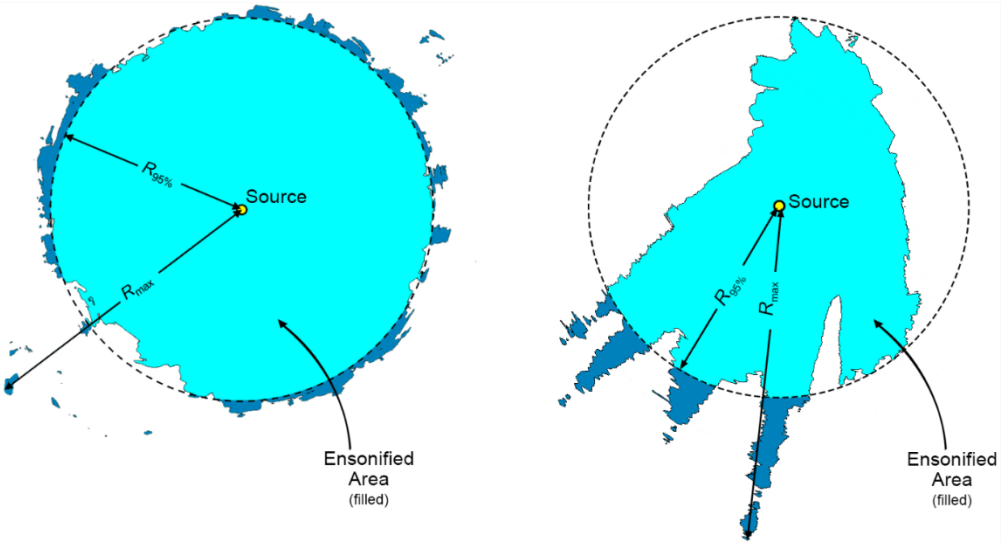
MONM treats frequency dependence by computing acoustic propagation loss at the centre frequencies of decidecade bands. Sufficiently many decidecade frequency-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the propagation loss is modelled within each of the N vertical planes as a function of depth and range from the source. The decidecade received per-second SEL are computed by subtracting the band propagation loss values from the directional source level in that frequency band. Composite broadband received per-second SEL are then computed by summing the received decidecade levels.

The received 1-s 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-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-second SEL. These maximum-over-depth per-second SEL are presented as colour contours around the source.

B.3. 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 B-4).

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 B-4(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 B-4(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.



(a) (b)

Figure B-4. 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}.

B.4. Estimating Sound Field from Moving Vessels

During vessel transit, new sound energy is constantly being introduced to the environment. The noise footprint for the transiting vessels considered in this report were estimated by modelling the 1-s SEL for the vessel at one location, and by translating and summing these footprints along the vessel transit routes. The vessel locations along the tracks were spaced uniformly, with an approximate step of $\Delta s \approx 100$ m for all scenarios with a track.

The SEL sound field at any given point along the path is dependent upon the duration of exposure, which with a fixed footprint spacing depends upon the speed of the vessel during each segment of the transit. The 1-s SEL footprint at each vessel location (i) were therefore scales based on the speed of the vessel following:

$$\mathrm{SEL}_i = \mathrm{SEL}_{1s} + 10\log_{10}\left(\frac{\Delta s}{v}\right). \qquad \text{(B-2)}$$

where v represents the vessel speed in m/s.

The present method acceptably reflects large-scale sound propagation features, primarily dependent on water depth, which dominate the cumulative field and is thus considered to provide a meaningful estimate of the SEL_{24h} field.

B.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 that 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 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 decidecade 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:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda} \qquad \text{(C-1)}$$

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 C-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.

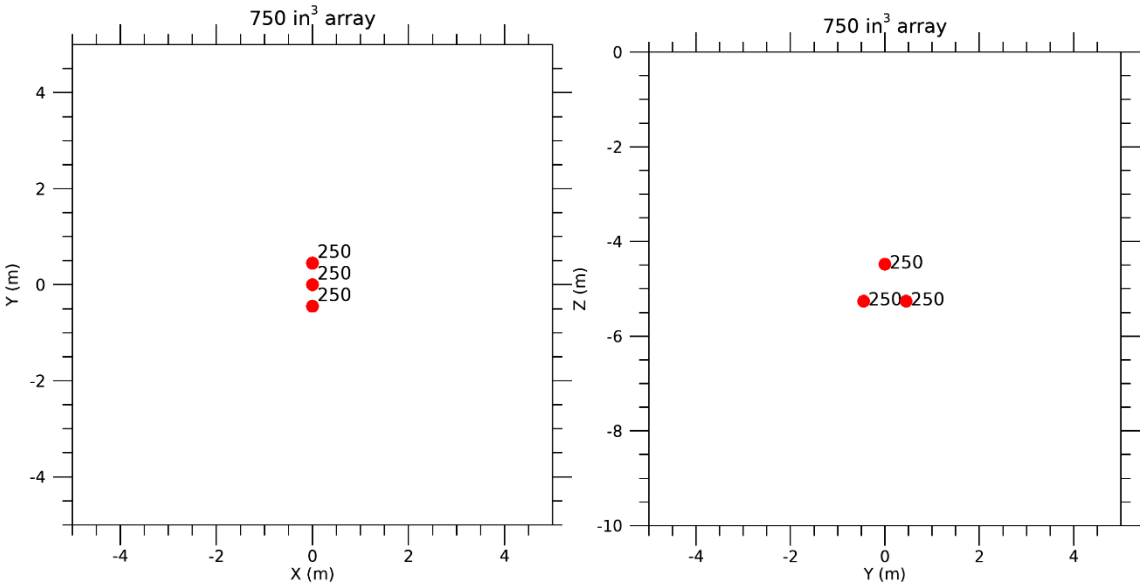


Figure C-1. (Left) Plan and (right) side layouts of the modelled 750 in³ seismic source array Operational depth is 5 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table C-1.

Table C-1. Layout of the modelled 750 in³ 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 (in³)
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 (see Appendix C.2). Horizontal decidecade band source levels shown as a function of band centre frequency and azimuth (Figure C-3) indicate that this array is mainly isotropic.

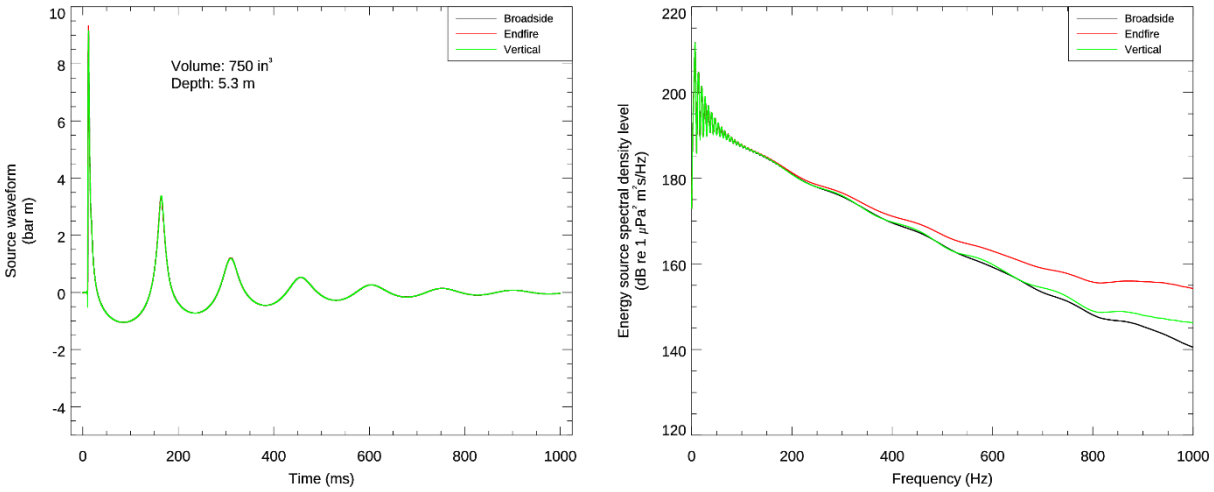


Figure C-2. Predicted source level details for the 750 in^3 array at a 5 m operational depth. (Left) the overpressure signature and (right) the power spectrum for horizontal (broadside and endfire) and vertical directions.

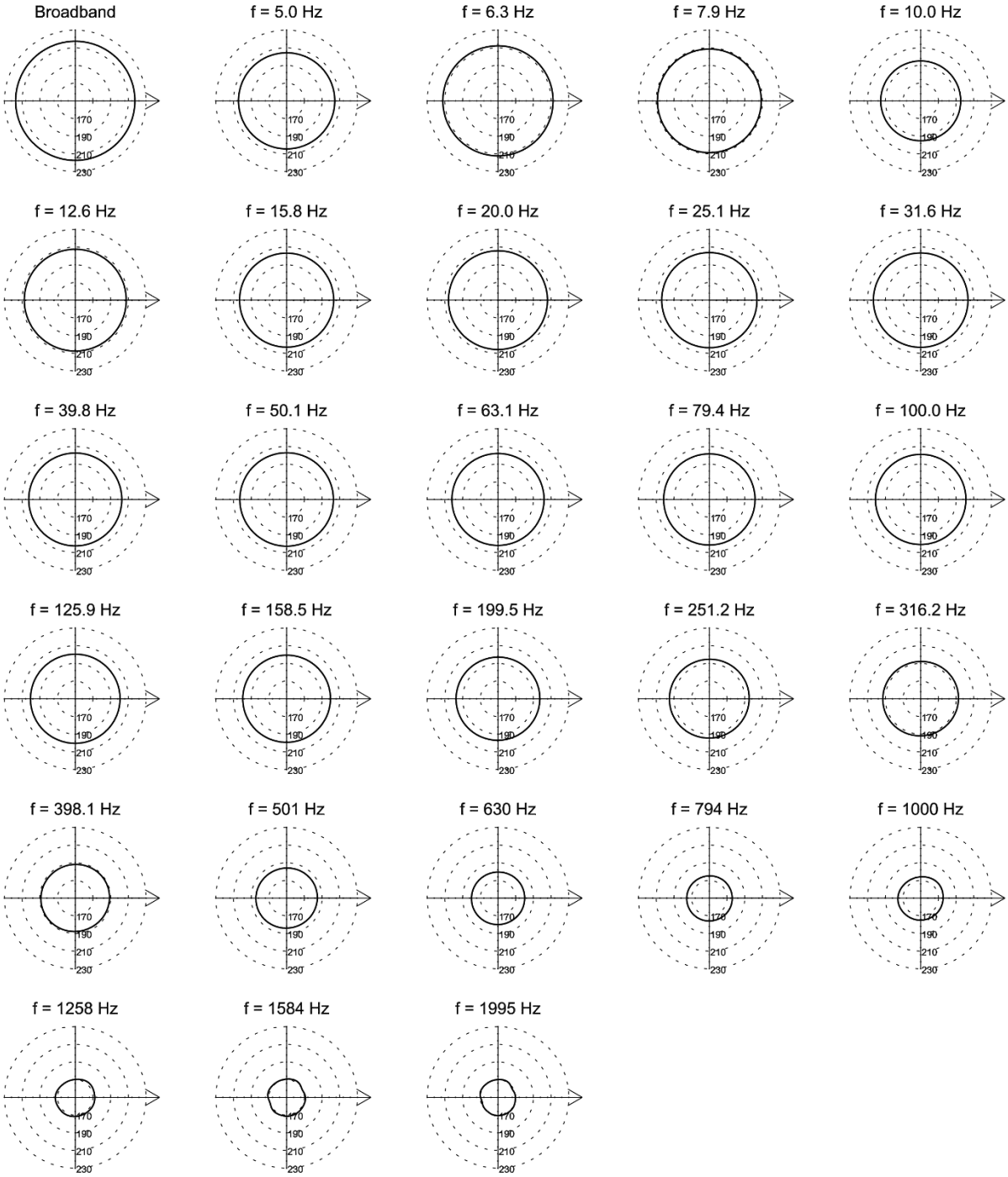


Figure C-3. Directionality of the predicted horizontal source levels for the 750 in^3 seismic source array, 10 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled, shown above the plots. The endfire axis (i.e., axis parallel to the sagittal plane) is to the right. Operational depth is 5 m.

Appendix D. Animal Movement and Exposure Modelling

Animal movement and exposure modelling considers the movement of both sound sources and animals over time. Acoustic source and propagation modelling are used to generate 3-D sound fields that vary as a function of distance to source, depth, and azimuth. Sound sources are modelled at representative sites and the resulting sound fields are assigned to source locations using the minimum Euclidean distance. The sound received by an animal at any given time depends on its location relative to the source. Because the true locations of the animals within the sound fields are unknown, realistic animal movements are simulated using repeated random sampling of various behavioural parameters. The Monte Carlo method of simulating many animals within the operations area is used to estimate the sound exposure history of the population of simulated animals (animats).

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more simulated animats, the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. Typically, the animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF can be scaled using the real-world density if it is available.

Several models for marine mammal movement have been developed (Ellison et al. 1987, Frankel et al. 2002, Houser 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behaviour. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth ranges can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source marine mammal movement and behaviour model (3MB, Houser 2006) and used to predict the exposure of animats to sound arising from the anthropogenic activities. Animats are programmed to behave like the species likely to be present in the survey area. The parameters used for forecasting realistic behaviours (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's modelled sound exposure levels are summed over the total simulation duration to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as 3MB (Houser, 2006), but has been extended to be directly compatible with JASCO's Marine Operations Noise Model (MONM) and Full Waveform Range-dependent Acoustic Model acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioural states based on time and space dependent modelled variables such as received levels for aversion behaviour, although aversion was not considered in this study.

D.1. Animal Movement Parameters

JASMINE uses previously measured behaviour to forecast behaviour in new situations and locations. The parameters used for forecasting realistic behaviour are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behaviour of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser 2006). Different sets of parameters can be defined for different behaviour states. The probability of an animat starting out in or transitioning into a given behaviour state can in turn be defined in terms of the animat's current behavioural state, depth, and the time of day. In addition, each travel parameter and behavioural state has a termination function that governs how long the parameter value or overall behavioural state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. The parameters relating to travel in these two planes are briefly described below.

Travel sub-models

- **Direction**– determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to range from strongly biased to undirected. A random walk model can be used for behaviours with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behaviour is used to emulate the foraging behaviour of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

D.2. Exposure Integration Time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (L_p) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behaviour collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. For this study, a representative 24-hour period was simulated.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the source during an operation is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited. In the simulation, every animat that reaches a border is replaced by another animat entering at the opposing border—e.g., an animat crossing the northern border of the simulation is replaced by one entering the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition. The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

D.3. Seeding Density and Scaling

Seeding density refers to the spatial sample rate, in units of animats/km^2, used in the simulation. It is not related to the real-world animal density, but rather is a model parameter that controls the how samples are drawn from the model space. The minimum required seeding density for any given project depends on several factors such as bathymetry, source characteristics, and the behavioural profile of the animats, with the main constraint being computation time and resources. Seeding density is adjusted as needed based on model conditions specific to a project or project area.

In the present study, the exposure criteria for continuous sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 4 animat/km^2 over the entire simulation area. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA.

appendix e ghg emissions inventory technical report



human energy®

backfill fields development greenhouse gas emissions technical note

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1 introduction

1.1 project overview

Chevron Australia Pty Ltd (CAPL) is proposing to undertake the Backfill Fields Development which comprises the construction, installation, operation, and decommissioning of seven backfill gas fields (Chandon, Chrysaor and Dionysus (C&D), Geryon and Eurytion (G&E), Semele, and West Tryal Rocks [WTR]) in the Greater Gorgon Area. The Backfill Fields Development is a subsea tieback development to existing Gorgon Foundation Project infrastructure. The intent of the Backfill Fields Development is to maintain gas supply to the existing Gas Treatment Plant (GTP) on Barrow Island to sustain current production rates of domestic gas and liquified natural gas (LNG).

1.2 purpose

The purpose of this Technical Note is to provide an overview of the methods used to estimate greenhouse gas (GHG) emissions for the Backfill Fields Development. The GHG emissions inventory has been developed to support the environmental impact and risk assessment within the Gorgon Gas Development: Backfill Fields Offshore Project Proposal (OPP; Ref. 1) which is required under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth) (OPGGS(E)R).

1.2.1 regulatory context

The National Offshore Petroleum Safety and Environmental Management Authority's (NOPSEMA's) decisions regarding petroleum activities are made in accordance with the OPGGS(E)R. As per regulation 7(5)(b) an OPP must include "an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk"[1].

NOPSEMA's decisions are also guided by other relevant Commonwealth legislation including the *Environment Protection and Biodiversity Conservation 1999* (EPBC Act). Specifically, NOPSEMA's decision making guideline for OPPs (Ref. 2) refers to an evaluation of relevant indirect impacts, having regard to the EPBC Act Policy Statement—'Indirect consequences' of an action: Section 527E of the EPBC Act (hereafter referred to as the EPBC Indirect Consequences Policy Statement; Ref. 3).

Section 527E of the EPBC Act defines the 'impact' of an action as follows:

> "(1) For the purposes of this Act, an event or circumstance is an ***impact*** of an action taken by a person if:
>
> (a) the event or circumstance is a direct consequence of the action; or
>
> (b) for an event or circumstance that is an indirect consequence of the action – subject to subsection (2), the action is a substantial cause of that event or circumstance.
>
> (2) For the purposes of paragraph (1)(b), if:

[1] Under the OPPGS(E)R an environmental impact of an activity means "any change to the environment, whether adverse or beneficial, that wholly or partially results from the activity".

(a) a person (the ***primary person***) takes an action (the ***primary action***); and

(b) as a consequence of the primary action, another person (the ***secondary person***) takes another action (the ***secondary action***); and

(c) the secondary action is not taken at the direction or request of the primary person; and

(d) an event or circumstance is a consequence of the secondary action;

then that event or circumstance is an ***impact*** of the primary action only if:

(e) the primary action facilities, to a major extent, the secondary action; and

(f) the secondary action is:

(i) within the contemplation of the primary person; or

(ii) a reasonably foreseeable consequence of the primary action; and

(g) the event or circumstance is:

(i) within the contemplation of the primary person; or

(ii) a reasonably foreseeable consequence of the secondary action."

1.3 scope

The GHG emissions inventory within this Technical Note is applicable to the petroleum activities comprising the Backfill Fields Development (as described in Section 4 of the OPP). Note: Unplanned events (including major repairs and responding to emergency events) are considered out of scope of the emissions inventory.

GHG emissions that constitute 'direct consequences' as well as GHG emissions that may constitute 'indirect consequences' of the Backfill Fields Development (in accordance with the EPBC Indirect Consequences Policy Statement [Ref. 3]) have been included in this inventory. In this Technical Note GHG emissions have been categorised based on the following definitions:

- **BFF GHG emissions**—these are GHG emissions that are a direct consequence of planned petroleum activities that comprise the Backfill Fields Development (as described in Section 4 of the OPP) from sources within the Development Area (DA) in Commonwealth waters
- **BFF gas processing GHG emissions**—these are GHG emissions from sources outside of the DA associated with CAPL's operation of the Gorgon Gas Development facilities (as outlined MS 800)[2] and that are an indirect consequence of the Backfill Fields Development
- **BFF secondary GHG emissions**—these are transport (shipping) and third-party end use GHG emissions that are a reasonably foreseeable consequence of the Backfill Fields Development from sources outside the DA .

Note: The GHG emissions from gas processing on Barrow Island and the transport and third-party end use for the Gorgon Gas Development have been

[2] This includes emissions from operation of the Gorgon GTP for the processing of LNG and domestic gas, as well as emissions from Barrow Island support operations. This is consistent with the presentation of GHG emissions for the Gorgon Gas Development in existing environment approvals (e.g. Ref. 4; Ref. 5; Ref. 6).

previously described and assessed within existing environmental approvals (e.g. Ref. 4; Ref. 5; Ref. 6; see also Section 1.3.1).

The Gorgon Gas Development, as described in existing environmental approvals, incorporates gas resources from the Greater Gorgon Area, and as such, the GHG emission estimates for the Gorgon Gas Development inherently incorporate emissions associated with the processing, transport and end use of gas resources from the Greater Gorgon Area. Therefore, a proportion of these previously described and assessed emissions for the Gorgon Gas Development are the **BFF gas processing GHG emissions** and **BFF secondary GHG emissions** associated with the seven gas fields of the Backfill Fields Development. These proportions of the overall Gorgon Gas Development's emissions have been included in this GHG emissions inventory to inform the evaluation of impacts and risks associated with the Backfill Fields Development in the OPP.

1.3.1 existing environmental approvals

GHG emissions occurring as a consequence of the Gorgon Gas Development have existing primary environmental approvals under the EPBC Act and the *Environmental Protection Act 1986* (WA) (EP Act), including:

- the three-train Revised and Expanded Gorgon Gas Development (Ref. 4) which was approved with conditions (EPBC 2008/4178 and MS 800 [as amended from time to time[3]])
  - the GHG emissions estimated for the three-train proposal were subsequently revised within the Fourth Train Expansion Proposal (Ref. 5) which was approved with conditions (EPBC 2011/5942 and MS 1002) and within the Gorgon Gas Development and Jansz Feed Gas Pipeline: Greenhouse Gas Abatement Program (Ref. 7) which was approved by the Ministers delegate of the WA Environmental Protection Authority in May 2015
  - the Gorgon GTP Greenhouse Gas Management Plan [GHGMP] (Ref. 6) was developed to to satisfy the requirements of condition 27 of MS 800 (as amended by MS 1198) and also included a revised estimate of secondary GHG emissions for the Gorgon Gas Development; this plan was approved by the Ministers delegate of the WA Environmental Protection Authority in February 2024
- the Development of Jansz–Io Deepwater Gas Field which was approved with conditions (EPBC 2005/2184)
- the Jansz Feed Gas Pipeline which was approved with conditions (MS 769).

Therefore, any Gorgon Gas Development gas processing GHG emissions should be considered in the context of the revised estimate for the three-train Revised and Expanded Gorgon Gas Development (i.e. average annual emissions of ~9.47 Mtpa CO_2-e[4]). Similarly, any secondary GHG emissions should be considered within the context of the revised estimate for a representative year of three-train production (~49.8 Mtpa CO_2-e[4]).

[3] Since the Revised and Expanded Gorgon Gas Development was approved, further changes to the Gorgon Gas Development have been made and/or approved and are now also part of the Gorgon Gas Development. These include MS 865, MS 965, MS 1136, and MS 1198.

[4] These GHG emissions estimates do not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken.

The majority of GHG emissions associated with the Backfill Fields Development relate to gas processing, transport and third-party end use of Gorgon Gas Development products as already assessed under these primary approvals. For the purpose of this Backfill Fields Development GHG emissions inventory, a proportion of the overall Gorgon Gas Development gas processing, transport and third-party end use GHG emissions have been included (see Sections 2.2 and 2.3 of this Technical Note).

For a detailed description of primary environmental approvals and relevant GHG emission estimates refer to Section 8.3.6 of the OPP.

Note: The fields proposed to be developed as part of the Backfill Fields Development (as described in the OPP) are not contingent on the additional LNG train (i.e. fourth-train) or the additional Feed Gas Pipeline System that were described within the Gorgon Gas Development Fourth Train Expansion Proposal (Ref. 5). The Backfill Fields Development (as described in the OPP) has been designed as a subsea tieback development to the existing Gorgon Foundation Project infrastructure (i.e. it will utilise the two existing Feed Gas Pipeline Systems and existing domestic gas and three-train LNG capacity at the Gorgon GTP).

1.4 limitations

As the Backfill Fields Development is in early planning phase, this GHG emissions inventory is based on conservative assumptions about design, vessel/equipment requirements, activity durations, reservoir recovery and gas supply forecasts, to support the environmental impact and risk assessment in the OPP. The GHG estimates presented in this inventory are based on the data and assumptions as described in this Technical Note (Section 2).

Estimates of GHG emissions will be refined for each field (or co-developed fields) development during of the subsequent Environment Plans (EPs). The GHG emissions estimates provided in EPs will be based on more detailed field development designs and incorporate contemporary data and/or calculation methods available at the time. Therefore, there may be differences between estimates presented in this GHG emissions inventory prepared to support the OPP and those presented in later EPs for the Backfill Fields Development.

2 GHG emissions inventory

The below GHG emissions inventory for the Backfill Fields Development does not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken for the Gorgon Gas Development or by third-parties. For example, there are regulatory GHG emission reduction requirements for the Gorgon Gas Development (e.g. Commonwealth Safeguard Mechanism and environmental approval conditions under the EP Act (WA)), or similarly any actions taken by third-parties in respect to transport or end use of products (see Section 3.2).

2.1 BFF GHG emissions

2.1.1 sources

The following activities have been identified as **BFF GHG emissions** sources for planned petroleum activities for the Backfill Fields Development:

- fuel combustion by vessels, mobile offshore drilling units (MODUs), and helicopters within the Development Area (DA)
- flaring and cold venting from the MODU within the DA
- fugitive emissions.

Any equipment (e.g. remotely operated vehicles, multibeam echo sounders, etc.) used during vessel-based activities are powered by the vessel itself, and as such these do not represent an additional emission source to that already accounted for by the vessel.

Fugitive emissions may occur from the Backfill Fields Development subsea hydrocarbon system in Commonwealth waters; however, these would represent a minor contribution to the overall GHG emissions inventory. Fugitive emissions for the Gorgon Gas Development are estimated based on product throughput (as per accepted National Greenhouse and Energy Reporting [NGER] scheme methodology), and therefore, any offshore component for the Backfill Fields Development cannot easily be separated. As such, fugitive emissions estimates for the Backfill Fields Development are incorporated into the **BFF gas processing GHG emissions** inventory in (Section 2.2).

2.1.2 calculation methods

2.1.2.1 combustion of liquid fuels

The emissions calculation for the combustion of liquid fuels for transport energy purposes uses Method 1 under section 2.41 of the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth) (NGER Measurement Determination):

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1{,}000}$$

where:

- $\mathbf{E_{ij}}$ is the emissions of gas type (j), being carbon dioxide (CO_2), methane (CH_4) or nitrous oxide (N_2O), released from the combustion of fuel type (i) measured in tonnes CO_2-e (t CO_2-e)

- **Q_i** is the quantity of fuel type (i) combusted for transport energy purposes measured in kilolitres (kL)
- **EC_i** is the energy content (EC) factor of fuel type (i)
- **EF_{ijoxec}** is the emission factor (EF) for each gas type (j) measured in kilograms (kg) CO_2-e per gigajoule (GJ) of fuel type (i)

The relevant energy content and emission factors are shown in Table 2-1.

Table 2-1: Energy content and emission factors

Fuel type and activity	Energy content	Emission factor		
		CO_2	CH_4	N_2O
Diesel oil combustion for transport energy purposes[5]	38.6 GJ/kL	69.9 kg CO_2-e/GJ	0.1 kg CO_2-e/GJ	0.4 kg CO_2-e/GJ
Kerosene combustion for transport energy purposes[5,6]	36.8 GJ/kL	69.6 kg CO_2-e/GJ	0.01 kg CO_2-e/GJ	0.6 kg CO_2-e/GJ
Natural gas flaring[7]	N/A	2.80 t CO_2-e/t gas	0.933 t CO_2-e/t gas	0.026 t CO_2-e/t gas

2.1.2.2 flaring

The emissions calculation for flaring of natural gas uses Method 1 under section 3.4.4 of the NGER Measurement Determination:

$$E_{ij} = Q_i \times EF_{ij}$$

where:

- **E_{ij}** is the fugitive emissions of gas type (j) from a fuel type (i) flared measured in t CO_2-e
- **Q_i** is the quantity of fuel type (i) flared measured in tonnes (t)
- **EF_{ij}** is the EF for gas type (j) measured in t CO_2-e emissions per tonne of the fuel type (i) flared.

The relevant emission factors are shown in Table 2-1.

2.1.2.3 cold venting

The emissions calculation for venting of natural gas is adapted from Equations 3-2 and 6-2 from API's Compendium of Greenhouse Gas Emissions Methodologies (Ref. 8):

$$E_x = V \times F_x \times \frac{MW_x}{molar\ volume\ conversion}$$

[5] Energy content and emission factors for transport energy purposes sourced from Division 4.1 of Schedule 1.

[6] Of the aviation fuel types listed in the NGER Measurement Determination, kerosene was used for calculation purposes as this has higher energy content and emission factors relative to other aviation fuel types (e.g. gasoline).

[7] Emission factors for flaring sourced from Section 3.44 of NGER Measurement Determination.

$$E(CO_2e) = \sum (E_x \times GWP_x)$$

where:

- **E_x** is emissions of gas type (x), being CO_2 or CH_4, measured in mass (tonnes)[8]
- **V** is the vent volume at standard temperature and pressure (STP) conditions, measured in standard cubic feet (sfc) or standard cubic metres (Sm^3)
- **F_x** is the molar fraction of gas type (x) in the vent gas stream
- **MW_x** is the molecular weight of gas type (x)
- **molar volume conversion** is the conversion from molar volume to mass (379.3 scf/lb-mole or 23.685 Sm^3/kg-mole at STP conditions)
- **E(CO_2e)** is the emissions measured in t CO_2-e
- **GWP_x** is the global warming potential of gas type (x) measured in t CO_2-e.

The relevant molecular weights and global warming potentials (GWPs) are shown in Table 2-2.

Table 2-2: Molecular weights and global warming potentials

Molecular weight[9]		Global warming potential[10]	
CO_2	CH_4	CO_2	CH_4
44.01	16.04	1	28

2.1.3 data inputs and assumptions

Table 2-3 provides a summary of the assumptions regarding sources (e.g. numbers and/or types of vessels) and durations that were used when developing this GHG emissions inventory.

Table 2-3: Summary of data inputs and assumptions for BFF direct GHG emission calculations

Phase	Inputs and assumptions
Surveys	Surveys, each of which may take ~3–4 weeks (Section 4.3.1 of OPP), may be undertaken at various times during the life of the Development. **Geophysical surveys**: • geophysical surveys may be required during the life of the Backfill Fields Development to supplement pre-existing geophysical data; however, the number and spatial and extent of these surveys is not yet known • for calculation purposes have allowed for: – drilling ▪ duration of pre-installation surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) – pipelay and subsea structures ▪ duration of pre-pipelay/pre-installation surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) ▪ duration of post-pipelay/post-installation surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields)

[8] Conversion factors for units of mass 1 tonne = 1,000 kg = 2,204.62 lbs (sourced from Table 3-4 in Ref. 8).

[9] Molecular weight sourced from Table 3-7 in Ref. 8.

[10] GWPs sourced from Table 3-1 in Ref. 8.

Phase	Inputs and assumptions
	▪ as-built surveys incorporated into main installation phase calculations – decommissioning ▪ duration of pre-decommissioning surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) ▪ duration of as-left surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) – one IMR vessel present within the DA for full duration of survey – fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets **Geotechnical surveys**: • geotechnical surveys may be required during the life of the Backfill Fields Development to supplement pre-existing geotechnical data; however, the number and spatial and extent of these surveys is not yet known • for calculation purposes have allowed for: – estimated duration at 4 weeks per field or co-developed field (i.e. 140 days for all fields) – one IMR vessel present within the DA for full duration of survey – fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets **Environmental surveys**: • environmental surveys may be required during the life of the Backfill Fields Development; however, the number and spatial and extent of these surveys is not yet known • for calculation purposes have allowed for: – duration of tangible underwater cultural heritage surveys estimated at 4 weeks; assumed at WTR only (due to water depth <130 m) – duration of pre-construction surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) – duration of post-decommissioning surveys estimated at 4 weeks per field or co-developed field (i.e. 140 days for all fields) • one IMR vessel present within the DA for full duration of survey • fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets
Drilling	**Production well drilling**: • duration of drilling activities is expected to take up to 24 months per field or co-developed field (Section 4.3.2 of OPP) – 24 months (2 years) = 730 days per field or co-developed field – i.e. 3,650 days for all 40 wells • MODU assumed to be present within the DA for full duration of drilling campaigns – the type of MODU has not yet been selected for the field developments – for calculation purposes have conservatively assumed a drillship using dynamic positioning (DP) – fuel consumption for DP drillship based on reported fuel consumption during the GS2 campaigns • conservatively assumed use of two offshore support vessels (OSVs) present within the DA for the duration of the drilling campaigns – fuel consumption for drilling OSVs based on reported fuel consumption during the GS2 campaigns • helicopter flight frequency is estimated to be ~5 flights per week for the MODU (Section 4.3.6.3 of OPP) – i.e. 24 months (104 weeks) = 520 flights per field or co-developed field

Phase	Inputs and assumptions
	– duration within the DA assumed to be one-hour per flight – estimated hourly fuel consumption based on data from existing CAPL-operated assets **Well flowback**: • wells may be subject to flowback at the end of well completions; and if well flowback occurs then flaring may be required (Section 4.3.2.9 of OPP) • based on typical rates and durations on previous CAPL campaigns, the estimated volume of natural gas flared during well flowback is ~60 MMscf per well flared over one day – using an approximate conversion factor of 1 MMscf = 21 tonnes (Ref. 9), then ~1,260 tonnes natural gas flared for each of the 40 wells • while it is acknowledged that unforeseen circumstances may cause flaring to be repeated (Section 4.3.2.9 of OPP); given that well flowback is not required to be undertaken at every well during a drilling campaign, an allowance of the equivalent of ~60 MMscf over one day for each of the 40 wells is considered sufficient to estimate GHG emissions for both initial and any contingency repeated flaring required **Well suspension**: • wells may be suspended after drilling; and if suspension occurs small volumes of natural gas may be vented (Section 4.3.2.6 of OPP) • the estimated volume of natural gas vented is ~0.5 MMscf per well (based on a typical volume within the landing string) • for calculation purposes have conservatively assumed gas composition is 90% CH_4 and 10% CO_2 (based on approximate maximum molar proportions of each gas constituent across the backfill fields as per Table 4-4 of OPP)
Installation and commissioning	**Pipelay installation**: • duration of pipelay activities is estimated at ~3–6 months per field or co-developed field (Section 4.3.3.3 of the OPP); for the purpose of the calculation a 6 month duration has been used – this duration accounts for use of both construction support (e.g. pre-lay works, pipeline crossings, excavation and trenching, as-built surveys, post-lay works) and pipelay installation (e.g. flowlines, pipelines, pipeline termination structure, as-laid surveys) – for calculation purposes have conservatively assume use of one light construction vessel (LCV) and one OSV, and one pipelay vessel (PLV) and one pipe supply vessel (PSV) for each of the campaigns (183 days each) – fuel consumption for LCV, OSV, PLV and PSV based on reported fuel consumption during the GS2 campaigns • rock stabilisation is not planned, but may be required as a contingency (Sections 4.3.3.2 and 4.3.3.5 of OPP) – for calculation purposes have conservatively estimated duration of rock-dumping activities ~2 months (61 days) per field or co-developed field with one rock-dumping vessel for duration of campaign ▪ further assumed rock stabilisation only relevant to field developments occurring on the continental shelf and/or scarp (i.e. WTR and C&D) – fuel consumption for rock-dumping vessel based on reported fuel consumption during the Gorgon umbilical campaign **Subsea structures installation**: • duration of subsea structure installation activities is estimated at ~4 months per field or co-developed field (Section 4.3.3.4 of the OPP) – i.e. 4 months (0.33 years) = 122 days per field or co-developed field

Phase	Inputs and assumptions
	• assumed use of one heavy construction vessel (HCV) and one LCV for full duration of subsea structures campaigns • fuel consumption for HCV and LCV based on reported fuel consumption during the GS2 campaigns **Pre-commissioning**: • duration of pre-commissioning activities is estimated at ~2 months per field or co-developed field (Section 4.3.3.6 of the OPP) – i.e. 2 months (0.17 years) = 61 days per field or co-developed field • assumed use of one LCV for full duration of pre-commissioning campaigns • fuel consumption for LCV based on reported fuel consumption during the GS2 campaign **Commissioning and start-up**: • duration of commissioning and start-up is estimated at ~3 months per field or co-developed field (Section 4.3.3.8 of the OPP) – i.e. 3 months (0.25 years) = 92 days per field or co-developed field – assumed use of one LCV for full duration of pre-commissioning campaigns – fuel consumption for LCV based on reported fuel consumption during the GS2 campaign • during commissioning dry methane gas will be used to pressurise the production flowlines, which may result in a controlled subsea release of this methane gas (Section 4.3.3.7 of OPP) – gas dispersion studies indicate that for all deepwater fields no surface expression of gas is expected to occur (Ref. 10) – for the shallower WTR field, some of the gas released may rise to the surface and release to the atmosphere ▪ based on the size of the production flowline and assuming the full volume is released to atmosphere (i.e. worst-case with no dissolution), the maximum methane gas release is estimated at 6,000 Sm^3 **Helicopter support during installation and commissioning**: • duration of installation and commissioning activities is estimated at ~12–15 months per field or co-developed field; for the purpose of the calculation a 15 month duration has been used • helicopter flight frequency is estimated to be ~15–16 flights per week for the largest construction vessels (Section 4.3.6.3 of OPP); for the purpose of the calculation a 16 flights/week has been used – i.e. 15 months (65 weeks) = 1040 flights per field or co-developed field – duration within the DA assumed to be one-hour per flight • estimated hourly fuel consumption based on data from existing CAPL-operated assets
Operations	**IMR—inspections (subsea hydrocarbon system)**: • frequency of inspection activities is risk-based (Section 4.3.4.2 of OPP) • duration of inspection activities estimated to be up to ~280 days per year (based on estimates for existing Gorgon and Jansz subsea hydrocarbon system [Ref. 11] and scaled proportionately) – indicative commencement of operations for the Backfill Fields Development is late-2028 (Table 4-2 of OPP) – indicative cessation of operations is mid-2066 (consistent with the Gorgon GTP GHGMP; Ref. 6) – i.e. 38 years @ 280 days per year = 10,640 days • one IMR vessel present within the DA for full duration of inspection activities

Phase	Inputs and assumptions
	• fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets **IMR—minor maintenance and repairs**: • frequency of maintenance and repair activities depends on the results of inspections (Section 4.3.4.3 of OPP) – if minor maintenance and minor repair is required, the duration could be up to ~6 months per event (Section 4.3.4.3 of OPP) • given these types of activities are typically triggered by inspection findings rather than specifically being scheduled, the following conservative allowance has been provided for calculation purposes – 85 days[11] of minor maintenance and repair activities per year – i.e. 38 years @ 85 days per year = 3,230 days • one IMR vessel present within the DA for full duration of inspection activities • fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets **Helicopter support during IMR**: • not generally required for shorter IMR campaign work, however, has been carried as a contingency allowance – estimated at 2 flights per fortnight (i.e. 52 flights per year) – 38 years @ 52 flights per year = 1,976 flights • duration within the DA assumed to be one-hour per flight • estimated hourly fuel consumption based on data from existing CAPL-operated assets. **IMR—well intervention**: • intervention on a single well may be required once a year; however, intervention activities may be more or less frequent depending on well performance (Section 4.3.4.5 of OPP) • duration of well intervention activities estimated to be ~50 days per well (based on estimates for existing Gorgon and Jansz wells; Ref. 13) – i.e. 38 years @ 50 days per year = 1,900 days • MODU or a well intervention vessel present within the DA for full duration of well intervention campaign – for calculation purposes have conservatively assumed use of a semi-submersible well intervention vessel on DP – estimated daily fuel consumption for well intervention vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets • conservatively assumed use of two OSVs present within the DA for the duration of the well intervention campaigns – fuel consumption for drilling OSVs based on reported fuel consumption during the GS2 campaigns – OSVs based on reported fuel consumption during the GS2 campaigns • flaring may be required as part of well intervention (Section 4.3.4.5 of OPP) – volume of natural gas flared assumed to be the same as for well flowbacks (~60 MMscf per well flared over one day) – using an approximate conversion factor of 1 MMscf = 21 tonnes (Ref. 9), then ~1,260 tonnes natural gas flared per year for 38 years

[11] This allowance for minor maintenance and repairs, in conjunction with the allowance for inspections, equates to an IMR vessel in-field 365 days per year. This is considered to provide a conservation allowance for routine IMR activities during operations.

Phase	Inputs and assumptions
	• if well suspension/de-suspension is required, venting may occur (Section 4.3.4.5 of OPP) – given well suspension is a contingency activity during both drilling and operations phases of the Backfill Fields Development, GHG emissions have only been estimated once (under the drilling phase) as part of this inventory **Temporary contingency power supply**: • if planned umbilical power supply is unavailable, temporary contingency options will be used to ensure power is available (Section 4.2.5.1 of OPP) • duration of temporary power supply estimated to be up to ~200 days per event (based on estimates for existing Gorgon and Jansz subsea hydrocarbon system [Ref. 11]) – as this is a contingency activity for the Backfill Fields Development, an allowance for the use of temporary power supply once for each field or co-developed field has been included for calculation purposes – i.e. 5 fields/co-developed fields @ 200 days each = 1,000 days • one IMR vessel present within the DA for full duration of temporary power supply activities • fuel consumption for an IMR vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets • helicopter flight frequency is estimated to be 2 flights per fortnight – i.e. ~30 flights for each contingency power campaign (150 flights for all fields/co-developed fields) – duration within the DA assumed to be one-hour per flight – estimated hourly fuel consumption based on data from existing CAPL-operated assets.
Decommissioning	**Well plug and abandonment (P&A)**: • duration of P&A activities estimated to be ~60 days per well (based on estimates for existing Gorgon and Jansz wells; Ref. 13) – i.e. 2,400 days for all 40 wells • MODU or a well intervention vessel present within the DA for full duration of P&A campaign – for calculation purposes have conservatively assumed use of a semi-submersible well intervention vessel on DP – estimated daily fuel consumption for well intervention vessel based on reported fuel consumption during campaigns for existing CAPL-operated assets • conservatively assumed use of two OSVs present within the DA for the duration of the P&A campaigns – fuel consumption for drilling OSVs based on reported fuel consumption during the GS2 campaigns – OSVs based on reported fuel consumption during the GS2 campaigns • flaring and venting may be required during well P&A (Section 4.3.5.8 of OPP) – the estimated volume of natural gas flared during P&A is ~1.5 MMscf per well; using an approximate conversion factor of 1 MMscf = 21 tonnes (Ref. 9), then ~31.5 tonnes natural gas flared for each of the 40 wells – the estimated volume of natural gas cold vented during P&A is ~0.5 MMscf per well – for venting calculation purposes have conservatively assumed gas composition is 90% CH_4 and 10% CO_2 (based on approximate maximum molar proportions of each gas constituent across the backfill fields as per Table 4-4 of OPP)

Phase	Inputs and assumptions
	• helicopter flight frequency is estimated to be ~5 flights per week for the MODU (Section 4.3.6.3 of OPP) – i.e. 60 days (~8.6 weeks) = ~43 flights per well – duration within the DA assumed to be one-hour per flight – estimated hourly fuel consumption based on data from existing CAPL-operated assets **Removal of all subsea property:** • given the unknowns in removal method (including availability of new technologies) and timing, the estimate of GHG emissions for the removal of all subsea property is assumed to the same as the pipelay and subsea structure installation

2.1.4 results

Based on the sources, methods, and inputs and assumptions described above, the estimate of total **BFF GHG emissions** over the life of the Backfill Fields Development[12] has been estimated at ~3.075 Mt CO_2-e (Table 2-4).

The proportion of estimated GHG emissions generated during each phase of the Backfill Field Development varies, with the highest proportions associated with drilling, operations, and decommissioning (Figure 2-1).

Table 2-4: Estimated total BFF GHG emissions over the life of the Backfill Fields Development

Phase	Estimated total BFF GHG emissions over the life of the Backfill Fields Development[12] (Mt CO_2-e)
Surveys	0.034
Drilling	0.855
Installation and commissioning	0.367
Operations	1.007
Decommissioning	0.812
Total	**3.075**

[12] Where 'life of the Backfill Fields Development' is represented as FY2027–FY2070 (44 years). This period is based on indicative commencement of drilling activities for the first of the backfill fields (refer to Table 4-2 of the OPP) and the indicative end of life of the Backfill Fields Development (consistent with that for the overall Gorgon Gas Development; refer to Section 4.1.4 of the OPP).

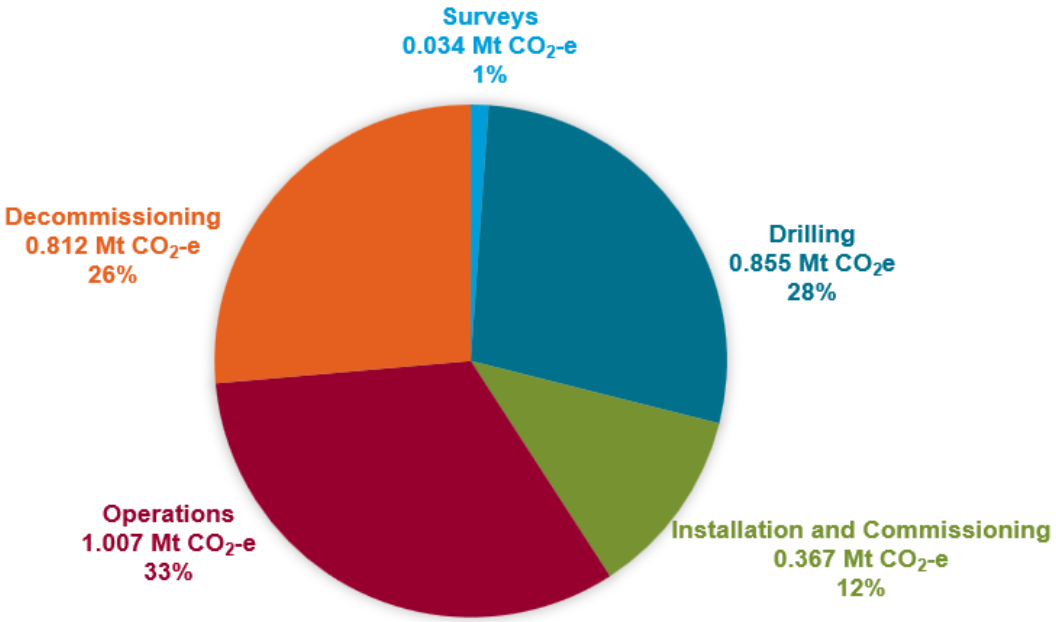


Figure 2-1: Estimated total BFF GHG emissions over the life of the Backfill Fields Development

2.2 BFF gas processing GHG emissions

The purpose of the Backfill Fields Development is to maintain gas supply to the existing Gorgon GTP on Barrow Island (part of the approved Gorgon Gas Development and constructed as part of the Gorgon Foundation Project). Therefore, in having regard to the EPBC Indirect Consequences Policy Statement (Ref. 3), the processing of the gas from the seven backfill fields at the GTP on Barrow Island has been assessed as an indirect consequence of the Backfill Fields Development.

All gas processing GHG emissions from the Gorgon Gas Development have been previously described and assessed in existing primary and secondary environmental approvals (e.g. Ref. 4; Ref. 5; Ref. 6; Ref. 12; see also Section 1.3.1). The detailed methods and assumptions for estimating these Gorgon Gas Development GHG emissions are not repeated here; however as described in the previous approvals the estimates were prepared based on methods consistent with the NGER Act and its supporting determinations and technical guidelines (Ref. 5). The estimated gas processing GHG estimate for the three-train Gorgon Gas Development was an average annual of ~9.47 Mtpa CO_2-e. No change to previously approved gas processing GHG emissions is being sought under the Backfill Fields Development OPP in relation to the overall Gorgon Gas Development GHG emissions.

As gas from the Backfill Fields Development will not be the only feed gas supply for the Gorgon GTP, a proportion of production and hence a proportion of GHG emissions from the overall Gorgon Gas Development will be substantially caused by the Backfill Fields Development. Therefore, this GHG emissions inventory has been prepared to estimate the proportion of the Gorgon Gas Development's gas processing GHG emissions associated with the Backfill Fields Development.

The portion of gas processing GHG emissions attributable to the Backfill Fields Development has been estimated by considering the proportion of production forecast from the seven backfill fields, as a subset of the total Gorgon Gas

Development production forecast[13] over the indicative operational life of the Backfill Fields Development[14]. The estimated total **BFF gas processing GHG emissions** over the operational life of the Backfill Fields Development is ~107.8 Mt CO_2-e. When converted to an annual average over the operational life of the Backfill Fields Development this equates to an estimate of ~2.8 Mtpa CO_2-e[15].

2.3 BFF secondary GHG emissions

With regard to the EPBC Indirect Consequences Policy Statement (Ref. 3), the transport and third-party end use of LNG, condensate and domestic gas products following processing at the existing Gorgon GTP on Barrow Island (part of the approved Gorgon Gas Development) have been assessed as reasonably foreseeable 'secondary actions' and the associated GHG emissions as reasonably foreseeable direct consequences of those 'secondary actions'. Accordingly, they are 'indirect consequences' of the Backfill Fields Development.

All secondary GHG emissions from the Gorgon Gas Development have been described and assessed in existing primary and secondary environmental approvals (e.g. Ref. 5; Ref. 6; Ref. 12; Ref. 14; see also Section 1.3.1). The estimated secondary GHG emissions for the Gorgon Gas Development is ~49.8 Mtpa CO_2-e for a representative production year (15.6 Mt net LNG) during three-train operations[16].

As described in the approved Gorgon GTP GHGMP (Ref. 6), contemporary guidance on estimating emissions was applied to develop the revised estimate of the Gorgon Gas Development's secondary GHG emissions using the following key documents and inputs:

- emissions from transport
  - estimated from shipping fuel consumption scaled for a representative year of production
  - emissions factors sourced from IMO Resolution MEPC.245(66) (Ref. 15) and 100-year GWPs (Ref. 8)

[13] Forecast production rates were based on information available at the time of development of the Backfill Fields Development OPP and Gorgon GTP GHGMP, and may be subject to change as modelling improves or business decisions change.

[14] Where 'operational life of the Backfill Fields Development' is represented as FY2029–FY2066 (38 years). This period is based on indicative ready for start-up for the first of the backfill fields (refer to Table 4-2 of the OPP) and the indicative date of the start of decommissioning (consistent with the Gorgon GTP GHGMP; Ref. 6).

[15] This annual average is a long-term estimate based on the 'operational life of the Gorgon Gas Development' represented as FY2029–FY2066 (38 years). However, as the forecast production takes into consideration lower production in the latter years of the Gorgon Gas Development, the annual average for **BFF gas processing GHG emissions** over a 'nominal period of three-train operations' represented as FY2029–FY2050 (22 years) is estimated at ~4.4 Mtpa CO_2-e, being higher than the long-term operational life estimate.

[16] The annual average for Gorgon Gas Development's secondary GHG emissions over the remainder of the life of the Gorgon Gas Development is expected to be lower than this estimate for a representative production year. The estimated long-term annual average based on the 'remainder of the life of the Gorgon Gas Development' represented as FY2029–FY2066, is ~38.3 Mtpa CO_2-e. This period is based on indicative ready for start-up date for the first of the backfill fields (refer to Table 4-2 of the OPP) and the indicative date of the start of decommissioning (consistent with the Gorgon GTP GHGMP; Ref. 6). This long-term estimate uses the same method, emission factors, and GWPs as the representative year three-train estimate, but incorporates forecast production rates over the remainder of the life of the Gorgon Gas Development (from the onset of the backfill fields in FY2029). As different source fields are utilised and forecast production rates are projected to decline as the project progresses towards end of life, emissions are expected to be lower in future years. The forecast production rates were based on information available at the time and may be subject to change as modelling improves or business decisions change.

- emissions from third-party use of products
  - calculated in alignment with methods in Category 11 of IPIECA's *Estimating Petroleum Industry Value Chain (Scope 3) Greenhouse Gas Emissions* (Ref. 16), including product quantity and fuel-specific higher heating values, and the CO_2, CH_4 and N_2O combustion emissions factors for each fuel type
  - evaluation based upon production data from a representative year (15.6 Mt net LNG), applying API compendium methodologies, factors and 100-year GWPs (Ref. 8; Ref. 17).

As additional context for the inputs and assumptions used to develop the Gorgon Gas Development's secondary GHG emissions estimate:

- LNG is the predominant product (by tonne) produced by the Gorgon Gas Development (with smaller tonnages of condensate and domestic gas); therefore, the LNG related transport and third-party end use represent the greatest proportion of emissions
- for LNG carriers the fuel consumption estimate was based on reported boil off gas (as a percentage per loaded tonne of LNG) from operational data
  - the use of a proportion per loaded tonne removes the effect on destination from this calculation (see also Section 8.3.7 in the OPP for a discussion on customer markets)
- GHG emission estimates for LNG carriers also included allowances for methane slip (Ref. 18)
- for condensate transport the fuel consumption estimate was based on reported fuel type and consumption from operational data
- the emissions from use of products are based on quantity of product (LNG, condensate, domestic gas) and emission factors; the location of where products are used does not affect the quantification of this GHG emissions estimate.

This above approach corresponds to total secondary GHG emissions and does not take into account any potential GHG emissions mitigations and/or reductions opportunities associated with shipping or undertaken by the end user.

As per the treatment of **BFF gas processing GHG emissions**, the **BFF secondary GHG emissions** presented in the inventory represent a proportion of the overall Gorgon Gas Development secondary GHG emissions.

The estimated total **BFF secondary GHG emissions** over the operational life of the Backfill Fields Development[14] is ~600.7 Mt CO_2-e. When converted to an annual average over the operational life of the Backfill Fields Development[14] this equates to an estimate of ~15.8 Mtpa CO_2-e[17].

[17] This annual average is a long-term estimate based on the 'operational life of the Gorgon Gas Development' represented as FY2029–FY2066 (38 years). However, as the forecast production takes into consideration lower production in the latter years of the Gorgon Gas Development, the annual average for **BFF secondary GHG emissions** over a 'nominal period of three-train operations' represented as FY2029–FY2050 (22 years) is estimated to be ~24.7 Mtpa CO_2-e, being higher than the long-term operational life estimate.

3 summary

3.1 GHG emissions inventory

The estimated total GHG emissions for the Backfill Fields Development are summarised in Table 3-1. A long-term annual average value is also presented in Table 3-1; this annual average is based on the estimated total divided by the life (or operational life) of the Backfill Fields Development. Actual annual GHG emissions will vary year to year based on activities/phases and production rates at the given time.

These estimated total GHG emissions have been used to inform the environmental impact and risk assessment in the OPP. However, it is recognised that there are emission reduction requirements and/or targets in place for both the Gorgon Gas Development and customer markets (see Section 3.2).

Table 3-1: Estimated total and annual average GHG emissions for the Backfill Fields Development

Emission source	Emission location	Jurisdiction for GHG emissions management	Estimated total[18] GHG emissions for the Backfill Fields Development[19] (Mt CO_2-e)	Estimated annual average[18] GHG emissions for the Backfill Fields Development[19] (Mtpa CO_2-e)
BFF GHG emissions				
Fuel combustion (MODU, vessels)	Development Area (Commonwealth waters)	Australia	2.64	0.06
Fuel combustion (helicopters)			0.04	0.001
Flaring (MODU)			0.37	0.01
Cold venting (MODU)			0.02	0.0004
BFF gas processing GHG emissions				
Gas processing at the GTP[20]	Barrow Island (State onshore, State waters)	Australia	107.8	2.8
Purchased electricity[21]	N/A	N/A	0	0
BFF secondary GHG emissions				
Transport and third-party end use (LNG, condensate, and domestic gas)	Western Australia (domestic gas)	Australia	600.7	15.8
	Subject to consumer location (LNG, condensate)	Subject to consumer location		
		Total	**711.6**	**18.7**

[18] All estimated GHG emissions presented in this table do not take into consideration any potential GHG emissions mitigations, reduction, or offset opportunities that may be undertaken (see Section 3.2).

[19] For **BFF GHG emissions** this refers to the 'life of the Backfill Fields Development' as represented by FY 2027–FY 2070 (44 years). However, for **BFF gas processing GHG emissions** and **BFF secondary GHG emissions** this refers to the 'operational life of the Backfill Fields Development') as represented by FY 2029–FY 2066 (38 years).

[20] This includes emissions from operation of the Gorgon GTP for the processing of LNG and domestic gas, as well as emissions from Barrow Island support operations.

[21] There is no purchased electricity associated with the Gorgon Gas Development. All electricity is generated on Barrow Island (including any power required for subsea operations) and any associated emissions are therefore already incorporated into the 'gas processing at the GTP' emissions estimate.

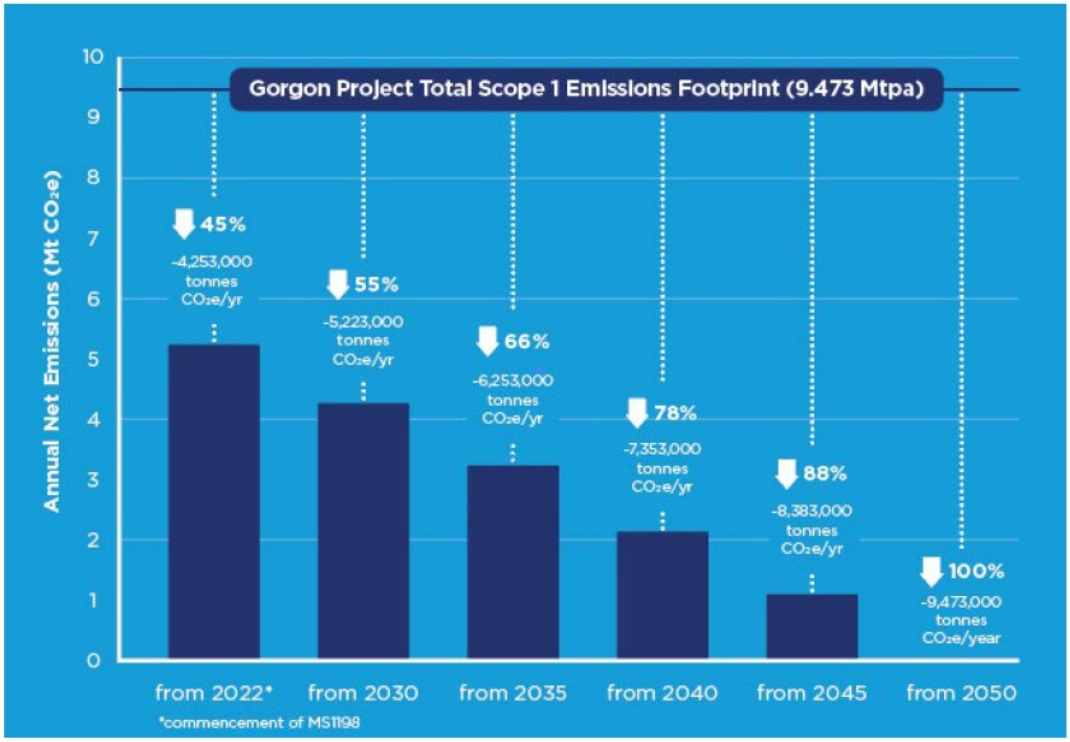
3.2 GHG emissions management

The Backfill Fields Development, as part of the overarching Gorgon Gas Development, is subject to legislated emission reduction requirements. At the time of writing this Technical Note, these requirements include:

- implementation of Reservoir Carbon Dioxide Injection System requirements as per condition 26 of MS 1198 under EP Act (WA) approvals
- implementation of Greenhouse Gas Management Plan requirements as per condition 27 of MS 1198 under EP Act (WA) approvals, including the Net GHG Emissions reductions as set by condition 27.1 (Figure 3-1)
- declining facility baselines under the Commonwealth Safeguard Mechanism
  - this is currently set a 4.9% each financial year from FY2024 to FY2030
  - from FY2031 the decline rates will be set for each year in 5-year blocks by the Department of Climate Change, Energy the Environment and Water.

Both sets of regulatory requirements have GHG emissions from the Gorgon Gas Development on a trajectory to net zero by 2050.

Customer markets for the Gorgon Gas Development are discussed in Section 8.3.7 of the OPP. GHG emissions associated with transport and third-party end use of products will be managed under the respective regulatory regimes of these markets. As described in the OPP, all customer markets with long-term sales agreements in place currently have GHG emission reduction targets in place.



Source: Gorgon GTP GHGMP (Ref. 6).

Figure 3-1: Net GHG Emissions targets (per condition 27.1 of MS 1198) and associated percent reduction in emissions from the 3-train Revised and Expanded Gorgon Gas Development GHG emissions estimate

4 acronyms and abbreviations

Table 4-1 defines the acronyms and abbreviations used in this document.

Table 4-1: Acronyms and abbreviations

Acronym / abbreviation	Definition
API	American Petroleum Institute
BFF	Backfill Fields Development
C&D	Chrysaor and Dionysus
CAPL	Chevron Australia Pty Ltd
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
Cth	Commonwealth
DA	Development Area
DP	Dynamic positioning
EC	Energy content factor
EF	Emissions factor
EP	Environment Plan
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation 1999* (Cth)
G&E	Geryon and Eurytion
GHG	Greenhouse gas
GHGMP	Greenhouse Gas Management Plan
GJ	Gigajoule
GS2	Gorgon Stage 2
GTP	Gas treatment plant
GWP	Global warming potential
HCV	Heavy construction vessel
IMO	International Maritime Organization
IMR	Inspection, maintenance, and repair
IPCC	Intergovernmental Panel on Climate Change
IPIECA	International Petroleum Industry Environmental Conservation Association
kg	Kilogram
kL	Kilolitre
lb	Pound
LCV	Light construction vessel
LNG	Liquified natural gas
m	Metre
m^3	Cubic metres

Acronym / abbreviation	Definition
MMscf	Million standard cubic feet
MS	Ministerial Statement
Mt	Million tonnes
MODU	Mobile offshore drilling unit
N_2O	Nitrous oxide
NGER Measurement Determination	*National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth)
NGER Scheme	National Greenhouse and Energy Reporting scheme
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
OPGGS(E)R	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth)
OPP	Offshore Project Proposal
OSV	Offshore support vessel
P&A	Plug and abandonment
PLV	Pipelay vessel
PSV	Pipe supply vessel
scf	Standard cubic feet
Sm^3	Standard cubic metres
STP	Standard temperature and pressure
t	Tonne (metric)
WA	Western Australia
WTR	West Tryal Rocks

5 references

The following documentation is either directly referenced in this document or is a recommended source of background information.

Table 5-1: References

Ref. No.	Description	Document ID
1.	CAPL. 2025 [under assessment by NOPSEMA]. *Gorgon Gas Development: Backfill Fields Offshore Project Proposal*. Chevron Australia Pty Ltd, Perth, Western Australia.	ACP-0000-RGL-PLN-CVX-000-00001-00
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Ref. No.	Description	Document ID
10.	Wood. 2023. *CVX Subsea Dispersion Study* [Slide Pack]. Presentation to Chevron Australia by Wood Group PLC.	
11.	CAPL. 2025 [under assessment by NOPSEMA]. *Gorgon Gas Development: Gorgon and Jansz Feed Gas Pipeline and Wells Operations (Commonwealth Waters) Environment Plan*. Revision 8.0. Chevron Australia Pty Ltd, Perth, Western Australia.	GOR-COP-0902
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appendix f aboriginal cultural heritage inquiry system reports

appendix f.1—hydrocarbon ecological EMBA

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Search Criteria

44 Aboriginal Cultural Heritage (ACH) Register in Shapefile - GS3_Ecological_EMBA

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- **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 ACH 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.
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  - **Women only:** Only *females* can view restricted information.

Status:

- **Register:** Aboriginal cultural heritage places that are assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972*.
- **Lodged:** Information which has been received in relation to an Aboriginal cultural heritage place, but is yet to be assessed under Section 5 of the *Aboriginal Heritage Act 1972*.
- **Historic:** Aboriginal heritage places assessed as not meeting the criteria of Section 5 of the *Aboriginal Heritage Act 1972*. Includes places that no longer exist as a result of land use activities with existing approvals.

Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.
Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
508	POINT MURAT 03	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07503
563	POINT MURAT 01	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07501
564	POINT MURAT 02	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07502
628	CAMP THIRTEEN BURIAL	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial	*Registered Knowledge Holder names available from DPLH	P07434
873	MONTEBELLO IS: NOALA CAVE.	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P07287
926	MONTEBELLO IS: HAYNES CAVE.	No	Yes	No	No Gender / Initiation Restrictions	Register	Sub surface cultural material; Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P07286
6311	POINT MURAT.	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial; Artefacts / Scatter; Camp; Midden; Other	*Registered Knowledge Holder names available from DPLH	P06628
6754	OSPREY BAY 6	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06165
6755	OSPREY BAY INTERDUNAL 1	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06166
6757	BLOODWOOD CREEK MIDDEN 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06168
6758	BLOODWOOD CREEK MIDDEN 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06169
6759	BLOODWOOD CREEK MIDDEN 3	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06170
6760	BLOODWOOD CREEK SHORELINE	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06171
6761	LOW POINT MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06172
6762	MILYERING MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06173
6764	CAMP 17 SOUTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06175
6765	CAMP 17 NORTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06176

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
6782	28 MILE CREEK NORTH 1	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06140
6784	MANDU MANDU CREEK SOUTH	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06142
6785	MANDU MANDU CREEK NORTH	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06143
6790	YARDIE CREEK SOUTH 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06148
6799	YARDIE BEACH MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06157
6800	OYSTER STACKS MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06158
6801	NORTH T-BONE BAY	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06159
6802	OSPREY BAY 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06160
6803	OSPREY BAY 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06161
6804	OSPREY BAY 3	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06162
6805	OSPREY BAY 4	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06163
6806	OSPREY BAY 5	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06164
7126	MESA CAMP	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05792
7206	WEALJUGOO MIDDEN.	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	P05710
7254	SANDY BAY NORTH	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05652
7265	LAKE SIDE VIEW	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05664
7299	YARDIE CREEK	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05645

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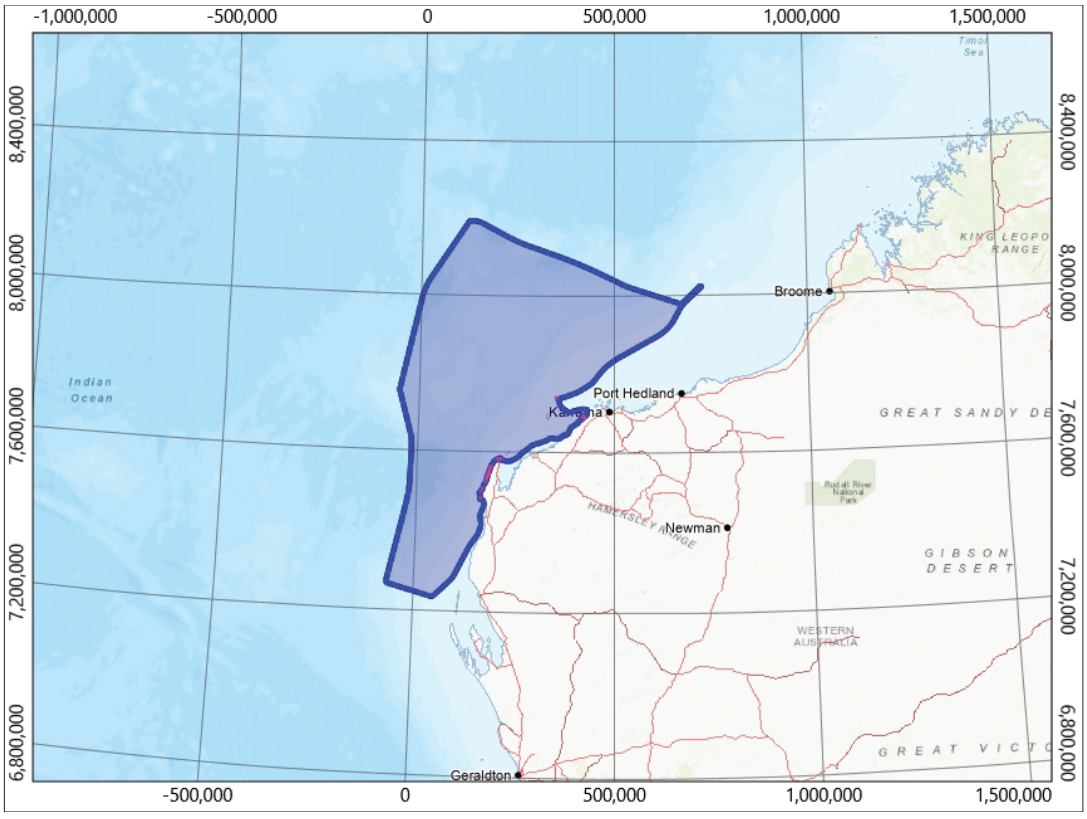
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7300	MANDU MANDU CK ROCKSHELTERS	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P05646
7303	TULKI WELL MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05649
7304	PILGRAMUNNA BAY MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05650
7305	MANGROVE BAY.	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial; Artefacts / Scatter; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	P05651
10381	VLAMING HEAD	Yes	No	Yes	No Gender / Initiation Restrictions	Register	Ritual / Ceremonial; Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	P01799
11458	NINGALOO (near)	No	No	No	No Gender / Initiation Restrictions	Register	Painting	*Registered Knowledge Holder names available from DPLH	P00701
17193	Ningaloo Station	No	No	No	No Gender / Initiation Restrictions	Register	Burial	*Registered Knowledge Holder names available from DPLH	
26005	Site No. 18	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	
26006	Site No. 25	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	
26736	ACHM - 09-05	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	

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883	BARROW ISLAND 01	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
884	I-24-S0001/S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
885	BARROW ISLAND 03	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
886	C-21-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
887	O-02-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
888	P-05-S0001	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
889	O-06-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
890	D-20-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
891	Bandicoot Bay Settlement	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
892	BARROW ISLAND 10	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
893	D-20-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
894	D-16-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
6346	MT SALT	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Burial	*Registered Knowledge Holder names available from DPLH	
6783	28 MILE CREEK NORTH 2	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
6786	LAKESIDE COASTAL PLAIN	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
6789	TURQUOISE BAY NORTH	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
7208	MILYERING ROCKS.	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Hunting Place	*Registered Knowledge Holder names available from DPLH	

Department of Planning, Lands and Heritage

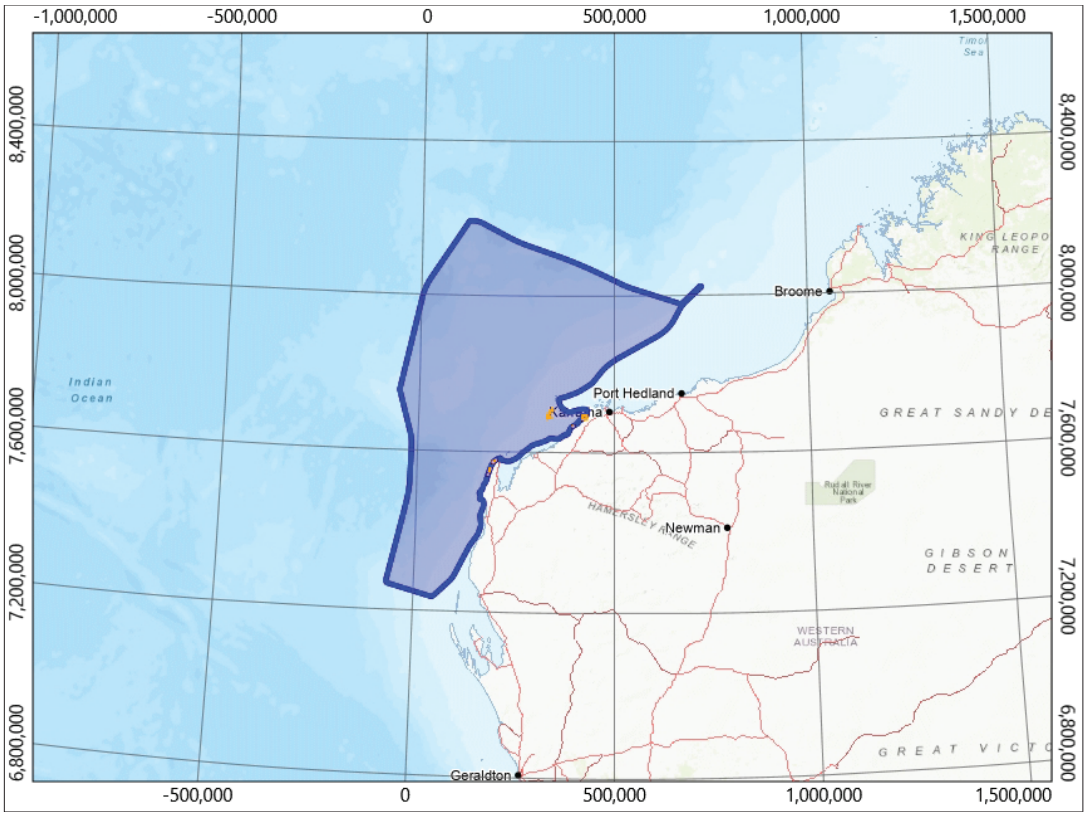
Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Lodged

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
11801	COASTAL MIDDEN, 5 MILE	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
19171	Ceremonial Ground	Yes	Yes	No	Men only	Lodged	Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving	*Registered Knowledge Holder names available from DPLH	
22943	Flacourt Bay 01	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Rock Shelter	*Registered Knowledge Holder names available from DPLH	
29549	Boodie Soak	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
31762	Site 1	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
31763	Site 2	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
36199	Boodie Cave	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36200	John Wayne Country Rockshelter	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	
36234	South End structures, Barrow Island.	No	No	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36261	G-13-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36262	H-24-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36263	H-24-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36264	I-23-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36265	I-23-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36266	I-24-S0003	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36267	J-23-S0001	No	Yes	No		Lodged	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	
36268	J-23-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
36269	J-23-S0003	No	Yes	No		Lodged	Modified Tree	*Registered Knowledge Holder names available from DPLH	
36270	M-03-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36271	N-02-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36272	O-02-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36273	O-05-S0003	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36344	N-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36345	N-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36346	O-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36347	O-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36348	P-04-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
40768	Jurabi Point	Yes		Yes	No Gender / Initiation Restrictions	Lodged	Burial	*Registered Knowledge Holder names available from DPLH	



Legend

- Aboriginal Cultural Heritage (ACH) Lodged
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

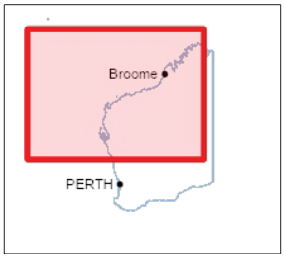
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Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

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Search Criteria

5 Aboriginal Cultural Heritage (ACH) Historic in Shapefile - GS3_Ecological_EMBA

Disclaimer

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All Aboriginal cultural heritage in Western Australia is protected, whether or not the ACH has been reported or exists on the Register.

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 provide the details to the Department via https://achknowledge.dplh.wa.gov.au/ach-enquiry-form and we will make every effort to rectify it as soon as possible.

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Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

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Terminology

ID: ACH on the Register is assigned a unique ID by the Department of Planning, Lands and Heritage using the format: ACH-00000001. For ACH on the former Register the ID numbers remain unchanged and use the new format. For example the ACH ID of the place Swan River was previously '3536' and is now 'ACH-00003536'.
Access and Restrictions:

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- Culturally Sensitive Nature:
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  - Men only: Only males can view restricted information.
  - Women only: Only females can view restricted information.

Status:

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Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.
Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 2020 Datum.

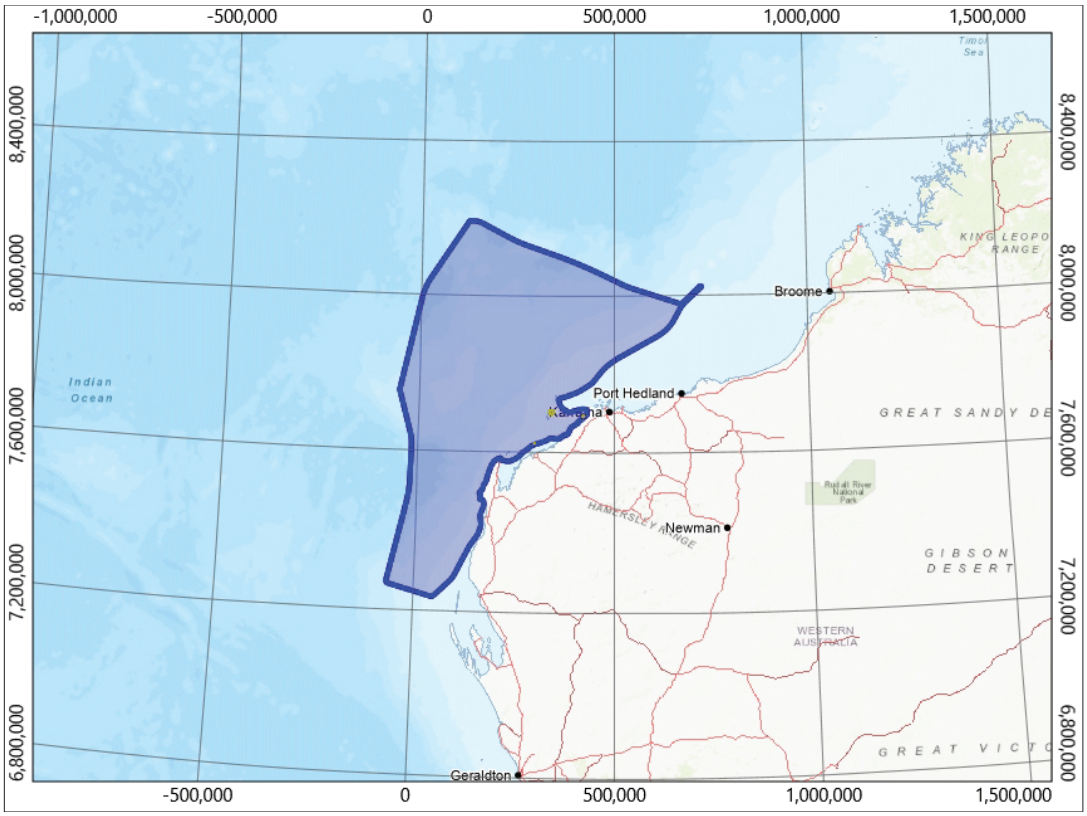
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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
8951	BARROW ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P03542
11403	THEVENARD ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Midden	*Registered Knowledge Holder names available from DPLH	P00753
26003	Site No. 6	Yes	Yes	Yes	Men only	Historic	Engraving	*Registered Knowledge Holder names available from DPLH	
26004	Site No. 7/8/9	Yes	Yes	Yes	Men only	Historic	Engraving; Grinding areas / Grooves; Quarry	*Registered Knowledge Holder names available from DPLH	
38763	Wapet Shell Midden	No	Yes	No		Historic	Shell	*Registered Knowledge Holder names available from DPLH	



Legend

- Aboriginal Cultural Heritage (ACH) Historic
- Search Area
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  - *Permanent*
  - *Seasonal*
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- Town
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444.29 kilometres

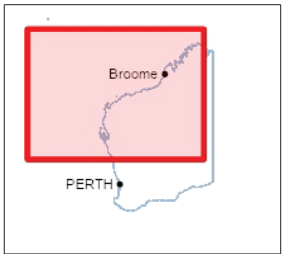
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appendix f.2—hydrocarbon social EMBA

Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Register

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Search Criteria

76 Aboriginal Cultural Heritage (ACH) Register in Shapefile - GS3_Social_EMBA

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Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
508	POINT MURAT 03	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07503
563	POINT MURAT 01	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07501
564	POINT MURAT 02	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07502
628	CAMP THIRTEEN BURIAL	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial	*Registered Knowledge Holder names available from DPLH	P07434
873	MONTEBELLO IS: NOALA CAVE.	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P07287
926	MONTEBELLO IS: HAYNES CAVE.	No	Yes	No	No Gender / Initiation Restrictions	Register	Sub surface cultural material; Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P07286
973	ROSEMARY IS.18: DEEP WATER	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07226
974	ROSEMARY IS.19: CHITON	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07227
975	ROSEMARY IS.20: HALFWAY CK	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P07228
6311	POINT MURAT.	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial; Artefacts / Scatter; Camp; Midden; Other	*Registered Knowledge Holder names available from DPLH	P06628
6575	JINTA 1 MIDDEN	Yes	No	Yes	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06370
6617	BURUBARLADJI	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	P06362
6618	DEW TALU.	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Ritual / Ceremonial; Water Source	*Registered Knowledge Holder names available from DPLH	P06363
6754	OSPREY BAY 6	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06165
6755	OSPREY BAY INTERDUNAL 1	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06166
6756	OSPREY BAY INTERDUNAL 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Midden	*Registered Knowledge Holder names available from DPLH	P06167
6757	BLOODWOOD CREEK MIDDEN 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06168

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Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Register

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
6758	BLOODWOOD CREEK MIDDEN 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06169
6759	BLOODWOOD CREEK MIDDEN 3	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06170
6760	BLOODWOOD CREEK SHORELINE	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06171
6761	LOW POINT MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06172
6762	MILYERING MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06173
6763	YARDIE ROCKSHELTERS NORTH.	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P06174
6764	CAMP 17 SOUTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06175
6765	CAMP 17 NORTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06176
6782	28 MILE CREEK NORTH 1	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06140
6784	MANDU MANDU CREEK SOUTH	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06142
6785	MANDU MANDU CREEK NORTH	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06143
6790	YARDIE CREEK SOUTH 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06148
6791	YARDIE CREEK SOUTH 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06149
6797	YARDIE WELL ROCKSHELTER.	No	Yes	No	No Gender / Initiation Restrictions	Register	Sub surface cultural material; Artefacts / Scatter; Midden; Other; Rock Shelter	*Registered Knowledge Holder names available from DPLH	P06155
6798	YARDIE INTERDUNAL SWALE	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06156
6799	YARDIE BEACH MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06157
6800	OYSTER STACKS MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06158

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
6801	NORTH T-BONE BAY	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06159
6802	OSPREY BAY 1	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06160
6803	OSPREY BAY 2	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06161
6804	OSPREY BAY 3	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06162
6805	OSPREY BAY 4	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06163
6806	OSPREY BAY 5	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P06164
7126	MESA CAMP	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05792
7203	BAUBOODJOO POINT (Bruboodjoo Midden Site)	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	P05707
7206	WEALJUGOO MIDDEN.	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	P05710
7254	SANDY BAY NORTH	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05652
7265	LAKE SIDE VIEW	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05664
7298	YARDIE CREEK ROCKSHELTERS	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P05644
7299	YARDIE CREEK	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05645
7300	MANDU MANDU CK ROCKSHELTERS	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P05646
7303	TULKI WELL MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05649
7304	PILGRAMUNNA BAY MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P05650
7305	MANGROVE BAY.	No	Yes	No	No Gender / Initiation Restrictions	Register	Burial; Artefacts / Scatter; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	P05651

Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Register

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
8301	NINGALOO STATION	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P04353
10381	VLAMING HEAD	Yes	No	Yes	No Gender / Initiation Restrictions	Register	Ritual / Ceremonial; Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	P01799
11401	5 Mile Well (Cape Range)	No	No	No	No Gender / Initiation Restrictions	Register	Sub surface cultural material; Artefacts / Scatter; Engraving; Painting; Quarry	*Registered Knowledge Holder names available from DPLH	P00751
11458	NINGALOO (near)	No	No	No	No Gender / Initiation Restrictions	Register	Painting	*Registered Knowledge Holder names available from DPLH	P00701
11772	ROSEMARY ISLAND 09	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	P00369
11775	ROSEMARY ISLAND 06	No	No	No	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	P00372
11820	ENDERBY ISLAND 01	No	No	No	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	P00364
17193	Ningaloo Station	No	No	No	No Gender / Initiation Restrictions	Register	Burial	*Registered Knowledge Holder names available from DPLH	
18822	Cape Preston 19	No	Yes	No	No Gender / Initiation Restrictions	Register	Quarry	*Registered Knowledge Holder names available from DPLH	
18823	Cape Preston 20	No	Yes	No	No Gender / Initiation Restrictions	Register	Quarry	*Registered Knowledge Holder names available from DPLH	
18824	Cape Preston 21	No	No	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
18825	Cape Preston 22	No	Yes	No	No Gender / Initiation Restrictions	Register	Quarry	*Registered Knowledge Holder names available from DPLH	
18826	Cape Preston 23	No	Yes	No	No Gender / Initiation Restrictions	Register	Quarry	*Registered Knowledge Holder names available from DPLH	
18827	Cape Preston 24	No	Yes	No	No Gender / Initiation Restrictions	Register	Quarry	*Registered Knowledge Holder names available from DPLH	
18838	Cape Preston 35	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
26005	Site No. 18	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	
26006	Site No. 25	Yes	Yes	Yes	No Gender / Initiation Restrictions	Register	Engraving	*Registered Knowledge Holder names available from DPLH	

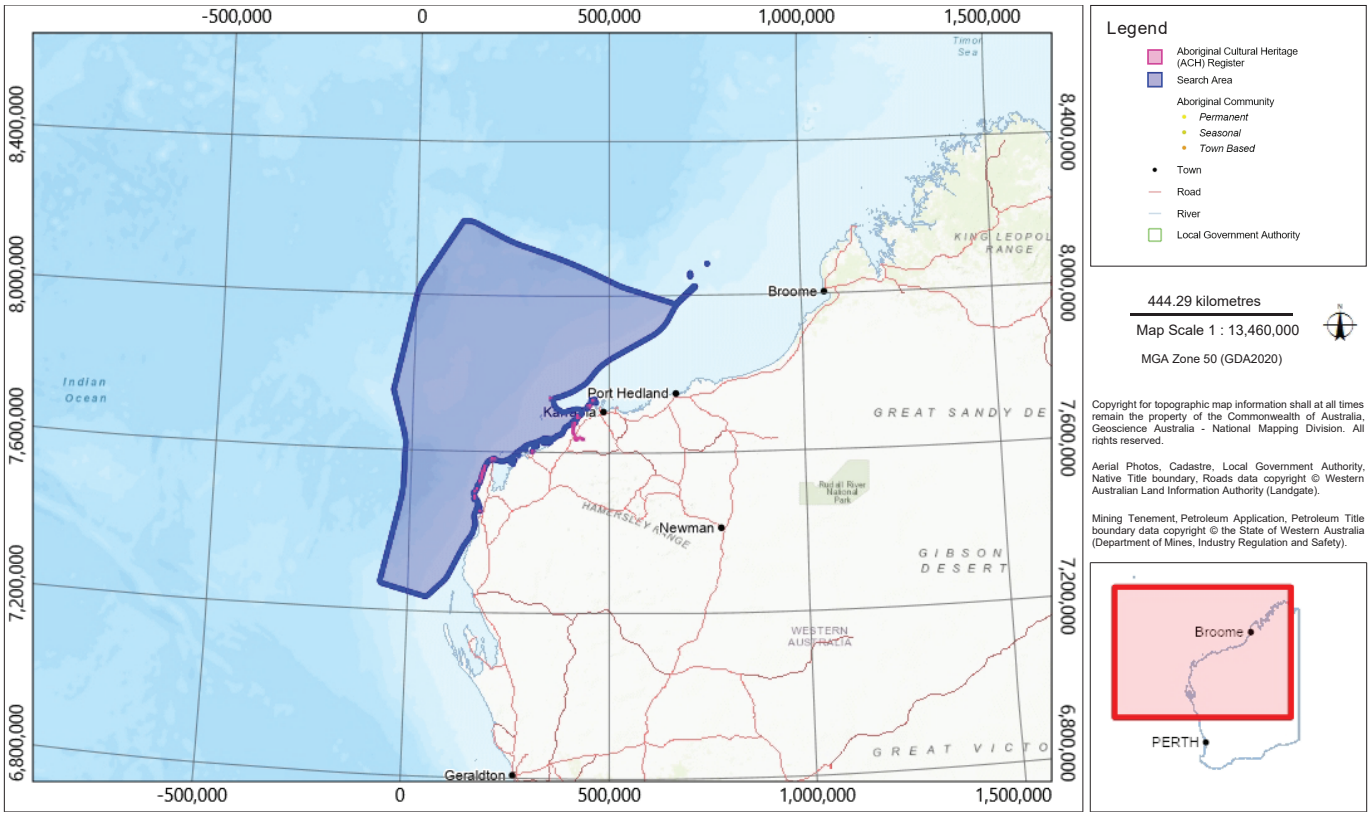
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26017	P08 - 02	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Engraving; Grinding areas / Grooves; Midden; Quarry; Shell	*Registered Knowledge Holder names available from DPLH	
26019	P08 - 08	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26020	P08 - 09	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26441	P09 - 01	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Shell	*Registered Knowledge Holder names available from DPLH	
26444	P09 - 04	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26446	P09 - 06	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26736	ACHM - 09-05	No	Yes	No	No Gender / Initiation Restrictions	Register	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
32879	Lower Fortescue River (Mardathuni)	No	No	No	No Gender / Initiation Restrictions	Register	Camp; Creation / Dreaming Narrative; Hunting Place; Landscape / Seascape Feature; Plant Resource; Water Source	*Registered Knowledge Holder names available from DPLH	

Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Register

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Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Lodged

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Search Criteria

47 Aboriginal Cultural Heritage (ACH) Lodged in Shapefile - GS3_Social_EMBA

Disclaimer

Aboriginal heritage holds significant value to Aboriginal people for their social, spiritual, historical, scientific, or aesthetic importance within Aboriginal traditions, and provides an essential link for Aboriginal people to their past, present and future. In Western Australia Aboriginal heritage is protected under the Aboriginal Heritage Act 1972.

All Aboriginal cultural heritage in Western Australia is protected, whether or not the ACH has been reported or exists on the Register.

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Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Lodged

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- Culturally Sensitive = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the ACH is restricted if it is considered culturally sensitive information. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the people who provided the information. To request access please contact via https://achknowledge.dplh.wa.gov.au/ach-enquiry-form.
- Culturally Sensitive Nature:
  - No Gender / Initiation Restrictions: Anyone can view the information.
  - Men only: Only males can view restricted information.
  - Women only: Only females can view restricted information.

Status:

- Register: Aboriginal cultural heritage places that are assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Lodged: Information which has been received in relation to an Aboriginal cultural heritage place, but is yet to be assessed under Section 5 of the Aboriginal Heritage Act 1972.
- Historic: Aboriginal heritage places assessed as not meeting the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.

Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.
Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 2020 Datum.

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
883	BARROW ISLAND 01	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
884	I-24-S0001/S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
885	BARROW ISLAND 03	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
886	C-21-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
887	O-02-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
888	P-05-S0001	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
889	O-06-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
890	D-20-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
891	Bandicoot Bay Settlement	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
892	BARROW ISLAND 10	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
893	D-20-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
894	D-16-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
6346	MT SALT	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Burial	*Registered Knowledge Holder names available from DPLH	
6783	28 MILE CREEK NORTH 2	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
6786	LAKESIDE COASTAL PLAIN	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
6789	TURQUOISE BAY NORTH	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
7208	MILYERING ROCKS.	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Hunting Place	*Registered Knowledge Holder names available from DPLH	

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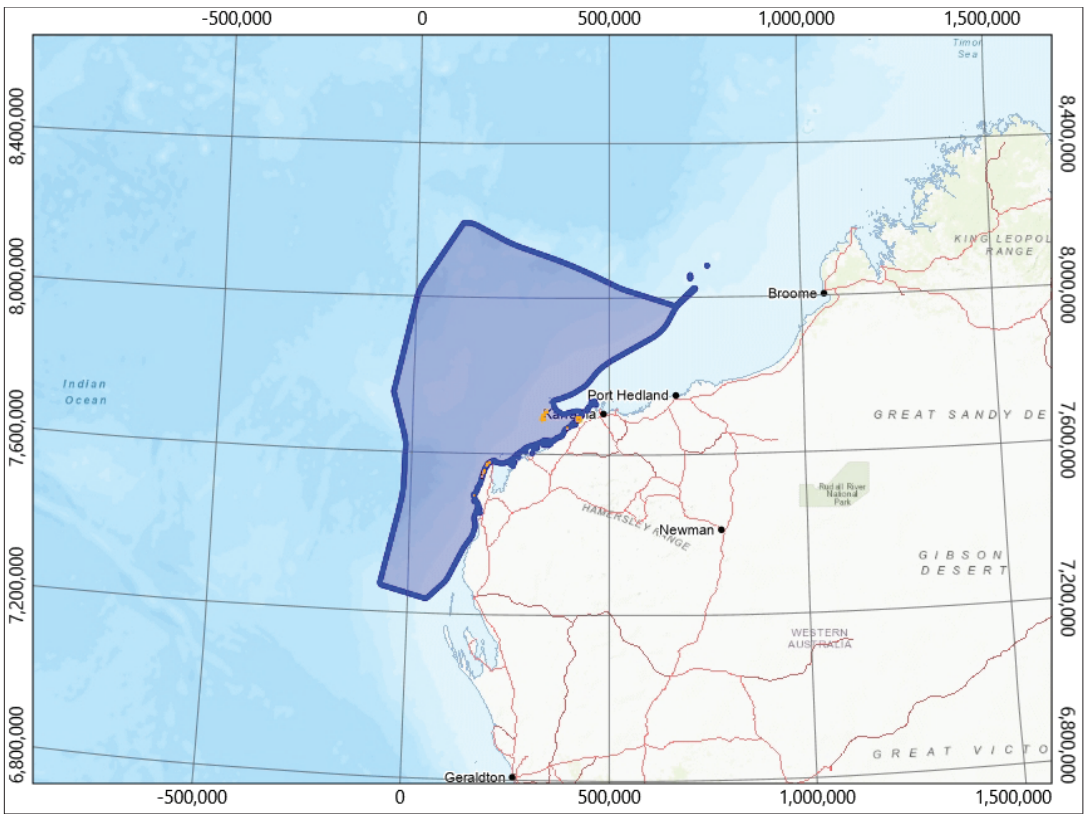
Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Lodged

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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
11801	COASTAL MIDDEN, 5 MILE	No	No	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	
19171	Ceremonial Ground	Yes	Yes	No	Men only	Lodged	Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving	*Registered Knowledge Holder names available from DPLH	
22943	Flacourt Bay 01	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Rock Shelter	*Registered Knowledge Holder names available from DPLH	
25076	Norwegian Bay Burial 01/2008	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Burial	*Registered Knowledge Holder names available from DPLH	
29549	Boodie Soak	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
31762	Site 1	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
31763	Site 2	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	
36199	Boodie Cave	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36200	John Wayne Country Rockshelter	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	
36234	South End structures, Barrow Island.	No	No	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36261	G-13-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36262	H-24-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36263	H-24-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36264	I-23-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36265	I-23-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36266	I-24-S0003	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36267	J-23-S0001	No	Yes	No		Lodged	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
36268	J-23-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36269	J-23-S0003	No	Yes	No		Lodged	Modified Tree	*Registered Knowledge Holder names available from DPLH	
36270	M-03-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36271	N-02-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36272	O-02-S0002	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36273	O-05-S0003	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36344	N-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36345	N-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36346	O-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36347	O-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
36348	P-04-S0001	No	Yes	No		Lodged	Historical; Other	*Registered Knowledge Holder names available from DPLH	
39730	Tantabiddi Midden 1	No	Yes	No	No Gender / Initiation Restrictions	Lodged		*Registered Knowledge Holder names available from DPLH	
40768	Jurabi Point	Yes		Yes	No Gender / Initiation Restrictions	Lodged	Burial	*Registered Knowledge Holder names available from DPLH	



Legend

- Aboriginal Cultural Heritage (ACH) Lodged
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

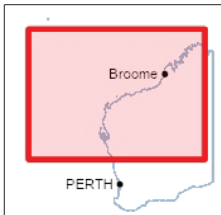
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Department of Planning, Lands and Heritage

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

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Search Criteria

16 Aboriginal Cultural Heritage (ACH) Historic in Shapefile - GS3_Social_EMBA

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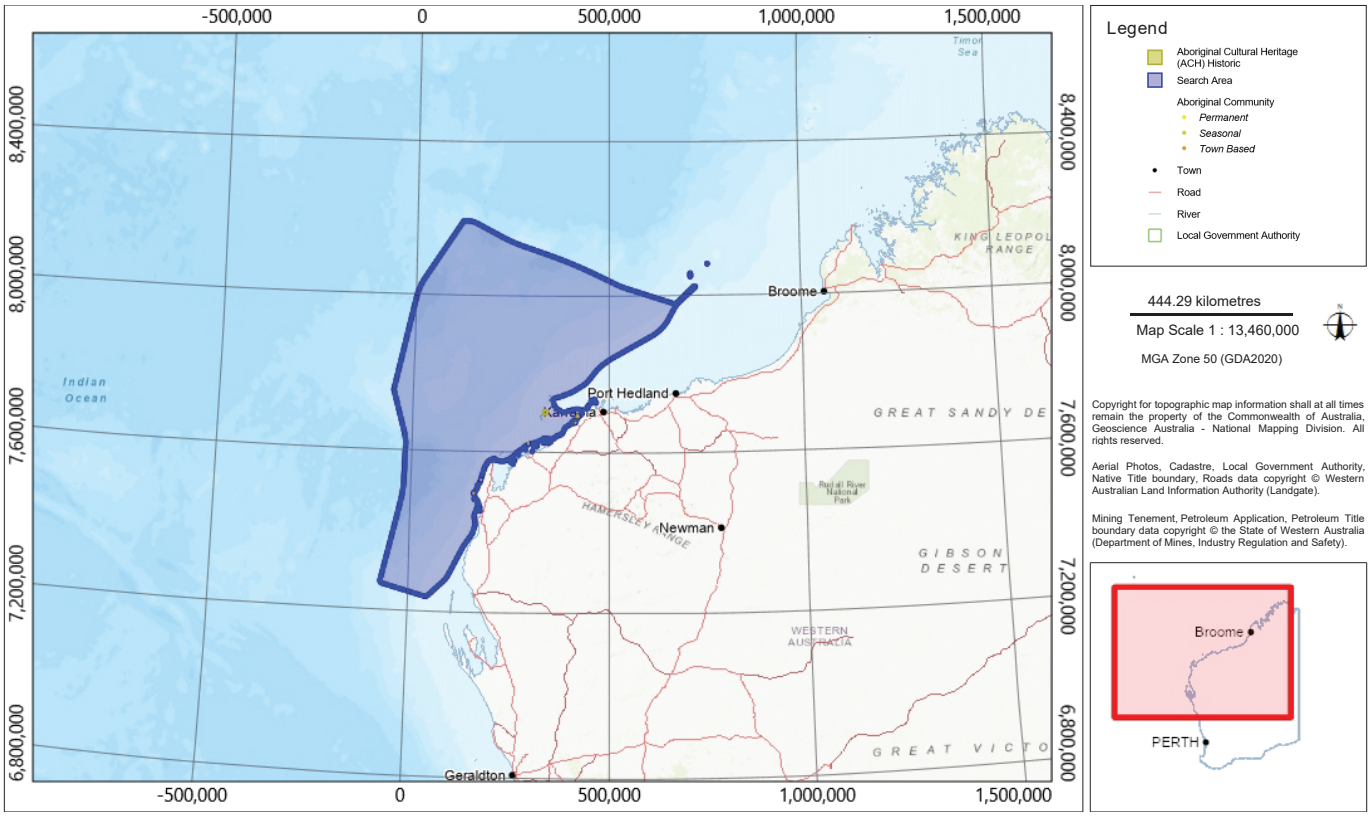
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ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	Place Type	Knowledge Holders	Legacy ID
599	NORWEGIAN BAY 2 #Duplicate of ID 7037	No	Yes	No	No Gender / Initiation Restrictions	Historic	Burial; Artefacts / Scatter; Midden; Other	*Registered Knowledge Holder names available from DPLH	P07441
6796	ROAD ALIGNMENT 4	No	Yes	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P06154
8951	BARROW ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	P03542
11403	THEVENARD ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Midden	*Registered Knowledge Holder names available from DPLH	P00753
18837	Cape Preston 34	No	Yes	No	No Gender / Initiation Restrictions	Historic	Midden	*Registered Knowledge Holder names available from DPLH	
25987	Site No 5	No	Yes	No	No Gender / Initiation Restrictions	Historic	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	
25988	Site No 10	No	Yes	No	No Gender / Initiation Restrictions	Historic	Engraving	*Registered Knowledge Holder names available from DPLH	
26001	Site No 24	No	Yes	No	No Gender / Initiation Restrictions	Historic	Engraving	*Registered Knowledge Holder names available from DPLH	
26003	Site No. 6	Yes	Yes	Yes	Men only	Historic	Engraving	*Registered Knowledge Holder names available from DPLH	
26004	Site No. 7/8/9	Yes	Yes	Yes	Men only	Historic	Engraving; Grinding areas / Grooves; Quarry	*Registered Knowledge Holder names available from DPLH	
26445	P09 - 05	No	Yes	No	No Gender / Initiation Restrictions	Historic	Engraving	*Registered Knowledge Holder names available from DPLH	
26447	P09 - 07	No	Yes	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26448	P09 - 08	No	Yes	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26449	P09 - 09	No	Yes	No	No Gender / Initiation Restrictions	Historic	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	
26457	WG14	No	Yes	No	No Gender / Initiation Restrictions	Historic	Engraving; Quarry	*Registered Knowledge Holder names available from DPLH	
38763	Wapet Shell Midden	No	Yes	No		Historic	Shell	*Registered Knowledge Holder names available from DPLH	



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appendix g response to public comments

Appendix Table G-1: Response to public comments on Revision 2[1] of the Backfill Fields OPP

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
1	Individual #1	NOPSEMA public comment submission	*Matter*: Supportive of proposed Development. *Objection or claim*: No objection or claim raised.	Chevron Australia Pty Ltd (CAPL) welcomes the support for the proposed Backfill Fields Development (the Development).	CAPL considers no amendments to the OPP are necessary.
2	Individual #2	NOPSEMA public comment submission	*Matter*: Comments were received citing concerns of potential adverse impacts to the marine environment. *Objection or claim*: 2A—The proposed Development would result in disruption and/or damage to the environment at the development site.	In developing the Backfill Fields Offshore Project Proposal (OPP), and in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (Cth) (OPGGS(E)R), CAPL has identified and evaluated the environmental impacts and risks associated with both planned activities and unplanned events associated with the petroleum activities within scope of the Development, including identifying environmental performance outcomes (EPOs) and control measures to demonstrate that these petroleum activities can be managed to an acceptable level. The definition of environment under the OPGGS(E)R is broad and includes ecological, socioeconomic, and cultural components. These elements have been incorporated into the description of environment (**Section 6**). An initial screening of environmental aspects was undertaken to identify potential interactions between the proposed Development and the environment (**Table 7-2**). Potential impacts and risks arising from these aspects were then identified (**Table 7-3**). Detailed evaluations of the potential impacts and risks are provided in **Section 8**. The spatial extent of the environment that may be affected (EMBA) from planned activities and unplanned events (except for major hydrocarbon spill events) associated with the Development occurs within, or within the vicinity of, the Development Area (DA) (i.e. an area offshore from Barrow Island in Commonwealth waters, as shown in **Figure 4-2** of the OPP). Detailed	CAPL considers that the OPP sufficiently addresses the matters contained within the public comment relating to the environmental impacts and risks associated with the Development, and as such no amendments to the OPP have been made.

[1] Revision 2 of the Backfill Fields Development OPP was released for public comment between 09 August and 01 November 2024. During the subsequent Stage 2 assessment phase by NOPSEMA further changes to the OPP have been made. Any references to components of the OPP (including figures, environmental performance outcomes and control measures) are as per the updated revisions of the OPP.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				environmental impact and risks assessments for the following aspects have been provided: • seabed disturbance (**Section 8.1**) • air emissions (**Section 8.2**) • light emissions (**Section 8.4**) • underwater sound emissions (**Section 8.5**) • planned discharges (MODU and vessel operations, subsea operations, drilling operations) (**Sections 8.6**, **8.7**, **8.8**) • unplanned interactions from physical presence of Development (other marine users, marine fauna) (**Sections 8.9**, **8.10**) • unplanned introduction of invasive marine species (**Section 8.11**) • unplanned releases (solid waste, minor loss of containment) (**Sections 8.12**, **8.13**) The highest consequence level of all the potential impacts from the above aspects was a 4 (moderate) associated with seabed disturbance. The highest residual risk level of all the potential risks from the above aspects was 6 (moderate) associated with underwater sound emissions. These aspects, and potential impacts or risks, are not dissimilar to those managed by CAPL (and other petroleum operators) for existing petroleum operations. To manage the impacts and risks associated with these aspects, CAPL has defined EPOs that set a level of environmental performance and identified preventative and/or mitigative control measures to ensure that the impacts and risks can be managed to an acceptable level. As such, CAPL consider that the potential for disruption and/or damage to the environment at the Development site can be managed to an acceptable level in alignment with regulatory requirements for an offshore project[2].	
			Objection or claim:	The risk of disruption and/or damage to the Exmouth and Onslow oceanic system is only associated with the risk of an unplanned major hydrocarbon spill event (and not directly from other	

[2] Where 'offshore project' is defined under regulation 5 of the OPGGS(E)R, as "one or more activities that are undertaken for the purpose of the recovery of petroleum, other than on an appraisal basis, including any conveyance of recovered petroleum by pipeline (whether or not the activity is undertaken for other purposes)".

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			2B—The proposed Development would result in disruption and/or damage to the Exmouth and Onslow oceanic system.	Development activities). The risk assessments for these two aspects are presented in **Section 8.14** and **Section 8.15**). The EMBA from unplanned major hydrocarbon spill events is much broader than the DA and extends towards the Onslow and Exmouth area (as shown in **Figure 6-1** and **Figure 6-2** of the OPP[3]). CAPL used oil spill modelling to inform its assessment of impacts and risks associated with these unplanned release of hydrocarbon events. The oil spill modelling (full modelling reports are included in **Appendix C**) indicated that for the Onslow and Exmouth area: • no exposure to surface (floating) oil above the ≥10 mg/L ecological threshold; some potential exposure above the visible (≥1 mg/L) threshold may occur in offshore waters • some potential shoreline accumulation (above the visible 10 g/m^2 and ecological 100 g/m^2 thresholds) may occur on some of the Pilbara inshore islands or along the western coast of the North West Cape • no exposure to dissolved hydrocarbons above the 50 ppb threshold • some potential exposure to entrained hydrocarbons above the 100 ppb threshold in waters offshore from Onslow and Exmouth • the probability of exposure varied due to the location and type of spill event. Some of the key environmental sensitivities within the vicinity of the Onslow and Exmouth area are Ningaloo (including the reef system, marine parks, World Heritage Area) and the Pilbara inshore islands, which were both specifically addressed within the impact and risk assessments in **Section 8.14** and **Section 8.15.** To manage the impacts and risks associated with an unplanned hydrocarbon release, CAPL has identified both preventative (e.g.**CM-16, CM-31, CM-32, CM-33, CM-43. CM-45, CM-46**) and mitigative (e.g. **CM-22, CM-44**) control measures to ensure that the impacts and risks can be managed to an acceptable level. As such, CAPL consider that the potential for	

[3] Note: The EMBA shown in these figures is based on the outcomes of stochastic oil spill modelling and is not representative of a single spill event.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				disruption and/or damage to the to the Exmouth and Onslow oceanic system can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	
3	Individual #3	NOPSEMA public comment submission	*Matter*: Supportive of proposed Development. *Objection or claim*: No objection or claim raised.	CAPL welcomes the support for the proposed Development.	CAPL considers no amendments to the OPP are necessary.
4	Individual #4	NOPSEMA public comment submission	*Matter*: Comments were received citing concerns of potential adverse impacts to the marine environment and marine fauna. *Objection or claim*: 4A—The proposed Development is within whale migration routes and these animals must be protected.	In developing the Backfill Fields OPP, and in accordance with the requirements of the OPGGS(E)R, CAPL has identified and evaluated the environmental impacts and risks associated with both planned activities and unplanned events associated with the petroleum activities within scope of the Development, including identifying EPOs and control measures to demonstrate that these petroleum activities can be managed to an acceptable level. The presence of cetaceans and any identified biologically important areas (BIAs) within the EMBA are described within **Section 6.3.3.1**. The very southern extent of the DA extends into the "migration (north and south)" BIA for humpback whales (**Figure 6-14**). Petroleum activities occurring within vicinity of this BIA include the development of West Tryal Rocks [WTR] and tie-in activities to existing Gorgon infrastructure (i.e. activities associated with the development of the Chrysaor and Dionysus [C&D] and WTR gas fields). The DA more broadly intersects with the "migration" BIA for pygmy blue whales (**Figure 6-16**). Petroleum activities occurring within or within vicinity of this BIA include the development of all gas fields (Chandon, Geryon and Eurytion [G&E], C&D, Semele, WTR). The presence of humpback whales within the Jansz region has been recorded from July to October (**Table 6-18**). Pygmy blue whale presence within the Jansz region has been recorded from late-March to mid-September (peak late-May to June) during northern migration, and from early-October to late-January (peak late-November and early-December) for the southern migration (**Table 6-18**). The gas fields will be developed over multiple campaigns with the G&E development indicatively scheduled to commence from late-2026 (**Section 4.14**). Detailed breakdown	CAPL considers that the OPP sufficiently addresses the matters contained within public comment relating to the environmental impacts and risks associated with the Development, and as such no amendments to the OPP have been made.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				of activity timings is not available at this stage of the Development but will be included in subsequent Environment Plans (EPs). The potential for petroleum activities to occur throughout the year has been carried into the impact and risk assessments presented in the OPP. The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following aspects as relevant to marine mammals (including cetaceans): • underwater sound emissions • planned discharges (drilling operations) • unplanned interactions from physical presence of Development (marine fauna) • unplanned releases (minor loss of containment) • unplanned hydrocarbon release (vessel collision, hydrocarbon system). Marine mammals form part of the detailed impact and risk assessment for each of the above aspects within **Section 8**. The highest residual risk level of all the potential risks from the above aspects was 6 (moderate) associated with underwater sound emissions. To mitigate the impacts and risks associated with this aspect, CAPL has set EPOs and identified preventative and/or mitigative control measures to ensure that the impacts and risks can be managed to an acceptable level. For underwater sound, there is also an adaptive management EPO and control measures (**EPO-23, CM-20 and CM-21**) that have been included which requires consideration of appropriate acoustic management controls to be further considered during the development of the subsequent EPs to ensure that the risks from underwater sound have been reduced to as low as reasonably practicable and can be managed to acceptable levels. There are also EPOs (**EPO-17**, **EPO-18**, **EPO-19**) in place to ensure that the risks from the petroleum activity are not inconsistent with the requirements for the Conservation Management Plan for the Blue Whale. As such, CAPL considers that the potential for impacts and risks to whale species, and specifically within migration routes, can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			Objection or claim: 4B—The proposed Development would impact the ocean and this environment must be protected.	Regarding the claim raised about impacts to the ocean, please refer to the response provided above to Item 2. CAPL considers that the potential impacts and risks to the ocean can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	
5	Individual #5	NOPSEMA public comment submission	*Matter*: Supportive of proposed Development. *Objection or claim*: No objection or claim raised.	CAPL welcomes the support for the proposed Development.	CAPL considers no amendments to the OPP are necessary.
6	Individual #6	CAPL consultation hub (website) submission	*Matter*: A comment was received citing "marine environment and whale migration". *Objection or claim*: No objection or claim has been defined due to lack of context in comment received.	CAPL attempted to contact the individual via email and phone following receipt of the comment asking if they wanted to discuss the Development, or if further information was required, to try and understand the context of the submission and if there were any objections or claims. No response from the individual was received on either attempt of contact. However, regarding the marine environment and whale migration, responses to comments on similar matters are provided above in Item 2 and Item 4.	CAPL considers no amendments to the OPP are necessary.
7	Individual #7	NOPSEMA public comment submission	*Matter*: Supportive of proposed Development. *Objection or claim*: No objection or claim raised.	CAPL welcomes the support for the proposed Development.	CAPL considers no amendments to the OPP are necessary.
8	Conservation Council of WA (CCWA)	NOPSEMA public comment submission	*Matter*: Comments were received citing that the description of the proposed Development is not always consistent. *Objection or claim*: 8A—Number of wells is reported as both seven and forty.	CAPL are unable to find reference to 7 wells in the OPP. However, CAPL can confirm that the Development comprises: • 7 backfill fields (Chandon, Geryon, Eurytion, Chrysaor, Dionysus, Semele, WTR) (**Sections 1.1**, **4.1**) • a maximum of 40 production wells across all fields (**Section 4.2.2**) – with a maximum of 8 wells per field or co-developed fields (i.e. a maximum of 8 wells in each of Chandon, G&E, C&D, Semele, and WTR) (**Section 4.2.2**)	CAPL considers no amendments to the OPP are necessary.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				• the wells are distributed between 10 drill centres (2 in Chandon, 1 in G&E, 3 in C&D, 2 in Semele, and 1 in WTR) (**Section 4.1.3**, **4.2.2**).	
			Matter: Comments were received citing concerns that the Development is near multiple sensitive environmental receptors. *Objection or claim*: 8B—The Development has the potential to produce impacts to ecologically significant communities (specifically the Commonwealth Montebello Marine Park, ancient coastline at 125 m dept contour key ecological feature [KEF], the continental slope demersal fish communities KEF, and the Exmouth Plateau KEF) from: • seabed disturbance • light pollution • noise pollution • hydrocarbon spills • wastewater discharge • drilling by-products.	The presence of KEFs within the EMBA are identified in **Section 6.3.6.1;** specifically, the DA intersects with a small proportion of each of the following KEFs: • ancient coastline at 125 m depth contour (activities associated with the development of WTR) • continental slope demersal fish communities (activities associated with the development of C&D) • Exmouth Plateau (activities associated with the development of Chandon). The values of the ancient coastline and Exmouth Plateau KEFs are listed as 'unique seafloor features with ecological properties of regionally significance' (**Table 6-20**). Parts of the ancient coastline KEF, particularly rocky escarpments, are thought to provide biologically important habitat in areas otherwise dominated by soft sediments (**Table 6-20**). The Exmouth Plateau KEF is likely to be an important area of biodiversity for communities adapted to deep-water conditions (**Table 6-20)**.However, findings from a benthic survey within the DA undertaken in 2022 found that • benthic habitats within the ancient coastline KEF were predicted to be comprised of smooth seabed with bioturbation and bare substrate and appeared to be devoid of epibenthic biota (**Section 6.3.1.1.1**; **Table 6-20).** • the survey did identify two discrete scarp features within the Exmouth Plateau KEF in an area that intersects with the indicative flowline route for Chandon; however, no epibenthic fauna were detected (**Section 6.3.1.1.1**; **Table 6-20)**. The values of the continental slope demersal fish communities KEF are listed as high level of endemism with a diversity of fish assemblages (**Table 6-20**). However, fish assemblage surveys (undertaken as part of the 2022 benthic survey) found that there was no significant difference in the mean number of fish taxa identified within the proportion of the DA that intersected with this demersal fish assemblages KEF compared to where the DA	In response this submission CAPL has revised the OPP to include an evaluation of risks to the values of the Commonwealth Montebello Marine Park from light emissions (**Section 8.4**) and underwater sound (**Section 8.5**). The aspect–receptor screening in **Table 7-3** has been updated to reflect the addition of AMPs for light emissions and underwater sound. **Table 7-3** has also been updated to reflect all relevant receptors that were evaluated within the planned discharges MODU and vessel aspect.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				intersected the other two (ancient coastline and Exmouth Plateau) KEFs (**Table 6-20**). The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following aspects as relevant to KEFs: • seabed disturbance • planned discharges (subsea operations, drilling operations) • unplanned introduction of invasive marine species • unplanned releases (solid wastes) • unplanned hydrocarbon release (vessel collision, hydrocarbon system). KEFs form part of the detailed impact and risk assessments for each of the above aspects within **Section 8**. The highest residual risk level of all the potential risks from the above aspects was 7 (low) associated with seabed disturbance. To mitigate the impacts and risks associated with these aspects, CAPL has set EPOs and identified preventative and/or mitigative control measures to ensure that the impacts and risks can be managed to an acceptable level. As such, CAPL considers that the potential for impacts and risks to KEFs can be managed to an acceptable level in alignment with regulatory requirements for an offshore project. The presence of Australian Marine Parks (AMPs) within the EMBA are identified in **Section 6.5.1**. There are no AMPs that intersect with the DA, the closest AMP is Montebello Marine Park which is ~16 km south-east of the DA. The original (Revision 2 of the OPP) screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following aspects as relevant to AMPs: • unplanned hydrocarbon release (vessel collision, hydrocarbon system). AMPs form part of the detail impact and risk assessment for each of the above aspects within **Sections 8.14** and **8.15**. The highest residual risk level of all the potential risks from the above aspects was 9 (very low). To manage the impacts and risks associated with these aspects, CAPL has identified preventative	

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				and/or mitigative control measures to ensure that the impacts and risks can be managed to an acceptable level. As such, CAPL considers that the potential for impacts and risks to AMPs from unplanned hydrocarbon releases can be managed to an acceptable level in alignment with regulatory requirements for an offshore project. The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to light emissions: • physical environment (ambient light) • marine fauna (seabirds and shorebirds, fish, marine reptiles) • heritage (First Nations cultural values). Given light emission sources from the Development typically occur above the water surface (e.g. from vessels), the fish species associated with the continental slope demersal fish communities KEF were not considered to be exposed to light emissions due to their demersal (i.e. seafloor) habitat (**Section 8.4.3**). With respect to the other two KEFs, as described above, the ancient coastline and Exmouth Plateau KEFs are seafloor features and as such were not considered relevant receptors for light emissions. CAPL has reviewed the maximum flaring and navigational/operational light extents used in the impact and risk assessment and has identified that the spatial extent for flaring does extend to within the boundary of the Commonwealth Montebello Marine Park. CAPL revised **Section 8.4** to include: • a new figure (**Figure 8-22**) showing flaring and light extents in relation to AMPs • identification and evaluation of the risk for changes to the values and sensitivities of Australian Marine Parks. CAPL have also updated the screening table (**Table 7-3**) to identify AMPs as a relevant receptor for the light emissions aspect.	

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to underwater sound: • physical environment (ambient sound) • marine fauna (fish, marine reptiles, marine mammals) • heritage (First Nations cultural values). Although fish may potentially be impacted by underwater sound, the area of influence is localised and is not expected to result in a change in the viability of the population of commercially important species or the continental slope demersal fish communities KEF (**Section 8.5.5**). With respect to the other two KEFs—as described above the ancient coastline and Exmouth Plateau KEFs are seafloor features and as such were not considered relevant receptors for underwater sound. CAPL has reviewed the maximum horizontal extents used in the impact and risk assessment and has identified that the spatial extent to the behavioral response threshold for marine mammals from non-impulsive sound does extend to within the boundary of the Commonwealth Montebello Marine Park. CAPL has revised **Section 8.5** to include: • a new figure (**Figure 8-28**) showing marine mammal maximum horizontal distance for behavioural response in relation to AMPs • identified and evaluated a risk for changes to the values and sensitivities of Australian Marine Parks. CAPL have also updated the screening table (**Table 7-3**) to identify AMPs as a relevant receptor for the underwater sound aspect. No further comment was provided in the submission regarding wastewater discharges. CAPL has interpreted this comment to be in relation to planned discharges from MODUs and vessels (which include sewage and greywater discharges). The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to planned discharges from MODUs and vessels: • physical environment (water quality).	

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				This table has been updated to capture all receptors that were included in the impact and risk assessment (**Section 8.6**), which also incorporated: • marine fauna (seabirds and shorebirds, fish, marine reptiles, marine mammals) and fish assemblages associated with KEFs. Given planned discharges from the MODU and vessels occur in surface waters, the fish species associated with the continental slope demersal fish communities KEF were not considered to be exposed due to their demersal (i.e. seafloor) habitat (**Section 8.6.2**). Planned discharges are expected to dilute and disperse within open ocean environments. Given the distance between the DA and the Montebello Marine Park, no exposure to planned discharges from MODUs and vessels is expected to occur (and therefore AMPs are not a relevant receptor for this aspect).	
			Objection or claim: 8C—A full survey of the Development Area and EMBA is necessary.	The description of environment (**Section 6**) was developed based on several sources of information, including studies specifically undertaken by CAPL. Field surveys were undertaken at sites within the DA to provide information on: • benthic habits • fish assemblages • water and sediment quality. The survey report has been provided in full (**Appendix A**) with key results provided in the relevant parts of **Section 6** and used to inform the impact and risk assessments in **Section 8**. Soundscape monitoring has also been undertaken by CAPL as part of the J-IC project. Findings from the monitoring have been incorporated into **Section 6.3.3.1**. A full survey of the EMBA is not considered practicable or necessary. Available literature has been used to provide a description of the values and sensitivities within the EMBA as appropriate to the nature and scale of the potential impacts and risks to this broader area. Further, in the event of an unplanned hydrocarbon spill, operational and scientific monitoring (**CM-44**; **Sections 8.14** and **8.15**) would be implemented which would	In response to this submission CAPL has revised the OPP to include a summary of the J-IC soundscape monitoring in **Section 6.3.3.1** (marine fauna), Section 6.3.3.1.1 (humpback whales) and **Section 6.3.3.1.2** (pygmy blue whales).

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				capture information on the environment at risk from the particular unplanned release event.	
			Matter: Comments were received citing concerns of potential adverse impacts from seabed disturbance associated with the Development. *Objection or claim*: 8D—The Development will disturb 18,850,329 m^2 of seabed, and will impact benthic communities and marine fauna.	As described in **Section 8.1.1.7** the 'long-term disturbance area' of 18.85 km^2 was developed based on a combination of the following allowances: • 30 m wide lay corridor along production flowlines, MEG pipelines, and umbilicals • 250 m radius around DCs and GFP tie-in locations • additional 50% contingency. CAPL considered this a conservative approach to defining the area in which all subsea infrastructure associated with the Development will be installed. That is, all infrastructure footprints will occur within this long-term disturbance area; but the actual infrastructure footprint is likely to be less than this total maximum area (e.g. individual pieces of subsea infrastructure will be placed within the 250 m radius around a GFP tie-in location, but infrastructure would not necessarily cover the full extent of this area). The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to seabed disturbance: • physical environment (water quality) • benthic habitats and communities • marine fauna (fish) • KEFs • heritage (First Nations cultural values). That is, both benthic communities and marine fauna form part of the detailed impact and risk assessment for seabed disturbance within **Section 8.1**. The highest consequence level of potential impacts associated with seabed disturbance was 4 (moderate), and the highest residual risk level from all potential risks was 7 (low). These potential impacts or risks are not dissimilar to those managed by CAPL (and other petroleum operators) for existing petroleum operations. To manage the impacts and risks associated with seabed disturbance from the Development,	CAPL considers that the OPP sufficiently addresses the matters contained within public comment relating to the environmental impacts and risks associated with seabed disturbance from the Development, and as such no amendments to the OPP have been made.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				CAPL has identified EPOs and preventative control measures to ensure that the impacts and risks can be managed to an acceptable level (**Section 8.1.4**). As such, CAPL considers that the potential for impacts and risks to benthic habitat and associated marine fauna from seabed disturbance can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	
			Matter: Comments were received citing concerns of potential adverse impacts from light emissions associated with the Development. *Objection or claim*: 8E—The Development will produce light emissions that may impact EPBC-listed marine turtles and birds within respective BIAs or areas identified as habitat critical to survival (HCTS).	The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to light emissions: • physical environment (ambient light) • marine fauna (seabirds and shorebirds, fish, marine reptiles) • AMPs • heritage (First Nations cultural values). That is, both marine turtles, seabirds and shorebirds were identified as relevant environmental values and sensitivities and were included in the detailed impact and risk assessment for light emissions within **Section 8.4**. The spatial extent used to describe the potential area that may be exposed to light emissions from flaring was based on 42.4 km radius buffer around the DCs (**Section 8.4.2.2**). This distance is based on visible light, which does not necessarily imply a measurable change in ambient light that would have a biological impact to marine fauna. The spatial extent used to describe the potential area that may be exposed to light emissions from navigational/operational lighting on a MODU was 12.6 km radius buffer around the DCs (**Section 8.4.2.3**), and from vessels was based on a 5.2 km radius buffer around the entire DA (**Section 8.4.2.3**). These distances were derived from analogue light monitoring and/or modelling studies. CAPL considered the use of these distances as a conservative approach to defining a spatial extent to be used to identify potential environmental values and sensitives that may be at risk. Note: The actual areas exposed to light emissions will be dependent on location of vessels/MODUs at the time of each activity. Further, where flaring is required, this activity is of limited duration (~1 day per well).	CAPL considers that the OPP sufficiently addresses the matters contained within the public comment relating to the environmental risks to marine fauna associated with light emissions to from the Development, and as such no amendments to the OPP have been made.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				The intersection between these potential light extents and the BIAs and HCTS for marine turtles, seabirds and shorebirds are illustrated in the following figures in the OPP: • flatback turtle—overlap between the flaring and navigational/operational light extents and an internesting buffer BIA and interesting HCTS (**Figure 8-11**) • hawksbill turtle— overlap between the flaring extent and an internesting buffer BIA and internesting HCTS (**Figure 8-13**) • loggerhead turtle—overlap between flaring extent and an internesting buffer BIA (**Figure 8-15**) • green turtle—overlap between the flaring extent and an internesting buffer BIA and internesting HCTS (**Figure 8-16**) • wedge-tailed shearwater—overlap between the flaring and navigational/operational light extents and a breeding BIA (**Figure 8-18**) • fairy tern and lesser crested tern—overlap between the flaring extent and a breeding BIA (**Figure 8-19**, **Figure 8-20**). Neither the navigational/operational lighting extent or the flaring light extent occurs within nearshore or coastal areas (i.e. areas used for nesting/breeding are not predicted to be exposed to light sources from the Development) (**Section 8.4.3**). The residual risk level from risks of behavior changes to marine turtles was 10 (very low), and to seabirds and shorebirds was 9 (very low). These potential impacts or risks are not dissimilar to those managed by CAPL (and other petroleum operators) for existing petroleum operations. To manage the impacts and risks associated with light emissions from the Development, CAPL has identified EPOs and preventative control measures to ensure that the impacts and risks can be managed to an acceptable level (**Section 8.4.5**). As such, CAPL consider that the potential for impacts and risks to marine fauna from light emissions can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	
			Objection or claim: 8F—The risk of impacts to marine turtles from light emissions may be increased by concurrent activities.	The predicted light extents from flaring and navigation/operational lighting in relation to marine turtle BIAs and/or HCTS are shown in **Figure 8-11** to **Figure 8-17** (for flatback, hawksbill, loggerhead, and green turtles). The predicted	In response to this submission CAPL has revised the OPP to include an

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				extent does not reach nearshore or coastal areas (i.e. areas used for nesting or preferred internesting habitat). In recognition that concurrent light emissions may occur from multiple vessels present within a single campaign or from concurrent campaigns, the risk evaluations for marine turtles (and other receptors) have been revised in **Section 8.4.3**. Given the spatial extent of the light emissions and their location to habitats used by marine turtles, no increase in residual risk was predicted to occur from concurrent light emissions.	evaluation of concurrent light emissions for all receptors within **Section 8.4** (light emissions).
			Objection or claim: 8G—The assessment and management of potential impacts and risks from light emissions should be thorough and align with National Light Pollution Guidelines for Wildlife.	The National Light Pollution Guidelines for Wildlife were determined as relevant to the Development in **Section 2.2**, and these were taken into consideration within the light emissions impact and risk assessment in **Section 8.4**. The guidelines were also assessed within the 'determination of acceptability' (**Section 8.4.4**) that demonstrated that the Development is not considered to be inconsistent with the guidelines. To capture further consideration of the mitigation and management tools within the guidelines, an adaptive management EPO (**EPO-16**) control measure (**CM-17**) has been included in the OPP. This adaptive management approach requires consideration of the National Light Pollution Guidelines for Wildlife at the EP stage when activity-specific controls can be considered to support the demonstration that impacts and risks have been reduced to as low as reasonably practicable (ALARP) and acceptable levels.	In response to this submission CAPL has revised the OPP to include an additional EPO (**EPO-16**) and control measure (**CM-17**) in **Section 8.4** (light emissions) regarding consideration of the mitigation toolboxes within the National Light Pollution Guidelines for Wildlife during the subsequent EPs for the Development.
			Objection or claim: 8H—The proponent should avoid generating artificial light emissions during peak nesting periods for several bird and turtle species protected under Part 3 of the EPBC Act.	As described above, neither the navigational/operational lighting extent nor the flaring light extent occurs within nearshore or coastal areas (i.e. areas used for seabird, shorebird, or marine turtle nesting, or the preferred internesting habitat for marine turtles) are not predicted to be exposed to light sources from the Development. Further, the mitigation and management tools within the National Light Pollution Guidelines (which includes consideration of management actions during peak nesting seasons) has been incorporated into the new control measure (**CM-17**).	CAPL considers that the OPP sufficiently addresses the matters contained within the public comment relating to control measures for activities during peak bird or turtle nesting seasons, and as such no further amendments to the

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
					OPP have been made.
			Matter: Comments were received citing concerns of potential adverse impacts from underwater sound emissions associated with the Development. *Objection or claim*: 8I—The Development will produce underwater sound emissions that may impact EPBC-listed sharks and whales within respective BIAs, and these risks should be assessed. 8J—Acoustic modelling for the Development indicates that behavioural changes, temporary temporal shift (TTS) and permanent temporal shift (PTS) in cetaceans, and TTS in some fish, may occur which presents an unacceptable risk to EPBC-listed threatened species.	The screening for potential impacts and risks associated with the Development (**Table 7-3**) identified the following receptors as relevant to underwater sound: • physical environment (ambient sound) • marine fauna (fish, marine reptiles, marine mammals) • AMPs • heritage (First Nations cultural values). That is, both EPBC-listed sharks and whales were identified as relevant environmental values and sensitivities and were included in the detailed impact and risk assessment for underwater sound within **Section 8.5**. As described in **Sections 8.5.3** and **8.5.4** (summary of modelling results) and **Section 8.5.5** (risk evaluation), the risk of TTS to fish from non-impulsive sounds and impulsive sounds is the order of tens of meters from the sound source. Given the transient and highly mobile nature of sharks (including the EPBC-listed whale shark) the risk of TTS onset was considered to be low (7) to very low (9). As described in **Section 8.5.3** and **8.5.4** (summary of modelling results) and **Section 8.5.5** (risk evaluation), the risk of TTS or PTS to cetaceans from impulsive and non-impulsive sounds was considered low (7) and very low (10) respectively. For low frequency cetaceans (such as the pygmy blue whale) the distances from the sound source that were predicted to be ensonifed above the relevant effect criteria were in the order of tens of meters when considering animat modelling (i.e. incorporating animal movement into acoustic modelling) for low frequency cetaceans. The risk of a behavioural response by cetaceans to either impulsive (e.g. vertical seismic profile [VSP]) or non-impulsive (e.g. from thrusters on a vessel) sounds is considered credible (**Sections 8.5.3, 8.5.4, 8.5.5**). The maximum horizontal distance associated with impulsive sounds was ~2.37 km, and up to ~18.3 km for non-impulsive sounds. These potential ensonified areas overlap with migration BIAs for humpback and pygmy blue	CAPL considers that the OPP sufficiently addresses the matters contained within the public comment relating to the environmental risks to EPBC-listed cetaceans and fish associated with underwater sound emissions from the Development, and as such no amendments to the OPP have been made.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				whales (**Figure 8-27**, **Figure 8-32**). The residual risk level from risks of behavioral changes to cetaceans was 7 (low) for non-impulsive sounds and 9 (very low) for impulsive sounds. Note: Where VSP activities are required, these are of a limited (~1 day per well) duration during the drilling campaigns. These potential risks are not dissimilar to those managed by CAPL (and other petroleum operators) for existing petroleum operations. To manage the risks associated with underwater sound emissions from the Development, CAPL has identified adaptive management EPOs and control measures (including **EPO-23**, **CM-20**, and **CM-21)** which requires acoustic mitigation measures to be further assessed during EPs to ensure that the risks are being reduced to ALARP and managed to an acceptable level. There are also EPOs in place (e.g. **EPO-19**) to ensure that the petroleum activity is not inconsistent with the Conservation Management Plan for Blue Whales (**Section 8.5.7**). As such, CAPL consider that the potential for risks to marine fauna from underwater sound emissions can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	
			Objection or claim: 8K—Information on migratory routes for southern right whales and dugongs are needed to support risk assessment of sound emissions.	The southern right whale and dugong are not expected to be present within the DA (**Table 6-8**, **Section 6.3.3.1**), and therefore are not predicted to be within ensonified areas from underwater sound emissions associated with the Development. The description of the southern right whale (**Section 6.3.3.1.3**) has been revised to clarify that the distribution range extends north to Exmouth/Ningaloo Reef area in WA (this is within the Hydrocarbon Ecological and Social EMBAs, but not within the DA). Indicative migration paths to/from the Exmouth region have also been shown on a new figure (**Figure 6-18**). The description of the dugong (**Section 6.3.3.1.4**) has been revised to incorporate additional information about dugong habitat. Dugongs habitat preference for seagrass meadows typically restricts them to shallow waters where light penetration allows seagrass to grow. No change has been made to the underwater sound impact and risk assessment (**Section 8.5**) of the OPP.	In response to this submission CAPL has revised the OPP to include additional information within the descriptions of the southern right whale (**Section 6.3.3.1.3**) and dugong (**Section 6.3.3.1.4**).

			Objection or claim: 8L—Further information is required on potential desensitisation of fishes to impulsive sounds associated with seismic airguns.	VSP uses a small (e.g. ~750 in^3) airgun array as an acoustic source; this differs from the larger airgun arrays used in traditional seismic surveys (e.g. for exploration or reservoir management purposes). Traditional seismic surveys are not within the scope of the OPP. The journal article referenced in the submission[4] describes a Norwegian study in which two fish species (Atlantic cod [*Gadus morhua*] and saithe [*Pollachius virens*]) were captured and placed within a sea cage, and then exposed to pulses from a small (40 in^3) airgun over a 3-day period. Results from the study showed some initial behavioural responses (e.g. reduced heart rate, changes to swimming depth and horizonal position), but did not indicate a startle response or long-term alterations to physiology or behaviour. An experimental seismic survey[5] was conducted on the North West Shelf that measured the composition, abundance, behavior, and movement of commercially important demersal fishes. This study was based on exposure to a 3D seismic source (2,600 in^3) over a 5-day period in 50–80 m water depths. The study found that the seismic survey did not alter fish abundance or behavior in multiple before-after-control-impact and dose–response experimental frameworks. The potential risk of behavioural changes to fish from VSP (impulsive sound) is evaluated within **Section 8.5.5**, and is considered appropriate to the nature and scale of the sound source. The residual risk level from impulsive sound on fish was determined as 9 (very low). Use of impulsive sound, and the potential impacts or risks, are not dissimilar to those managed by CAPL (and other petroleum operators) for existing petroleum operations. To manage the impacts and risks associated with these aspects, CAPL has identified EPOs and preventative control measures to ensure that the impacts and risks can be managed to an acceptable level. These include adaptive management EPOs and control measures (**EPO-23**, **CM-20** which requires consideration of activity-specific control measures to ensure that the risks are being reduced to ALARP and managed to an acceptable level. . As such, CAPL consider that the potential for impacts to fish from impulsive sound sources associated with the Development can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	CAPL considers that the OPP sufficiently addresses the matters contained within the public comment relating to the environmental risks to fish from impulsive sound sources associated with the Development, and as such no amendments to the OPP have been made.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			Objection or claim: 8M—Where data gaps exist about marine fauna and the effect of underwater sound, the precautionary principle should be applied.	The Precautionary Principle is applied as part of the demonstration of principles of ecologically sustainable development (ESD): "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 'determination of acceptability' table within **Section 8.5.6** demonstrates how the principles of ESD, and the Precautionary Principle, have been applied to the underwater sound impact and risk assessment.	CAPL considers no amendments to the OPP are necessary.
			Objection or claim: 8N—EPBC Act Policy Statement 2.1 provides guidance for control measures for consideration by the Development.	EPBC Act Policy Statement 2.1 was prepared for managing the risks of seismic surveys on cetaceans, i.e. the Policy was developed for use with larger traditional seismic surveys, not for the smaller airguns used as part of VSP. The EPBC Act Policy Statement 2.1 was determined as relevant to the Development in **Section 2.2** in that it provides an existing framework for minimising acoustic injury and disturbances to cetaceans from impulsive sound sources. Note: the scope of the OPP does not include seismic surveys. To manage the impacts and risks associated with impulsive sounds (i.e. VSP), CAPL has included adaptive management EPOs and control measures (**EPO-23**, **CM-20**) which requires consideration of activity-specific control measures to ensure that the risks are being reduced to ALARP and managed to an acceptable level. The types of controls that may be considered include those within the Policy.	CAPL considers no amendments to the OPP are necessary.
			Matter: Comments were received citing concerns of potential adverse impacts from	Unplanned hydrocarbon spill scenarios resulting in a release of marine fuel (**Section 8.14**) or gas/condensate (**Section 8.15**) have been identified in the OPP. The worst-case scenarios for each hydrocarbon type were identified:	CAPL considers no amendments to the OPP are necessary.

[4] Davidsen, J., Dong, H., Linné, M., Andersson, M., Piper, A., Prystay, T., Hvam, E., Thorstad, E., Whoriskey, F., Cooke, S., Sjursen, A., Rønning, L., Netland, T., and Hawkins, A. 2019. Effects of sound exposure from a seismic airgun on heart rate, acceleration and depth use in free-swimming Atlantic cod and saithe. *Conservation Physiology*, 7(1). https://doi.org/10.1093/conphys/coz020.

[5] Meekan, M., Speed, C., McCauley, R., Fisher, R., Birt, M., Currey-Randall, L., Semmens, J., Newman, S., Cure, K., Stowar, M., Vaughan, B., and Parsons, M. 2021. A large-scale experiment finds no evidence that a seismic survey impacts a demersal fish fauna. *Proceedings of the National Academy of Sciences*, 118 (30) e2100869118, https://doi.org/10.1073/pnas.2100869118.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			unplanned hydrocarbon spills associated with the Development. *Objection or claim*: 8O—An unplanned spill from the Development has the potential to produce widespread reduction in water quality and sub-lethal to lethal toxicity impacts to marine wildlife, presenting an unacceptable risk to the Australian marine environment.	• marine fuel—vessel collision event • condensate—loss of effective well control (LOWC) event. Oil spill modelling was undertaken for one vessel spill scenario (at WTR as this site is the closest field to shore and represents the worst-case unplanned hydrocarbon release location for hydrocarbon exposure to sensitive receptors (including shorelines; **Section 8.14.2**), and five LOWC events (one at each of Chanon, G&E, C&D, Semele, and WTR; **Section 8.15.2**). A stochastic spill modelling approach (300 simulations under differing metocean conditions) was applied for each of the modelled scenarios. The results from all six sets of oil spill modelling were used to develop the boundaries for the Hydrocarbon Ecological and Social EMBAs (**Section 6.1**, **Figure 6-1**, **Figure 6-2**) and inform the respective risk assessments (**Sections 8.14.3**, **8.15.3**). The highest residual risk level of all the potential risks from the unplanned hydrocarbon release aspects was 8 (low). To manage the impacts and risks associated with an unplanned hydrocarbon release, CAPL has identified both preventative (e.g. **CM-16, CM-31, CM-32, CM-33, CM-43. CM-45, CM-46**) and mitigative (e.g. **CM-22, CM-44**) control measures to ensure that the impacts and risks can be managed to an acceptable level. As such, CAPL considers that the potential for reduced water quality and sub-lethal to lethal impacts on marine fauna can be managed to an acceptable level in alignment with regulatory requirements.	
			Objection or claim: 8P—Given the high-risk to the surrounding environment from an unplanned hydrocarbon spill, a clean-up contingency plan is critically important.	An oil pollution emergency response plan is required as part of the implementation strategy of the EP, as per regulation 22(8) of the OPGGS(E)R. This requirement is reflected in a control measure (**CM-44**) of the OPP. Oil spill response planning is undertaken for the EPs so that the oil spill scenarios, risk assessments, and response planning are undertaken at an activity-specific level. This is aligned with NOPSEMA's Oil Pollution Risk Management guidance note[6].	CAPL considers no amendments to the OPP are necessary.

[6] NOPSEMA. (2024). *Guidance Note: Oil Pollution Risk Management*. Document No. N-04750-GN1488 A382148.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			Matter: Comments were received citing concerns of potential cumulative impacts from the Development in conjunction with other marine activities. *Objection or claim*: 8Q—The impacts from the Development should be assessed in the context of other heavy industrial activity within the North-west Marine Region, to determine the cumulative impact of the activities.	Regulation 13(4)(c) of the OPGGS(E)R requires the identification and evaluation of environmental impacts and risks of the petroleum activities that are part of the proposed Development. NOPSEMA's decision making guideline[7] and content requirements guidance[8] for OPPs both clarify that environmental impacts and risks include cumulative impacts. To address this requirement, a cumulative impact assessment was undertaken (**Section 9**). This cumulative impact assessment identified and evaluated potential cumulative impacts to environmental values and sensitivities that may occur from: • interactions occurring between multiple aspects of the Development • interactions occurring between the Development and third-party activities. The third-party activities included those known to occur within the same vicinity as the proposed Development, including commercial shipping, commercial shipping, and other petroleum activities. The outcomes of the cumulative impact assessment (**Section 9.2**) demonstrated that the EPOs and adopted control measures already in place (within **Section 8**) were also appropriate for the management of any potential cumulative impact. CAPL consider that the potential for cumulative impacts associated with the Development (including those associated with interactions with other industrial activities in the area) have been identified, evaluated, and can be managed to an acceptable level in alignment with regulatory requirements for an offshore project.	CAPL considers no amendments to the OPP are necessary.
			Matter: Comments were received citing concerns that the Development produces significant greenhouse gas (GHG) emissions	The proposed Development comprises the development of seven backfill gas fields in the Greater Gorgon Area that will tie-in to existing Gorgon Foundation Project (GFP) infrastructure. The GFP has primary environmental approvals in place via the *Environment Protection and Biodiversity Conservation Act 1999*	In response to this submission CAPL has revised the OPP to introduce terminology

[7] NOPSEMA. (2024). *Guideline: Offshore project proposal decision making*. Document No: N-04790-GL1816 A630598.

[8] NOPSEMA. (2024). *Guidance Note: Offshore project proposal content requirements*. Document No: N-04790-GN1663 A473026.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
			Objection or claim: 8R—Over its life, the Development will produce approximately 214.7 Mt CO_2-e of GHG emissions (comprising 3.7 Mt CO_2-e of direct emissions and 211 Mt CO_2-e of indirect emissions) and therefore the Development represents an unacceptable source of GHG emissions, when urgent reductions are needed to avoid catastrophic climate change. 8S—The Development's current GHG emissions are incompatible with the IPCC 1.5°C pathway and net zero commitments, and therefore presents unacceptable risk of climate change impacts. 8T—The Development's GHG emissions were not easily identified in the OPP; this information should be made clear to facilitate consultation and assessment.	(Cth) (EPBC Act) and *Environmental Protection Act 1986* (WA) (EP Act), and these primary approvals included assessment and acceptance of GHG emissions associated with the GFP (**Sections 1.2** and **8.3.6**). This OPP is the primary environmental approval, being sought under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) for the Development. For clarity, the GHG emissions identified in the OPP are as follows[9]: • BFF direct GHG emissions – estimate of ~3.07 Mt CO_2-e over the life of the Development (**Section 8.3.4.2**, **Appendix E**) – the proportion of GHG emissions generated during each phase of the Development varies, with the highest proportions associated with drilling, operations and decommissioning (**Figure 8-1**) – CAPL are seeking primary environmental approval associated with these 'BFF direct GHG emissions' by means of the OPP. • BFF gas processing GHG emissions – estimate of ~107.8 Mt CO_2-e over the operational life of the Development (**Section 8.3.4.3**, **Appendix E**) – this is a subset of the total Gorgon Gas Development gas processing emissions already described and assessed under previous approvals • BFF secondary GHG emissions associated with transport and third-party end of use of products – estimate of ~600.7 Mt CO2-e over the operational life of the Development (**Section 8.3.4.4**, **Appendix E**) – these 'GFP secondary GHG emissions' are third-party GHG emissions that are a reasonably foreseeable consequence of the Development – as per the treatment of BFF gas processing GHG emissions, the BFF secondary GHG emissions represent a proportion of	(**Section 8.3.1**) and assessment boundary (**Section 8.3.2**) concepts at the beginning of GHG section. An additional control measure (**CM-10**) has also been included in **Section 8.3.15**. In addition to changes in response to the submission, CAPL has also revised **Section 8.3** of the OPP to include additional information regarding national strategies, legislative and policy framework, corporate context, and projected domestic and global energy trends to support the potential impact and risk evaluations and demonstration of acceptability.

[9] Note: The GHG Inventory (Appendix E) for the Development was revised during Stage 2 OPP assessment, and a new Technical Note has now replaced the previous report that was released during the public comment period. The revised inventory provides additional clarity on the sources of emissions, and the inputs and assumptions used to generate the GHG emissions estimate.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				the overall Gorgon Gas Development secondary GHG emissions. The proposed Development is not increasing the processing capacity or the duration of the Gorgon Gas Development, it is a backfill development that will maintain gas supply to the GTP on Barrow Island (**Section 1.1**), and as such no additional quantity of gas production, or GHG emissions from the GTP, transportation or end-use is associated with the Development that was not already accounted for by existing GFP approvals (**Sections 8.3.3** and **8.3.4**, and **Appendix E**). As presented within the risk evaluation (**Section 8.3.13**) the BFF direct GHG emissions (~3.07 Mt CO_2-e or annual average of ~0.07 Mtpa CO_2-e over the life of the Development) represents ~0.016% of Australia's national annual emissions. These emissions also represent a potential ~0.0002–0.0006% reduction in the total remaining global carbon budget (as described in the outcomes of the IPCC AR6 WGI) for a 50% likelihood to limit global warming to 1.5 °C, and 2.0 °C respectively. This decrease is *de minimis*. The combined BFF GHG emissions and BFF gas processing GHG emissions represent a potential ~0.01–0.02% reduction in the remaining global carbon budget (as estimated to remain at the beginning of 2020) for a 50% likelihood to limit global warming to 1.5–2°C. The BFF secondary GHG emissions (i.e. those emissions from transport and third-party use of products from the Development, represent ~0.04–0.12% of the remaining global carbon budget (as estimated to remain at the beginning of 2020) for a 50% likelihood to limit global warming to 1.5–2°C. To manage the potential impacts and risks associated with GHG emissions, CAPL has identified EPOs and preventative and mitigative control measures (**Section 8.3.15**) to ensure that the impacts and risks associated with the Development can be managed to an acceptable level (as defined within **Section 7.6** of the OPP). GHG emissions associated with the Development are also managed under other legislative requirements, in particular the Commonwealth's Safeguard Mechanism scheme and State primary environmental approvals:	

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				• The 'Gorgon Operations Facility' is registered with the Clean Energy Regulator (CER) as a facility under both the National Greenhouse and Energy Reporting (NGER) and Safeguard Mechanism schemes. The scope of the Gorgon Operations Facility includes GHG emissions from both the GTP and associated facilities on Barrow Island, as well as from any activities or facilities in Commonwealth waters. Under the 2023 reforms to the Safeguard Mechanism, an annual decline rate (currently 4.9%) is applied to a facilities baseline (**Section 8.3.5.3**). • The Gorgon GTP Plant Greenhouse Gas Management Plan (GHGMP) is applicable to all GHG emissions from the current operational GFP facilities (as outlined in MS 800[10]), including the three LNG processing trains, domestic gas unit, and Carbon Dioxide Injection System. The GHGMP was developed to satisfy the requirements of condition 27 of MS 800 (as amended by MS 1198), which specifies limits for Net GHG Emissions[11] in 5-yearly intervals, decreasing to net zero by 1 July 2025 (**Section 8.3.6.1**). • Reservoir CO_2 emissions are managed via condition 26 of MS 800 (as amended by MS 1198) and the Safeguard Mechanism • under MS 800 at least 80% of Reservoir CO_2 is injected underground, and offsets acquired for the quantity of Reservoir CO_2 that is not injected underground • under the Safeguard Mechanism reforms new gas fields that supply extant facilities are required to meet zero net reservoir CO_2 emissions. The OPP has been revised to include these other legislative requirements within an EPO (**EPO-11**) and control measure (**CM-10**). As such, CAPL consider that the potential for impacts and risks from the GHG emissions associated with the Development can	

[10] Ministerial Statement 800 (MS 800), as amended by MS 1198, are approval conditions associated with the primary environmental approval for the GFP under the EP Act (WA).

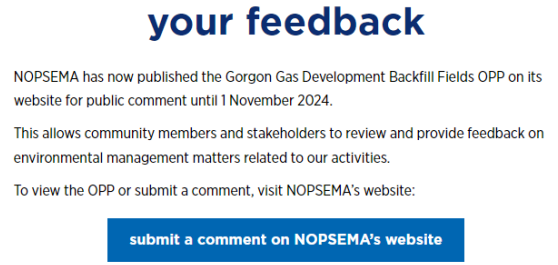
[11] Net GHG Emissions and Reservoir CO_2 and are defined within MS 1198.

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				be managed to an acceptable level in alignment with regulatory requirements for an offshore project. In any subsequent Environment Plan, CAPL is required to include details of the control measures that will be used to reduce the impacts and risks of the petroleum activity to ALARP and an acceptable level.	
			Matter: Comments were received citing concerns that the Development lacks an adequate decommissioning plan. *Objection or claim*: 8U—The Development needs a comprehensive decommissioning strategy prior to the end of field life, and this should be available to the public. 8V—The Proponent should remove all property to ensure that the area is left safe, stable and non-polluting. 8W—If infrastructure is not completely removed, there must be ongoing maintenance and monitoring by the Proponent to ensure long-term stability of the infrastructure. 8X—A decommissioning bond sufficient to complete full decommissioning and rehabilitation should be held to protect the Australian government from decommissioning liability.	The overview of CAPL's approach to decommissioning planning (**Section 4.3.5.1**) and description of decommissioning activities (**Sections 4.3.5.2** to **4.3.5.8**) are appropriate to this early-stage of an offshore project. To provide further clarity around decommissioning planning, and how the level of information and detail changes as the Development progresses, additional descriptive material has been incorporated into the introduction of **Section 4.3.5**, including that finalised details of decommissioning activities will be specified in the EP phase. In alignment with requirements under the OPGGS(E)R, relevant persons will be consulted during the preparation of EPs (**Section 3.3**) and the full-text EPs will become public upon submission to NOPSEMA for assessment. Additional clarification around regulatory obligations including other relevant legislation (e.g. *Environment Protection (Sea Dumping) Act 1981* (Cth)) and CAPL's obligations under section 270 of the OPGGS Act for title surrender have also been included in **Section 4.3.5.1**. These criteria under section 270 include the obligation to 'make good' the seabed before the title can be surrendered. Obligations under section 572 of the OPGGS Act regarding the inspection and maintenance of property to ensure full removal can be achieved (unless an alternative arrangement has been accepted by NOPSEMA) is described within existing material in **Sections 4.3.5.1** and **4.3.5.2**. An EPO (**EPO-06**) had also been adopted in the OPP requiring legislative requirements to be met during decommissioning. There is no formal requirement under the OPGGS Act for a titleholder to hold a bond to cover projected decommissioning costs. As described above, and in the OPP, decommissioning is the responsibility of titleholders and section 572 must be met during activities, and criteria under section 270 met before a title can be surrendered at the end of activities. Further, the	In response to this submission CAPL has revised the OPP to include an additional information within the descriptions of the decommissioning phase of the Development (**Section 4.3.5**).

ID	Stakeholder	Source	Comments received (in general terms)	Titleholder response	Changes to OPP
				OPGGS Act was amended to include provisions for enhanced remedial directions (commonly referred to as trailing liability provisions). These amendments came into effect in March 2022, and apply to all titles as they existed on or after 1 January 2021. Trailing liability is designed to ensure that the costs and liabilities associated with decommissioning will be borne by the petroleum industry and do not become the responsibility of government or the Australian community[12].	
			Matter: Comments were received citing concerns that access to the Development's consultation documents is inadequate. *Objection or claim*: 8W—The Proposal documents were not provided on the Proponent's public comment page.	Under regulation 9 of the OPGGS(E)R, it is NOPSEMA's responsibility to publish the OPP and a notice inviting public written comments on their website. The Gorgon Gas Development: Backfill Fields OPP was uploaded to NOPSEMA's Offshore Project Proposals website, with a link to both a PDF version of the full Backfill Fields OPP and NOPSEMA's Consultation and Public Comment webpage (which also had a link to the full OPP as well as instructions for submission of written comments). The OPGGS(E)R specify a period of at least 4 weeks is given for comment; the public comment period for the Backfill Fields OPP was 12 weeks (9 August to 1 November 2024). NOPSEMA's information paper on public comment on OPPs[13] states that the "proponent for the OPP is also requested to promote availability of, and invite comment on, the OPP its website and in a national, state and regional newspapers". The proposed Development was first listed on CAPL's Consultation Hub website during June 2023 as part of the Phase 1 early consultation activities (**Section 3.1**). At the commencement of the NOPSEMA public comment period, CAPL's main website homepage was updated to include a feature box advertising the public comment period, linking directly to the NOPSEMA consultation webpage (see images below).	CAPL has revised **Section 3.2** of the OPP to reflect the NOPSEMA public comment period, advertising by CAPL to support the public comment period, and summary of comments received (this table).

[12] DISER. (2022). *Guideline: Trailing liability for decommission of offshore petroleum property in relation to the Offshore Petroleum and Greenhouse Gas Storage Act 2006*, Department of Industry, Science, Energy and Resources, Australian Government.

[13] NOPSEMA. (2024). *Information Paper: Public comment on offshore project proposals*. Document No. N-04790-IP1664 A473111.

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				 The Development's activity information page was also updated at the commencement of the NOPSEMA public comment period to provide a link to the NOPSEMA consultation webpage that had links to a PDF version of the full OPP and details on how to provide written submissions to NOPSEMA (see image below).  In addition to providing a weblink connecting the CAPL consultation page to the NOPSEMA public comment submission page, the following actions were also undertaken by CAPL to promote the NOPSEMA public comment process: • half-page adverts were placed in the following national, state and regional newspapers – The West, and The Australian (12 August 2024) – Pilbara News, Midwest Times, and North West Telegraph (14 August 2024) – National Indigenous Times (27 August 2024) – Business News (2 September 2024) • prominent advertisements were placed in local Onslow and Karratha Chamber of Commerce newsletters, local Facebook	

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				discussion boards and a CAPL LinkedIn post, all including a direct link to the NOPSEMA consultation webpage • directly notified stakeholders identified during Phase 1 consultation (**Section 3.1**) with a link to the NOPSEMA consultation webpage for the formal public comment period. These actions are consistent with the Phase 2 public consultation process (**Section 3.2**) described in the OPP and with NOPSEMA's request within their information paper. As such, CAPL consider that while a copy of the OPP was not directly available on their own webpage, that sufficient actions and advertising was taken to direct stakeholders to the NOPSEMA consultation webpage. As the public comment period is a NOPSEMA driven process, this was considered the most efficient way for stakeholders to access all the information they required in the one location.	